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CONTENTS:

FEATURE ARTICLES:

SUPPLIERS NEWS SECTION:

DATA COMPILATION:

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Nonlinear Finite Element Analysis of the Fluted Corrugated Sheet in the Corrugated Cardboard

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The choice of corrugated medium, flute size, combining adhesive, and linerboards can be varied to design a corrugated board with specific properties. In this paper, the nonlinear finite element analysis of the fluted corrugated sheet in the corrugated cardboard based on software SolidWorks2008 was investigated. The model of corrugated board with three or more flutes is reliable for stress and displacement measurement to eliminate the influence of the number of flutes in models. According to the static pressure test, with the increase of flute height H or arc radius of flute, the maximum stress in the models decreased and the maximum displacement increased. However the maximum stress and maximum displacement in the models increase nonlinearly in the static pressure test with the increase of the flute angle θ. According to the drop test, with the increase of flute height H, the maximum stress of goods on the upper board in the drop test decreased. The maximum stress of the model in the drop test decreases firstly and then increases with the increase of flute angle, and the optimal flute angle θ could be 60° for corrugated board. All the conclusions are consistent with experimental data or product standards.

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Research Article

Nonlinear Finite Element Analysis of the Fluted Corrugated Sheet in the Corrugated Cardboard

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1. Introduction

Corrugated containers are the most important structural application of paperboard. Corrugated cardboard is a paper-based material consisting of a fluted corrugated sheet and one or two flat linerboards. It is widely used in the manufacture of corrugated cardboard boxes and shipping containers. The corrugated medium is often 0.026 pounds per square foot ($0.13\,kg/m^2$) basis weight in the USA; in the UK, a 90 grams per square metre (0.018 lb/sq ft) fluting paper is common. At the single-facer, it is heated, moistened, and formed into a fluted pattern on geared wheels. This is joined to a flat linerboard with a starch based adhesive to form single face board. At the double-backer, a second flat linerboard is adhered to the other side of the fluted medium to form single wall corrugated board. Linerboards are test liners (recycled paper) or kraft paperboard (of various grades). The liner may be bleached white, mottled white, colored, or preprinted [1–3]. The basic geometry of typical twin corrugated wall board is illustrated in Figure 1.

Common flute sizes are “A,” “B,” “C,” “E,” and “F.” The letter designation relates to the order that the flutes were invented, not the relative sizes. Flute size refers to the number of flutes per linear foot, although the actual flute dimensions for different corrugator manufacturers may vary slightly. Measuring the number of flutes per linear foot is a more reliable method of identifying flute size than measuring board thickness, which can vary due to manufacturing conditions. The most common flute size in corrugated cardboard boxes is “C” flute. The choice of corrugated medium, flute size, combining adhesive, and linerboards can be varied to engineer a corrugated board with specific properties to match a wide variety of potential uses.

The structural performance of a corrugated container is a function of numerous factors including the quality of the input cellulose fibers, the mechanical properties of the liner and medium, and the structural properties of the combined board. The complicated nonlinear behavior or paper makes modeling of the mechanical response of corrugated board

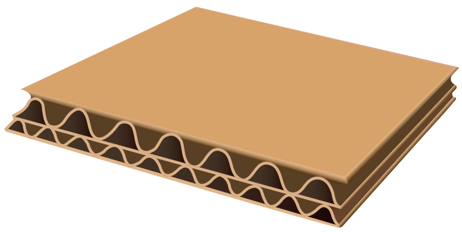


Figure 1: Twin corrugated wall board structure.

and structures composed of corrugated board a difficult task [4].

Numerous studies have been focused on the properties of corrugated cardboard and external environment's effects on the performance of corrugated carton [5–10]. Gilchrist et al. [4] have developed nonlinear finite element models for corrugated board configurations. Results from the finite element simulations correlated reasonably well with the analogous experimental measurements performed using actual corrugated board specimens. Biancolini and Brutti [11] have developed a finite element "corrugated board" by means of a dedicated homogenization procedure in order to investigate the buckling of a complete package. The FEM model of the package, assembled with this new element, can accurately predict the experimental data of incipient buckling observed during the standard box compression test, despite the few degrees of freedom and the minimal computational effort. Biancolini [12] also presented a numerical approach to evaluating the stiffness parameters for corrugated board. The method is based on a detailed micromechanical representation of a region of corrugated board modelled by means of finite elements. Conde et al. [13] have developed a methodology for modelling corrugated board adhesive joints subjected to shear, considered to be the main load in most of these joints. The corrugated board adhesive joint model reproduced quite well the stiffness obtained in the test samples, as well as the failure load with a deviation of less than 14%.

Biancolini et al. [1] compared results obtained from the simplified formula, an extended formula, and two numerical models developed by authors using finite elements (FE): an FE model realised with homogenised elements and an FE model representing the entire corrugation geometry. Numerical results of the capability to resist stacking loads obtained with FE models were consistent with experimental results. Haj-Ali et al. [14] presented a refined nonlinear finite element modeling approach for analyzing corrugated cardboard material and structural systems. This method can accurately predict overall mechanical behavior and ultimate failure for wide range corrugated systems. Talbi et al. [15] presented an analytical homogenization model for corrugated cardboard and its numerical implementation in a shell element.

The shape and size of flute have an important effect on the performance of corrugated cardboard. However, there are no strict standards of flute size parameter to achieve the best elasticity and compressive strength of corrugated cardboard. There is also little literature regarding the finite element analysis of flute size. Yuan et al. [16, 17] have developed a model of UV-shaped corrugated cardboard by ANSYS. The results show that the closer the model to the U-shaped flute, the larger the corrugated board strain becomes. It is consistent with the empirical data, which prove the feasibility of finite element analysis method. In this paper, we focus on the investigation of nonlinear finite element analysis of the fluted corrugated sheet in the corrugated cardboard based on software SolidWorks2008. The shape and size of flute will be discussed with the help of SolidWorks and compared with the empirical data.

Table 1: Parameters of linear elastic material [18].

Name		Numerical value	Unit
Elastic modulus	E_x	7600	MPa
	E_y	4020	MPa
	E_z	38	MPa
Shear modulus	G_{xy}	2140	MPa
	G_{xz}	20	MPa
	G_{yz}	70	MPa
Poisson's ratio	V_{xy}	0.34	—
	V_{xz}	0.01	—
	V_{yz}	0.01	—
Density		404.5	kg/m^3

Table 2: Parameters of rigid plate material.

Name	Numerical value	Unit
Elastic modulus	1.0×10^{12}	N/m^2
Density	1.0×10^{-8}	kg/m^3
Poisson's ratio	0.3	—

2. Modeling

SolidWorks2008 has powerful structural modeling functions, among which Cosmos/Works is a function module which is specially used to make finite element analysis on structure. The model of common UV-shaped corrugated board is shown in Figure 2. In Figure 2, L is flute length, H is flute height, h is facing paper thickness, δ is fluting paper thickness, θ is flute angle, and r is arc radius.

The principal aim of this work is to study the fluted corrugated sheet. So we added a piece of rigid plate with large elastic modulus on upper facing paper (as shown in Figure 3) to eliminate the influence of the facing paper deformation. The maximum stress and strain of the improved model occur in the point in which flute contact with the upper facing paper in all cases. The material parameters of corrugated board model are given in Table 1 [18]. The material parameters of rigid plate model are given in Table 2 from the SolidWorks material library.

3. Results and Discussion

3.1. The Numbers of Flutes in Models. In order to eliminate the influence of the number of flutes in models, a series

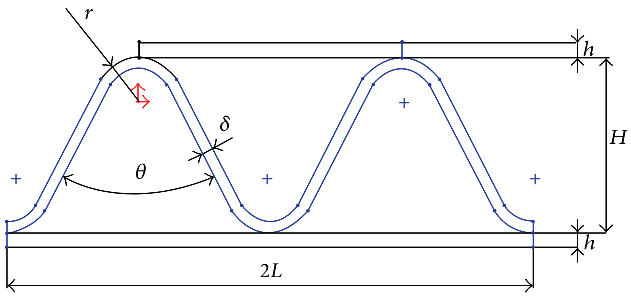


Figure 2: Model of UV-shaped corrugated board.

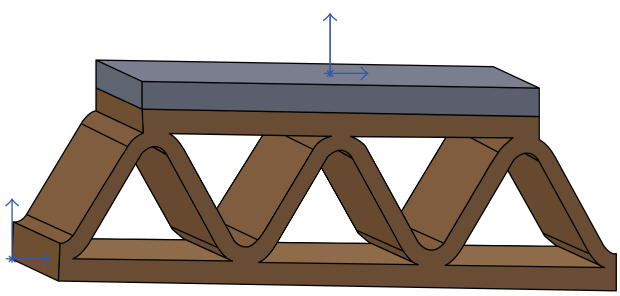


Figure 3: Improved model of UV-shaped corrugated board with rigid plate.

of models with different number of flutes were built and shown in Figure 4. The numbers of flutes in models are 2, 3, 4, and 5. Fixing the bottom of models and then a static pressure test were made with a pressure of 150 Pa on the top floor. Then the stress and displacement contours of models of corrugated board were obtained as shown in Figure 5 (model with three flutes as example). From above calculation, the maximum displacement and maximum stress of the models with different number of flutes were obtained and the results are shown in Figure 6.

From Figure 6, we can see that, with the number of flutes increased, the maximum stress in the models increased and the maximum displacement decreased. While the number of flutes increased to 3 or more, the maximum stress and displacement changed slightly. Therefore, the model of corrugated board with three or more flutes is reliable for stress and displacement measurement. In the coming simulation, the numbers of flutes in the models are all greater than 2.

3.2. Flute Height H. Effects of flute height H on the mechanical properties of corrugated cardboard model were investigated. A series of models with different flute height H were built and shown in Figure 7. The flute heights H in models are 2, 3, 4, and 5 mm. These models can be roughly classified as A flute (5 mm), C flute (4 mm), B flute (3 mm), and E flute (2 mm). Fixing the bottom of models and then a static pressure test were made with a pressure of 150 Pa on the top floor. Then the maximum displacement and maximum stress of the models with different flute height H were obtained and the results are shown in Figure 8.

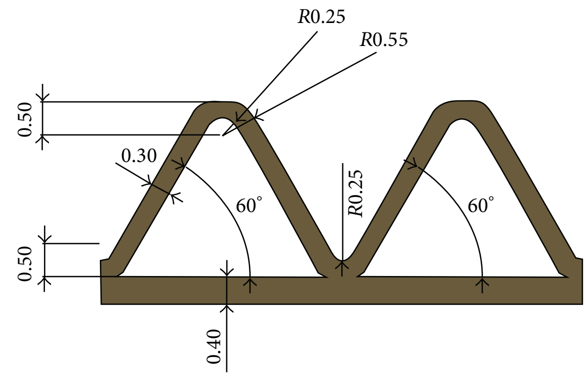


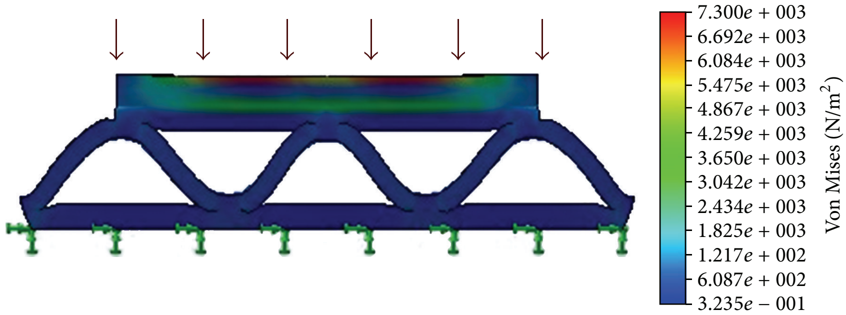
Figure 4: Model of corrugated board with two flutes.

From Figure 8, we can see that, with the flute height H increased, the maximum stress in the models decreased and the maximum displacement increased. Therefore, with the flute height H increased, the flat compression strength of corrugated board decreased and cushioning properties of corrugated board increased. As is well known, the cushioning properties of different shapes of corrugated cardboard have the sequence A > C > B > E, and the flat compression strength of corrugated board has the sequence A < C < B < E. Our simulation results are consistent with these conclusions.

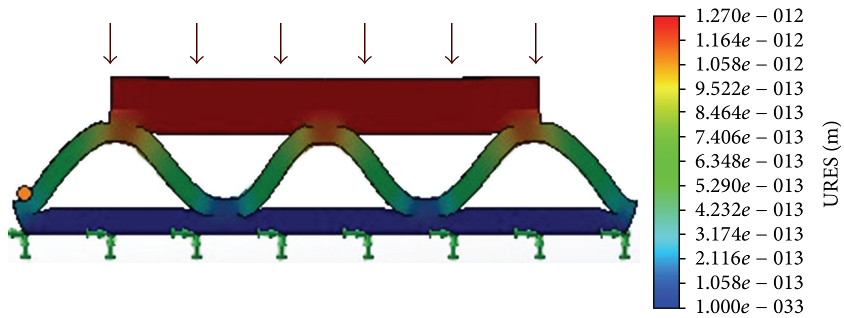
3.3. Arc Radius r. Effects of arc radius r on the mechanical properties of corrugated cardboard model were investigated in this section. A series of models with different arc radius of flute were built and shown in Figure 9. The arc radius r in models are 0, 0.1, 0.2, 0.25, 0.3, 0.35, and 0.4 mm. Fixing the bottom of models and then a static pressure test were made with a pressure of 150 Pa on the top floor. Then the maximum displacement and maximum stress of the models with different arc radius were obtained and the results are shown in Figure 10.

From Figure 10, we can see that, with the arc radius of flute increased, the maximum stress in the models decreased and the maximum displacement increased. It means that when the arc radius r increases the flat compression properties get worse and the cushioning properties get better. In fact, the smaller the arc radius, the closer the model to the V-shaped flute; the larger the arc radius, the closer the model to U-shaped flute. The simulation result also verified that the flat compression properties of V-shaped flute corrugated board are better than that of the U-shaped flute corrugated board and its cushioning properties are worse than that of the U-shaped flute.

Actually, the triangle is the most stable structure. It is difficult to deform when a force was applied at the vertex of a triangle. But this structure is not suitable for the cushioning design. As the arc radius r increases, the maximum displacements of the structure increase. So the stress can be dispersed to other parts rather than concentrating on one point. In this situation the cushioning properties of corrugated board get better to protect goods. In order to meet the needs of



(a) Stress contours



(b) Displacement contours

FIGURE 5: The stress and displacement contours of models of corrugated board with three flutes.

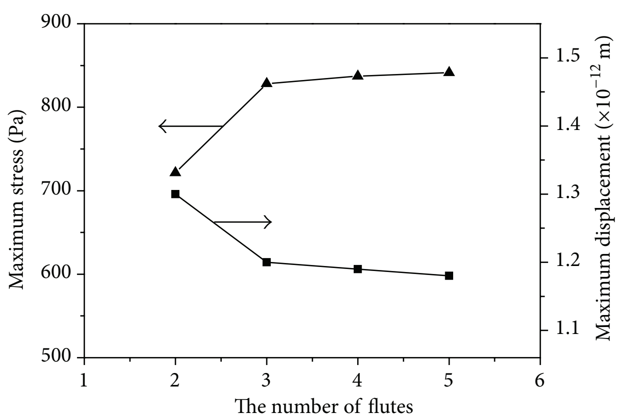


FIGURE 6: Maximum stresses and maximum displacements of corrugated board models with different number of flutes.

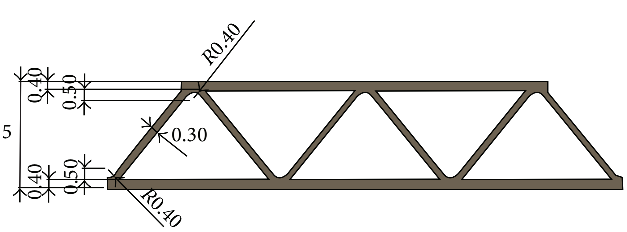


FIGURE 7: Model of corrugated board with flute height H of 5 mm.

packaging cushioning design, we should determine the arc radius r according to the actual packaging requirements.

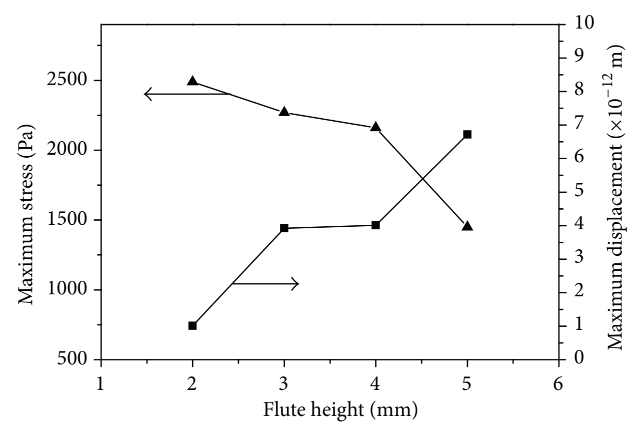


FIGURE 8: Maximum stresses and maximum displacements of corrugated board models with different flute height.

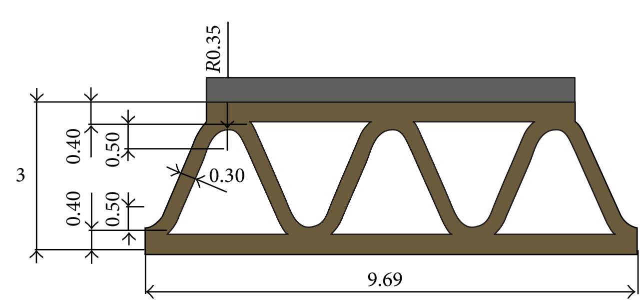


FIGURE 9: Model of corrugated board with arc radius of 0.35 mm.

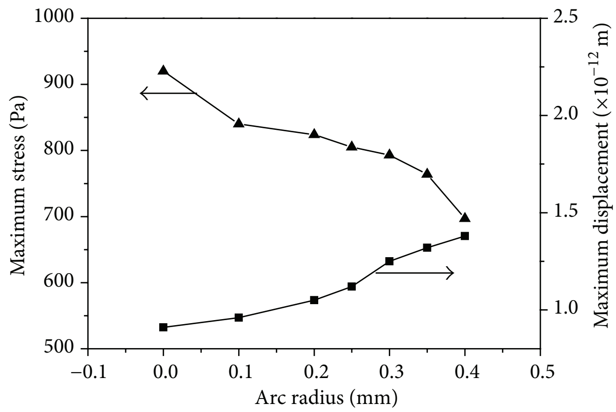


FIGURE 10: Maximum stresses and maximum displacements of corrugated board models with different arc radius of flute.

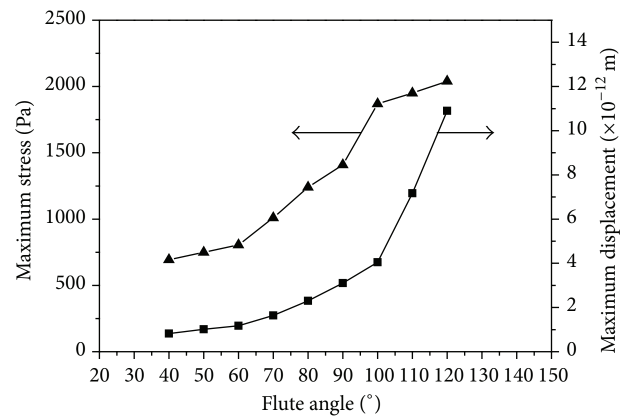


FIGURE 12: Maximum stresses and maximum displacements of corrugated board models with different flute angle θ.

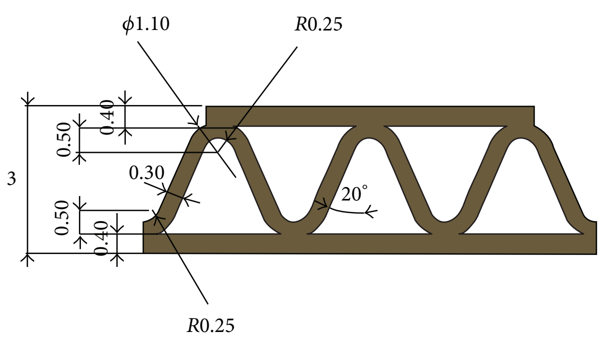


FIGURE 11: Model of corrugated board with flute angle of 40°.

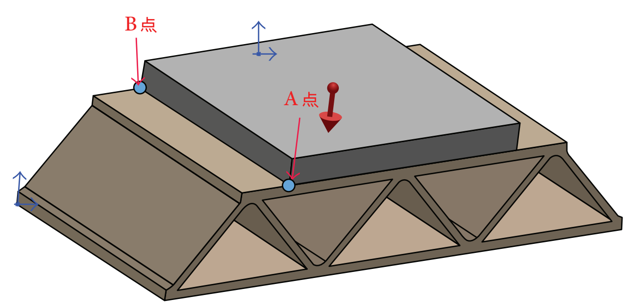


FIGURE 13: The drop test model with different flute height.

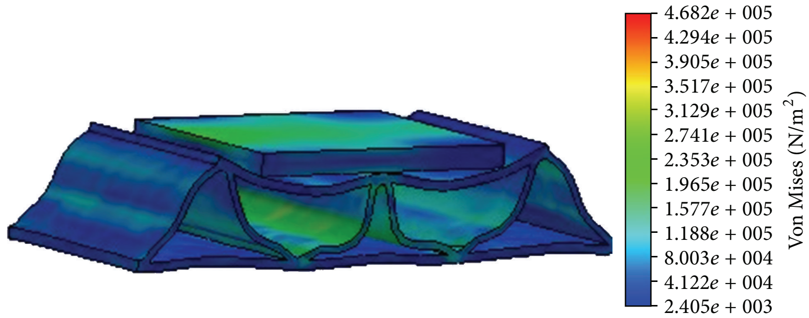
3.4. Flute Angle θ. Effects of flute angle θ on the mechanical properties of corrugated cardboard model were investigated in this section. A series of models with different flute angle θ were built and shown in Figure 11. The flute angles θ in models are 40, 50, 60, 70, 80, 90, 100, 110, and 120°. Fixing the bottom of models and then a static pressure test were made with a pressure of 150 Pa on the top floor. Then the maximum displacement and maximum stress of the models with different flute angle θ were obtained and the results are shown in Figure 12.

From Figure 12, we can see that, with the increase of the flute angle θ, the maximum stress and maximum displacement in the models increase nonlinearly. The maximum stress and maximum displacement change slowly when θ is less than 60° and then increase sharply when θ is larger than 60°. In addition, the number of flute per unit length increases as the θ decreases, and it means that the corrugated board needs more materials. Therefore, the optimal flute angle θ could be 60° for corrugated board. According to the Chinese national standards "Corrugated board and standard test method" (GB6544~6548-86), the UV-shaped flute corrugated board should be 60° in the manufacture process. The simulation result is consistent with the standards of corrugated board.

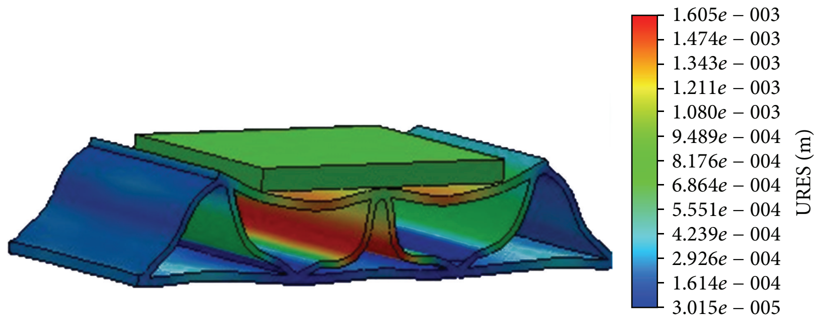
3.5. Drop Test

3.5.1. Flute Height H. Both primary (consumer) packages and shipping containers have a risk of being dropped or being impacted by other items. Package integrity and product protection are important packaging functions. Drop tests are conducted to measure the resistance of packages and products to controlled laboratory shock and impact. Drop testing also determines the effectiveness of package cushioning to isolate fragile products from shock.

Effects of flute height H on the dynamic mechanical properties of corrugated cardboard model in the drop test based on Cosmos/Works were investigated. A series of models with different flute height H were built and shown in Figure 7. The flute heights H in models are 2, 3, 4, and 5 mm. The drop test model was shown in Figure 13. A simplified model of corrugated board and goods on the upper board were investigated. Drop height is 0.3 m, initial velocity is 0 m/s, acceleration of gravity is 9.81 m/s^2, and impact time is 600 μs. The material of the object on the upper board is Acrylonitrile Butadiene Styrene (ABS) and the mass is 1.224×10^{-4} kg. Then the stress and displacement contours of models of corrugated board were obtained and shown in Figure 14 (model with flute height H of 5 mm). In order to investigate the stress of goods on the upper board in the drop test, we selected 2 points (A and B point as shown in Figure 13) from the model as the object of study. Then the time-dependent



(a) Stress contours



(b) Displacement contours

Figure 14: The stress and displacement contours of model with flute height H of 5 mm in drop test.

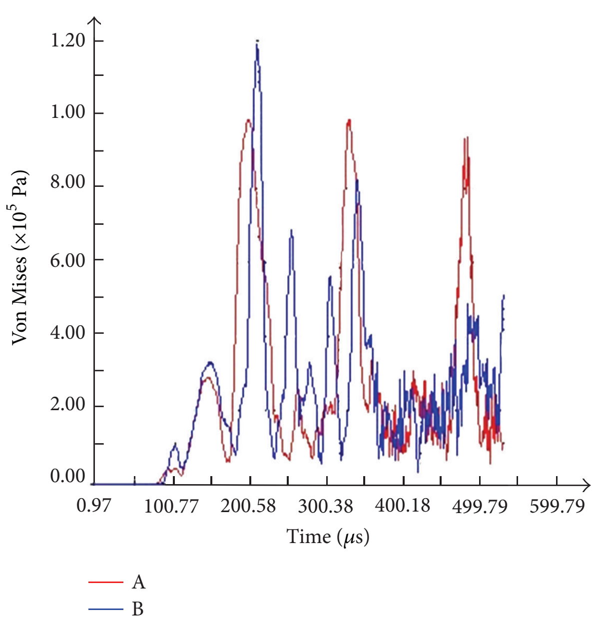


Figure 15: Time-dependent stress of A, B point in drop test (model with flute height H of 5 mm).

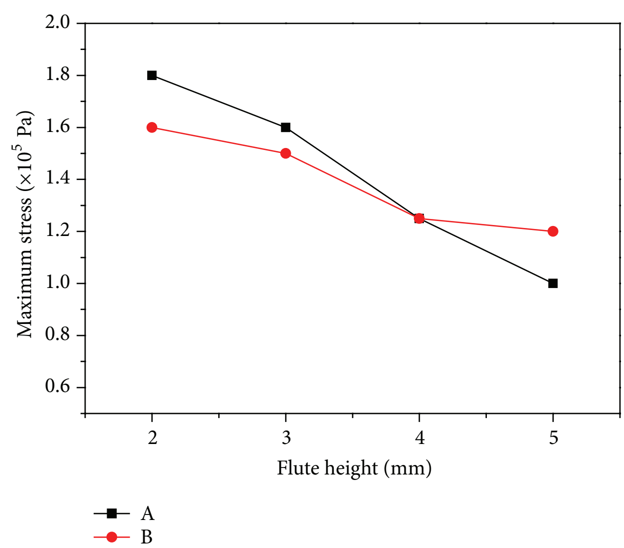


Figure 16: Maximum stress of A, B point in the models with different flute height H in the drop test.

stress of A, B point in the drop test was obtained and shown in Figure 15 (model with flute height H of 5 mm). From above simulation, the maximum stresses of A, B point in the models with different flute height H in the drop test were obtained and the results are shown in Figure 16.

From Figure 16, we can see that, with the increase of flute height H, the maximum stress of goods on the upper board in the drop test decreased. Therefore, with the increase of flute height H, the cushioning properties of corrugated board increased. This conclusion is consistent with the conclusions of Section 3.2.

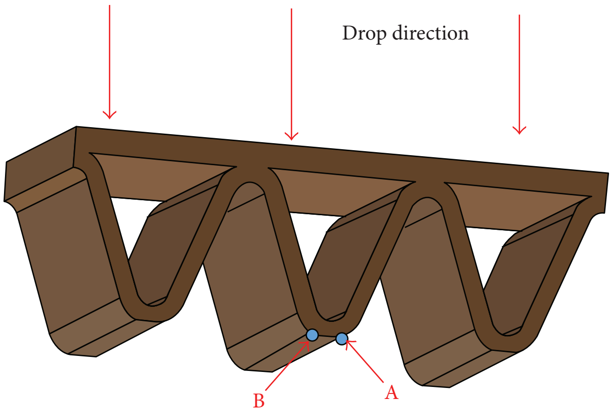


Figure 17: The drop test model with different flute angle θ.

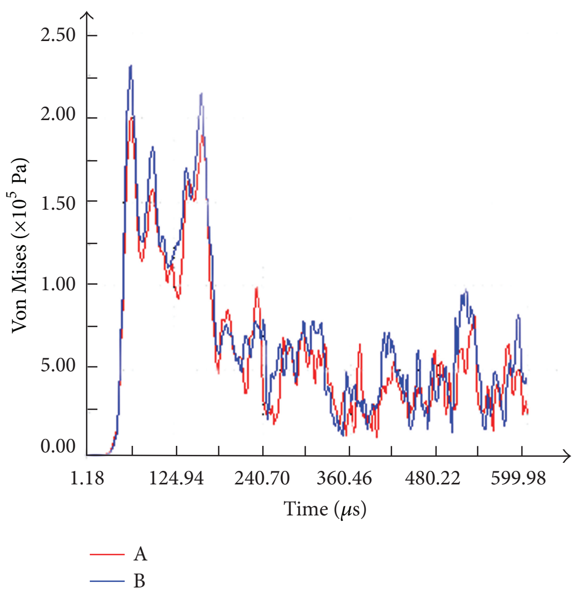


Figure 18: Time-dependent stress of A, B point in drop test (model with flute angle θ of 40°).

3.5.2. Flute Angle θ. Effects of flute angle θ on the dynamic mechanical properties of corrugated cardboard model in the drop test based on Cosmos/Works were investigated. A series of models with different flute angle θ were built and shown in Figure 11. The flute angles θ in models are 40, 50, 60, 80, and 100°. The drop test model was shown in Figure 17. Drop height is 0.3 m, initial velocity is 0 m/s, acceleration of gravity is 9.81 m/s^2, and impact time is 600 μs. The stress distribution of corrugated cardboard was obtained and we have found that the maximum stress occurs in the point which fluted corrugated sheet contact with the ground in all cases. So we selected 2 points (A and B point as shown in Figure 17) from the model as the object of study in the drop test. Then the time-dependent stress of A, B point in the drop test was obtained and shown in Figure 18 (model with flute angle θ of 40°). From above simulation, the maximum stresses of A, B

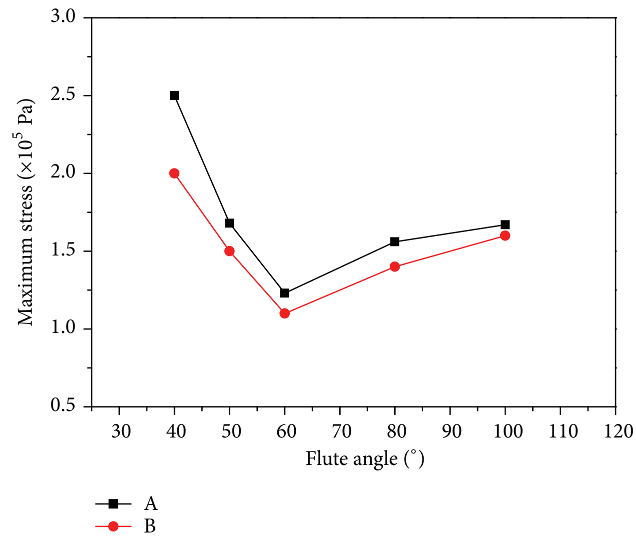


Figure 19: Maximum stress of A, B point in the models with different flute angle in the drop test.

point in the models with different flute angle θ in the drop test were obtained and the results are shown in Figure 19.

From Figure 19, we can see, that with the increase of flute angle, the maximum stress of the model in the drop test decreases firstly and then increases. The maximum stress of the corrugated board bears is smallest when the flute angle θ reaches 60°. The reason is that the stress of the corrugated board could be dispersed to the flute structure efficiently and then reduces the maximum stress of the corrugated board in drop test. Therefore, the optimal flute angle θ could be 60° for corrugated board. This conclusion is consistent with the conclusions of Section 3.4.

4. Conclusions

The shape and size of flute have an important effect on the performance of corrugated cardboard. In this paper, the non-linear finite element analysis of the fluted corrugated sheet in the corrugated cardboard based on software SolidWorks2008 was investigated. The obtained conclusions are as follow.

(1) According to the static pressure test, with the flute height H increased, the maximum stress in the models decreased and the maximum displacement increased.

(2) According to the static pressure test, with the arc radius of flute increased, the maximum stress in the models decreased and the maximum displacement increased.

(3) According to the static pressure test, with the increase of the flute angle θ, the maximum stress and maximum displacement in the models increase nonlinearly. The optimal flute angle θ could be 60° for corrugated board.

(4) According to the drop test, with the increase of flute height H, the maximum stress of goods on the upper board in the drop test decreased.

(5) According to the drop test, with the increase of flute angle, the maximum stress of the model decreases firstly and then increases. The maximum stress of the corrugated board bears is smallest when the flute angle θ reaches 60°. Therefore, the optimal flute angle θ could be 60° for corrugated board.

All the conclusions are consistent with experimental data or product standards.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Efficacy of dispersion of magnesium silicate (talc) in papermaking

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The understanding of the dispersion chemistry of papermaking grade fillers is as important as their effect on paper. Magnesium silicate (talc) is one of the major fillers used for papermaking. It is hydrophobic and chemically inert. The dispersion chemistry of talc of different particle sizes was studied with wetting agent (non-ionic triblock copolymer) and anionic dispersant (sodium salt of polyacrylic acid). Both wetting agent and dispersant were added in talc slurry separately and in combination. The dispersion behavior was studied through measuring the Brookfield viscosity. The wetted and dispersed talc was also added to paper to understand its effect on papermaking process and paper properties. Wetting and dispersion changed the colloidal charge chemistry of talc making it more anionic which reduced the talc retention in paper. Lowering the particle size of talc significantly improved the light scattering coefficient (LSC) of paper and decreased its retention. Controlling colloidal charge of papermaking suspension with cationic polyacrylamide polymer helped in protecting the retention of talc without affecting the LSC of both filler and paper.

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Efficacy of dispersion of magnesium silicate (talc) in papermaking

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Abstract The understanding of the dispersion chemistry of papermaking grade fillers is as important as their effect on paper. Magnesium silicate (talc) is one of the major fillers used for papermaking. It is hydrophobic and chemically inert. The dispersion chemistry of talc of different particle sizes was studied with wetting agent (non-ionic triblock copolymer) and anionic dispersant (sodium salt of polyacrylic acid). Both wetting agent and dispersant were added in talc slurry separately and in combination. The dispersion behavior was studied through measuring the Brookfield viscosity. The wetted and dispersed talc was also added to paper to understand its effect on papermaking process and paper properties. Wetting and dispersion changed the colloidal charge chemistry of talc making it more anionic which reduced the talc retention in paper. Lowering the particle size of talc significantly improved the light scattering coefficient (LSC) of paper and decreased its retention. Controlling colloidal charge of papermaking suspension with cationic polyacrylamide polymer helped in protecting the retention of talc without affecting the LSC of both filler and paper.

1. Introduction

Paper consists of not only cellulosic fibers but also considerable amounts of mineral fillers. Fillers are highly desirable in printing papers because they increase the light scattering, opacity and brightness, and generally improve printing properties. The mineral fillers for acid papers are talc, hydrous kaolin, calcined kaolin, precipitated silica and silicates, and titanium dioxide. For neutral and alkaline papers, layered magnesium silicate (talc), hydrous kaolin, calcined kaolin, ground calcium carbonate (GCC), precipitated calcium carbonate (PCC), silica and silicates, and titanium dioxide are used. The use of filler is important when opacity is needed at a low-basis weight; they are invaluable in packaging grades where low permeability is combined with opacity to protect food from light. The presence of fillers, however, affects fiber-to-fiber contact and reduces the paper strength (Wilson, 2006; Chauhan et al., 2012a). Other properties are improved rendering the paper useful for special

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purposes. Filler also decreases the energy demand in pulp and papermaking process due to lesser usage of fibrous mass (Dong et al., 2008; Chauhan et al., 2011). Loading of higher filler content in paper is always desirous by the papermaker due to decreasing cost and increasing optical properties.

The filler particles added to fibers suspended in water are not easily retained in the forming sheet, as they are too small to be entrapped mechanically. Additionally both filler and fibers are negatively charged, so they repel each other (Al-Mehbad, 2004). The properties of filler are linked with the ability of the same to refract and backscatter light through the surface of the sheet. If the filler is not evenly dispersed and flocculates in small clumps, then the optical efficiency of the filler is reduced. No filler is capable of yielding high light scattering for the development of brightness and opacity without having any detrimental impact on wet-web strength and physical properties of paper. The filler used for the development of brightness and opacity debonds fibers because of its inherent high surface area (Wilson, 2006).

Filler is supposed to be well dispersed prior to its addition to papermaking slurry in order to get its impact on light scattering power of both filler and paper. The light scattering primarily depends upon the particle size and shape of filler. For the particles of same shape, the higher the particle size the lower is the scattering coefficient. The good dispersion of filler may help in increasing the light scattering for the same type of filler. The dispersion behavior of talc powders has been reported in few literatures (Charnay and Lagerge, 2003; Goalard et al., 2006; Chauhan et al., 2012b). The role of dispersion science in pulp and papermaking process was reviewed by Rojas and Hubbe (2005). They explored the scientific principles that underlie the art of papermaking, emphasizing the state of dispersion of the fibrous slurries during various stages of the paper manufacturing process. The literature on dispersion of talc filler for use in papermaking is scarce.

The filler/pigment used in paper coating are dispersed well with suitable dispersing agents prior to their application on the paper surface, however they are added as such in paper. The effect of wetting and dispersion of filler in papermaking is not, so far, available in detail.

The most suitable wetting agent suggested in the literature is nonionic triblock copolymer. The triblock copolymer is having a central hydrophobic chain of poly(propylene oxide) flanked by two hydrophilic chains of poly(ethylene oxide) (Lee et al., 2010). It results in a complete removal of the bubble-induced attractive forces (Wallqvist et al., 2009). The widely used dispersing agent is sodium salt of anionic poly(acrylic acid) i.e. sodium polyacrylate. Sodium polyacrylate is a polymer with the chemical formula $[-CH_2-CH(COONa)-]_n$. It has the ability to absorb as much as 200–300 times its mass in water. Acrylate polymers generally are considered to possess an anionic charge. It does not adsorb to the basal plane of talc and affects the measured forces (Wallqvist et al., 2009).

Now-a-days calcium carbonate based fillers (GCC and PCC) are manufactured in situ and available in the pre-dispersed slurry form. They are mixed with some amount of dispersant to avoid the agglomeration of particles. This practice is not yet commercialized for talc ($Mg_3Si_4O_{10}(OH)_2$). This may be because of a comparatively higher particle size of talc fillers which is less favorable to particle agglomeration than the lower particle size calcium carbonate fillers. It is characteristically hydrophobic, generally inert and the softest mineral on earth. Because both sides of this structure expose an oxide surface, individual talc platelets are held together only by weak van der Walls forces (Fig. 1) (Trivedi, 1997). Compared to other silicates, talc is relatively hydrophobic due to the oxide surfaces (Trivedi, 1997; Ciullo and Robinson, 2003). The edge face is, however, hydrophilic as a result of the –SiOH and –MgOH groups where the surface potential is pH dependent (Mälhammar, 1990; Fuerstenau et al., 1988). Being hydrophobic in nature, proper dispersion of talc might be required before its addition in papermaking slurry. This may affect the light scattering and opacity of paper through properly dispersed particles.

These considerations are used in the present study. Five samples of talc with different particle size distribution have been chosen in order to understand their dispersion chemistry and the role of dispersed talc in papermaking.

2. Experimental

2.1. Materials

The bleached mixed hardwood chemical pulp was collected from an integrated pulp and paper mill in north India. The pulp furnish was 50% eucalyptus, 35% poplar and 15% bamboo. The initial freeness of the pulp measured on Canadian Standard Freeness (CSF) tester (Tappi test method T 227 om-09) was 620 ml which was decreased to 430 ml through refining in the PFI mill following the Tappi test method T 248 sp-00. Dry powders of talc filler with five different particle sizes were sourced from a talc manufacturer in north India. The talc fillers were designated as Talc-1, Talc-2, Talc-3, Talc-4, and Talc-5 based on the decreasing particle size. The nonionic triblock copolymer having a central hydrophobic chain of poly(propylene oxide) flanked by two hydrophilic chains of poly(ethylene oxide) and nominal molecular weight of 6300 Da was used as a wetting agent to wet the surface and remove the air from the surface of talc particles. The sodium salt of poly(acrylic acid) based anionic polymer (sodium polyacrylate) having a nominal molecular weight of 5100 Da was used as a dispersant. Both wetting and dispersing agents were procured from a chemical supplier in north India. The commercial grade medium to high molecular weight cationic polyacrylamide (CPAM) was procured from a chemical manufacturer in India, and used for the retention of filler and fiber fines.

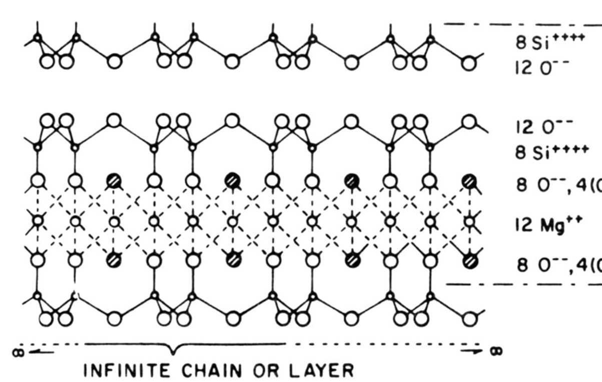

Figure 1 Molecular structure of pure talc mineral.

Table 1 Physico-chemical and optical properties of talc fillers of different particle size distribution.

Particular	Talc-1	Talc-2	Talc-3	Talc-4	Talc-5
ISO brightness, %	92.5	92.7	93.7	94.1	93.2
Ionic nature	Anionic	Anionic	Anionic	Anionic	Anionic
Colloidal charge demand, μeq/g	+1.1	+1.6	+2.0	+2.1	+2.1
Zeta potential, mV	−501	−373	−455	−410	−492
pH	9.0	9.2	9.3	9.1	9.1
Particle shape	Lamellar	Lamellar	Lamellar	Lamellar	Lamellar

2.2. Characteristics of talc fillers

The fillers were characterized for optical and physico-chemical characteristics; brightness, colloidal and surface charge, particle size distribution (PSD), and shape. The moisture free fillers were compacted in the dice with the help of arbor press. The filler dice was then used to measure the optical properties in brightness tester (Datacolor Spectraflash 300). Filler suspension (10% w/v) was filtered through a 300 μm screen and the pH of the filtrate was measured with the help of a pH meter. The colloidal charge or ionic behavior of 10% (w/v) slurry of fillers was examined on Mutek particle charge detector (PCD 03 pH). The surface charge on fillers was determined in the form of zeta potential on Mutek system zeta potential meter (SZP 06). About 500 ml filler sample (10% w/v) was taken and mixed thoroughly before measurement. The PSD of the fillers was measured using Laser scattering particle size distribution analyzer (Horiba LA950S2). The talc fillers were wetted with ethanol and then dispersed in deionized water to make 10% (w/v) slurry. In the case of Talc-3 filler, the particle size of filler was also measured after dispersing it in different manners i.e. in water only, with wetting agent, with dispersing agent, and with both wetting and dispersing agent. The measurement conditions in the analyzer were kept constant for all talc fillers. The particle shape of the fillers was determined by X-ray diffraction (Bruker AXS, D8 Advance, Switzerland) using Cu Kα radiation. The micrographs of fillers were taken on Field emission scanning electron microscope (Quanta, FEI, Czech Republic).

2.3. Wetting and dispersion of talc filler

Initially, the effect of agitation time on dispersion of talc filler was studied. The talc filler was dispersed in deionized water (no wetting agent and dispersant) for different time periods of 30, 60, 90 and 120 min in an emulsifier at 2000 rpm speed. Secondly, the dosage of wetting agent and dispersant were optimized based upon the viscosity behavior of talc slurry. The talc filler was first diluted with deionized water at 50% solids (w/v). The slurry was agitated in high speed emulsifier for around 30 min. The wetting agent was added to the diluted filler slurry, agitated for around 5 min and the rheology of talc slurry was measured in terms of Brookfield viscosity. A graph between dosage of wetting agent/dispersant and viscosity of talc slurry was plotted to get the minima of viscosity. The dosage was selected based upon the lowest viscosity of talc slurry. The optimized dosage of wetting agent and dispersant were then used together to completely disperse the talc filler.

2.4. Handsheet preparation and testing

The fillers were dispersed in water to 10% (w/v) slurry prior to the addition in the refined pulp stock of 1% consistency (w/v). The paper handsheets of 60 g/m^2 with target ash content of around 15% were prepared as per the Tappi test method T 205 sp-02. The ash content in paper was determined at 525 °C as per the Tappi test method T 211 om-93. The ash content and first pass ash retention (FPAR) were calculated with the following formula:

$$\text{Ash content in paper, } \% = \frac{\text{o.d. weight of ash in paper (g)}}{\text{o.d. weight of handsheet (g)}} \times 100 \tag{1}$$

$$\text{FPAR, } \% = \frac{\text{Ash in paper (\%)}}{\text{Filler added based on pulp and filler (\%)}} \times 100 \tag{2}$$

The light scattering coefficient of paper was measured on brightness tester (Datacolor Spectraflash 300) as per the Tappi test method T 519 om-02. The scattering coefficient of filler was calculated from the following formula:

$$S_{\text{sheet}} = S_{\text{unfilled sheet}}(1 - L) + LS_{\text{filler}} \tag{3}$$

where S is the light scattering coefficient and L is the filler loading amount.

3. Results and discussion

3.1. Physico-chemical and optical properties of talc fillers

The filler characteristics are important for the optical and structural developments in the paper matrix. All talc fillers were having almost comparable optical properties. They were anionic in nature which was indicated by their cationic colloidal charge demand and anionic zeta potential. The cationic charge demand was indirectly proportional to the particle size of talc filler. It was increased on decreasing the particle size, due to exposure of more oxide surfaces. All mineral fillers were alkaline in nature with a pH of around 9.0–9.2 (Table 1).

3.2. Particle size distribution and shape of talc fillers

The particle size distribution (PSD) and shape of fillers are the important factors responsible for the retention of filler and light scattering in paper. The PSD of Talc-1 was the broadest among all talc fillers followed by Talc-2, Talc-3, Talc-4 and

Talc-5. The particles of Talc-1, Talc-2, Talc-3, Talc-4, and Talc-5 fillers less than 10 μm were 56.9%, 76.9%, 92.5%, 93.3% and 95.6%, respectively. Similarly, the particles of Talc-1, Talc-2, Talc-3, Talc-4, and Talc-5 fillers less than 3 μm were 0.5%, 1.3%, 2.8%, 6.4% and 7.9%, respectively. The median particle size of Talc-1, Talc-2, Talc-3, Talc-4, and Talc-5 fillers was 9.3, 7.6, 6.0, 5.7 and 5.4 μm, respectively (Table 2). The particle shape of talc fillers measured with X-ray diffractometer was lamellar (Table 1).

3.3. Wetting and dispersion of talc filler

In order to get the positive effect of the filler particles on light scattering coefficient, they were dispersed in a different manner prior to their addition to paper. In our previous study, the effect of wetting and dispersion of talc filler of medium particle size (i.e. Talc-3) on papermaking was studied (Chauhan et al., 2012b). In this study too, we have used the nonionic triblock copolymer and sodium polyacrylate as wetting and dispersing agents, respectively, and have studied their effect on the dispersion of talc fillers of different PSD. It is known that because of the amphiphilic structure of the poly(acrylic acid) based dispersant, it can be used to increase the water solubility of hydrophobic substances such as talc. Due to the anionic charge on both dispersant and platelet talc, the dispersant was not adsorbed on the basal plane of talc, rather it would more likely be adsorbed on the hydrophilic edges of talc (Wallqvist et al., 2009).

Initially, Talc-3 filler was used to select the appropriate dosage of wetting and dispersing agent for the proper dispersion. As shown in Fig. 2, the viscosity of talc filler dispersed in water only was 234 cP (Chauhan et al., 2012b). The lowest viscosity of separately wetted and dispersed talc slurries was around 56 and 40 cP with the addition of 7 kg/t of wetting agent and 3 kg/t of dispersant in the talc filler, respectively. Thereafter, further increasing the dosage of wetting agent and dispersant did not affect the viscosity very much.

In order to analyze the combined effect of wetting and dispersing agent, wetting agent was first added in the talc slurry at a dosage of 7 kg/t on talc and agitated for 5 min. The dispersant was then added at three dosage levels, 3, 6 and 10 kg/t on talc. As shown in Fig. 3, it was observed that the combination of 7 kg/t of wetting agent and 3 kg/t of dispersant was sufficient enough to decrease the viscosity to its lowest level i.e. 24 cP (Chauhan et al., 2012b). The viscosity of talc slurry increased slightly on increasing the dosage of dispersant. Henceforth, the dispersion of talc filler was performed with the optimized dosage of both wetting agent and dispersant.

3.3.1. Micrographs of fillers

The literature shows that the talc has platelet/lamellar structure. This was further confirmed from the scanning electron micrographs of all talc fillers taken at 5000× magnification (Fig. 4). The micrographs also corroborate the difference in particle size of talc fillers measured through a particle size analyzer. The images of Talc-3 filler dispersed in water, wetting agent, dispersant, and wetting agent with dispersant taken from the Image analyzer are shown in Fig. 5. The images clearly indicated that there was no effect of dispersion method on the particle separation. The particles of Talc-3 filler were equally dispersed through using either of the dispersion techniques.

3.3.2. Particle size distribution of Talc-3 filler

It is obvious that the wetting and dispersion of mineral particles are always desirous to avoid the agglomeration of particles. It was observed that the PSD of Talc-3 filler wetted/dispersed in different manners was almost comparable. The median particle size of Talc-3 filler dispersed with water, wetting agent, dispersant, and wetting agent with dispersant was

Table 2 Particle size distribution of talc fillers.

Particulars	Abundance, %				
	Talc-1	Talc-2	Talc-3	Talc-4	Talc-5
< 20 μm	96.8	99.5	100	100	100
< 10 μm	56.9	76.9	92.5	93.3	95.6
< 7 μm	24.7	41.9	66.5	70.3	76.4
< 5 μm	7.1	14.5	29.7	36.2	42.9
< 4 μm	2.6	5.7	12.5	18.3	22.9
< 3 μm	0.5	1.3	2.8	6.4	7.9
< 2 μm	0.0	0.0	0.1	0.7	1.2
Median (D50), μm	9.3	7.6	6.0	5.7	5.4
Mean, μm	10.1	8.1	7.1	6.0	5.7

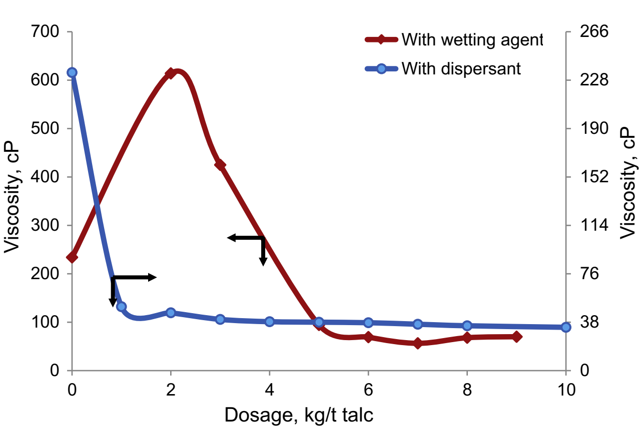

Figure 2 Viscosity behavior of Talc-3 filler treated with varying dosages of wetting and dispersing chemicals.

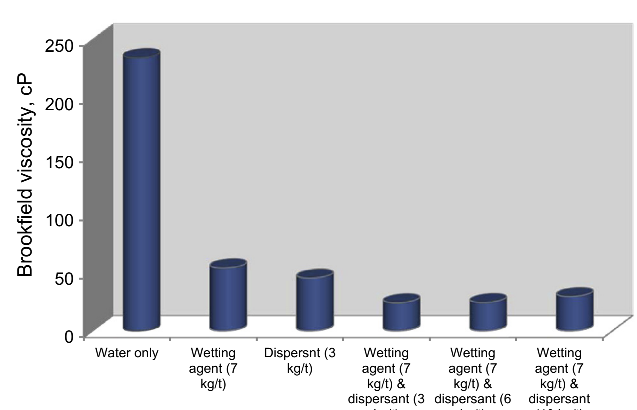

Figure 3 Effect of wetting and dispersing chemicals on viscosity of Talc-3 filler.

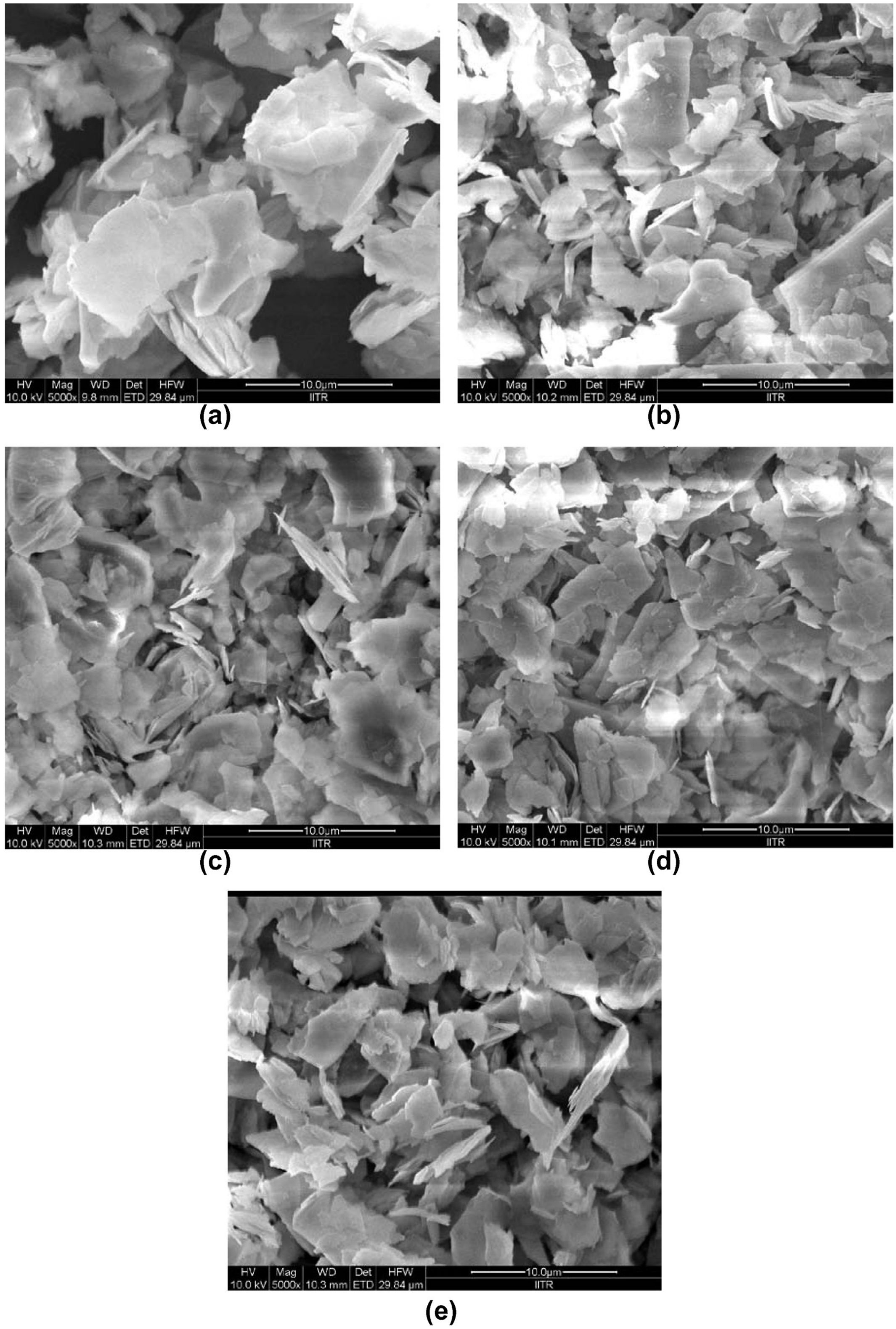

Figure 4 Scanning electron micrographs of talc fillers of different particle size distribution taken at 5000× magnification, (a) Talc-1, (b) Talc-2, (c) Talc-3, (d) Talc-4, and (e) Talc-5.

similar (6.0 µm) (Table 3). Under our experimental conditions, it was illustrated that the wetting and/or dispersion of talc filler did not accelerate the particle separation.

Similar results were presented by Wallqvist et al. (2009). They showed that the addition of poly(acrylic acid) did not affect the measured forces and it does not adsorb to the basal

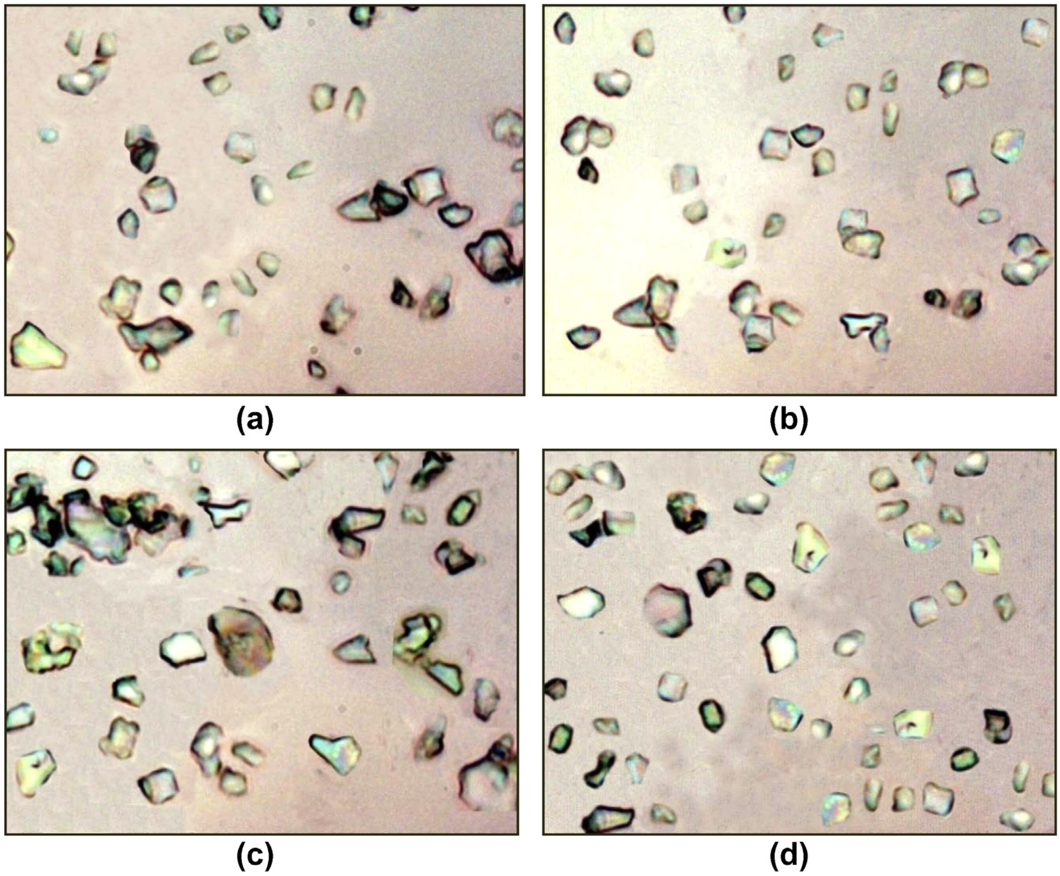

Figure 5 Micrographs of Talc-3 filler dispersed in different mediums taken from an Image analyzer at 1000 magnification dispersed with (a) water only, (b) wetting agent, (c) dispersant, and (d) wetting agent and dispersant.

Table 3 Particle size distribution of Talc-3 filler dispersed using different methods.

Particular	Abundance, %			
	With water only	With wetting agent[a]	With dispersant[b]	With wetting agent[a] and dispersant[b]
< 20 μm	100	100	100	100
< 10 μm	92.1	93.4	92.3	93.0
< 7 μm	65.8	68.3	66.8	67.6
< 5 μm	30.0	31.8	31.5	31.4
< 4 μm	13.1	14.0	14.2	13.9
< 3 μm	3.2	3.4	3.6	3.4
< 2 μm	0.2	0.2	0.2	0.2
Median (D50), μm	6.0	6.0	6.0	6.0
Mean, μm	6.4	6.3	6.4	6.3

[a] Wetting agent, 7 kg/t filler.
[b] Dispersant, 3 kg/t filler.

plane of talc. Moreover, the nonionic triblock polymer used as a wetting agent resulted in a complete removal of the bubble-induced attractive force.

Moreover, there was only one component affected by the wetting/dispersion that is colloidal charge of talc filler slurry. As the pH has an effect on the colloidal charge demand of filler, the latter was measured at 9.0–9.2 pH. The cationic colloidal charge demand of Talc-3 filler dispersed in water only was 2.0 μeq/g which increased slightly to 3.3 μeq/g in the case of Talc-3 dispersed using wetting agent. The anionicity of Talc-3 filler increased substantially in the case of its dispersion with the dispersing agent; the cationic colloidal charge demand increased to 24.2 μeq/g. These results indicated that the anionicity of the talc filler increased on the addition of dispersant. The use of talc filler of higher anionicity will ultimately increase the anionicity of the papermaking slurry and will reduce the filler retention due to more repulsion of anionic–anionic particles. This effect was confirmed from the results of first pass ash retention (FPAR) of Talc-3 filler dispersed in different manners. The FPAR of Talc-3 filler dispersed in water only was 41.1% which decreased to 38.8%, 25.0% and 23.4% when Talc-3 filler was dispersed with wetting agent, dispersant, and both wetting agent and dispersant, respectively (Fig. 6).

3.3.3. Effect of dispersion time on retention and light scattering coefficient of Talc-3 filler

The Talc-3 filler was dispersed in deionized water and agitated in an emulsifier (2000 rpm) for different time intervals. The talc slurry was agitated for 30, 60, 90 and 120 min, and was then added to the refined pulp stock. Paper handsheets of 60 g/m^2 were prepared with the target ash content of around 15%. It was observed that the ash retention as well as scattering

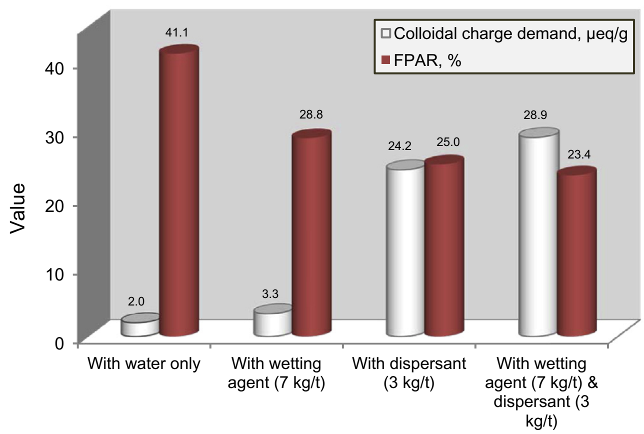

Figure 6 Effect of wetting and dispersing chemicals on colloidal charge and first pass ash retention of Talc-3 filler.

coefficient of both filler and paper were not affected by the change in the dispersion time. In all cases, the FPAR was 45.0–46.5%. The scattering coefficient of paper having 15.5% filler was 49.5 m^2/kg. The calculated scattering coefficient of Talc-3 filler was 123.0 m^2/kg (calculated using Eq. (3)). The scattering coefficient of paper sheet with no filler content was 36.0 m^2/kg (Fig. 7).

3.4. Effect of particle size of talc filler on FPAR and scattering coefficient

The retention of filler particles increases on increasing the particle size of filler and vice versa. Our study also showed a similar trend. The filler retention decreased with decreasing the particle size of talc filler. It was highest in the case of coarsest filler i.e. Talc-1 followed by Talc-2, Talc-3, Talc-4 and Talc-5. The reduction in FPAR on wetting and dispersion of filler was also dependent upon their particle sizes. The rate of decrease in FPAR for Talc-1, Talc-2, Talc-3, Talc-4 and Talc-5 fillers was 18.8%, 35.8%, 45.4%, 44.8% and 45.0%, respectively (Table 4). There was an enormous difference in the rate of reduction in FPAR of Talc-1, Talc-2 and Talc-3 fillers whereas that of Talc-4 and Talc-5 filler was almost comparable to Talc-3.

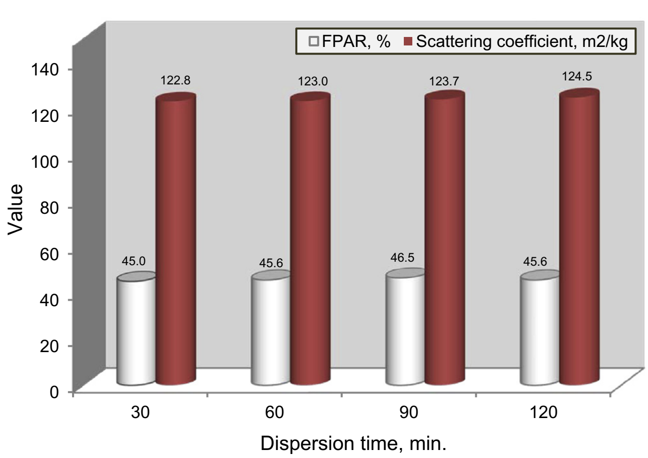

Figure 7 Effect of dispersion time of Talc-3 filler in water on first pass ash retention and scattering coefficient of talc.

Table 4 Effect of dispersion mechanism of different talc fillers on filler retention, and light scattering coefficient of talc filler and paper.

Particular		FPAR, %	Light scattering coefficient of paper, m^2/kg	Light scattering coefficient of talc, m^2/kg
Talc-1	A[a]	50.1	44.9	88.3
	B[b]	45.3	46.5	110.2
Talc-2	A[a]	42.9	48.8	126.8
	B[b]	41.7	50.1	137.5
Talc-3	A[a]	39.3	52.4	148.1
	B[b]	40.8	44.5	89.3
Talc-4	A[a]	29.1	47.4	108.9
	B[b]	23.4	48.2	127.1
Talc-5	A[a]	20.1	50.3	140.0
	B[b]	21.5	51.2	151.4

[a] With water only.
[b] With wetting agent, 7 kg/t filler and dispersant, 3 kg/t filler.

This showed that the particle size of filler has a great role in papermaking. If PSD of filler is broader, more fillers can be retained in paper however the light scattering will be decreased and vice versa.

The effect of PSD of talc fillers was examined through their dispersion with water only and the optimized dosage of wetting agent along with dispersant. In these experiments no retention aid was used. The reason was to observe the effect of particle size and dispersion medium on as such filler retention. The filler addition levels were selected to get around 15% ash content in paper. The FPAR vis-à-vis ash content in paper was lower in the case of fillers wetted and dispersed as compared to those dispersed in water only. The FPAR of Talc-1, Talc-2, Talc-3, Talc-4 and Talc-5 fillers dispersed in water only was 50.1%, 45.3%, 42.9%, 41.7% and 39.3%, respectively which decreased to 40.7%, 29.1%, 23.4%, 23.0% and 21.6%, respectively when the fillers were wetted and dispersed (Table 4). In order to get the same ash content in paper, the filler addition levels were increased in the case of fillers wetted and dispersed. Under our experimental conditions, there was no change in scattering coefficient of paper and filler in both the dispersion techniques. This was true for all talc fillers. The scattering coefficient of filler vis-à-vis paper increased on decreasing the particle size of filler due to more number of solid-air interfaces.

In order to observe the effect of retention aid polymer on the retention of talc filler dispersed using different methods, the Talc-3 filler was added in refined pulp along with cationic polyacrylamide retention aid (200 g/t pulp). The ash content in paper, FPAR and scattering coefficient of paper were measured. The target ash content in paper was around 15–16%. When no retention aid was used the FPAR of Talc-3 filler dispersed with water, and wetting and dispersing agent was 42.9% and 23.4%, respectively which increased to 49.2% and 50.0%, respectively with the addition of retention aid polymer. The cationic retention aid was helpful to maintain the charge chemistry of the papermaking slurry which, in turn, was helpful to maintain the same FPAR for differently dispersed Talc-3 fillers. Under our experimental conditions, the

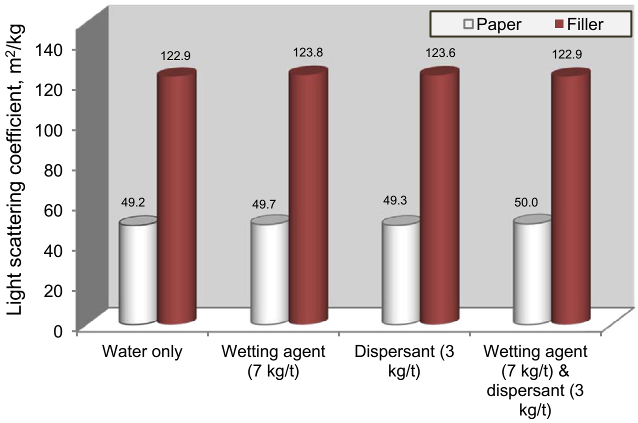

Figure 8 Effect of wetting and dispersing chemicals on scattering coefficient of paper and Talc-3 filler with addition of CPAM.

dispersion technique was not having any effect on scattering coefficient of filler which was comparable for all Talc-3 fillers (~50 m^2/kg). As the scattering coefficient of filler was comparable and the ash content in paper was also same, the scattering coefficient of paper (~123 m^2/kg) was comparable with the loading of differently dispersed Talc-3 fillers in paper. The dispersion technique was not having any effect on filler retention and light scattering coefficient of paper and talc filler (Fig. 8).

4. Conclusions

The amphiphilic structure of the sodium polyacrylate enhanced the dispersion of hydrophobic talc. The wetting and dispersing chemicals added in talc changed the rheology of talc slurry through reducing the viscosity. They also reduced the filler retention due to an increase in anionicity and cationic colloidal charge demand. The particle size distribution of talc was not affected with the addition of wetting and dispersing agents. The decreased filler retention could be compensated using poly(acrylamide) based retention aid polymer in the pulp stock. There was no effect of wetting and dispersing chemicals on the light scattering power of either paper or filler. Due to this behavior it may be concluded that the wetting and dispersing chemicals are not essential for the dispersion of talc for use in papermaking. The talc dispersed in water and agitation for around 30 min in the high speed agitator could be used efficiently for papermaking applications. The light scattering coefficient of both talc and paper was increased on reducing the particle size of talc. However, the retention of talc of a lower particle size was critical and had an inversely proportional relationship with particle size. The decrease in the filler retention in paper was due to higher specific surface area of a lesser particle size talc filler. The retention aid polymer helped in maintaining the charge chemistry of papermaking slurry and increased the filler retention.

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Natural and Sustainable Raw Materials for Sanitary Napkin

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The present paper highlights the issue of non-biodegradability of personal hygiene product and how it has become a serious environmental concern all over the world. Emphasis is given to use naturally available absorbent fibres such as organic cotton, banana fibre, jute, bamboo etc., which are widely available and biodegradable in nature having low carbon footprint which not only makes it eco-friendly but also reduces the cost of sanitary pad. And to enhance the retention of fluid cellulose based hydro gel can be used instead of synthetic super absorbent polymer. Sustainability of hygiene product can be attained by replacing petroleum based raw material with an eco-friendly one.

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Abstract

The present paper highlights the issue of non-biodegradability of personal hygiene product and how it has become a serious environmental concern all over the world. Emphasis is given to use naturally available absorbent fibres such as organic cotton, banana fibre, jute, bamboo etc., which are widely available and biodegradable in nature having low carbon footprint which not only makes it eco-friendly but also reduces the cost of sanitary pad. And to enhance the retention of fluid cellulose based hydro gel can be used instead of synthetic super absorbent polymer. Sustainability of hygiene product can be attained by replacing petroleum based raw material with an eco-friendly one.

Keywords: Biopolymer; Biodegradability; Natural fibre; Sustainable material

Introduction

Currently, the world is facing a very big problem of carbon footprint of feminine hygiene product. As there is a huge amount of non-biodegradable material dumped in landfill, which releases harmful gasses into to the atmosphere. India being a developing country, with a population of 1.34 billion, out of which 323.6 million female between the age group of 15-49 [1]. If we consider that 10% of Indian women uses disposable sanitary pad then each individual will generate at least half a kilo of waste a month. In that way, 10% of the female population in India will generate 16180 tons of waste every month. In order to deal with it, we need to focus on developing a more sustainable product by choosing the raw material having low carbon footprint. Material which are used in feminine hygiene product are derived from natural resource mostly petroleum based which cannot be reused or compost and at the same time over-exploitation of these resources have to be stopped otherwise nothing will be left for our future generation. We have to find an alternative raw material that is sustainable in nature, without compromising on the functional requirement of the product [2].

Conventional structure and material used in sanitary napkin

In order to classify the raw material for sanitary pad, first we have to understand the basic mechanism how a sanitary pad works, what are their requirements and accordingly we have to select the same. Sanitary pad comprises of multilayered structure in which each layer have specific function to perform. It consists of three main layers the top sheet, absorbent core and barrier sheet (Figure 1).

a) Top sheet: It is designed to transfer fluid quickly from the top sheet to secondary layers. The top sheet contains thermoplastic fibers to prevent capillary collapse of this layer, and small amount of hydrophilic absorbent fibre to allow fluid to absorb. Commercially available top sheet are made up of polypropylene fibre [3].

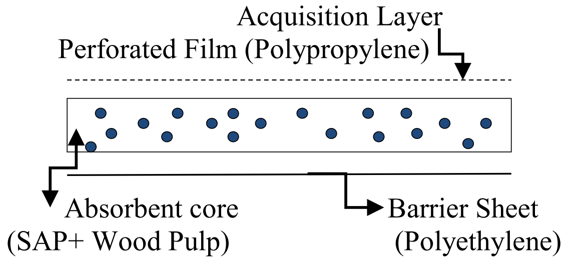

Figure 1: Conventional structure and material used in sanitary napkin.

b) Absorbent core: It is interposed between top sheet and barrier layer main function is to absorb and retain the fluid. Moreover, to have comfort, absorbent core need to be thin, soft and pliable. The core was made up of wood pulp traditionally but there is constant effort to replace it by air laid wood pulp and SAP to improve its absorption efficiency. SAP turns the absorbed liquid into a jelly-like state so that it would not retract back [4,5].

c) Barrier sheet: It seals the fluid from staining or leakages. It is a breathable but fluid impermeable film made up of polyethylene [6].

Few components of sanitary pad will disintegrate and be attacked by the bacteria in a public or private sewage disposal system but polyethylene or polymeric films used as a barrier sheet remain intact as this polymer are inert and are not broken down by bacteria and thus pollutes the environment.

Alternative sustainable raw material to disposable hygiene product

The following raw materials can be used to replace existing material used in sanitary pads.

Raw material for top sheet: Organic cotton as top sheet is one the commonly advised raw material for sanitary napkin because of its non-irritant, skin friendly and superior liquid retention properties. It is soft and breathable which gives comfort and dryness. Cotton wicks away moisture and keeps skin dry and its pH compatibility makes it skin friendly [7,8]. Organic cotton are cultivated from non-treated Genetically Modified (GMO) seed and is grown using method and materials having low impact on environment that is without any use of synthetic agricultural chemical such as fertilizer and pesticides. The crop needs to be certified by a certifying body or the USDA. As cotton fibre comes directly from nature, it degrade when disposed [9].

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Recently Lenzing have come up with a new fibre called TENCEL® Biosoft which is a lyocell fibre, fully biodegradable and hydrophobic in nature with extra softness that makes it an excellent choice to be used as top sheet. Tencel is incredibly comfortable because of its even surface and has excellent moisture transfusion through capillary action and wicking [10]. It has a distinctive fibril configuration; fibrils are like fine hair like structure. The submicroscopic channel between the individual fibrils control absorption and liberate moisture. Thus, these tiny fibrils assure best possible transportation of moisture. The ideal moisture management of this cellulosic fiber is responsible for the reduced bacteria growth [11].

Raw material for absorbent core: The primary requirement of sanitary pad is absorbency of menstrual fluid. Therefore, selection of core material totally depends on the absorbency and retention property of fibre. *Bamboo fibre* is a novel alternative raw material for absorbent core. Bamboo absorbs and wicks water 3-4 times better than cotton and reduces odor as the fiber is filled with multiple micro-holes and micro-gaps. Bamboo is soft to feel as the fibre is naturally round in shape it does not require any chemical treatment to smoothen it. An additional significant property of bamboo is the anti-microbial agent that is bamboo kun naturally present in it [9,12]. In one of the research work done by IIT Kharagpur, *Jute fibre* was used to substitute cotton pad. And it was found that jute fibre is one of the best replacements for cotton as healthy production of jute in eastern India facilitates this fiber with 65-70% cellulose content and high water affinity. Jute is having lower price than cotton fibre and abundant in north-east of India. The additional advantage of jute fibers to cotton is that the fiber length is much shorter in the case of jute easing the preparation of cellulose pulp [13,14].

Sanitary pads from banana fibre were developed by SHE (Sustainable Health Enterprises) a non-profitable NGO, their intention was to make affordable, quality and eco-friendly sanitary napkins available to girls and women in developing country. Banana is a natural absorbent fibre; the key reason is its natural porosity. Banana fibre is an eco-friendly fibre like jute fibre. It is bio-degradable and has no negative effect on environment and thus can be categorized as eco-friendly fibre. Banana fibre is mainly cultivated for fruit. The fibres are harvested from the plant's trunk, which are normally unused and go to waste [15,16].

Studies have been done to replace cotton fillers by flax spinning waste to be used as an absorbent core of sanitary pad, which is much cheaper than pure cotton as well as highly absorbent and have natural cellulosic composition. It was observed that absorbency of fibre increased after scouring and bleaching. To give antimicrobial activity flax absorbent core was treated with 70% aloegel extract which showed satisfactory antimicrobial and antifungal potential [17].

To further improve the absorbency of sanitary pad cellulose based hydrogel were manufactured to imitate synthetic superabsorbent polymer by a sustainable process using a nontoxic cross linking agent. Cellulose based hydro gel are based on sodium carboxy methylcellulose (NaCMC) and hydroxyethyl cellulose (HEC) cross linked with divinylsulfone (DVS). It can swell like SAP and shows fluid retention under centrifugal load. These has been possible by introducing microporous structure into the hydrogel ,by introducing phase inversion desiccation technique in acetone, which increases the retention and swelling kinetics due to capillary effect. Main advantage of cellulose-based hydrogel over current SAP is that they are environment friendly, biodegradable and excellent biocompatibility [18,19].

Raw material for barrier sheet

Widely used protective film in hygiene products are polyethylene and polyurethane, which are non-biodegradable plastic. This plastic material can be replaced by bio-based plastic prepared from starch. Many research works on bio-plastic are in progress. Biodegradable plastic can be a bio-derived and biodegradable/compostable (e.g., polylactides, polyhydroxyalkanoates) or a fossil fuel-derived and biodegradable (e.g., polycaprolactone) [20]. Nonabsorbent fibres such as polypropylene, ethylene etc. are derived from petroleum resources, which have high carbon footprint and non-biodegradable in nature. An alternative sustainable replacement of petroleum- based fibre is the PLA (Poly Lactic Acid) fibre, which is derived from cornstarch using latest biotechnology. It is most promising thermoplastic biodegradable polymer material. In order to enhance the functional property of PLA, TiO_2/Ag^+ is added which give an antimicrobial property to PLA. After adding a copy of inorganic nano-TiO_2/Ag^+, the antibacterial rate of PLA films to Coli bacillus, *Staphylococcus* and Mildew were exceeded 95% [21]. Non-toxic, anti-bacterial and biodegradable characteristic of modified PLA makes it an excellent choice to be used in hygiene industry. The only drawback at present is the high cost of synthesis of this high molecular weight PLA that is 5-6 times more than conventional plastic [22].

Conclusion

Nature has encompassed every solution within itself. With more and more use of natural fibre in hygiene product will make it eco-friendly. Use of natural fibre in sanitary pad will reduce the cost of the product will lower accessible to low income group women. As the product is biodegradable, prevent non-biodegradable waste generation. We as a technologist have to find a sustainable way so that we endow a better world for next generation.

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Characterizing bacterial communities in paper production—troublemakers revealed

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Biofilm formation is a major cause of reduced paper quality and increased down time during paper manufacturing. This study uses Illumina next-generation sequencing to identify the microbial populations causing quality issues due to their presence in biofilms and slimes. The paper defects investigated contained traces of the films and/or slime of mainly two genera, Tepidimonas and Chryseobacterium. The Tepidimonas spp. found contributed on average 68% to the total bacterial population. Both genera have been described previously to be associated with biofilms in paper mills. There was indication that Tepidimonas spp. were present as compact biofilm in the head box of one paper machine and was filtered out by the paper web during production. On the other hand Tepidimonas spp. were also present to a large extent in the press and white waters of two nonproblematic paper machines. Therefore, the mere presence of a known biofilm producer alone is not sufficient to cause slimes and therefore paper defects and other critical factors are additionally at play. For instance, we identified Acidovorax sp., which is an early colonizer of paper machines, exhibiting the ability to form extracellular DNA matrices for attachment and biofilm formation.

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Characterizing bacterial communities in paper production—troublemakers revealed

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Abstract

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KEYWORDS

biofilms, diversity, indicators, metagenomics, microbial contamination

1 | INTRODUCTION

Paper manufacturing requires a large volume of water, which, today, is permanently recycled at the various stages during the production process. As such, bacterial growth and biofilm formation in the paper machines are inevitable. These recycled waters are a main cause of slime production related to the presence of bacteria which leads to smell, discoloration, and irregularities in the paper formation and web breaks (Blanco, Negro, Gaspar, & Tijero, 1996; Kolari, 2007). To mitigate these effects the microbial population is continuously treated with biocides (Blanco, Negro, Monte, Fuente, & Tijero, 2004). But when bacterial colonization is out of control, the consequences are variable paper quality, increasing down time, and higher maintenance costs (Kolari, Nuutinen, Rainey, & Salkinoja-Salonen, 2003).

Various bacterial species may be responsible for biofilm formation in paper machines. *Deinococcus geothermalis* is a primary colonizer leading to thick, synergistic biofilms with different bacilli species (Kolari, Nuutinen, & Salkinoja-Salonen, 2001). Furthermore, *Tepidimonas* spp., belonging to the Betaproteobacteria, were identified directly in the paper process already at the early stage of biofilm formation (Tiirola, Lahtinen, Vuento, & Oker-Blom, 2009). Several bacterial classes and genera are known to populate the waters and raw products in paper machines. Vaisanen et al. (1998) analyzed 390 cultivable aerobic bacteria from process steps and raw materials and demonstrated a vast bacterial diversity. A thorough phylogenetic analysis of 404 cloned 16S rRNA gene amplicons was performed by Granhall et al. (2010), who analyzed two different paper mills that showed similar overall profiles but still unique individual populations. Bacteroidetes (including the genus *Chryseobacterium*) predominated, but several other Phyla were identified such as members of the Firmicutes (including *Clostridium* sp.), Alpha—and Gammaproteobacteria, but not Betaproteobacteria.

Most of the published research focuses on cultivable bacteria from smoothly running paper machines. However, in this study we use, to our knowledge for the first time, Illumina next-generation sequencing to analyze the total bacterial community, including the uncultivable bacteria, to compare the communities present in the process waters of four paper machines at the same mill. The exemplified paper mill in this report experienced recurring problems in one of the four paper machines. We identified and compared the bacterial population found directly in the irregularities on the paper sheets consistently produced by this machine. Such a thorough process analysis allows us to identify process steps harboring the problematic microbial populations, and thus, in principle, enabling a more efficient strategy to be followed in the future for their control.

2 | MATERIALS AND METHODS

2.1 | Sampling and enumeration of cultivable bacteria

All samples were provided from a northern German paper manufacturer (undisclosed) and are listed in Table S1. Defective paper samples were derived from paper machine 1 (PM1). Additionally, waters (press water, white water, and clear filtrate) were sampled from all four paper machines (PM1, PM2, PM3, and PM4) located at the same site. Figure 1 represents a simplified scheme of the process and water circulation, and illustrates the three types of water (press water, white water, and clear filtrate) sampled. The total viable count (TVC) of water samples was determined by plating 0.1 ml of a 10-fold dilution in phosphate buffered saline (PBS) (pH 7.4, Sigma-Aldrich) onto Tryptic Soy Broth Agar (TSA) (Sigma-Aldrich). Plates were incubated for 48 h at 30°C prior to enumeration of colony-forming units (cfu). Counts with 1–9 cfu/plate and 10–99 cfu/plate were reported as $>10^2$ cfu·ml^{-1} and $>10^3$ cfu·ml^{-1}, respectively. Higher counts were reported as $>10^4$ cfu·ml^{-1} when colonies remained separated or $>10^5$ cfu·ml^{-1} when colonies fused to bacterial lawns. No bacterial viable count was done for paper samples.

2.2 | Propidium monoazide treatment and DNA extraction

For better accessibility of bacteria in slurries, bacteria were separated from turbid insoluble compounds, such as minerals and pigments, using density gradient centrifugation. For this, 1-ml water samples were overlaid onto 0.3 ml of 1.6-mol·l Histodenz™ (Sigma-Aldrich) in 2-ml microcentrifuge tubes and centrifuged at 10 000 rcf (relative centrifugal force; 1 rcf = 9.81 m·s^{-2}) for 6 min with slow deceleration. The upper phase, including the interphase was pelleted in a new tube at 10,000 rcf for 3 min. For propidium monoazide (PMA) treatment (Nocker, Cheung, & Camper, 2006), the pellet was resuspended in 0.5-ml sterile PBS and PMA added to a final concentration of 0.05 mmol·l, placed on ice and exposed to a 500 W halogen light source for 4 min to cross-link the PMA with the free DNA. This ensures that DNA from dead cells is not amplified in the following PCR reaction. The PMA-treated samples were then pelleted again. From these final pellets, DNA was isolated using the DNeasy Blood & Tissue Kit (QIAGEN, Hilden, Germany) according to the manufacturer's instructions.

To identify the causative bacterial community for the defect paper, we also analyzed the bacterial population present at the defect sites on the paper sheets. For these paper samples, DNA was isolated using the PowerSoil® DNA Isolation Kit (MO BIO Laboratories, Inc., Carlsbad, USA) also according to the manufacturer's instructions.

2.3 | Bacterial DNA quantification

DNA was quantified by real-time PCR targeting the 16S rRNA gene as described previously (Clifford et al., 2012). Briefly, in a 25-µl final reaction volume the primer pair rtPCR_f (ACTCCTACGGGAGGCAGCAGT) and rtPCR_r (TATTACCGCGGCTGCTGGC) were used (Clifford et al., 2012) at 500 nmol·l, 10% (v/v) of template DNA, and FastStart SYBR Green Master Mix (Roche cat. No. 4673484001). Using the Thermocycler RotorGene (Qiagen) and the sequential thermal profile (1) 10 min at 95°C followed by (2) 45 cycles of 20 s at 95°C, 56°C, and 72°C, the concentration of bacterial DNA was quantified relative to a DNA standard curve consisting of a known concentration of *Escherichia coli* K1 genomes (approx. 3000 16s rRNA copies per µl).

2.4 | 16S rRNA amplicon sequencing and data analysis

For library generation the V3 and V4 region of 16S rRNA region was amplified by PCR with 30 cycles from the extracted DNA. PCR protocol, primer, and library generation were performed exactly as described by (Illumina (2013) using MiSeq Reagent Kit v3 600-cycles (Illumina, San Diego CA., Cat. No. S102-3003). Data were acquired using the MiSeqDx System MiSeq and metagenomic analysis of the raw data was performed using the in-system software MiSeq Reporter. For taxonomic classification, the Greengenes Database files were used (Mc Donald et al., 2012). In Greengenes an OTU refers to the terminal level at which the sequence is classified.

3 | RESULTS AND DISCUSSION

The exemplified paper mill experienced recurring problems in one of the four paper machines (PM1). The final paper showed defects in terms of irregular spots and holes of approximately 1 cm diameter due to slime deposits in the web during continuous line production. Consequently, the machine had to be stopped and cleaned more frequently than the other paper machines (PM2, PM3, and PM4) leading to costly down time and maintenance. Biofilms have been described as a reason for such slimes and consequently the resulting paper defects (Lahtinen, Kosonen, Tiirola, Vuento, & Oker-Blom, 2006).

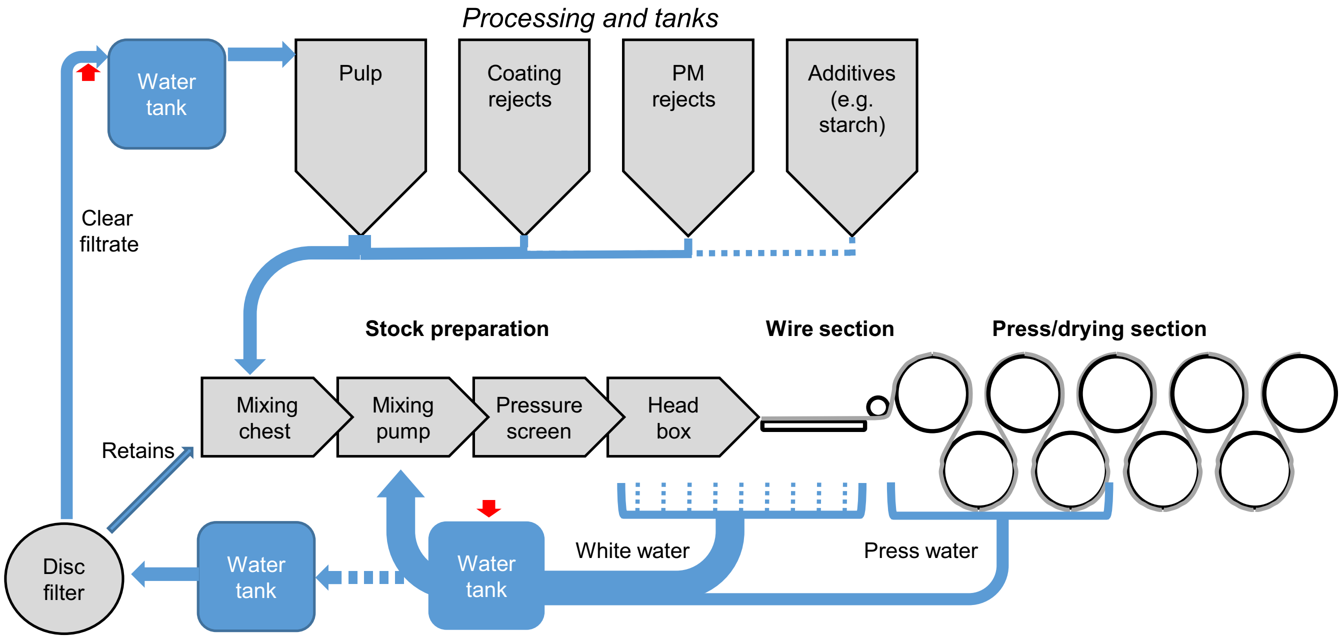

FIGURE 1 Simplified scheme of water circulation in a typical paper machine displaying the three sampling points: clear filtrate, white water, and press water. Red arrows indicate sites of biocide addition. Remark: waters from the clear filtrate water tanks of all paper machines are used for pulping

TABLE 1 Quantification of bacterial contents in paper samples by 16S real-time PCR relative to a standard consisting of genomic DNA equivalents of *E. coli* K1

Paper sample no.	Genome equivalents cm^{-2}
1	$2{\cdot}10^6$
2	$5{\cdot}10^5$
3	$5{\cdot}10^5$
4	$1{\cdot}10^6$
5	$4{\cdot}10^5$
6	$7{\cdot}10^5$
7	$6{\cdot}10^5$
8	$5{\cdot}10^5$
9	$1{\cdot}10^5$

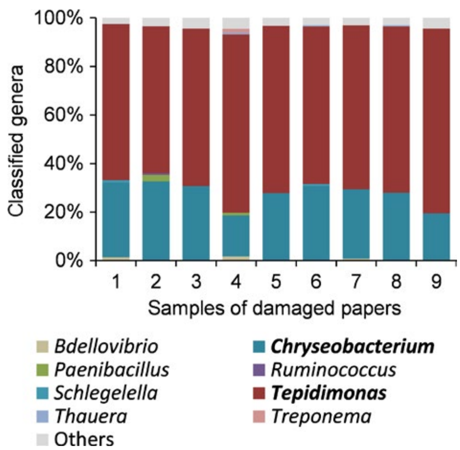

FIGURE 2 Bacterial population, identified by 16S rRNA metagenomics analysis, at sites of damage in the final paper of PM1

To identify the causative bacterial community we analyzed the bacterial population present at the paper defect site. The DNA was isolated from the paper samples and the amount of bacterial DNA quantified by 16S rDNA PCR (Table 1). All paper samples contained a high amount of bacterial DNA equivalent to approximately 10^5 to 10^6 *Escherichia coli* genomes per cm^2. Using the purified DNA, the bacterial population was further characterized and quantified by Illumina 16S rRNA metagenomics analysis (Illumina, 2013). Interestingly, all nine samples analyzed showed the exact same genus distribution with two extraordinarily predominant genera; *Tepidimonas* and *Chryseobacterium* (Figure 2). These two genera represented at least 90% (average 95%) of all classified genera in all paper samples analyzed, whereby *Tepidimonas* contributes by far the majority with at least 60% (average 68%). Out of the more than 80 *Chryseobacterium* species that exist (Parte, 2014), only one *Chryseobacterium soli* was found here. For *Tepidimonas* four different species out of five known to date were found (Albuquerque, Tiago, Veríssimo, & Da Costa, 2006). *Tepidimonas* has been associated previously with biofilms in different paper mills (Tiirola et al., 2009). Particularly at early stages of biofilm formation, this genus represented more than 40% of the population as quantified by length-heterogeneity PCR analysis of 16S rRNA (Tiirola et al., 2009). The other genus, *Chryseobacterium*, and related genera from the Bacteroidetes have been identified by T-RLFP in biofilms of paper mills (Granhall et al., 2010) and they have been described to form slimes (Oppong, King, & Bowen, 2003). Our data point toward *Tepidimonas* spp. and *Chryseobacterium* sp. as causative agents for the defects in the paper sheets. It was very

TABLE 2 Quantification of bacterial counts in water samples

A	Total viable count [cfu·cm^{-3}]			
	PM1	PM2	PM3	PM4
Clear filtrate	>10^3	>10^3	>10^3	>10^4
White water	>10^4	>10^5	>10^4	>10^4
Press water	>10^4	>10^4	>10^5	>10^4
B	**Total DNA [genome equivalents cm^{-3}]**			
	PM1	**PM2**	**PM3**	**PM4**
Clear filtrate	$2{\cdot}10^3$	$4{\cdot}10^3$	$6{\cdot}10^4$	$5{\cdot}10^3$
White water	$3{\cdot}10^4$	$3{\cdot}10^4$	$1{\cdot}10^5$	$4{\cdot}10^4$
Press water	$3{\cdot}10^3$	$1{\cdot}10^4$	$5{\cdot}10^3$	$5{\cdot}10^3$
C	**PMA-treated DNA (live) [genome equivalents cm^{-3}]**			
	PM1	**PM2**	**PM3**	**PM4**
Clear filtrate	$1{\cdot}10^3$	$3{\cdot}10^3$	$6{\cdot}10^3$	$5{\cdot}10^3$
White water	$1{\cdot}10^4$	$2{\cdot}10^4$	$1{\cdot}10^4$	$3{\cdot}10^3$
Press water	$8{\cdot}10^2$	$1{\cdot}10^4$	$3{\cdot}10^3$	$2{\cdot}10^3$

(A) Total viable count as colony-forming units (cfu) per cm^3. (B) Total bacterial DNA. (C) DNA from live bacteria. For live fraction, the samples were PMA-treated prior DNA isolation and quantification to remove DNA from dead bacteria. Bacterial DNA was quantified by 16S real-time PCR relative to a standard consisting of genomic DNA equivalents of *E. coli* K1.

surprising, though, that the bacterial diversity in the samples was extremely low, reduced to mainly these two genera.

As the problem with defect irregularities on the paper was mainly on PM1 (as informed by the paper mill), we assessed the bacterial communities in the water circulations of all paper machines to compare them and identify differences. The clear filtrates are well filtered and used to prepare the raw material (e.g. pulp fiber) and, as such, may enter the circulation of all four paper machines. The two recycled waters from the wire section (white water) and from the press section (press water) are turbid waters that are, for the majority, recycled continuously for wet end fiber stock preparations.

The samples taken from the recycled waters from the paper machines showed a moderate bacterial contamination, as determined by culturing methods and quantitative PCR of total DNA (Table 2). In addition to the total DNA extraction from the waters, we treated the samples prior to DNA extraction with PMA to assess the fraction of DNA arising from live bacteria (Table 2). The PMA treatment removed the free DNA from dead cells and reduced the DNA values measured in all samples compared to the total DNA fraction.

The total and PMA-treated (live) DNA samples were subsequently used to identify and quantify the genera present in the bacterial community (Figure 3). There were only minor differences apparent between the genus diversity determined using total DNA and PMA-treated DNA. The proportions of the genera varied between the two DNA preparation methods, but the main genera show up in both samples, as shown in Figure 3. The number of abundant genera (i.e. at least 0.5% of all classified genera) correlates between the live and total DNA sample with linear correlation coefficient of $R^2 = 0.82$. Table S2 displays the number of the abundant genera identified in the different samples as well as the calculated Shannon's diversity (Shannon & Weaver, 1946), evenness, and statistical data of the analysis.

Even though all samplings were from the same mill, the bacterial diversities were, nonetheless, unique for each paper machine and sample type. This confirms previous observations showing the unique bacterial population in different paper machines and mills (Granhall et al., 2010). Nevertheless, several similarities between the machines and samples became apparent.

The most distinct bacterial population appears in the samples from PM2, with members of the Gammaproteobacteria predominating in all waters where the genera *Pseudomonas* and *Azorhizophilus* are dominating. PM1, PM3, and PM4 mainly harbor members of the Bacteroidetes and Betaproteobacteria. Abundant genera besides *Chryseobacterum*, *Tepidimonas*, and *Acidovorax* which are discussed below were *Clostridium*, *Pseudomonas*, and *Steroidobacter*. The genus *Pseudomonas* is vast and consists of many environmental bacteria that can be basically found in every habitat (Peix, Ramírez-Bahena, & Velázquez, 2009). The genus *Clostridium* was mainly found in the white water of PM3. They are anaerobic and endospore forming and were found in diverse environments (Rodloff, 2005). Of the genus *Steroidobacter* found in PM1, only one species could be found was *Steroidobacter denitrificans*. It was isolated from wastewater of a wastewater treatment plant (Fahrbach et al., 2008).

Interestingly, the two genera *Chryseobaterium* and *Tepidimonas*, identified as causative factors for bad paper quality from PM1, could also be identified in all other paper machines. Especially in the water cycle of PM3 and PM4 the two genera represented the majority of all the classified genera. In PM1, these two genera were a minority in the two immediate recycled turbid waters (white water and press water).

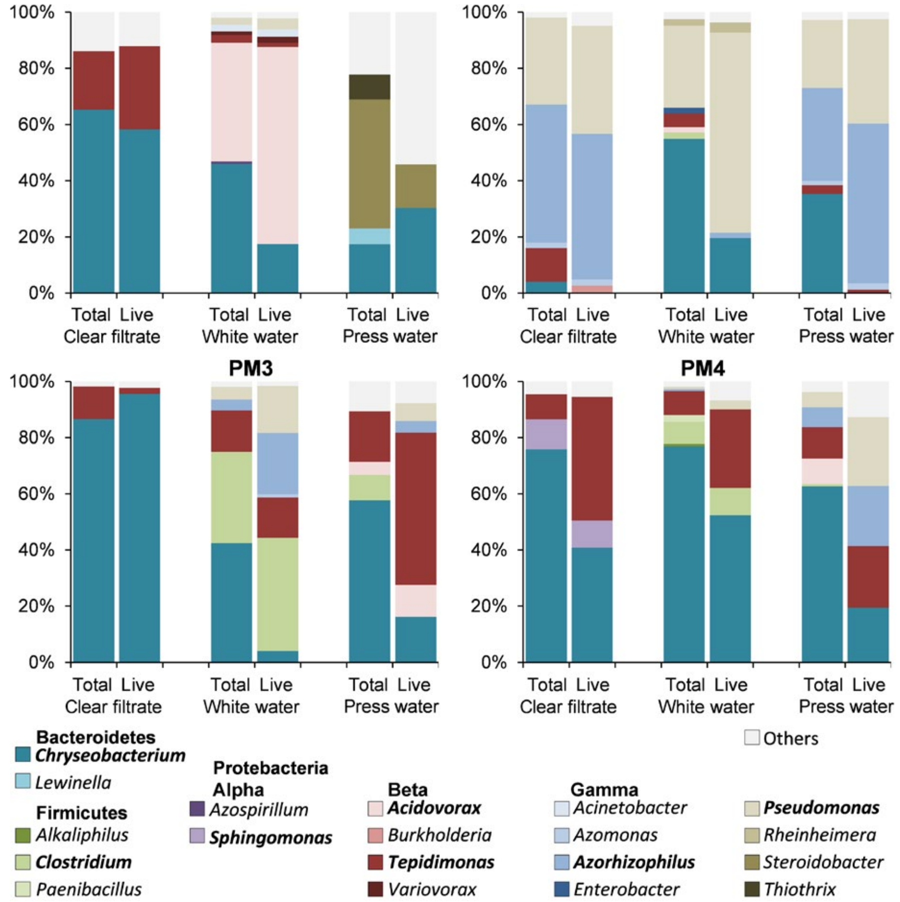

FIGURE 3 Bacterial population, identified by 16S rRNA metagenomics analysis, in process waters of the four different paper machines (PM1-PM4) located at the same paper plant. For each sample, the **total** bacterial population and the PMA-treated fraction, representing the **live** bacterial population, were quantified

On the other hand, the clear filtrate, which is heavily reduced in particles, and represents water leaving the PM1 to be reused for all paper machines, showed predominantly the two troubling genera. Different possibilities could account for the seemingly contradicting results. First, PM1 experienced more frequent maintenance periods due to the defective paper sheets. These different frequencies could influence the bacterial population. The nearly complete absence of *Tepidimonas* spp. in the white and press water was, however, very surprising, as the defect problems remained after maintenance. Even more surprising is that although *Tepidimonas* spp. were the most abundant genera in slime deposits on the paper sheets of PM1, they were found to be present in all clear filtrates used for the raw material preparation (e.g., pulping) and abundantly identified in all waters of the smoothly running paper machines PM3 and PM4. One explanation could be that *Tepidimonas*, together with *Chryseobacterium*, grow as compact biofilms and slimes in PM1 exclusively due to an unknown trigger. This would then lead to defect paper due to deposit of the slime. When these slimes dislocate, they remain in the paper web. As such, by far the majority of bacterial cells present in the biofilm (i.e., *Tepidimonas* sp.) would be filtered out by the paper web and not enter the white and press water. Such a trigger for film formation could be the identified species *Acidovorax*, mainly identified in PM1 white water. This genus was shown to be an important colonizer of the head box adapted to the available carbon sources (Kashama, Prince, Simao-Beaunoir, & Beaulieu, 2009) and abundant in activated sludge communities (Willems & Gillis, 2005). It is known for its aggregating abilities due to generation of an extracellular DNA matrix for attachment (Heijstra, Pichler, Liang, Blaza, & Turner, 2009). As such *Acidovorax* sp. contribute to young biofilms (Liu et al., 2012). It is very well possible that *Chrysobacterium* sp. and *Tepidimonas* spp. require the extracellular matrix produced by *Acidovorax* sp. to generate compact slimes, and, as such, cause the paper defects. The bacteria cells of *Acidovorax* sp., however, are not part of the slime. This is consistent with Kolari et al. (2001) who showed that *Bacillus* sp. uses *Deinococcus geothermalis* as an auxiliary factor to form biofilms in paper machines. Interestingly, some *Bacillus* species then emit heat-stable metabolites in order to inhibit the growth of *Deinococcus geothermalis*. This could explain that we did not find *Acidovorax* sp. in our samples as it was suppressed by the two later colonizers. Another explanation is that *Acidovorax* sp., as a primary colonizer is present in PM1 due to the more frequent maintenances and that the trigger for the biofilm formation is due to another factor.

Although this study offers an overview of the likely contributory bacterial factors in slime formation, besides not investigating replicate samples, a vital remaining factor also not investigated here is the substrate and environment upon which the slime is formed. Surface morphology, surface chemistry, and physical conditions such as normally stagnant regions in water flows occasionally exposed to shear flow and/or presence of vibration encouraging detachment, as well as oxygenation and moisture levels, exposure to biocide concentration variations, etc., all contribute to the impact of biofilm and slime in sensitive processes such as papermaking.

As a conclusion we can say that as *Tepidimonas* spp. was found in all paper machines, the development of problematic slimes is obviously not only dependent on the mere presence of given bacteria in a system. Auxiliary factors generating the necessary environment, possibly other bacterial species, can be as important. A thorough process analysis for the bacterial communities present helps to shed light on critical factors controlling slime formation. In the present case, targeting *Chrysobacterium* sp. and *Tepidimonas* spp. would bring little success as they are present in all paper machines, and even in the clear filtrate. However, the established bacterial population at the process steps is indicators for the given environmental conditions. Such differences as seen between the paper machines (PM1-4) are recommended as the points of action to change the environmental conditions for the good (e.g. aeration, stirring adaption). The success of modifications to a favorable microbial community and environment can again be followed by population analysis.

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CONFLICT OF INTEREST

No conflict of interest declared.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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Multi-layer nanopaper based composites

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Native cellulose nanofibrils (CNF) were prepared from bleached birch pulp without any chemical or enzymatic pre-treatment. These CNF were modified by adsorption of a small amount of watersoluble polysaccharides and used to prepare nanopapers, which were processed into composites by lamination with an epoxy resin and subsequently cured. The results were compared to the properties of composites prepared using bacterial cellulose nanopapers, since bacterial cellulose constitutes highly pure and crystalline cellulose. It was found that both types of nanopapers significantly improved both the thermal stability and mechanical properties of the epoxy resin. As anticipated, addition of only 2 wt% of watersoluble polysaccharides efficiently hindered crack propagation within the nanopaper and significantly improved the tensile strength and work of fracture compared to composites containing a conventional nanopaper reinforcement. The mechanical properties of the composites thus reflected the improvement of the nanopaper properties by the polysaccharides. Moreover, it was possible to predict the properties of the final composite from the mechanical performance of the nanopapers.

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ORIGINAL PAPER

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Abstract Native cellulose nanofibrils (CNF) were prepared from bleached birch pulp without any chemical or enzymatic pretreatment. These CNF were modified by adsorption of a small amount of water-soluble polysaccharides and used to prepare nanopapers, which were processed into composites by lamination with an epoxy resin and subsequently cured. The results were compared to the properties of composites prepared using bacterial cellulose nanopapers, since bacterial cellulose constitutes highly pure and crystalline cellulose. It was found that both types of nanopapers significantly improved both the thermal stability and mechanical properties of the epoxy resin. As anticipated, addition of only 2 wt% of water-soluble polysaccharides efficiently hindered crack-propagation within the nanopaper and significantly improved the tensile strength and work of fracture compared to composites containing a conventional nanopaper reinforcement. The mechanical properties of the composites thus reflected the improvement of the nanopaper properties by the polysaccharides. Moreover, it was possible to predict the properties of the final composite from the mechanical performance of the nanopapers.

Keywords Nanocellulose · Bacterial cellulose · Epoxy resin · Nanocomposite

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Introduction

During the last decades natural fiber composites have gained renewed attention due to environmental issues associated with conventional composites produced from synthetic materials (Moon et al. 2011; Blaker et al. 2014; Mariano et al. 2014). Even though progress was made in recycling of high performance composites, these types of materials still pose significant waste issues (Montrikittiphant et al. 2014; Pimenta and Pinho 2011). Thus, composites based on renewable resources, utilizing clean and cheap production routes have been proposed as an alternative (Lee et al. 2012c). Among the most promising approaches identified for the production of high performance renewable composites was the use of cellulose nanofibrils as reinforcement for polymers (Lee et al. 2014a).

Recently, cellulose nanofibrils (CNF) with diameters at the nanoscale received much attention due to their outstanding chemical and mechanical properties (Chen et al. 2010; Lee et al. 2012a; Klemm et al. 2011). They were utilized for a wide range of applications (Klemm et al. 2011), such as membranes (Mautner et al. 2014, 2015), flame-retardant and fire-protection applications (Carosio et al. 2015, 2016; Liu and Berglund 2013) and in particular for the production of composites (Blaker et al. 2011; Lee et al. 2009, 2012b c, 2014b; Nogi and Yano 2008; Lee and Bismarck 2012; Eichhorn et al. 2010; Pommet et al. 2008; Wan et al. 2006). Accordingly, numerous approaches to utilize CNF in composites have been proposed and tested. One approach to utilize the potential of CNF was to directly reinforce a soft matrix with small amounts of CNF, which resulted in improved strength of the composites provided that the affinity between matrix and cellulose fibrils was high enough. Mikkonen et al. (2011) utilized 5–15 wt% of CNF to reinforce spruce O-acetyl galactoglucomannan films while Peng et al. (2011) and Hansen et al. (2012) reinforced xylan films. Additionally, chitosan based and thermoplastic starch composites were reinforced by CNF (Tomé et al. 2013): Addition of 10–20 wt% of CNF was sufficient to improve the thermal stability and mechanical properties of the composites, i.e. the Young's modulus and the tensile strength improved significantly at the expense of the ductility of the composite. To manufacture hierarchical composites, cellulose microfibers were combined with CNF (Lee et al. 2012a, 2014c), but also utilization of CNF as sole reinforcing agent was considered a possible track en route to high performance composites (Eichhorn et al. 2010).

The best results have been obtained using a biomimetic approach; introducing a very high loading of CNF in a small amount of a soft polymer. While the CNF matrix provides stiffness and strength, the role of the soft polymer is to dissipate energy and hinder crack propagation, thus improving toughness. This ultimately aims at exceeding the mechanical properties of the individual constituents of the composite. For example, a cationic block-co-polymer was combined with highly negatively charged CNF, resulting in synergistic effects (Wang et al. 2011; Sehaqui et al. 2013). Unfortunately, this led to the removal of water from the CNF gel due to ionic interactions between cationic polymer chains and anionic fibrils resulting in fibril aggregation. CNF aggregation easily leads to defects in the composite, therefore it is very important to control the interactions between the individual fibrils and avoid aggregation (Benítez et al. 2013). Thus, approaches utilizing non-ionic interaction between a polymer matrix and cellulose have been suggested, e.g. CNF were combined with poly(ethylene glycol) grafted carboxymethyl cellulose (Olszewska et al. 2013a, b). Furthermore, bacterial cellulose (BC) was combined with hydroxyethyl cellulose (Zhou et al. 2009). Within these systems, the contact points between fibrils during film formation were lubricated by the water-swollen polysaccharides, leading to the formation of strong films. Further aligning the fibrils did substantially improve the strength and stiffness of the composite in one direction (Sehaqui et al. 2012).

While there have been extensive efforts to prepare thin nanopapers and composites from CNF, there are only a few reports where these nanopapers have been used to prepare (nano)paper based laminated composites to utilize the CNF properties. This would be of outmost practical importance. The use of nanopapers as reinforcement for polymers was first demonstrated by Yano (Yano et al. 2005; Nakagaito and Yano 2005). Henriksson and Berglund (2007) later prepared nanopaper-composites with a water-soluble melamine–formaldehyde resin while Lee et al. (2012c), Ansari et al. (2014) and Aitomäki et al. (2016) manufactured epoxy composites by vacuum infusion and impregnation, respectively. However, as of yet, not much research has focused on the effect of the nanopaper properties on composite properties. We hypothesize that the properties of the nanopaper reinforcement strongly affect the properties of the composite in multi-layer laminates. It would be very desirable to have a process at hand in which the mechanical properties of final multi-layer composites were defined by the mechanical performance of the nanopaper base.

It was previously found that adding only 2 wt% of water-soluble polysaccharides to a suspension of CNF significantly improves the dry and wet strength of CNF nanopapers (Lucenius et al. 2014). In this study, we aimed to make use of this increased nanopaper strength for production of multi-layer, laminated paper based composites with improved mechanical and thermal stability. Furthermore, it was our aim to demonstrate a process resulting in predictable nanocomposite properties. Nanocomposites were prepared by lamination of nanopapers. The production of these nanopaper laminates and their characterization are reported. Furthermore, composites based on bacterial cellulose (BC) nanopapers were produced as control and compared with the CNF nanopaper composites. The reasons behind the observed effects were discussed.

Experimental

Materials

Cellulose nanofibrils (CNF) were prepared by disintegration of unmodified never dried industrial bleached birch pulp. The pulp was passed six times through a high-pressure fluidizer (Microfluidics, M-110Y, Microfluidics Int. Co., Newton, USA) following a procedure described previously (Österberg et al. 2013). The CNF had diameters ranging between 5 and 100 nm but the majority of the fibrils were in the range of 5–20 nm with a few larger fibril bundles being present. The length of the fibrils was a few micrometers. No loss of mass was observed during the fibrillation process. Commercially available bacterial cellulose was kindly supplied by fzmb GmbH (Bad Langensalza, Germany) in the form of wet pellicles containing 92 wt% water. The diameter of BC was found to be approximately 50 nm with fibril lengths of up to several micrometers (Lee and Bismarck 2012).

Two types of water-soluble polysaccharides (WSPS) were introduced into the CNF network. Commercial guar gum galactomannan (GG, $M_w > 1000$ kDa) from Sigma Aldrich (Lot#041 M 0058 V, Pcode 10011170894) was used after enzymatic modification. Spruce galactoglucomannan (GGM, Picea abies, M_w 20–60 kDa) was extracted from the process water of a Finnish pulp mill in an industrial-scale isolation trial after ethanol precipitation (Xu et al. 2008). Enzymes were used to hydrolyze and oxidize GG. Endo-1,4-β-mannanase (Lot 00803, from Aspergillus niger, EC number 3.2.1.78, 42 U mg^{-1}) was purchased from Megazyme (Wicklow, Ireland), galactose oxidase (GO, G7400, 3685 U g^{-1}, EC 1.1.3.9), catalase (from bovine liver, C30, 22,000 U mg^{-1}) and horseradish peroxidase (HRP, P8250, type II, 181 U mg^{-1}) from Sigma-Aldrich.

Epoxy resin (Araldite LY 556) and amine hardener (XB 3473) were purchased from Mouldlife (Suffolk, UK). The water used for all experiments was deionized and further purified in a UV unit (Synergy Millipore, Molsheim, France). $NaNO_3$ and $NaBD_4$ were purchased from Aldrich and used as received.

Methods for CNF modification, nanopaper and composites production and testing

Hydrolysis and oxidation of GG

Endo-1,4-β-mannanase was used to partially hydrolyze GG. GG was dissolved in deionized water to produce a 1.0% (w/v) solution, the enzyme added and the solution incubated at 40 °C in a water bath for 4 h. In order to deactivate the enzyme it was heated to 100 °C for 10 min. The samples were centrifuged at 5000 rpm and the supernatant was collected and freeze-dried.

Hydrolyzed GG was enzymatically oxidized (OGG) whereby the dosage of the enzymes was based on the amount of galactose present in the GG sample: 1.50 units (U) of GO, 150 U of catalase and 0.9 U of HRP per mg of galactose (Lucenius et al. 2014; Parikka et al. 2010). 1% (w/v) solutions of GG were stirred in the presence of the enzymes at +4 °C for 72 h. Afterwards the sample was heated to 90 °C while mixing in order to inactivate the enzymes.

Determination of the molecular weight and the degree of oxidation of GG

The molecular weight (M_w) of GG hydrolyzed with mannanase was determined using size exclusion chromatography (SEC). M_w was calculated using a dn/dc value of 0.15 mL g^{-1}. The hydrolyzed GG was dissolved in 0.1 M $NaNO_3$ by stirring for 7 d and filtered through a 0.45 µm filter. The method is described in detail by Parikka et al. (2010).

Gas chromatography mass spectrometry (GC–MS) was used to determine the degree of oxidation (DO). Briefly, the samples (1 mg of polysaccharide) were deuterium labelled with $NaBD_4$, precipitated and acid methanolyzed. GO was used to selectively oxidize the galactosyl units of GG. The degree of oxidation was calculated as described in literature (Parikka et al. 2010).

Nanopaper preparation

To avoid nanofibril aggregation, the CNF suspension was diluted to 0.8 wt% (105 mL, corresponding to a dry mass of 0.84 g) and mixed overnight using a magnetic stirrer. To this suspension, 2 wt% (based on CNF dry content) of water soluble polysaccharides OGG or GGM, respectively, were added and further stirred for 24 h to ensure homogeneity (Lucenius et al. 2014). Sequential filtering and pressing (Österberg et al. 2013) was used to prepare the CNF-WSPS nanopapers. CNF-nanopapers with grammages of 60 g m^{-2} were prepared.

Nanopapers from BC were prepared as previously reported (Mautner et al. 2015; Lee et al. 2012c). Briefly, the BC pellicles were first cut into small pieces (with a length of approximately 5–10 mm) and blended (Breville VBL065-01, Oldham, UK) for 2 min at a consistency of 0.2 wt% in deionized water to produce a homogeneous suspension of BC-in-water. These suspensions were then vacuum-filtered onto a cellulose filter paper (VWR 413, 5–13 µm pore size, Lutterworth, UK). The wet filter cake was wet-pressed under a weight of 10 kg between blotting papers (3MM Chr VWR, Lutterworth, UK) for 5 min to further remove excess water. These wet filter cakes were then consolidated and dried in a hot-press (25-12-2H, Carver Inc., Wabash, USA) under a compression weight of 1 t for 1 h at 120 °C by sandwiching the wet filter cakes between fresh blotting papers and metal plates. BC-nanopapers with grammages of 50 g m^{-2} were prepared.

Preparation of nanopaper based composites

Composites were manufactured by laminating nanopapers with a two-component epoxy resin. Commercially available epoxy resin Araldite LY 556 plus 23 phr amine hardener XB 3473 were mixed and degassed under vacuum at 80 °C for 10 min. Two nanopapers (diameter 120 mm) were laminated using a K Printing Proofer (RK PrintCoat Instruments Ltd, Hertfordshire, UK) at room temperature by applying a 50 µm layer of epoxy resin in between two nanopapers. After lamination the nanopaper-epoxy laminate was sandwiched between two Teflon films in a custom-made mold and placed into a hot-press. The hot-press was heated to 120 °C. When reaching this temperature the sandwich was pressed at 2 t for 2 h. Afterwards the temperature was increased to 180 °C for an additional 2 h. The composite was de-molded after cooling under pressure to room temperature. From the final composites, strips with dimensions of 40 × 5 mm^2 were cut with a lab paper cutter.

Mechanical properties of the composites

Dynamic Mechanical Analysis of the composites was performed with a G2 RSA (TA Instruments, Eschborn, Germany) in three point bending mode. Specimens sized 40 × 5 mm^2 were cut from the composites and tested between −50 and 250 °C at 3 °C min^{-1} and a frequency of 1 Hz, an applied strain of 0.05% and a span distance of 25 mm.

Tensile properties of the composites were determined on at least five specimens for each material at 25 °C and 50% RH using a 5969 Dual Column Universal Testing System (Instron, Darmstadt, Germany) equipped with a 1 kN load cell. The thickness of the composites was measured for each specimen before each test at ten different spots using a digital micrometer (705–1229, RS components, Corby, UK). The gauge length was 20 mm and the testing velocity 0.5 mm min^{-1}.

Morphology of the composites

The morphology of CNF-GGM composite films was studied using a high resolution scanning electron microscope (JEOL JSM-7500FA, Tokyo, Japan) in the Nanomicroscopy center at Aalto University and a Benchtop SEM (Jeol JCM-6000 Neoscope) in Vienna. The samples were freeze-dried in liquid nitrogen and fractured in half using tweezers while in the liquid nitrogen bath. Dust and loose particles were removed from the samples by blowing with nitrogen. A thin layer of gold/palladium (Emitech K100, Aalto) or gold only (JEOL JFC-1200 Fine Coater, Vienna) was sputtered on the sample surface to ensure sufficient electrical conductivity.

Thermal degradation behavior of nanopapers and composites

The thermal degradation behavior of nanopapers and composites in nitrogen and air, respectively, was investigated using a high resolution modulated TGA (Discovery TGA, TA Instruments, Eschborn, Germany). A sample size of approximately 5 mg was used. The samples were heated from 30 to 650 °C at a heating rate of 10 °C min^{-1} and a gas flow rate of 25 mL min^{-1}. The onset of degradation was computed to be the temperature at which the mass loss rate was exceeding 0.2% per °C.

Results and discussion

A small amount of water-soluble polysaccharides (WSPS) as low as 2 wt% was introduced into the fibril network of non-pretreated CNF nanopapers and their influence on the thermal and mechanical performance of laminated nanopaper-epoxy composites evaluated. The polysaccharides studied were the mannans GGM and GG, which contain ca. 10 and 40% terminal α-D-galactosyl residues, respectively. These residues are directly attached to the C-6 of the mannosyl units of the backbone (Wielinga 2009). GG was hydrolyzed to reduce the molecular weight and enzymatically oxidized at the C-6 position of the mannosyl units to improve the mechanical performance (Lucenius et al. 2014). The effect of the polysaccharides used to modify the CNF and the differences between BC, constituting highly pure and crystalline cellulose, and modified CNF on the nanopaper and composite properties are discussed.

Structure and properties of the WSPS and nanopapers

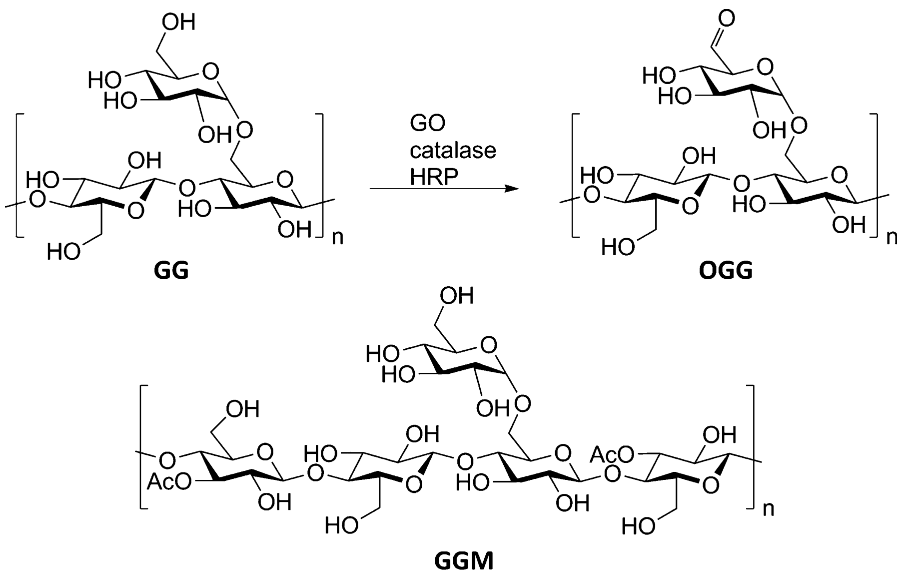
WSPS GGM was utilized in its unmodified state, whereas low molecular weight GG was prepared by partial hydrolysis with β-mannanase (Lucenius et al. 2014). The M_w of the hydrolyzed GG, as determined by size exclusion chromatography, was approximately 30 kDa as compared to 1000 kDa before hydrolysis (Wielinga 2009).

Hydrolyzed GG was subsequently oxidized (Scheme 1) with galactose oxidase (GO), catalase and horseradish peroxidase (HRP) (Parikka et al. 2010). The degree of oxidation (DO) of oxidized galactosyls in OGG was 50% (OGG-50) and 80% (OGG-80), respectively. The total amount of oxidized carbohydrates in hydrolyzed GG was 20 and 31%, respectively, and the total relative amount of oxidized galactosyls in the final modified nanopaper was found to be 0.375 and 0.60% of total carbohydrates, respectively. The backbone of GG remained unmodified due to the selective oxidation of the galactosyls, facilitating good compatibility with cellulose. Furthermore, the viscosity of the OGG solutions was low at both degrees of oxidation, enabling good mixing with the CNF suspension. Extensive mixing was used to ensure homogeneous distribution of WSPS in the CNF suspension. Nanopapers with grammages of 60 g m^{-2} were produced from CNF with and without 2 wt% of GGM or OGG, respectively, and from BC (50 g m^{-2}) using a simple papermaking process (Mautner et al. 2015). The final thickness of the nanopapers was 60 ± 5 μm for (modified) CNF and 50 ± 5 μm for BC nanopapers.

The tensile strength (88 MPa) of unmodified CNF nanopapers improved by more than 50% by CNF modification with oxidized GG (135 MPa) or GGM (141 MPa). This took place at the expense of stiffness, as shown by the slight decrease of the modulus from 9 GPa for unmodified CNF to 7.9 GPa for oxidized GG. For GGM (8.7 GPa) on the other hand no significant modulus decrease was observed. This was expected for WSPS modified nanopapers, in which WSPS act as plasticizer between stiff CNF, enhancing the ductility of the nanopaper in accordance with previous results (Lucenius et al. 2014; Olszewska et al. 2013b). During film formation from aqueous suspensions, the WSPS form a water-swollen dissipative layer on the CNF surface (Lozhechnikova et al. 2014; Eronen et al. 2011), thus enhancing the dispersibility of CNF. This is crucial to avoid CNF aggregation and defects in the final nanopaper resulting in improved mechanical properties. For BC nanopapers, a Young's modulus of 8.3 GPa and a tensile strength of 144 MPa were measured, which are values typically found for BC nanopapers prepared without prior removal of fibril aggregates (Lee et al. 2012c).

Multi-layer epoxy-nanopaper composites

Multi-layer composites were produced by a laminating technique impregnating (modified) CNF as well as BC nanopapers with a two-component epoxy resin. Resulting CNF composites had thicknesses around 100 μm and a fibril content of around 80 vol%. For BC composites the thickness was around 90 μm and the fibril content around 80 vol%. The reduced thickness of the composites was explained by further compaction of the nanopapers in the compression step



Scheme 1 Structures and modification of used polysaccharides. *(O)GG* (oxidized) guar gum galactomannan, *GGM* galactoglucomannan

during composite production. The mechanical performance of laminated nanopaper-epoxy composites as a function of temperature was evaluated by means of DMTA in three point bending mode.

The nanopaper-epoxy composites, as exemplarily shown for a BC and a CNF-OGG 80 composite in Fig. 1, exhibited the typical behavior of stiff, high glass transition thermosets; the modulus decreases slightly with increasing temperature and tanδ stays constant at a very small value. The CNF nanopaper based composites exhibited slightly lower modulus compared to BC nanopaper based composites with a stronger decrease at elevated temperatures. It was shown that these composites can be used up to almost their degradation temperature (see below) without passing the glass transition region of the epoxy matrix. The pure, cured epoxy resin follows the same principal trend up to 170 °C, but has a significantly lower storage modulus. The storage modulus at 20 °C was 2.54 GPa compared to around 17 GPa for nanopaper composites. However, at 170 °C the storage modulus of the epoxy resin decreased significantly, while tanδ increased indicating the onset of the glass transition. The glass transition temperature (T_g), taken as the maximum of tanδ, was 196 °C. Thus the introduction of nanopapers into an epoxy resin matrix not only improved mechanical properties, but also increased the application temperature range significantly. No T_g of neither BC nor CNF composites could be detected up to the onset of the degradation temperature around 250 °C, at which the composites still had a storage modulus of around 10 GPa.

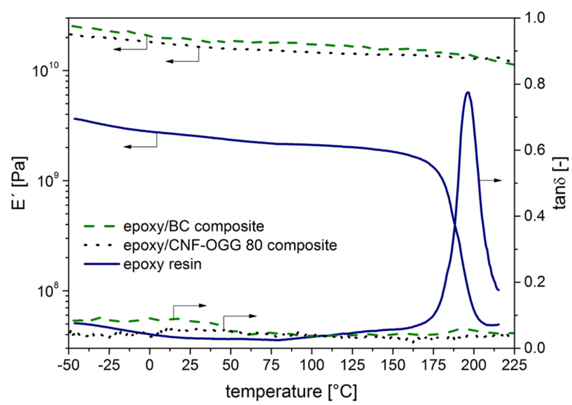


Fig. 1 Storage modulus E′ and loss factor tanδ as function of temperature for cured epoxy resin films (*blue full line*), an epoxy-CNF-OGG 80 composite (*black dotted line*) and an epoxy-BC composite (*green dashed line*). (Colur figure online)

The storage modulus at 20 °C was used to assess the influence of different WSPS on the mechanical performance of laminated nanocomposites (Table 1). As already shown for (modified) nanopapers (Lucenius et al. 2014), also the modulus of the composites depended on the type of polysaccharide introduced into the nanopaper. Composites containing an unmodified CNF nanopaper reinforcement had a storage modulus of 20 GPa, whereas for composites containing WSPS modified CNF nanopapers it was slightly lower, indicating the capacity of WSPS to act as

Table 1 Results of DMTA and tensile tests of BC and (modified) CNF-epoxy composites: Storage modulus at 20 °C, Young's modulus, tensile strength, strain at break and work of fracture

Sample	Storage modulus (GPa)	Tensile strength (MPa)	Young's modulus (GPa)	Strain at break (%)	Work of fracture (MJ m^{-3})
Epoxy	2.54 ± 0.05	36.1 ± 1.7	1.6 ± 0.1	4.16 ± 0.39	0.87 ± 0.12
Epoxy + CNF	20.0 ± 2.4	84.6 ± 4.3	12.2 ± 0.5	0.88 ± 0.09	0.34 ± 0.03
Epoxy + CNF/OGG-50	17.2 ± 1.0	89.8 ± 3.2	12.2 ± 0.5	0.78 ± 0.09	0.35 ± 0.03
Epoxy + CNF/OGG-80	17.4 ± 0.6	107.1 ± 6.1	10.7 ± 0.4	1.23 ± 0.17	0.63 ± 0.09
Epoxy + CNF/GGM	17.4 ± 0.2	116.8 ± 4.5	12.0 ± 1.0	1.17 ± 0.12	0.69 ± 0.11
Epoxy + BC	18.5 ± 0.5	150.8 ± 9.3	9.0 ± 0.1	2.76 ± 0.29	2.68 ± 0.41

lubricant. For BC nanopapers, a storage modulus of 18.5 GPa was measured, thus being in between the CNF nanopapers with and without WSPS modification.

In addition to DMTA, tensile tests were performed to determine the ultimate tensile strength, tensile modulus, strain at break and work of fracture. The work of fracture can be considered to be an indicator of the toughness of the composites. Representative stress–strain-curves from tensile tests of (modified) CNF nanopaper based composites are shown in Fig. 2 and all results are collected in Table 1.

The ultimate tensile strength was determined to be 85 MPa for the epoxy composite reinforced by two pure CNF nanopaper layers, compared to 36 MPa for the pure epoxy resin. Addition of OGG with a DO of 50% to the CNF did not significantly influence the tensile strength, while a DO of 80% for OGG led to a significantly improved tensile strength of the nanocomposites. This dependency on the DO was as to be expected (Lucenius et al. 2014) and showed that only a sufficiently high DO leads to an improved tensile strength. This can be explained by the low total amount of oxidized galactosyls in the composite, whereby oxidized galactosyls create hemiacetal cross-links between hydroxyl and aldehyde groups of CNF and WSPS, which is likely to be the reason for stronger nanopapers as intermolecular crosslinks formed between fibrils. The higher the degree of oxidation was, the higher the tensile strength of CNF nanopapers (Lucenius et al. 2014) and correspondingly also of the composites. The effect was more pronounced for composites containing OGG-80 modified nanopaper reinforcements. Crosslinking has previously been shown to be beneficial for CNF composites (Lee et al. 2014a). Here it was shown that it is possible to control the mechanical properties of CNF

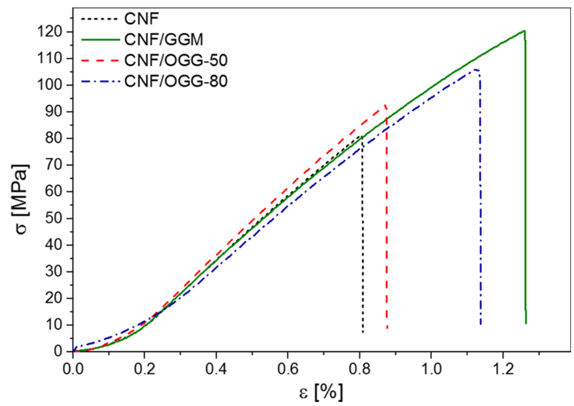


Fig. 2 Representative stress–strain curves for composites with pure CNF (*black dotted line*), CNF/OGG-50 (*red dashed line*), CNF/OGG-80 (*blue dash-dotted line*) and CNF/GGM (*green full line*) reinforcement. The setting behavior (up to 0.2% strain) of the specimens were due to handling difficulties owing to the thin laminates. (Colur figure online)

nanocomposites by controlling the composition and thus mechanical properties of nanopapers.

As anticipated, the highest tensile strength among CNF composites was observed when using CNF/GGM nanopaper reinforcements. Accordingly, just as for the pure nanopapers, GGM exhibited the highest reinforcing ability also within composites. This means that 80% of the original strength of the nanopapers was retained in the composites, which can be expected considering that a fibril fraction of 80 vol% was used to reinforce the resin. Thus the hypothesis of producing better performance cellulose nanocomposites when using better nanopapers was proven to be correct. The introduction of only 2 wt% WSPS into a CNF nanopaper network resulted in nanopapers with improved mechanical properties and the preparation of high loading fraction CNF nanocomposites from these nanopapers led to increased tensile strength of the nanocomposites. Furthermore, the extent of the improvement could be estimated based on the mechanical properties of the nanopapers. The increase of the strength went hand in hand with a reduction of the modulus, as was already demonstrated in three point bending mode by DMTA (see above). While there was no detectable influence of the low DO OGG-50 on the composite modulus, for the higher DO OGG-80 grade a slight reduction compared to pure CNF and CNF/OGG-50 reinforced composites was observed. For GGM a small reduction of the tensile modulus was found. Modified CNF composites exhibited both enhanced Young's modulus and tensile strength compared to a previous study (Lee et al. 2012c) utilizing CNF nanopapers that were vacuum-infused with a brittle epoxy resin. This improvement was enabled by modification of the CNF by adsorbed WSPS. The introduction of WSPS seems to affect crack propagation in the nanopapers and thus also in the composites. The higher modulus compared to the nanopapers can be explained by further compaction of the laminates and accordingly the nanopapers during composite manufacturing.

The strain at break and work of fracture were determined for the composites from stress–strain-curves. For the nanopaper reinforcement modified with low DO OGG-50 grade again no detectable difference was found compared to pure CNF, which was explained by a too low DO leading to an insufficient amount of hemiacetal bonds forming within the nanopapers. For OGG-80 modified nanopaper reinforced composites the strain at break was significantly higher, which, in conjunction with higher tensile strength, resulted in significantly increased work of fracture. The same was found for GGM modified CNF nanopaper based composites.

Bacterial cellulose nanopapers were also tested for their reinforcing ability in composites. BC is purer than wood derived CNF due to the absence of hemicelluloses and lignin (Klemm et al. 2011). Moreover, long, entangled and homogeneous fibrils are responsible for good mechanical performance (Paakko et al. 2008; Klemm et al. 2011; Lee et al. 2014b). Therefore a higher reinforcing ability compared to CNF can be anticipated. This assumption was proven correct; the tensile strength of the BC nanopaper composites was the highest within this study with 151 MPa. However, BC composites had a lower tensile modulus compared to CNF nanopaper based composites, due to lower packing efficiency caused by thicker BC fibrils. Furthermore, hemicelluloses present in CNF nanopapers, which are absent in BC, enable a better stress transfer between CNF fibrils (Iwamoto et al. 2008; Lee et al. 2012c; Gröndahl et al. 2004). This was in good agreement with the DMTA results and literature (Lee et al. 2012c). BC composites even had higher tensile strength and modulus compared to pure BC nanopapers. This can be explained by further compaction of the nanopapers during composite manufacturing; i.e. the composites are thinner than 2 nanopaper layers. Moreover, a very high strain at break and thus work of fracture was measured for BC composites. The higher strain to break for BC composites can be explained by fewer physical crosslinking points between the BC nanofibrils, allowing for realignment of the fibrils during tensile loading (Lee et al. 2012c) and the higher length of BC fibrils compared to CNF. The reorientation of the fibrils even within the composites was still possible since the resin did not fully impregnate the BC nanopapers because of the small pore dimensions and low nanopaper porosity of 33%.

The fracture surfaces of the composites were inspected by SEM. In Fig. 3, the fracture surfaces of composites made from CNF, CNF/GGM, CNF/OGG-50, CNF/OGG-80 and BC nanopapers are shown.

The layered structure of the nanopapers can be easily seen. In the center of the composites, a pure, 5–10 μm thick epoxy resin phase can be observed. The resin spreads into both nanopapers, thus ensuring good adhesion between nanopapers and resin, as well as holding the nanopapers together. However, the larger part of the nanopapers was not impregnated, thus allowing for realignment of the fibrils within the nanopapers. This is particularly true for the nanopapers containing WSPS, in which those polysaccharides act as lubricant in between the nanocellulose fibrils.

In the review by Lee et al. (2014b) poly-L-lactic acid (PLLA) was used as a benchmark because it is the best performing commercially available renewable bulk polymer. Compared to the PLLA standard, having a tensile modulus of 4 GPa and tensile strength 63 MPa, all the reinforced samples studied here well exceeded the mechanical properties of PLLA. If compared to other BC or CNF reinforced composites we note that especially the Young's modulus obtained for the GGM modified CNF nanopaper laminates exceeded most of the previously reported results, but

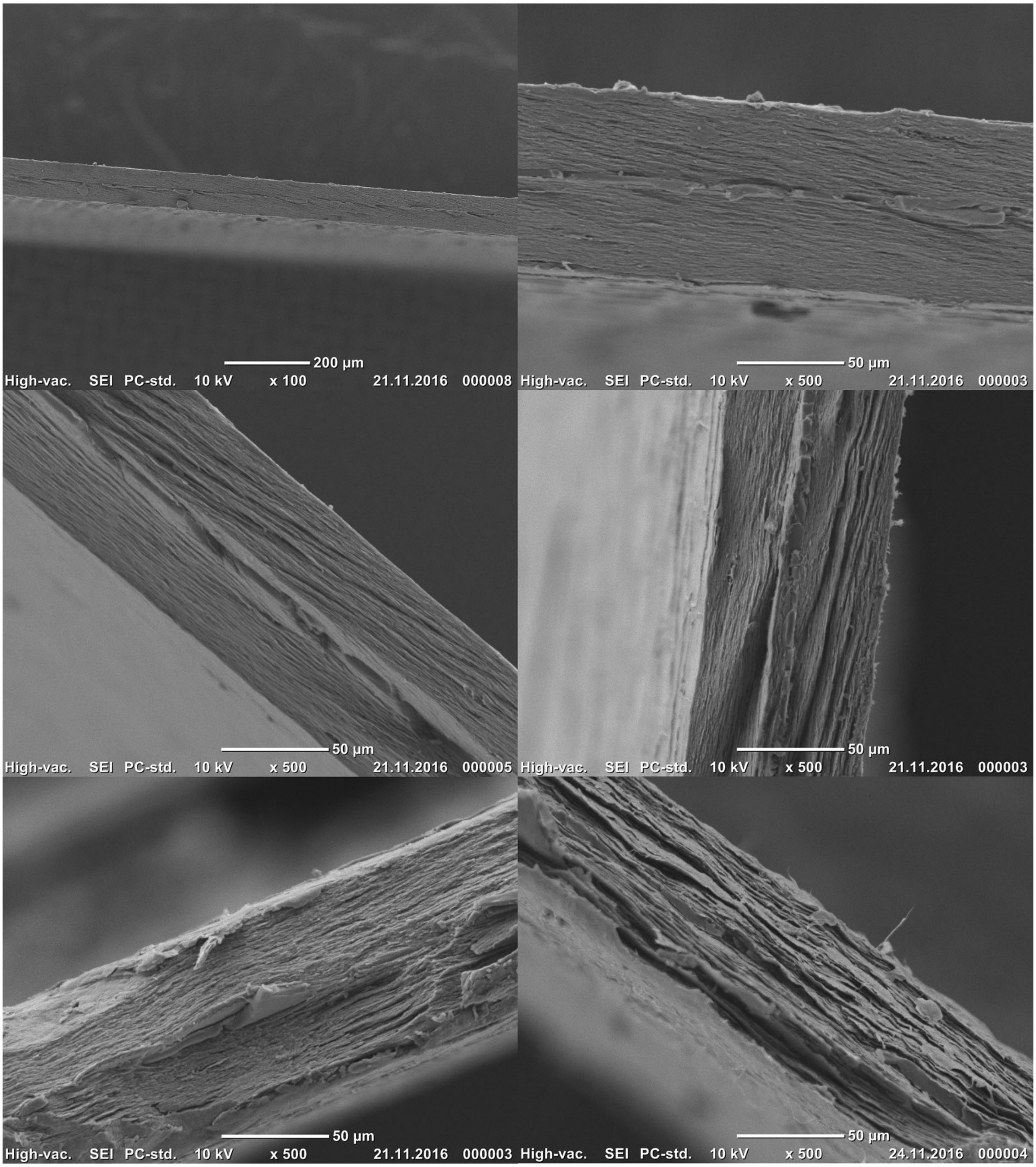


Fig. 3 SEM images (magnification: ×100 or ×500) of the fracture site of composites made from CNF (*top*, *left* ×100, *right*: ×500), CNF/GGM (*centre left* ×500), CNF/OGG-50 (*centre right* ×500), CNF/OGG-80 (*bottom left* ×500) and BC (*bottom right* ×500) nanopapers

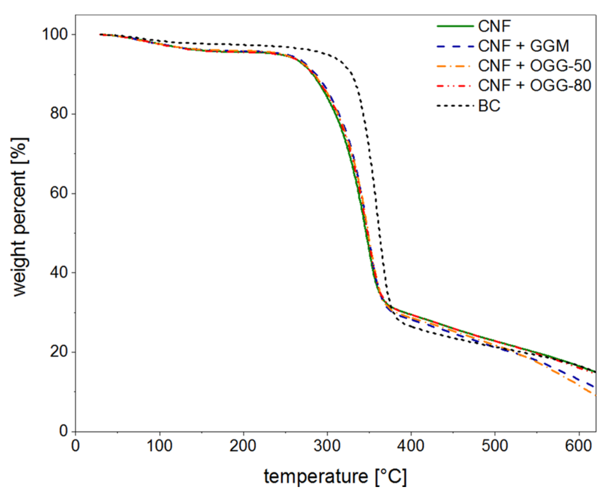
the tensile strength was average. Other groups reported much higher values (Ansari et al. 2014; Henriksson et al. 2008; Sehaqui et al. 2010; Zhou et al. 2009), but since these have been obtained for thin nanopapers of chemically pre-treated CNF, they are not fully comparable to the results presented here. The nanopaper properties determine the properties of the final nanopaper based multi-layer composites, allowing predicting the composites properties. It was found that addition of only 2 wt% of GGM for the preparation of CNF nanopaper resulted in doubling the work of fracture of the final composite. This result was obtained without any chemical pretreatment or synthetic polymers. Since the extraction of GGM from wood is scalable (Leppänen et al. 2011) this result is quite interesting. To produce even higher strength, copolymers with grafted soft chains like CMC-g-PEG could be used, but that would at the same time increase the complexity of the system. It is further noteworthy that the nanopapers used also significantly improved the thermal stability of the epoxy composites.

Thermal behavior of nanopapers and nanopaper composites

The thermal degradation behavior of BC and CNF nanopapers alone was tested in both nitrogen (Fig. 4, left) and air (Fig. 4, right) atmosphere. A one-step degradation regime was observed for all types of nanopapers in inert atmosphere. During the initial testing phase between 30 and 150 °C, no significant difference was found for the different CNF nanopapers. Around 5% of moisture was removed for (modified) CNF nanopapers and the onset of the thermal degradation took place at around 275–280 °C. This degradation step was attributed to cleavage of glycosidic linkages of cellulose (USDA 1970). A smaller amount of moisture (2%) was removed from BC and the onset of the first degradation step occurred at 320 °C. This difference can be explained by a higher degree of crystallinity of BC (72 ± 1%) compared to CNF (60 ± 5%) (Österberg et al. 2013), which is due to the absence of residues of lignin and hemicelluloses (Lee et al. 2012c). A char residue at 600 °C of 12 and 13% was found for OGG-50 and OGG-80 modified CNF, respectively. For GGM modified CNF it was 16% and BC and unmodified CNF had a char residue of 17%.

In air atmosphere again around 5 and 2%, respectively, of moisture was removed between 30 and 150 °C for CNF and BC nanopapers, respectively. The first degradation step, attributed to the degradation of low-molecular weight glycosidic compounds (Cheng et al. 2009; Seifert et al. 2004), occurred around 250 °C for all the CNF nanopapers tested. For BC this temperature was higher (300 °C), similar to results reported in literature (Lee et al. 2012c). The second degradation step, attributed to the degradation of pyran structures, started for all types of CNF and BC nanopapers around 450 °C. Only minor deviations were found for modified CNF nanopapers; all modified nanopapers were completely degraded at 500 °C.

The thermal decomposition of composites is shown in Fig. 5. Similar to the pure nanopapers, a one-step degradation regime was observed for all types of composites in inert atmosphere (Fig. 5, left). This demonstrated that the overall thermal behavior was mainly governed by the nanopapers, which constitute



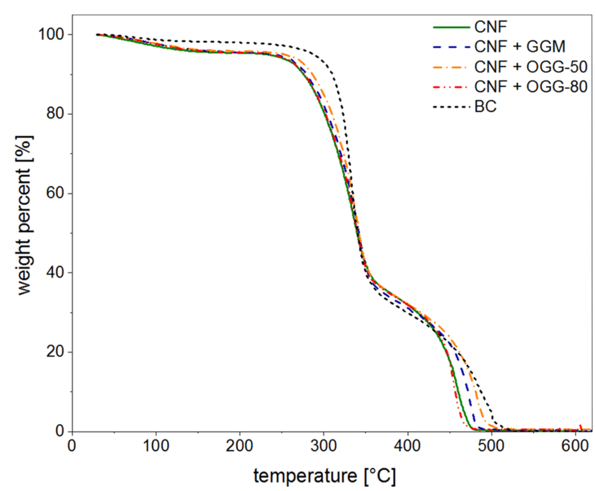


Fig. 4 TGA under nitrogen (*left*) and air (*right*) of CNF and BC nanopapers. CNF (*green full line*), CNF + GGM (*blue dashed line*), CNF + OGG-50 (*orange dash-dotted line*), CNF + OGG-80 (*red dash-double dotted line*) and BC (*black narrow dashed line*). (Colur figure online)

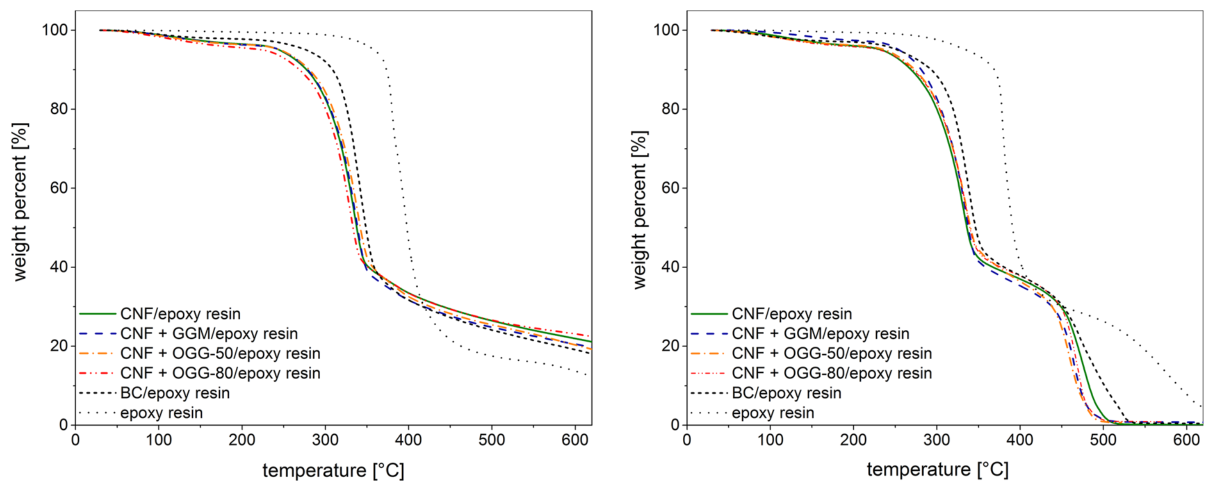


Fig. 5 TGA under nitrogen (*left*) and air (*right*) of CNF and BC-epoxy composites. CNF (*green full line*), CNF + GGM (*blue broad dashed line*), CNF + OGG-50 (*orange dash-dotted line*), CNF + OGG-80 (*red dash-double dotted line*), BC (*black narrow dashed line*) and epoxy resin (*black dotted line*). (Colur figure online)

the majority of the composites. However, during the initial degradation phase between 30 and 150 °C, only around 3% (compared to 5% for the CNF nanopapers) of moisture was removed for CNF composites. This was attributed to the increased overall hydrophobicity caused by the epoxy matrix. For BC composites this value (2%) was similar to the pure BC nanopaper. The onset of thermal degradation of CNF composites occurred at around 270 °C, comparable to the CNF nanopapers. For BC composites, the degradation commenced at 300 °C, which was slightly lower than for pure BC nanopapers. Final degradation was found to be somewhat different for the different sets of polysaccharide phases within the CNF nanopaper. A char residue at 600 °C of 19–22% was found for the various types of composites, thus being slightly higher than for the pure nanopapers and the epoxy resin alone.

In air atmosphere (Fig. 5, right), regarding removal of moisture, the same tendencies for differences between nanopapers and composites were found as in nitrogen. The first degradation step occurred at 270 °C (compared to 250 °C for CNF nanopapers), demonstrating the influence of the protecting epoxy matrix. Between (modified) CNF samples, no obvious difference was observed. For BC composites the onset temperatures of the first degradation step occurred at 293 °C, which was similar to pure BC nanopapers. Also for the onset of the second degradation step around 430 °C, hardly any deviations were found for the composites containing modified CNF nanopapers. For BC composites the onset of the second degradation step occurred at 450 °C, similar to those of the pure nanopapers and higher compared to CNF composites, which again was ascribed to the higher degree of crystallinity of BC. All the composites were completely degraded around 500 °C. The cured epoxy resin starts decomposing at 350 °C and was completely degraded at 650 °C.

In Fig. 6, the degradation of composites containing GGM modified CNF and BC, respectively, in inert atmosphere is contrasted to the degradation of the corresponding nanopapers. Furthermore, a theoretical degradation graph is displayed, constructed from the degradation of the epoxy resin and the nanopapers, assuming a resin content of 20%. Only minor differences between theory and experiment can be observed. The composites apparently start to degrade at slightly lower temperatures compared to the nanopaper, whereas a small increase would be theoretically expected. This might be due to thermal damage the nanopaper experiences during the composite production at 180 °C. Furthermore, a higher than expected amount of char residue was found. This can be explained by mutual protection of both nanopaper and epoxy resin.

Figure 7 shows the degradation behavior of the pure and modified nanopapers and composites containing GGM modified CNF and BC nanopapers in air together with the theoretical degradation graph constructed from the degradation of the epoxy resin and

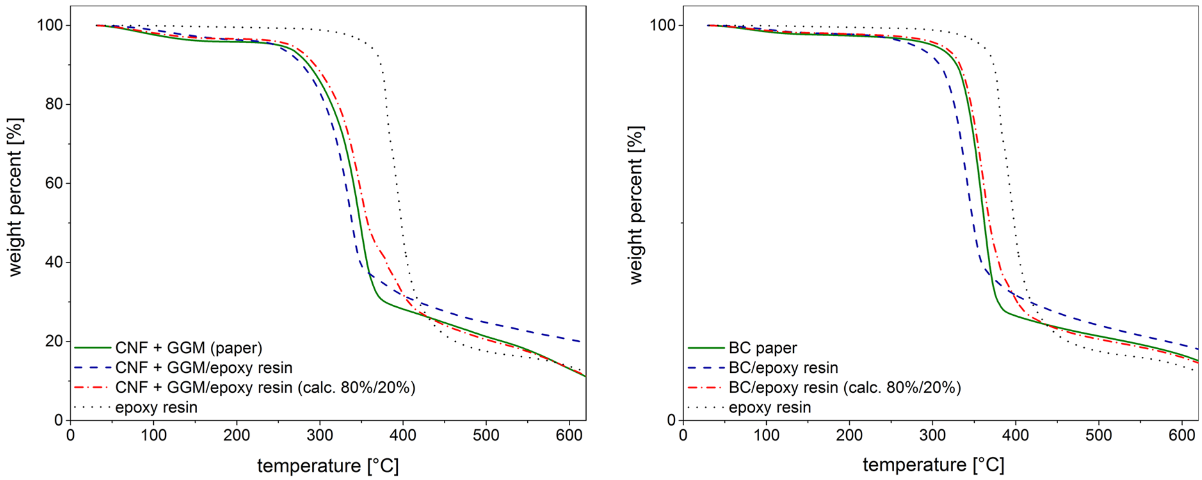


Fig. 6 TGA under nitrogen of CNF + GGM (*left*) and BC (*right*) epoxy composites and nanopapers. Nanopaper (*green full line*), composite (*blue broad dashed line*), theoretical degradation of a composite assuming 20% resin content (*red dash-dotted line*) and epoxy resin (*black dotted line*). (Colur figure online)

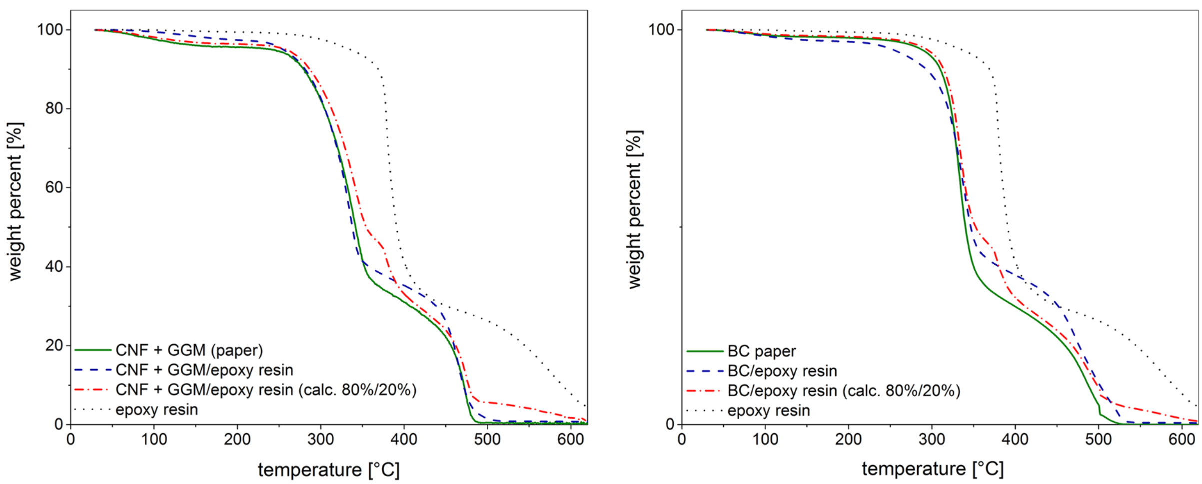


Fig. 7 TGA under air of CNF + GGM (*left*) and BC (*right*) epoxy composites and nanopapers. Nanopaper (*green full line*), composite (*blue broad dashed line*), theoretical degradation of a composite assuming 20% resin content (*red dash-dotted line*) and epoxy resin (*black dotted line*). (Colur figure online)

the nanopapers assuming a resin content of 20%. In air the differences observed were even smaller as in nitrogen. Just as under inert atmosphere, the first degradation step starts at slightly lower temperatures whereas for the second degradation step hardly any difference was found at all.

Conclusions

Nanopapers prepared from non-pretreated CNF and water-soluble polysaccharide modified CNF were used as 2D reinforcement for epoxy resins, utilizing an easy process allowing for the preparation of multi-layer laminates with predictable properties. The CNF nanocomposites were produced by wet lamination and compared to BC nanopaper composites. Both CNF and BC nanopapers were successfully processed into multi-layer composites by lamination with an epoxy resin followed by curing in a hot-press. Significant improvements in both mechanical properties and application temperature were achieved. The mechanical properties of the paper based composites are determined by the properties of CNF nanopapers.

These improvements could be estimated based on the mechanical properties of the nanopapers and epoxy resin matrix. An addition of only 2 wt% of galactoglucomannan to CNF resulted in significantly improved tensile strength (50%) of the nanopaper, which in turn resulted in a 40% increase of the strength of the corresponding laminated epoxy composite containing 80 vol% CNF. Furthermore, the strain at break and work of fracture also improved. This was explained by the lubricating effect of the WSPS affecting crack propagation in the nanopaper. BC nanopaper composites exhibited even higher tensile properties as compared to the modified CNF nanopaper reinforced composites, which was explained by its higher degree of crystallinity. Moreover, it was found that the WSPS hardly affected the thermal degradation behavior of the CNF nanopapers and the thermal stability of the nanocomposites was mainly governed by the thermal behavior of the CNF nanopapers as they made up around 80 vol% of the composites.

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Utilization of Waste Polyethylene and its Effects on Physical and Mechanical Properties of Oriented Strand Board

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The effect of adding waste polyethylene (WPE) was investigated at various ratios on some physical and mechanical properties of oriented strand board (OSB) panels. All of the test panels were bonded with 6% phenol-formaldehyde resin in three layers. The manufacturing parameters was 0/100, 10/90, 20/80, 30/70, 40/60, and 50/50 by weight% of WPE/wood strand. All the boards were manufactured to achieve targeted specific gravity of 0.65 g/cm3. Polyethylene improved the water resistance of the OSB panels because of its hydrophobicity. Based on the results of this study, thickness swelling, humidity, dimensional stability, water absorption, and screw withdrawal resistance of the samples were improved significantly. However, MOE, MOR, and internal bond strength values of the samples decreased with increasing WPE in the panels when compared to the control panels but met minimum requirements in EN 300 (type 1-2-3-4) control panels. The conclusion was reached that waste polyethylene can be used in the manufacture of OSB panels, resulting in the enhancement of above mentioned physical and mechanical properties, as well as a safe disposal and economical utilization.

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Keywords: Oriented strand boards; Wood composite; Waste polyethylene; Physical and mechanical properties; Screw withdrawal; Internal bond; Water absorption; Dimensional change

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INTRODUCTION

Wood composite materials such as plywood, fiberboard, particleboard, and oriented strandboard (OSB) are commonly utilized for various applications in the construction industry (Howard 2000; Hu 2000). Oriented strandboard is a material that is manufactured from thin wood strands bonded together with water-resistant adhesive under heat and pressure (Cai and Ross 2010). Main applications in Turkey include roofs and walls, I-beams, wood and steel construction systems, coatings, and chest for transportation of materials, *etc*.

Because of rapid industrialization and technological development, especially in some developing countries, environmental pollution problems and a shortage of natural resources have occurred. Various types of polyethylene are industrial products that produce a large quantity of waste materials every year (Tayyar and Ustun 2010). Polyethylene (PE) is the most commonly used plastic in the world. Depending on its density, PE can be produced in various viscosity levels because of its low melting temperature, typically between 106 and 130 °C. Additionally, polyethylene is a soft material that enables PE-based composite boards to be nailed, screwed, cut easily, and it shows near-zero moisture absorption (approximately below 0.02% after 24 h of underwater immersion) (Klyosov 2007).

Today, recycling waste products by utilizing them in manufacturing processes is very attractive because it can prevent environmental pollution and lower production costs (Ayrılmis *et al.* 2009). Polyethylene is a material that is not able to biodegrade rapidly in the environment. In order to recycle such materials, different kinds of waste products have been increasingly used (Prideaux 2007). Yilgor *et al*. (2014) manufactured wood based panels using waste Tetra Pak material and evaluated some chemical and physical properties as well as biological, weathering, and fire performance. In their study, Ozdemir and Mengeloglu (2008) showed that thickness swelling and water absorption properties of recycled high density polyethylene (HDPE) based wood plastic composites decreased.

In the literature, there is no information related to the effects of waste polyethylene on the physical and mechanical properties of OSBs. Therefore, this study offers a solution to the waste polyethylene problem by investigating the effects of WPE on some physical (density, humidity, dimensional changes, thickness swelling, and water absorption) and mechanical properties (internal bond, modulus of elasticity, modulus of rupture, and screw withdrawal) of OSB panels produced by adding WPE in different ratios.

EXPERIMENTAL

Materials

In this study, Scots pine wood (*Pinus sylvestris* L.) was used in the manufacture of the OSBs. The strand dimensions were approximately 80 mm long, 20 mm wide, and 0.7 mm thick. Resin, containing 47% liquid phenol-formaldehyde (pH 10.5), was applied at a 6% ratio, based on the weight of the oven-dry wood strands for all boards produced. WPE granules between 0.7 mm and 1.3 mm in thickness were chosen from industrial waste polyethylene. Low-density polyethylene typically has a density value ranging from 0.91 to 0.925 g/cm^3 and Scots pine wood has a density of 0.56 g/cm^3.

Panel Manufacture

Six panels, including one control panel (non-WPE) and five panels manufactured with different ratios of WPE (10/90, 20/80, 30/70, 40/60, 50/50) by weight, were tested for physical and mechanical properties. Two boards for each combination of variables and total of 12 boards were produced. Dimensions of the boards were 500 mm x 500 mm x 12 mm. OSB panels were aimed to manufacture with a density of 0.65 g/cm^3. The panels were manufactured with three layers and particle weight ratios of 25:50:25 (face, core, and face, respectively). The core layer was spread perpendicular to the face layers. The waste polyethylene was used in all layers homogeneously. Polyethylene capped the pores among strands when it melted.

The wood strands were dried to 3% moisture content, and then the resin was sprayed straight away once the wood strands got out from the dryer for 3 min. The OSBs were manufactured in the Laboratory of Forestry Faculty, Karabuk University. All mats were pressed in a hot press at a temperature of 180 °C and a pressure of 3.92 N/mm^2 for 9 min to 12 mm- the target thickness.

Evaluation of Physical and Mechanical Properties

After the pressing process, the boards were conditioned at 65 ± 5% relative humidity and at a temperature of 20 ± 2 °C until their weight was stable (ISO 554 (1976)). The moisture content and density, thickness swelling, water absorption, modulus of rupture and elasticity, and internal bond were determined according to the relevant standards TS-EN 322 ; EN 323; EN 317; EN 310; EN 319 respectively.

All physical and mechanical tests were performed in accordance with current Turkish (TS) and European standards (EN). Physical properties (water absorption, (WA 24 h to 48 h), thickness swelling (TS 24 h to 48 h) and dimensional changes (DC 24 h to 48 h)) and mechanical properties (internal bond (IB 24 h to 48 h), screw withdrawal strength (SW 24 h to 48 h), modulus of elasticity (MOE) in static bending, and modulus of rupture (MOR) in static bending) were evaluated. Static bending and dimensional change tests were carried out in parallel (//) and perpendicular (⊥) directions, depending on the surface layer. When testing physical properties such as TS, DC, and WA, distilled water was used.

For screw withdrawal experiments, screws of 3.5 × 40 and 4 × 40 mm dimensions were used, and the screws were applied perpendicular to the surface of the test samples. For each experiment, 10 samples with dimensions of 50 × 50 × 12 mm^3 were tested according to EN 320 (1993). Each screw was inserted into a pre-bored hole and screwed into the board through its depth.

The boards were evaluated according to EN 300 (2006), which classifies and distinguishes boards into four types: 1) OSB/1 – general purpose boards and boards for interior fitments for use in dry conditions; 2) OSB/2 – load-bearing boards for use in dry conditions; 3) OSB/3 – load-bearing boards for use in humid conditions; 4) OSB/4 – heavy duty load-bearing boards for use in humid conditions. Board properties were compared to the requirements of OSB types 1, 2, 3, and 4 (EN 300 2006) and notated in this work in brackets.

Data for each test were statistically analyzed. Analysis of variance (ANOVA) was used ($\alpha < 0.05$) to test for significant differences among factors of all OSB groups. The values were evaluated with the Duncan test to identify which groups were significantly different from other groups.

RESULTS AND DISCUSSION

Density, Moisture Content, and Dimensional Changes

The average and standard deviation values of density (D), moisture content (MC), and dimensional changes (DC) of the treated OSB panels are shown in Table 1.

Table 1. Average and Standard Deviation Values of Treated OSB Panels Produced by Adding WPE in Various Ratios

Wood (%)	Polyethylene (%)	Air-dry Density (g/cm^3)	Moisture Cont. (%)	Dimensional changes (%) // 24 h	// 48 h	⊥ 24 h	⊥ 48 h
100	-------	0.620$^{(0.03)}$	5.79$^{(0.25)}$	0.59	0.8	0.98	1.2
90	10	0.621$^{(0.03)}$	5.34$^{(0.27)}$	0.43	0.7	0.64	0.9
80	20	0.624$^{(0.04)}$	4.87$^{(0.32)}$	0.35	0.6	0.32	0.6
70	30	0.634$^{(0.05)}$	4.22$^{(0.29)}$	0.37	0.5	0.23	0.5
60	40	0.655$^{(0.03)}$	3.37$^{(0.21)}$	0.31	0.5	0.24	0.4
50	50	0.665$^{(0.03)}$	3.34$^{(0.19)}$	0.17	0.32	0.12	0.2

Data were statistically analyzed by means of average and standard deviation, respectively.

⊥: perpendicular to major axis of panel, //: parallel to major axis of panel

According to Table 1, the air-dry density values of treated samples ranged from 0.620 to 0.665 g/cm^3. The panels that were manufactured with different ratios of WPE had similar density values. Moisture content values decreased due to increasing WPE amount; similarly, dimensional change values decreased significantly based on increasing WPE amount compared to the control samples. Hydroxyl groups in treated OSB decreased with an increase of WPE amount, thus improving the dimensional change stability. For wood, dimensional changes are commonly assumed to be linearly related to changes in moisture content (Zelinka and Glass 2010). The highest moisture content was obtained (5.79%) from the non-WPE sample, and the lowest value was obtained (3.34%) from the sample with 50% WPE.

The physical and mechanical properties of wood materials, such as MOE, MOR, IB, *etc.*, are affected greatly by moisture content (MC) (Niemz 2010). In this study, dimensional changes after 24 and 48 h were considerably lower than the control values. The greatest dimensional change after 24 h was obtained (0.59%) from the untreated sample, and the lowest value after 24 h was obtained (0.17%) from the sample with 50% WPE parallel to the grain. The greatest dimensional change after 48 h was 0.98% in the untreated sample, and the lowest value of DC after 48 h was 0.12% in the sample with 50% WPE perpendicular to grain. According to these results, using polyethylene in OSB affected the MC value positively. The DC value was also positively affected because of the decrease in MC value. In wood and wood-based materials, swelling occurs because of absorbed water and shrinkage occurs when the absorbed water is released (Niemz 2010).

Thickness Swelling and Water Absorption

Average and standard deviation values of thickness swelling (TS) and water absorption (WA) of treated OSB panels are shown in Table 2.

Table 2. Average Values of Thickness Swelling and Water Absorption Rate in the OSB Panels Produced by Adding WPE in Various Ratios

Wood	Polyethylene	TS (%)		WA (%)	
%	%	24 h	48 h	24 h	48 h
100	-------	27.46$^{(4.84)}$ A [1]	28.85$^{(5.15)}$ A [1]	65.78$^{(8.81)}$ A	70.97$^{(8.25)}$ A
90	10	26.32 $^{(4.06)}$ A [1]	28.06 $^{(5.36)}$ A [1]	64.49$^{(11.95)}$ A	69.93$^{(10.20)}$ AB
80	20	19.24$^{(4.40)}$ B [2]	22.08$^{(3.50)}$ B [2]	53.74$^{(6.24)}$ B	60.39$^{(8.32)}$ B
70	30	13.65 $^{(4.34)}$ C [3]	16.96$^{(4.23)}$ C [3]	45.43$^{(5.94)}$ C	50.01$^{(6.18)}$ C
60	40	8.84 $^{(3.61)}$ D [4]	12.75$^{(4.67)}$ CD[3]	31.68$^{(8.50)}$ D	35.35$^{(8.06)}$ D
50	50	8.11 $^{(3.08)}$ D [4]	9.58$^{(4.26)}$ D [4]	22.47$^{(6.65)}$ E	23.97$^{(5.37)}$ E

*Groups with the same letters in each column indicate that there is no statistical difference (pr < 0.05) between the samples according to the Duncan's multiple range test.
*Data were statistically analyzed by means of average and standard deviation.
*Quality requirements were compared to OSB type 1-2-3-4 (EN 300 OSB minimum property requirement 2006) and are notated in brackets.

Both 24 and 48 h thickness swelling values were considerably lower than the control values. The highest value of TS after 24 h was 27.46% in the non-WPE panel sample, of TS after 48 h was 28.85% in the non-WPE sample, and the lowest value of TS after and the lowest value of TS after 24 h was 8.11% in the sample with 50% WPE. The highest value 48 h was 9.58% in the sample with 50% WPE. According to Table 2, minor differences were obtained between 24 h and 48 h TS values but as seen, the variance from

24 h to 48 h was much bigger in manufactured OSB because wood absorbs the most amount of water especially in 24 h; manufactured OSB that were produced using polyethylene does not absorb water as rapidly as wood. Because of the hydrophobic properties of polyethylene, the TS values of OSB panels manufactured using WPE decreased with an increasing amount of WPE.

These results were in agreement with a study carried out by Ayrılmıs *et al.* (2009). In the cited study, by increasing the rubber content to 30% in OSB, TS values decreased from 21.1% to 14.3%. Linear results have been obtained between moisture content and thickness swelling in particleboard (Watkinson and Gosliga 1990). Additionally, Linville (2000) stated that board properties and TS are influenced by resin level. Yapici (2008) researched TS values of OSBs depending on the amount of adhesive and observed that with an increase in the adhesive amount from 3% to 6%, TS values decreased 49%. In the present study, although the amount of adhesive was fixed (6%) in OSB panels manufactured with WPE, TS values decreased from 27.46% to 8.11%, depending on the WPE used in OSB. This may result in reduction of costs and contribute to greater recycling of WPE.

The quality requirements were compared to OSB types 1-2-3-4 (EN 300 2006), and the results are shown in brackets in Table 2. According to these results, the control panel met the minimum requirements of type 1, and 40-50% polyethylene-containing panels met the minimum requirements of type 4, regarding TS. Homogeneous groups for TS are shown by Duncan's multiple comparison tests (Table 2). It was observed that there was a statistical difference among the average TS values of the panels. WA values followed a similar pattern to the values of TS. Accordingly, WA values after 24 and 48 h were considerably lower than the control values. The highest value of WA after 24 h was 65.78% in the non-WPE panel sample, and the lowest value of WA after 24 h was 22.47% in the sample with 50% WPE. The highest value of WA after 48 h was 70.97% in the non-WPE sample, and the lowest value of WA after 48 h was 23.97% in the sample with 50% WPE. Homogeneous groups for WA were shown by Duncan's multiple comparison tests (Table 2). It was observed that there was a statistical difference among the average WA values of the panels.

Similar results were obtained by (Yilgor *et al*. 2014). According to his study, water may have penetrated through the small cracks and fractures occurred during panel manufacturing process using waste Tetra Pak. In his study, fibers were not coated enough by melted LDPE in Tetra Pak so the penetration of water could not have been prevented wholly.

Modulus of Elasticity, Modulus of Rupture, and Internal Bond

Average and standard deviation values of MOE, MOR, and IB of OSB panels are shown in Table 3.

MOR and MOE have important roles when describing the mechanical properties of OSB panels. Average values of modulus of rupture (MOR) and modulus of elasticity (MOE) at static bending in the parallel and perpendicular directions, as well as the internal bond (IB) for each OSB panel are given in Table 3. According to the results, there was a significant difference among the manufactured panels for both parallel and perpendicular MOR. As shown in Table 3, MOE and MOR values of the OSB panels decreased with increasing WPE amount when compared to the control panels. Similar trends and results between the MOE and MOR values were obtained. For MOE and IB, when the WPE amount in OSB panels exceeded 30%, the minimum quality requirements of EN 300 could not be met. In addition, differences between parallel and perpendicular MOE/MOR values decreased depending on the increasing WPE amount. The reason for the decrease in IB values can be explained with the weak adhesion between wood strands and WPE. This situation leads decrease of MOE/MOR values. In this case, by increasing resin level IB strength of OSBs can be enhanced depending on increased WPE amount (Maloney 1977). Therefore, the more WPE is used in boards, the more isotropic they become. Similar results were obtained in a study by Ayrılmıs *et al.* (2009). In his study, MOE/MOR values decreased depending on increasing waste tire rubber amount.

Table 3. Average Modulus of Elasticity, Modulus of Rupture and Internal Bond Values at Static Bending of OSB Panels Produced by Adding WPE in Various Ratios

Wood %	Polyethylene %	Modulus of elasticity (MOE) (N/mm^2) //	⊥	Modulus of rupture (MOR) (N/mm^2) //	⊥	Internal bond (IB) (N/mm^2) Untreated	24 h
100	-----	5728$^{(358)}$ A[4]	3355$^{(353)}$ A[4]	33$^{(2)}$ A[4]	24$^{(5)}$A[4]	0.43$^{(0.03)}$ A[3]	0.07$^{(0.02)}$ A
90	10	5034$^{(340)}$ B[4]	3019$^{(315)}$AB[4]	30$^{(4)}$ A[4]	21$^{(4)}$AB[4]	0.40$^{(0.02)}$ B[3]	0.09$^{(0.01)}$ B
80	20	4034$^{(371)}$ C[3]	2717$^{(297)}$ B[4]	22$^{(2)}$ B[3]	19$^{(1)}$BC[4]	0.34$^{(0.04)}$ C[3]	0.11$^{(0.02)}$ C
70	30	2751$^{(296)}$ D[1]	1833$^{(258)}$ C[3]	18$^{(1)}$ C[2]	16$^{(3)}$ C[4]	0.27$^{(0.05)}$ D[*1]	0.12$^{(0.02)}$ D
60	40	2208$^{(226)}$ E[*]	1277$^{(261)}$ D[1]	15$^{(2)}$ D[1]	13$^{(2)}$DE[3]	0.21$^{(0.03)}$ E[*]	0.16$^{(0.03)}$ E
50	50	1506$^{(242)}$ F[*]	1040$^{(167)}$ D[*]	14$^{(1)}$ D[1]	11$^{(2)}$E[3]	0.19$^{(0.04)}$ E[*]	0.16$^{(0.04)}$ E

*Groups with the same letters in each column indicate that there is no statistical difference ($pr < 0.05$) between the samples according to the Duncan's multiple range test.
*Data were statistically analyzed by means of average and standard deviation.
*Quality requirements were compared to OSB type 1/2/3/4 (EN 300 OSB minimum property requirement 2006) and are notated in brackets.

The results of Duncan's multiple range tests are also shown in Table 3 using letters. The average MOE parallel to the major axis of the OSBs containing WPE ranged from 5728 to 1506 N/mm^2, and values perpendicular to the major axis ranged from 3355 to 1040 N/mm^2. The average MOR parallel to the major axis values of the OSBs containing WPE ranged from 33 to 14 N/mm^2, and values perpendicular to the major axis ranged from 24 to 11 N/mm^2.

Ayrılmıs *et al.* (2009) stated that the MOE and MOR values of the OSBs with tire rubber can be enhanced by increasing the amount of resin. Wilson (1980) researched the correlation between resin amount and mechanical properties and observed that mechanical properties (MOR, MOE, and IB) improved with an increase in the amount of resin. Therefore, in this study, the decrease in the values of some mechanical properties due to an increase of WPE can be compensated by adding extra resin. According to the results of Table 3, the IB values of unsubmerged OSBs diminished from 0.43 to 0.19 N/mm^2 with the increase of WPE amount; however IB values of panels that are exposed to water submersion for 24 h increased from 0.07 to 0.16 N/mm^2 with the increase of WPE amount;

whereas OSB panels are exposed to submersion in water, internal forces are weakened, which results in swelling of the panels. These results may be explained with the existence of WPE. In addition, there was a statistical difference among the average IB values of the panels. The bond strength values showed similar trends to the results of MOR and MOE tests.

Screw Withdrawal Resistance

Screw withdrawal resistance (SWR) has an important role when describing mechanical properties of OSB panels because OSB panels are generally fixed with screws in various construction works. Strength values obtained in experiments for 3.5 and 4 mm screws, as well as average and standard deviation values of SWR-treated OSB panels are shown in Table 4.

Table 4. Average Screw Withdrawal Resistance Values of OSB Panels Produced by Adding WPE in Various Ratios

Wood	Polyethylene	**3.5 × 40**		**4 × 40**	
%	%	Untreated (N)	24 h (N)	Untreated (N)	24 h (N)
100	------	$584^{(45)}$ A	$258^{(35)}$ A	$690^{(42)}$ A	$302^{(55)}$ A
90	10	$639^{(77)}$ A	$313^{(45)}$ B	$761^{(81)}$ AB	$352^{(43)}$ AB
80	20	$707^{(75)}$ B	$345^{(45)}$ B	$814^{(90)}$ B	$418^{(77)}$ B
70	30	$835^{(68)}$ C	$396^{(68)}$ C	$943^{(88)}$ C	$504^{(62)}$ C
60	40	$926^{(69)}$ D	$421^{(35)}$ C	$1019^{(66)}$ C	$601^{(87)}$ D
50	50	$975^{(71)}$ D	$481^{(57)}$ D	$1138^{(94)}$ D	$614^{(78)}$ D

*Groups with the same letters in each column indicate that there is no statistical difference (pr < 0.05) between the samples according to the Duncan's multiple range test.
*Data were statistically analyzed by means of average and standard deviation.

Homogeneous groups for SWR are shown by Duncan's tests (Table 4). It was observed that there was a statistical difference among the average SWR values of the panels. SWR values after 24 h were considerably lower than the control values. It was observed that the greater the increase of WPE, the greater the increase in SWR values when compared to control samples. The highest value of SWR (3.5 × 40) was 975 (N) for 50% WPE sample, and the lowest value was 258 (N) for the non-WPE control sample after 24 h. The highest value of SWR (4 × 40) was 1138 (N) for 50% WPE sample, and the lowest value was 302 (N) for the non-WPE control sample after 24 h. Eckelman (1990) studied the SWR properties of wood composite materials using various processing variables. He observed that SWR and IB values have an interaction, and that the density of boards improves SWR values.

CONCLUSIONS

1. This study investigated the physical and mechanical properties of OSBs manufactured with waste polyethylene. According to the results, the amount of waste polyethylene influenced the mechanical and physical properties of the OSB panels.
2. By using WPE materials in OSB panels, thickness swelling, humidity, dimensional stability, water absorption, and screw withdrawal resistance of the samples were

improved significantly. However, the MOE, MOR, and internal bond strength values of the samples decreased with increasing WPE amount in the panels when compared to control panels but met the minimum requirements of EN 300 (type 1-2-3-4). By increasing PF resin levels, weak adhesion between wood strands and WPE can be improved.

3. Optimum results for MOR, MOE, and IB mechanical properties were obtained from the samples with 30% waste polyethylene. They met the minimum requirements for OSB type 1 (EN 300).
4. Based on these results, it is suggested that OSB panels should be manufactured with WPE in order to contribute to recycling WPE, which is industrial waste material. This will also help protect the environment and reduce the manufacturing costs of OSB panels.

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Global Life Cycle Paper Flows, Recycling Metrics, and Material Efficiency

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Despite major improvements in recycling over the last decades, the pulp and paper sector is a significant contributor to global greenhouse gas emissions and other environmental pressures. Further reduction of virgin material requirements and environmental impacts requires a detailed understanding of the global material flows in paper production and consumption. This study constructs a Sankey diagram of global material flows in the paper life cycle, from primary inputs to end-of-life waste treatment, based on a review of publicly available data. It then analyzes potential improvements in material flows and discusses recycling and material efficiency metrics. The article argues that the use of the collection rate as a recycling metric does not directly stimulate avoidance of virgin inputs and associated impacts. An alternative metric compares paper for recycling (recovered paper) with total fibrous inputs and indicates that the current rate is at just over half of the technical potential. Material efficiency metrics are found to be more useful if they relate to the reuse potential of wastes. The material balance developed in this research provides a solid basis for further study of global sustainable production and consumption of paper. The conclusions on recycling and efficiency should be considered for improving environmental assessment and stimulating a shift toward resource efficiency and the circular economy.

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Global Life Cycle Paper Flows, Recycling Metrics, and Material Efficiency

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Summary

Despite major improvements in recycling over the last decades, the pulp and paper sector is a significant contributor to global greenhouse gas emissions and other environmental pressures. Further reduction of virgin material requirements and environmental impacts requires a detailed understanding of the global material flows in paper production and consumption. This study constructs a Sankey diagram of global material flows in the paper life cycle, from primary inputs to end-of-life waste treatment, based on a review of publicly available data. It then analyzes potential improvements in material flows and discusses recycling and material efficiency metrics. The article argues that the use of the collection rate as a recycling metric does not directly stimulate avoidance of virgin inputs and associated impacts. An alternative metric compares paper for recycling (recovered paper) with total fibrous inputs and indicates that the current rate is at just over half of the technical potential. Material efficiency metrics are found to be more useful if they relate to the reuse potential of wastes. The material balance developed in this research provides a solid basis for further study of global sustainable production and consumption of paper. The conclusions on recycling and efficiency should be considered for improving environmental assessment and stimulating a shift toward resource efficiency and the circular economy.

Introduction

High recycling rates are often cited as evidence for the environmental performance of the paper sector. The global paper system nevertheless contributes to numerous environmental problems, including climate change, water pollution, and air pollution. Allwood and colleagues (2010) show that, even under a highly optimistic business-as-usual scenario, carbon emissions from the paper sector in 2050 will far exceed the reduction target of 50%. The necessary impact reductions are unlikely to be met unless all potentials are explored. To discover these potentials, a detailed material flow analysis (MFA) of paper production, consumption, and waste treatment is needed. This article provides such an analysis for global paper flows from virgin inputs to end-of-life waste treatment.

The MFAs for paper and pulp in the existing literature are detailed at the national level (Hekkert et al. 2000; Cote et al. 2015; Hong et al. 2011; Sundin et al. 2001) or highly aggregated at the global level (Allwood et al. 2010). The aim of this study is to produce a detailed global material balance of paper flows like those published for steel (Cullen et al. 2012) and aluminum (Cullen and Allwood 2013; Liu et al. 2012). Such a material

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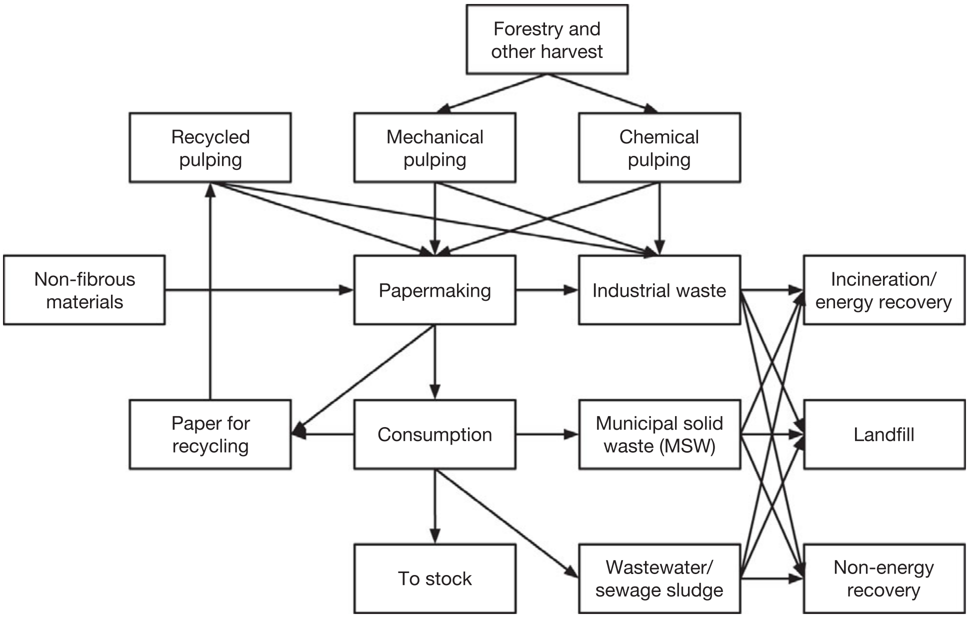

Figure 1 The paper system.

balance helps identify options for reducing virgin material inputs and associated environmental impacts. An analysis based on the mass balance principle can approximate important but ill-reported flows such as virgin wood inputs, non-fibrous inputs, and waste treatment flows.

The material balance is a useful contribution for two reasons. First, it is used in this article for comparing and analyzing mass-based performance metrics. Such mass-based metrics are used by governments around the globe to track environmental performance and therefore deserve critical analysis. This article shows the shortcomings of commonly used recycling and efficiency metrics and makes recommendations for improving them. The article also quantifies the technical recycling potential. Second, the material balance can serve as a basis for more advanced methods that may consider energy, water, emissions, land use, and other environmental impacts. Such life cycle assessments (LCAs) require a material balance to start with, and no such balance yet exists for the paper system.

The article is structured as follows. The next section explains the data sources, assumptions, and methods used for constructing the material balance. This is followed by the results, in the form of a Sankey diagram, and a discussion of recycling metrics, efficiency metrics, and appraisal of waste reuse. The article concludes by suggesting improvements in environmental performance metrics and indicating directions for future research.

Data and Methods

This study constructs a material balance to indicate the origin, destination, and size of global flows of wood, pulp, paper, and waste paper for 2012. The data are drawn from a variety of sources and the values are calculated using material-balance equations and matrix algebra. The assessment considers the dry masses of all flows—gases and water are not included. The consumption of five categories of paper, chemical pulp, mechanical pulp, and paper for recycling is based on the Food and Agriculture Organization of the United Nations (FAO) (FAO 2016). The flows in each life cycle stage are further specified using parameters from the literature and industry reports (see section SI-1 in the supporting information available on the Journal's website). Materials referred to as by-products or co-products in the literature are consistently referred to as wastes in this analysis and include black liquor, tall oil, and turpentine. Waste paper that is recycled, sometimes called recovered paper, is referred to as paper for recycling. Pulp from paper for recycling, sometimes called secondary pulp or recovered pulp, is referred to as recycled pulp. The fraction of postconsumer waste paper that is neither recycled nor ends up in the sewer is referred to as residual waste paper.

Figure 1 displays the main stages in the life cycle of paper from harvest to waste treatment. Paper is produced from wood, non-wood harvest, waste paper, and non-fibrous material. Wood is converted into mechanical, chemical, and semichemical wood pulp. Mechanical pulping consists of grinding wood and is highly energy intensive. Chemical pulping is used for higher-quality products since it removes undesirable lignin from wood. Semichemical pulping combines a grinding stage with chemical treatment, but is split into equal fractions of chemical and mechanical pulping in the further analysis. In addition to wood, a fraction of non-wood pulp from materials such as straw is used, mainly in China and India. Paper for recycling is pulped separately and often deinked. The different pulps, together with non-fibrous materials, are used in different combinations for papermaking of different grades (omitted in figure 1). After consumption, paper is either added to stock, recycled, or ends up in incineration (with or without energy

Table 1 Yield ratios for pulping and papermaking

Parameter	*Range*	*Reference*	*Value used*	*Notes*
Chemical pulping	0.40 to 0.55	(Martin et al. 2000)	0.48	Median value
Mechanical pulping	0.90 to 0.95	(Martin et al. 2000)	0.93	Median value
Recycled pulping	0.73 to 0.89	(Stawicki and Read 2010; FAO 2016)	0.81	See section S1-3 in the supporting information on the Web
Papermaking	—	(Eurostat 2016; FAO 2016)	0.95	—

Table 2 Fraction of inputs in five main grades of paper

	Outputs				
Inputs	*Newsprint*	*Printing + writing*	*Sanitary + household*	*Packaging*	*Other*
Recycled pulp	0.68	0.08	0.34	0.56	0.27
Chemical pulp	—	0.62	0.66	0.22	0.51
Mechanical pulp	0.22	—	—	0.11	—
Non-fibrous	0.10	0.30	—	0.10	0.23

recovery), landfill, or the sewer. The paper sector generates paper for recycling and industrial waste such as sludge, which is used for energy recovery, non-energy recovery, or landfilled.

Yield Ratios

The inputs to chemical and mechanical pulping can be calculated from reported global pulp production (FAO 2016) and the yield ratios for pulping (table 1). Martin and colleagues (2000) suggest ranges of yield ratios for pulp relative to the wood input for mechanical pulping and chemical pulping. This analysis uses the median values. Other references such as MacLeod (2007) and Briggs (1994) suggest similar values. The yield ratios for non-wood pulping are assumed similar to those for chemical wood pulping. The recycled pulping yield ratio is calculated by considering the use of paper for recycling per paper grade and the yield ratio per paper grade. The calculation uses the production matrix in table 2 and recycled pulping yield ratios from Stawicki and Read (2010). It assumes that between 0% and 50% of recycled inputs to packaging are deinked (see section SI-3 in the supporting information on the Web).

Yield ratios for papermaking are dependent on the paper grade that is being produced and can vary significantly per paper product. The papermaking yield ratio is therefore derived from aggregate waste paper losses and total paper production in the pulp, paper, and print sector in the European Union (EU) 28 (Eurostat 2016; FAO 2016). These losses are recycled and part of the total global paper for recycling quantity reported by the FAO. The resulting yield ratio is very close to the value in the International Energy Agency (IEA) (IEA 2007, 264) and used by Allwood and colleagues (2010). It should be noted that these wastes result mostly from paper converting and printing and do not constitute inefficiencies in paper mills. The quantity of non-fibrous filler materials is calculated from the final difference between pulp inputs, conversion losses, and paper outputs in papermaking and cross-checked with European data (CEPI 2012).

Production Matrix

Table 2 shows the fractions of pulp and non-fibrous material inputs in the five main paper grades. The total quantities of pulp, the four paper grades, and "other paper" are taken from the FAO (2016). The total pulp and filler requirement is adjusted for losses in papermaking. The values in table 2 are calculated in a three-step procedure. First, the fraction of recycled pulp in each grade is calculated from paper for recycling utilization reported by the Confederation of European Paper Industries (CEPI) (CEPI 2012) and the yield ratio for recycled pulping. Each fraction for recycled pulp is scaled downward based on the total global amount of recycled pulp, to correct for the difference between European and global recycling levels. Second, the fraction of non-fibrous material are approximations based on Cote and colleagues (2015). The fraction of non-fibrous materials in "other" is calculated from the final difference between the total non-fibrous material use and the use in all other paper grades. Last, in accord with Laurijssen and colleagues (2010), the further input to newsprint is assumed to be mechanical pulp, and for printing + writing and sanitary + household paper it is chemical pulp. The remaining quantity of mechanical pulp is allocated to packaging. The remainder of chemical pulp is allocated to "other."

Postconsumer Waste and Stock

Table 3 displays the relevant parameters for calculating postconsumer waste flows. Each year, consumers add some newly purchased paper to stock and dispose of some of their purchases or old stock. The net additions to stock are assessed in three ways. First, product lifetime distributions were used. The

Table 3 Parameters for waste treatment and net additions to stock

Parameter	*Value*	*Reference*
Net addition to stock	0.09 (0.06 to 0.12)	(Cote et al. 2015; IEA 2007; FAO 2010)
Fraction of consumption to sewage	0.03	(Cote et al. 2015)
Fraction of residual waste to energy recovery	0.12	(OECD 2015)
Fraction of residual waste to incineration	0.08	(OECD 2015)

distribution of product lifetimes can be flexibly captured using, among others, a Weibull distribution (Müller et al. 2014). This study uses a Weibull distribution of total annual waste paper outputs in Germany based on the parameters determined by Cote and colleagues (2015) and applies it to global paper and cardboard consumption. The second method follows the FAO (2010) and uses a decay model with a half-life of 2 years for all paper products. For both methods, the net addition to stock in a single year is highly sensitive to variations in annual consumption. To deal with this, the global paper and cardboard consumption time series (1961–2012) was approximated with a least squares quadratic regression function. The two methods result in fractions of net additions to stock of 0.06 and 0.09, respectively. A third estimate was taken from the IEA (2007, 264). This report suggests a value of 0.12 to 0.15, but because of the discrepancy with the results from the more advanced estimations, only the lower value of 0.12 is considered.

The quantities of residual waste paper per country are calculated from FAO (2016) and the parameters for additions to stock and losses to sewage. The parameter for sanitary paper to sewage is set based on the fraction of toilet paper reported for Germany (Cote et al. 2015). It was assumed that all residual waste paper ends up effectively treated as residual municipal solid waste (MSW). The rates of residual MSW going to energy recovery, incineration without energy recovery, and landfill (or other disposal) for 30 of 34 Organization for Economic and Cooperative Development (OECD) countries and China are taken from OECD (2015). Residual waste paper from the rest of the world is assumed to go to landfill. Paper in sewage sludge is assumed to receive the same treatment as residual waste paper with the difference that the non-burned fraction is divided equally between landfill and non-energy recovery such as land application.

Industrial Waste

The fate of industrial waste generated during pulping is extrapolated from industry sustainability reports and annual reports. Table 4 summarizes the data from four of the largest paper companies in the world, covering 11% of global paper and cardboard production. It shows total paper production per company and the reported amounts of waste landfilled or used for non-energy recovery. Some of these quantities were calculated from reported waste treatment per tonne of final product or treatment as a percentage of total waste generation. Non-energy recovery includes land application or composting of sludge. Waste used for energy recovery is not directly reported by most companies, but follows from the difference between pulping losses and the amounts of waste landfilled and used for non-energy recovery. Monte and colleagues (2009) list many pretreatments for energy recovery, but company reports tend not to differentiate such pretreatments.

The representativeness of the data is compromised by a selection bias—reporting is voluntary and the worst performers naturally stay silent—but the sample does feature good geographical coverage. Data reported by UPM, Stora Enso, Resolute FP, and SCA were excluded as these companies also produce significant amounts of timber. Small fractions of waste dealt with by third parties are allocated to non-energy recovery. Incineration without energy recovery is considered negligible. It is assumed that, on average, the companies produce as much pulp as needed for their own paper and cardboard production and thus reflect the global average for pulping waste per unit of final product. The figures reveal significant differences in performance between the different companies. On average, 0.06 (0.04 to 0.12) tonne/tonne of paper and cardboard production goes to non-energy recovery and 0.06 (0.04 to 0.11) tonne/tonne goes to landfill.

Table 4 Paper production and industrial waste flows as reported by major paper producers

		Paper production	*Industrial waste treatment (megatonnes)*	
Company	*Country*	*(megatonnes)*	*Landfill*	*Non-energy recovery*
International Paper	United States	23.8	1.5	0.9
APP	Indonesia	8.3	0.3	0.7
Sappi	South Africa	5.4[a]	0.6	0.5
Kimberly Clark	United States	4.8	0.3	0.6
	Total	42.2	2.6	2.7

[a]Based on reported capacity and assumed 90% capacity utilization.

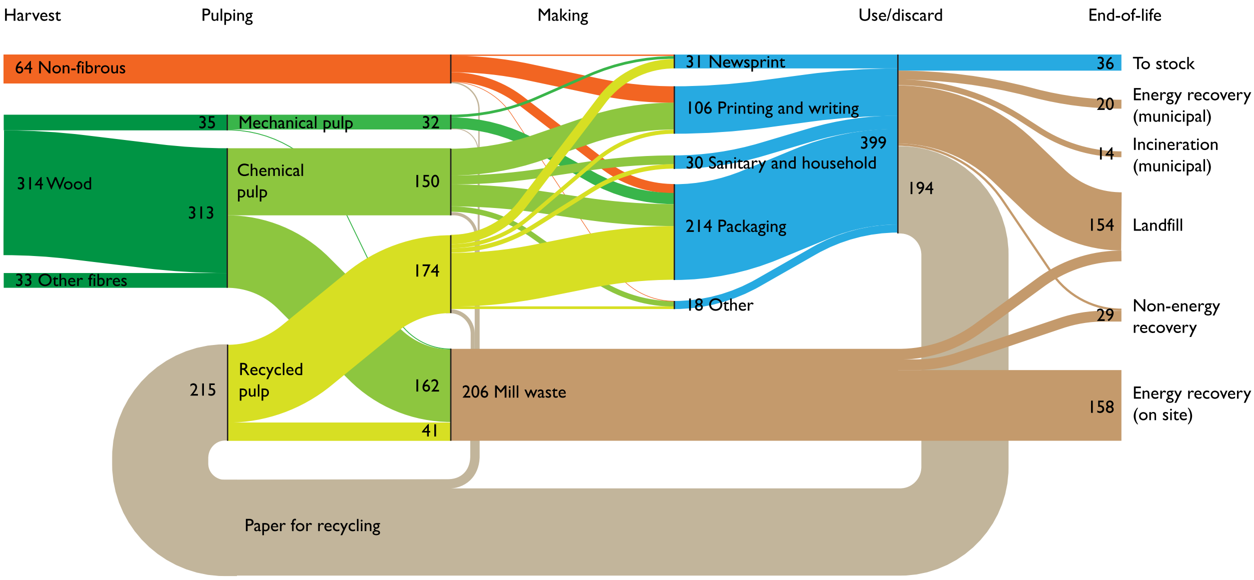

Figure 2 Global paper flows in 2012 in megatonnes.

Uncertainty

The data sources are sufficiently reliable to allow construction of a complete and consistent material balance. The apparent match between parameters and values from independent data sources reinforce the validity of the results. The following flows cannot be validated using the mass balance principle: non-fibrous input, virgin fibrous inputs, industrial waste generation, residual waste paper treatments, and industrial waste treatments. The amount of non-fibrous materials was calculated as a final difference. The non-fibrous content is 15.1% of final paper and cardboard production in 2012. Cross-checking reveals that this value is very close to the amount of non-fibrous materials (14.9%) used in a selection of European countries (CEPI 2012). The uncertainty of the other aforementioned flows is quantified through sensitivity analysis.

Sensitivity analysis shows the effect of parameter variation and is frequently applied to assess the robustness of material flow models (Laner et al. 2014). The approach in this article is to calculate a lower and upper bound for a flow based on the range of the relevant parameter. The parameter for the yield ratio of chemical and mechanical pulping affects virgin fibrous inputs and industrial waste generation, the parameter for net additions to stock affects the residual waste paper treatments, and the parameters for industrial waste treatment affect the total quantities going for non-energy recovery and landfill. The fraction of waste that is burned, but remains as ash, is included with non-energy recovery or landfill. All flows are reported to the nearest 1 megatonne.

Results and Discussion

Figure 2 shows the Sankey diagram of global paper flows in 2012. The diagram displays the flow of materials from harvest (left) to end-of-life (right). The flow width reflects the quantity. Mill wastes indicate waste flows in the industry that are either used in on-site energy recovery, are non-energy recovered, or landfilled. On-site energy recovery by paper producers is displayed separately from incineration with and without energy recovery of paper in residual MSW. Waste paper from papermaking is visualized as separate fibrous and non-fibrous losses, and they enter the same recycling loop as postconsumer waste paper. The detailed results including equations are given in section SI-2 of the supporting information on the Web.

Table 5 Material flows and their upper and lower bound

Material flow	*Lower bound (megatonnes)*	*Value used (megatonnes)*	*Upper bound (megatonnes)*
Virgin fibrous inputs	307	347	411
Net additions to stock	24	36	48
Postconsumer waste to energy recovery	19	20	22
Postconsumer waste to incineration	13	14	14
Postconsumer waste to landfill	116	130	145
Industrial waste to energy recovery	134	158	178
Industrial waste to non-energy recovery	16	24	48
Industrial waste to landfill	16	24	44

Table 5 shows the upper and lower bounds for several material flows based on the sensitivity analysis. The relative variation of the lower and upper bounds from the used value is largest for non-energy recovery and landfill of industrial waste. The ranges are skewed toward higher values because of the distribution of company performance. Despite the uncertainty, the material balance is useful for comparing the relative sizes of flows and analyzing potential improvements. Over time, the balance may be updated and improved with new data. The following sections discuss recycling and efficiency metrics and waste reuse appraisal based on the material balance.

Recycling Metrics

Current recycling metrics provide only a distorted image of the paper system. Recycling is commonly calculated by dividing paper for recycling by total production of paper and cardboard (Ervasti et al. 2015). For the global paper system, this results in a collection rate of 54%. However, this metric is both inconsistent and lacks meaning. It is inconsistent because it compares a quantity from the pulping stage (paper for recycling inputs) with a quantity from the papermaking phase (total production or consumption). The metric omits the losses that occur in between the two stages and ignores that not all paper is discarded and therefore not available for recycling. The metric also lacks meaning because its value does not reflect the purpose of recycling. The main goal of recycling is the reduction of impacts by displacing virgin production (Geyer et al. 2016). A recycling metric can only reflect the avoidance of virgin inputs by focusing directly on the harvest stage of the life cycle. A recycling metric that is both consistent and meaningful should compare waste paper inputs (paper for recycling) with total inputs (paper for recycling plus virgin fibrous harvest). Such a metric was discussed by Graedel and colleagues (2011) and named the *recycled input rate* (RIR).

The value of the RIR is 38% while the collection rate is 54%. The difference reflects the relatively high yield ratio of recycled pulping compared to chemical pulping. In other words, an increase in paper for recycling inputs does not imply a proportional decrease in virgin input requirements. Due to the differences in pulping efficiencies, 1 mass unit of paper for recycling may either displace 0.9 units of wood for mechanical pulping or 1.7 units of wood for chemical pulping. When paper for recycling substitutes virgin inputs without affecting the ratio between mechanical and chemical pulp inputs, the average global substitution rate is around 1.5. In practice, it depends on the desired properties of the final product whether recycled pulp will substitute mostly mechanical or chemical pulp. The RIR should be used with care because it can be inflated through inefficient use of secondary material (Chen 2013). The metric is also sensitive to the fraction of non-fibrous inputs since these could also substitute virgin pulp. It is beyond the scope of this article to discuss desirable levels of substitution of fibers by non-fibrous material.

Recycling metrics expressed as percentages may create the false impression that 100% recycled paper is technically possible. It is therefore important to report the technically achievable maximum performance alongside actual performance. At 2012 consumption levels, 351 tonnes (± 12 tonnes) of paper for recycling can be collected. The rest of consumption is irretrievably lost in the sewer or added to stock. The lower and upper bound is based on variability in additions to stock. In addition, papermaking generates 21 tonnes of paper for recycling. The total potential quantity of paper for recycling implies a collection rate of 90% to 96%. This large supply of paper for recycling can only be used with improved control of contamination. Pivnenko and colleagues (2015) show that 51 contaminants currently found in paper can pose challenges for recycling. Contamination may exclude certain uses of paper for recycling or lead to lower pulping yields. The most effective measure is not source separation or removal, but to phase out the use of chemicals altogether (Pivnenko et al. 2016).

The maximum value of the more desirable RIR can be calculated assuming a fixed non-fibrous content fraction and a fixed ratio between mechanical and chemical pulp for virgin fibrous inputs. The calculation assumes the lower recycled pulping yield ratio of 0.73 to reflect the increased need for deinking. Under these assumptions, the technical limit of the RIR is 67% to 73% (see section SI-4 in the supporting information on the Web). In other words, only 67% to 73% of fibrous inputs can be supplied by waste paper, the rest needs to be virgin fibers. The current performance for the metric is 38%, which is just over half of the technical potential. The inclusion of a technical potential in the reporting of recycling metrics can support better decision making. It would be useful for policy makers and industry to know how much more recycling is possible. An LCA would be required to assess the environmental merit of maximizing recycling.

Material Efficiency Metrics

Another way to improve paper production is by increasing the material efficiency of conversion processes since it reduces input requirements. The overall material efficiency (or yield ratio) of paper production strongly depends on the paper grade and required pulp inputs. For example, mechanical pulping has a much higher yield (0.90 to 0.95) than chemical pulping (0.40 to 0.55). However, the wastes from chemical pulping are used for energy recovery and can be sufficient to meet the energy demand of the mill. Low yield in chemical pulping therefore does not necessarily represent an undesirable inefficiency. The beneficial use of waste materials needs to be captured when discussing material efficiency.

Basic material efficiency calculations ignore the role of waste reuse. The standard metric for material efficiency is the ratio between material used in the product (M_p) and material supplied to it (M_s) (Lifset and Eckelman 2013).

$$\eta_m = \frac{M_p}{M_s}$$

Allwood and colleagues (2011) show how energy use and carbon emissions associated with conversion processes can be included in this equation. However, the example of the paper industry shows that energy needs can also be met by energy recovery from wastes from the same conversion process. In addition, wastes can be used for non-energy recovery. Material efficiency metrics would be more useful if they counted in all these types of waste reuse. The term reuse is defined here as any further use of wastes including recycling, energy recovery, and non-energy recovery—all the uses that potentially substitute virgin inputs and contribute to the overall resource efficiency of production and consumption.

The reuse of wastes can be included in efficiency metrics by considering the *reuse potential* of waste flows. The concept of a reuse potential has been suggested and explored by Park and Chertow (2014) for coal-combustion by-products. The waste reuse potential depends on the material properties and contextual factors and may change over time. A major challenge is data availability, especially since materials can have multiple uses. The reuse potential is operationalized as a value between 0 (no reuse possible) and 1 (full reuse possible) (Park and Chertow 2014). In part, standards for waste utilization are already found in documentation on best available techniques (Suhr et al. 2015). The reuse potential could be included numerically in material efficiency calculations. In addition, for complex material systems, such as analyzed in this article, the ideal total flow pattern could be assessed by assuming the full exploitation of the reuse potential of each flow. A Sankey diagram could serve to display both actual flows (as in this article) and ideal flows based on maximum waste reuse. The latter idea coincides with one of the first uses of the Sankey diagram by its namesake. In 1898, Sankey used two diagrams to compare actual and ideal flows of energy flows in a steam engine (Schmidt 2008; Sankey 1898)—the same could be done for material flows.

The assessments of recycling rates and material efficiency are closely related since both rely on the identification of a potential. For postconsumer waste, the reuse potential can be more precisely specified as a *technical recycling potential* and concerns the amount of wastes actually available to be collected as resources for reprocessing. For material efficiency, the reuse potential of a number of process wastes should be considered. In other words: The performance of a system of production and consumption ought to be judged by the extent to which wastes that can be used as resources are actually used as resources. Importantly, a waste qualifies as a resource if it can (beneficially) substitute virgin inputs. This rule holds both for postconsumer waste and for industrial waste. The technical recycling potential of waste paper was already calculated in this article. The calculation of the reuse potential of industrial wastes requires detailed knowledge of the relevant flows and the establishment of standards for waste reuse and is left for further study, as is the challenge of prioritizing between different types of waste reuse.

Conclusions

This study calculated detailed global paper flows and critically discussed recycling and material efficiency metrics. The material balance was presented as a Sankey diagram and displays, for the first time, material flows in all stages of the global paper life cycle from virgin inputs to end-of-life waste treatment. The discussion of environmental performance metrics led to three distinct conclusions.

1. The currently common recycling metric divides paper for recycling by total paper production. This metric does not directly stimulate avoidance of virgin inputs and associated impacts. A better indicator is the RIR, which divides paper for recycling by total fibrous inputs.
2. Recycling metrics are more meaningful if the achievable potential is known. The *technical recycling potential* is constrained by additions to stock and losses to sewage. Assuming effective control of contamination, the fraction of paper for recycling in total fibrous inputs can still be almost doubled.
3. Material efficiency should consider both final products and reused wastes as outputs of a process. The reuse of wastes can be contrasted with the *reuse potential*, which depends on material properties and contextual factors. The fulfillment of the reuse potential may be included in material efficiency metrics.

Further research should build on the above three conclusions. This study provided a start by mapping the global flows of paper. Future work could assess the reuse potential of the different waste flows and their fulfillment in a circular economy. In addition, the material balance can be used as the basis for a variety of environmental assessments.

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Supporting Information

Supporting information is linked to this article on the *JIE* website:

Supporting Information S1: This supporting information contains: (1) the model parameters; (2) the material balance equations and flow quantities; (3) the recycled pulping yield ratio calculation; and (4) the technical recycling potential calculation.

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Nonwoven: A Versatile Fabric

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Nonwoven is a textile product which is engineered in a very sophisticated way with the aid of modern technologies. Probably, these modern technologies are one of most important force which brought nonwovens up to the age of technical textiles. The term 'Nonwoven' came in existence more than half a century ago and at that time it was regarded as the low grade cheap substitute for traditional textiles. In its early stage it was manufactured from dry laid carded webs with the help of modified textile processing machines. Europe is the place where nonwoven originated, grown and matured. Now, the whole world together is making it more and more famous and useful.

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Opinion Open Access

Nonwoven: A Versatile Fabric

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Introduction

Nonwoven is a textile product which is engineered in a very sophisticated way with the aid of modern technologies. Probably, these modern technologies [1] are one of most important force which brought nonwovens up to the age of technical textiles. The term 'Nonwoven' came in existence more than half a century ago and at that time it was regarded as the low grade cheap substitute for traditional textiles. In its early stage it was manufactured from dry laid carded webs with the help of modified textile processing machines. Europe is the place where nonwoven originated, grown and matured. Now, the whole world together is making it more and more famous and useful.

EDANA (The European Disposables and Nonwovens Association) and INDA (North America's Association of the Nonwoven Fabrics Industry) has defined nonwoven [2] very well. It can be better understood as 'a manufactured sheet, web or batt of directionally or randomly oriented fibres, bonded by friction, and/or cohesion and/or adhesion, 50% by weight of which contains fibre having length to diameter ratio more than 300'. So, it is a textile product in sheet form, having equivalent (or better properties for some specific applications) properties as traditional fabric, manufactured directly from fibres.

Manufacturing process

Manufacturing process of nonwoven can be divided in three steps- web formation, web bonding and finishing. Figure 1 gives a brief idea of various system and techniques of nonwoven production.

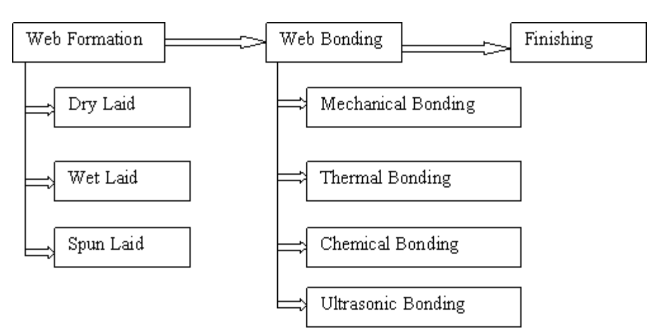

Figure 1: Nonwoven manufacturing process

Current situation

Now a day, it is very difficult to identify an area where nonwoven is not in use. The field of garment is the only field where nonwoven is not the primary material due to low strength but used extensively as a support and auxiliary material such as glove linings, shoulder pads, fusible interlinings, linings etc. for the completion of any garment. Nonwoven has excellent compression and transmission behavior which makes it suitable for numerous technical and nontechnical applications.

Most sophisticated application of nonwoven is in the field of medical. Nonwoven medical textiles enhanced the healing rate by controlled drug delivery and adequate compression behavior. Nonwoven medical products are many such as surgical swabs, wound dressings, surgical gowns, mask, cap, transdermal drug delivery system etc. Looking at the health and hygiene sector, one can find that nonwoven has taken around 90 % share. Most of the products of health and hygiene sector such as sanitary napkins, baby diapers, cosmetic removal pads etc. are made up of nonwoven.

Civil engineering and geosynthetics [3] are another field in which nonwoven is a major player. Nonwovens structure, compression and transmission behavior make is most suitable material for this field. Nonwovens have pores of non-uniform sizes which are uniformly distributed all over of it. This type of pore characteristics and its distribution are only possible with the nonwovens not with the other type of structures such as woven fabric, knitted fabrics etc. These characterizes of the nonwoven helps in filtration and reinforcement of civil engineering sites and constructions.

Household applications of nonwovens have increased sharply during last few years due to its low cost and better qualities. Nonwovens are being used as blanket, sheet, curtains, mattress pads, waddings and fillings, window blinds etc. Boom of nonwovens can really be seen in the wipe sector. About 98% of wipes are made up of nonwovens. The reason behind this is probable due the better cleaning and absorbing properties of nonwovens. It absorbs mixture of water and dust particle inside its body and present fresh surface for more wiping and cleaning action.

As the uses of the nonwoven are increasing, the demand of the market is also increasing. This demand has caused great increase in the production of nonwoven. The total global production of nonwoven has reached to around 5.1 million tonnes. Western Europe and Northern America is the major producer contributing up to 60%. Asia Pacific Region produces around 25 % of total production.

Future prospective

Several developments are in the process all over the world for the structural modifications of the nonwovens. The need for improved performance has induced these research and developments. The future is for composite nonwovens and nonwoven composites. Three dimensional characteristics of nonwoven make it suitable for high performance composite applications where de-lamination properties are required. Nonwoven having many layers of different fibre, constructional and functional behavior are known as composite nonwoven. Nonwoven impregnated [4] with resin is known as nonwoven composite. Composite nonwovens are required for better filtration behavior. High quality masks are made up of composite nonwovens. Modified fibres such as electrically charges fibres are used in the inner layer of the composite nonwovens to be used in these high quality masks. Fibres of different cross sections have also been used to enhance the performance of the nonwovens.

Europe has recently overtaken the America and become the largest nonwoven producer with help of new developments in air laid and spun laid technology. In American market, the expansion of the absorbent hygiene industry is expected to be modest. Strong growth is expected in wipes sector. With the new industries and intensive research, Indian subcontinent is expected to come up with the highest growth rate in the nonwoven production and quality.

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PAPERmaking!
FROM THE PUBLISHERS OF PAPER TECHNOLOGY
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LORENTZEN & WETTRE PRODUCTS: A COMPLETE RANGE OF INSTRUMENTS FOR THE CORRUGATED BOARD INDUSTRY

Lorentzen & Wettre, the major Swedish instrument manufacturer, produces a whole range of instruments for characterising corrugated boards. This article lists their range of products, describing their uses and benefits.

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L&W Crush Tester code 248 tests corrugated board, liner and fluting as well as performing compression tests on small boxes. The instrument measures new crush properties such as flat crush hardness and the total energy absorbed during a FCT measurement.

A built-in plate distance sensor can also be used to measure the corrugated board thickness.

All measured properties are programmed into the instrument before delivery.

Benefits

a) Easy to use with pre-programmed start position and evaluation of measurements, all for easy shift between measurements such as RCT and ECT
b) Robust construction for reliable measurement results, especially important when measuring FCT so that the test piece does not shear and cause "leaning" flutes
c) Gives automatically correct FCT value – Manual settings for each flute type is not needed
d) Measures new crush properties such as flat Crush Hardness, flat crush energy and flat crush stiffness

L&W Bursting Strength Tester code 181 measures (according to Mullen) bursting strength of corrugated board. Furthermore it also measures bursting energy absorption (BEA) and diaphragm-compensated bursting strength.

Sample is automatically detected, measurement starts once a test piece has been placed in the measuring gap. To maximize the sample measurement rate, L&W Bursting Strength Tester takes a minimal amount of time between bursts, so that a series of 10 measurements can be done in less than 45 seconds.

Benefits

a) Very fast testing cycle gives fast feedback to the production
b) Auto-start, a photocell detects the presence of a sample and automatically initiates a measurement sequence, thus allowing hands-free operation
c) Auto-cycling function permits the continuous cycling of the upper pressure foot to facilitate representative and continuous measurements
d) Available with automatic test strip feeder

L&W Compressive Strength Tester STFI code 282 measures the compressive strength of liner and fluting according to the SCT-method. Compressive strength determines the stacking ability of corrugated boxes. The aim is to produce strong boxes, and use a minimum of raw material.

Ultra precision clamping unit:

Benefits

a) an improved measuring unit designed for higher accuracy and reproducibility between measuring units
b) all important tolerances has been tighten so they surpasse the requirement from ISO and Tappi
c) the new design leads to less wear of critical parts, longer life time, simplifies maintenance work, and is less sensitive to build up fibres and dust

L&W Micrometer code 251 gives precise and exact thickness measurements corrugated board. Thickness (caliper) is an important characteristic that affects bending stiffness. Controlling thickness uniformity means producing printing paper that performs well in the printing press.

The automatic start allows the user to keep both hands on the sample to precisely place the sample in the measurement area.

Benefits

a) Auto-start, a photocell detects the presence of a sample and automatically initiates a measurement sequence, thus allowing hands-free operation
b) Auto-cycling function that permits the continuous cycling of the upper pressure face to facilitate representative and continuous measurements
c) Adaptive lifting height optimizes the height adjustment of the upper pressure face to allow whole series to be measured as quickly as possible
d) Consistent result, due to high quality manufacturing standards (hardened and polished stainless steel)

L&W 4-Point Bending Stiffness Tester code 287 measures the bending stiffness of corrugated board and heavy paperboard rapidly and accurately. The unique design of the pneumatic clamps permits measurements of warped and twisted samples without impairing results.

Benefits

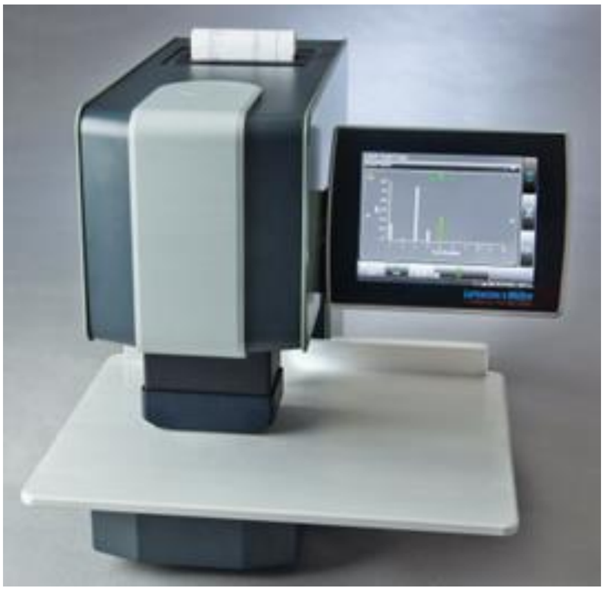
a) Fully automated testing sequence
b) Pneumatic clamping effectively eliminates any problems with twisted and curled test pieces
c) Recommended settings for different flute types are pre-programmed

L&W Moisture Tester code 862 is the ultimate offline moisture measurement solution for corrugated board. It measures moisture content at all stages of the process chain. Thanks to the quick measurement procedure, L&W Moisture Tester can also be used for product checking when online moisture sensors indicates out of specifications.

Benefits

a) Time saving (replaces the gravimetric method), the measurement takes only a few seconds
b) Measurement results are not affected by curled materials, uneven surfaces or multilayer structures
c) Well proven measurement method
d) Suitable for trouble shooting
e) Back-up for online moisture sensors

L&W OptiTopo code 269 is an instrument for measuring surface roughness and predicting printability of paper. It is a faster, better and yet less expensive instrument compared to traditional optical methods for measuring surface roughness. The measurement method is developed by Innventia and has, for over a decade, proven to be an outstanding technique to assess the correlation between paper surface and print defects.



Benefits

a) Fast optical method – reports in a few seconds
b) Comprehensive prediction of printability
c) Extensive measuring area
d) High-resolution CMOS camera

L&W Cobb Sizing Tester code 146 measures the weight increase of a sample, when exposed to water for a given time. L&W Cobb Sizing Tester is also available in a special version with rubber gasket for corrugated board to avoid leakage.

Benefits

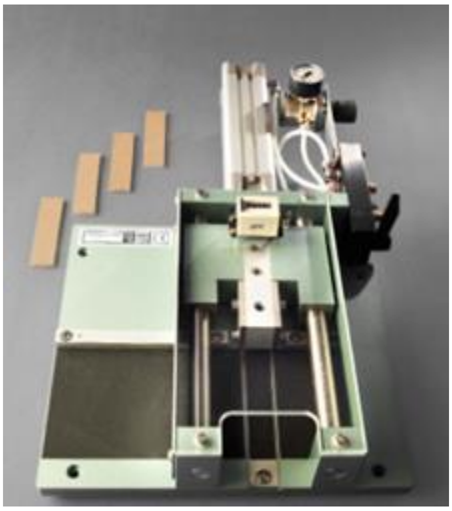
a) Single handed operation
b) Fast locking of the sample
c) Couch roll is included

L&W Strip Punch code 108 provides you with precisely cut sample strips, which can be used in tensile strength tests, fracture toughness tests, compression strength tests, bending stiffness tests, or ring crush tests.

Benefits

a) Precision cutting of samples
b) Easy to operate
c) Sturdy model
d) Feeding table for easy handling

L&W ECT Cutter Billerud code 008 prepares accurate samples of corrugated board for ECT testing. This method, which cuts the edges parallel, is the established tool for preparing the edges of an ECT test piece, no matter which standard is used.



Benefits

a) Cuts straight, parallel and rightangled edges
    a. vital to the test result
b) Pneumatically driven cutter head
c) A built-in counter checks the life of the knives

L&W Circular Cutter code 123 cuts circular test pieces of corrugated board for use in flat crush tests (FCT).

Benefits

a) Precision cutting of samples
b) Simple operation
c) Easy to use

L&W Autoline Data Acquisition Workstation (DAW) connects existing or new stand-alone instruments from Lorentzen & Wettre, and instruments from other manufacturers, into a data gathering network, where recording, presentation, and archiving of results is performed.

Benefits

a) Up to 10 stand-alone instruments can be connected to each station
b) The Windows based software enables simultaneous operation of all instruments
c) The system is delivered complete with PC, software and connections for the instruments
d) The system is enabled for networking
e) Several pre-programmed testing sequences available
f) Remote viewing station provides real time data

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Update to BS EN ISO 13849-1, third edition 2015 – standard for safety related controls on machines

David Collier, Sales Manager at Pilz Automation Ltd, UK

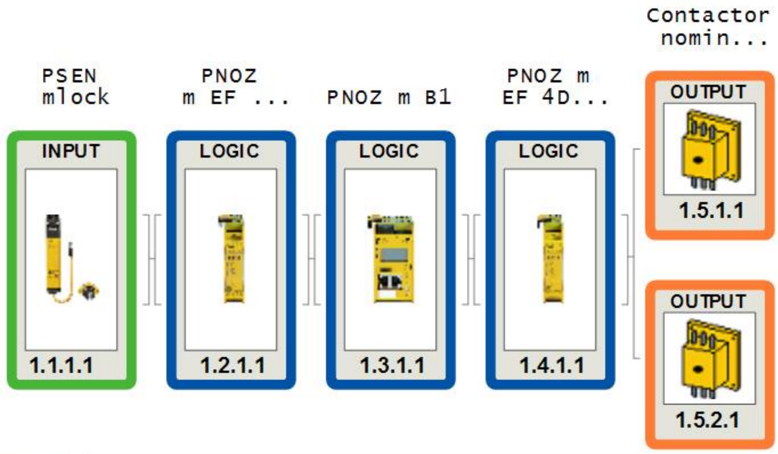
The planned merger of EN ISO 13849-1 and EN 62061 into IEC/ISO 17305 by the Joint Working Group JWG1 did not eventually come to pass, however, during the attempt an official request was made to alter the existing version of EN ISO 13849-1 which did take place in December 2015. The latest 2015 edition is now harmonised to the Machinery Directive.

The modifications are in some cases purely editorial (such as the suffix "d" used in $MTTF_d$, $B10_d$ and elsewhere being replaced by "D"), however, some important clarifications and shifts have been included, and it is now the case that EN ISO 13849-1:2015 is the go-to standard for safety-related controls on machines since the previous edition is no longer harmonised to the Machinery Directive 2006/42/EC.

In section 1 the table comparing the recommended application of EN ISO 13849-1 and EN 62061 has been removed, but EN 62061 is still mentioned. In section 2 normative references to other standards have been updated, such as ISO 12100:2010 for risk assessment and risk reduction.

In section 3 (terms and definitions) one addition is the mention of "proven in use" which means demonstration, based upon operation experience for a specific configuration of a component that a likelihood of a dangerous failure is low enough not to impact the Performance Level of all safety functions incorporating that component. Later in the standard it becomes clear in 4.5.5 that this is only "allowed" for mechanical, hydraulic and pneumatic elements where omission of $MTTF_D$ is to be justified, and proven in use would need to be stated by the manufacturer of the component.

Quite a lot of change has happened in section 4 Design Considerations. In section 4.5.2 the limitation of $MTTF_D$ to 100 years (capping) was previously applicable to all subsystems regardless of category, which had the undesirable effect of limiting the number of category 4 subsystems which could be combined without a drop in Performance Level from PL e to PL d. This was thought to be too conservative, therefore, for category 4 subsystems the capping limit has been raised to 2500 years which means later in the informative annex K the table K1 now covers this extended range instead of 100 years. This higher value is justified because in Category 4 other quantifiable aspects (structure and Diagnostic Coverage) are at their maximum point. As a result of this there is no longer a need to combine input and actuator elements as one subsystem in some cases, which was previously sometimes needed especially for hydraulic and pneumatic components.



SRP/CS Editor | CCF Editor

Calculation Graph

Subsystem/channel	Contribution to PL	PL	PFH_D	Cat.	DCavg	$MTTF_D$: Limited	$MTTF_D$: sym.	$MTTF_D$/Ch1	$MTTF_D$/Ch2	DC	CCF
Interlocked guard		e	3.73E-09								
1.1.1.1 - PSEN mlock		e	2.35E-09	4							
1.2.1.1 - PNOZ m EF 16DI		e	4.27E-11	4							
1.3.1.1 - PNOZ m B1		e	4.19E-10	4							
1.4.1.1 - PNOZ m EF 4DI4DOR		e	7.52E-12	4							
Output		e	9.06E-10	4	99.00%	2500.00years	2500.00years	2500.00years	2500.00years		65
1.5.1.1 - Contactor nominal								82727.27years		99.00%	
1.5.2.1 - Contactor nominal									82727.27years	99.00%	

In section 4.5.4 the assumption made for Category 2 that the demand rate must be less than 1/100 of the test rate has been changed to “the demand rate is less than or equal to 1/100 test rate; or testing occurs immediately upon demand of the safety function and the overall time to detect the fault and to bring the machine to a non-hazardous condition (usually to stop the machine) is shorter than the time to reach the hazard (see also ISO 13855)”. The added possibility to test “on demand” allows a dual channel category 2 design with one active channel and one monitoring channel, the latter recognising and appropriately responding to demand placed on the former but only actively getting involved in the case that the first channel fails. This could be useful for retrofit applications (second channel as an add-on to the existing first channel), if timing constraints are met to ensure that for safety distances are maintained with respect to stopping times (see also EN ISO 13855).

Up until the change, Table 5 in section 4 was used to select the optimum category / DC / $MTTF_D$ combination to achieve a desired PL. This is now supplemented by another table in 4.5.5 Description of the outputs part of the SRP/CS by category, which refers to actuators (such as power drives) or mechanical, hydraulic or pneumatic components (or components comprising a mixture of technologies) where no application-specific reliability data is available. The machine builder has scope to evaluate the PL without any reference to $MTTF_D$ calculation, and use only Category, Diagnostic Coverage and steps against Common Cause Failure (CCF). Table 8 shows recommended and optional categories which can be used to achieve the desired PL in a subsystem comprising such components, providing that they are “proven in use” or “well tried” (regardless of Category) which means in practise usability will be limited. However, it may be used where calculation of the PL of the final actuator subsystem in a safety function is not possible.

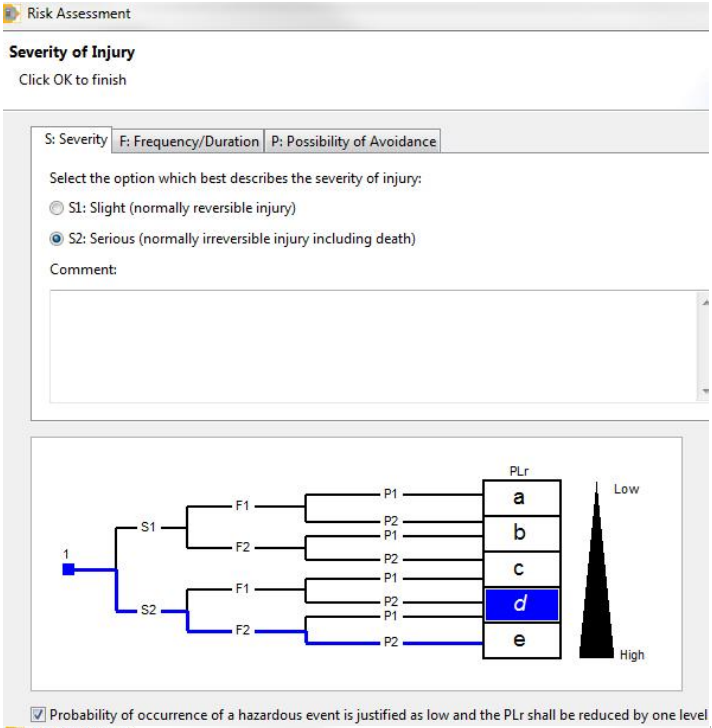
Section 4.6 covers software and a new statement is made about non-failsafe PLCs whose manufacturer-developed embedded firmware does not meet the requirements of SRESW (safety related embedded software needs to be developed in accordance with IEC 61508-3 which is a very detailed task only ever conducted by safety PLC / controller manufacturers). The requirement is that for standard PLCs to be used in safety functions the PL must be limited to PL a or b when in Category B, 2 or 3, and for PL c or d to be achieved two diverse PLCs must be used in two channel architecture. In practise such as structure would not be used due to installation and maintenance efforts (two different PLCs running together) and probably also space and cost. Therefore, for PL c and above and above the obvious choice is to use safety PLCs.

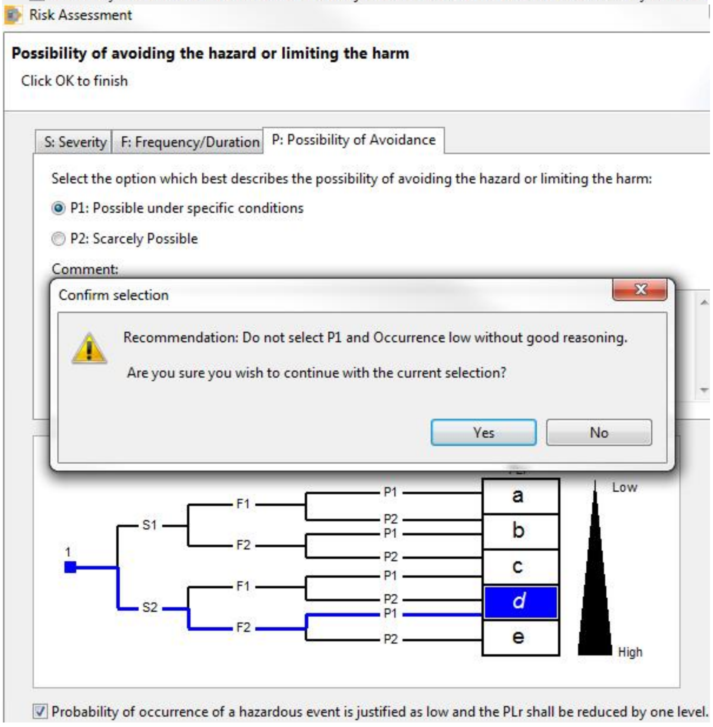
In section 6.2.2 reference is still made to the fact that the structure (Category) is the key characteristic having the greatest influence on the PL. The statement that it is admissible to design according to a machine-specific C-standard specifying just a Category (as was in EN 954-1) and not the PL (hence obviating the need to consider $MTTF_D$, DC and CCF) has been removed. It is the view of the author that one should always use state of the art when defining a safety function and working with the full requirements of EN ISO 13849-1 is better than using the superseded EN 954-1 and just the Category.

The informative Annexes have undergone some significant changes.

Annex A concerns the risk analysis used to determine the required PL. It must be pointed out that the risk graph method is not mandatory, and it assumes the worst case (probability of occurrence is 100%). It is also possible to deduce the PLr by other methods, or refer to a PL stated in a machine-specific C-standard. The terms S (severity), F (frequency) and P (possibility of avoidance) remain. The term F is now better clarified as F1 seldom being accumulated exposure time being less than 1/20 of the overall operating time and the frequency not higher than once per 15 minutes – the aim of this is make sure that duration is better defined, which is very relevant to relating a safety function to a task such as maintenance and not just the number of times persons are exposed to hazards.

Now consideration can also be given to the additional term **probability of occurrence** (which is a parameter considered in EN 62061 when determining a target SIL, but note previously considered in EN ISO 13849-1). Rather than assuming 100% there is now a statement that “where the probability of occurrence of the hazardous event can be justified as low, the PLr may be reduced by one level”. This means that after considering severity (e.g. S2 irreversible injury), frequency of exposure (e.g. F2 twice a shift) and possibility of avoidance (e.g. P2 unavoidable) the PLr would be PL e, but by using the argument that it’s actually not likely to happen you could instead select PL d. This is not a massive stretch, however, a drop from PL d to PL c is a big step, because the design requirement could change from requiring dual channel architecture such as Category 3 with Diagnostic Coverage of 60% to single channel Category 1 without any Diagnostic Coverage. This is dramatic and even more so if taking the reduction from PL c (which at a minimum requires Category 1 and the use of well-tried components) to PL b (which would remove the need to use even well tried components). It is the view of the author that the use of such a reduction could be used if a safety solution is being designed on-top of an existing control solution, but it should not be used to rectify an existing poorly designed safety function. More importantly, **extreme caution** should be used when applying the reduction if one has already reduced the PL r by selecting P1. Note the option to do this appears in both Sistema and PAScal software, with the warning about applying the reduction of PLr where P1 has been selected. It is probably worthy of note that anyone buying a machine should be asking the machine supplier about this, as there may be a temptation to reduce the cost of the safety-related controls and this should not be at the expense of safety!





There are many other changes but the above are some of the most significant. The fact that this new edition is harmonised means that software tools, such as PAScal v1.8 have been updated to reflect these changes.

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If You're Stressed, Stop Doing This Now

The pace of life gets ever faster, which can cause a build-up of stress. This article teaches some simple ploys on how to control and reduce stress both in the workplace and daily life.

www.ccl.org/articles/

More than 15 years ago, Nick Petrie walked off a rugby field in Japan feeling more exhausted than he ever had in his life.

The 6-foot-6 professional athlete, just in his late twenties, was used to being in peak physical condition. But when he arrived back home in New Zealand for a visit, his mother didn't mince words. "You don't look well," she told him.

She was right.

Testing and surgery revealed a nightmare diagnosis — stomach cancer.

An operation removed the cancer. A year later, it came back in Petrie's liver. Another surgery followed. Then 5 years ago, the cancer came back again.

Here's one surprising piece of this story: Petrie, who still harbours cancer in his liver, is thriving as a senior faculty member at the Center for Creative Leadership.

And here's another twist you might not expect: He's not stressed at all.

Petrie and Derek Roger co-authored the new book *Work Without Stress: Building a Resilient Mindset for Lasting Success*. He credits Roger, a British researcher, with transforming his approach to stress and making it possible to live fully in the face of a terrifying illness.

This duo's insights have important implications for us not only as individuals but also as leaders who are charged with unleashing the full potential of the people we are privileged to serve. Petrie and Roger reject the conventional notion that stress is caused by external circumstances beyond our control, such as our job or our boss or family members. Instead, their work is grounded in 2 fundamental assumptions.

First, there's a critical difference between pressure and stress. Pressure is the need to perform, and it's something we all feel at one time or another as we compete in athletics, build a career, or raise a family. Stress, however, is what happens when we let pressure overwhelm us.

Second, we let pressure overwhelm us because of our tendency to ruminate — that is, to continuously churn over emotional upsets. To paraphrase Petrie, rumination is what you do when you wake up at 3 a.m. and can't get back to sleep because you are thinking about all the things you have to do or haven't done or should have done. It's an invitation for worry and permits negative thoughts to take over our minds, and we all let it happen. Some of us even spend most of our lives in this state.

Certainly, it's where Petrie found himself, ruminating endlessly and understandably over his cancer diagnosis, when he met Roger more than a decade ago. He was able to break the cycle of rumination by following Roger's advice, and sharing that guidance with others has become one of Petrie's main missions. Just a couple weeks ago, in fact, he led a workshop for more than 100 pilots at a major airline in the morning and then flew straight to CCL's headquarters to lead a similar session that afternoon with our board — all the while looking remarkably relaxed!

Here are the 4 main steps that Petrie and Roger advise us to take:
1. Wake up: Most of us spend the majority of our time preoccupied or daydreaming about the past or future, never really plugged into the very moment we are experiencing now. It's how we can drive to work and forget how we got there or lock the front door at night for the fifth time without realizing it.

It's a habit that breeds rumination, and it's pretty much inevitable. The key is to snap out of it as quickly as possible by getting out of our heads and back into our bodies. So clap your hands, stand up, or stretch. If you're in a meeting, bounce your foot up and down, focus on the colours in the room, listen to the nearest sounds — anything to get you back into the present moment.

2. Control your attention: It seems logical to say, "Why worry about things I can't do anything about?" But many of us worry about these things anyway. One thing we actually can control is our attention. We can practice consciously putting our attention where want it to be and leaving it there. Petrie likes to draw a circle and then put things he can control inside of it and things he can't control outside of it as a reminder of where his priorities should be.

3. Detach: This is the ability to keep things in perspective. Look at the current challenge or situation that is causing rumination. Compare it to other things you have experienced over the years. Most of us, hopefully, will not have a reference point as bracing as Nick's long battle with cancer. But tough challenges come to all of us. How does the current one compare? How much will it matter 12 months from now?

4. Let go: This doesn't mean doing nothing or letting go of responsibilities. It does mean releasing the negative emotions, or rumination, that have ensnared us. That's not easy to do of course. Still, we can practice acknowledging situations for what they are, reflecting on what we've learned from them, and doing something about it if we can. Beyond that, we do not want to remain focused on them.

These steps take some time to master, but I've been working on them myself and seeing real progress, as have many leaders who have employed them over the past 30 years. And there's no better proof of their power than the inspirational story of Nick Petrie himself.

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Note-Taking

Effective note-taking is an important transferable skill that can be applied in all aspects of life, socially, at work and during study. Learn how with this short article.

www.skillsyouneed.com

Note-taking is a powerful aid to communication, a way of summarising and retaining the key points from what you've heard and understood.

There are different approaches to note taking, depending on the type of communication you're engaged in. This page covers effective note-taking for verbal exchanges – that is, summarising what has been said, in face-to-face conversations, over the phone and in group situations – like in meetings or when attending a lecture.

What is Note-Taking?
Note-taking is, simply, a way of concisely recording important information so that you can recall it later.

Regardless of how good you think your memory is - you will need to take notes in certain situations to remind yourself what was said. It is a mistake to think, when going to a meeting or attending a lecture or some other important talk, that you will remember the details of what has been said - you won't. You may well remember the overall topic of the discussion, even some very specific details, but you won't remember everything.

It is important to recognise that taking notes should not distract you from listening intently to what the speaker is saying. Effective note-taking involves listening whilst jotting down key points that will be important later: in a business meeting this may include action points that you have agreed to attend to; in a lecture this may include new vocabulary or theories that you can investigate further later.

Before you can take effective notes you need to be somewhat organised. It may seem obvious but you need to remember to take some appropriate note-taking equipment with you to meetings, lectures etc. The nature of the 'appropriate' note-taking equipment will depend partly on you and partly on the circumstances. The simplest low-tech way of taking notes is to use a pen (or series of different coloured pens) and a pad of paper. Bring plenty of paper and at least one spare pen or pencil.

Some people prefer to take notes on a laptop, tablet, smartphone or some other device – this is fine as long as you are very comfortable with the technology - so that they can concentrate fully on their notes – not on the actual process of writing them. If you are using some form of computer to take notes it is usually a good idea to turn off any messaging services first – otherwise you are likely to be distracted by new emails, text messages or the like.

When you arrive at the meeting or lecture try to sit so that you can clearly see and hear the main speaker.

General Note-Taking Guidelines:

- Before you start taking any notes be clear about why you are attending the talk or meeting. What are you hoping to learn or gain from it? Think of your notes as a guide to your learning and development after the event. You notes form part of a working document that you'll return to and add to later.
- Think about whether or not a point is noteworthy before you write it down – do not take notes for the sake of taking notes. Otherwise you'll end up with lots of irrelevant points, which will distract you from the important things. You probably only really need to make notes on things that are new to you.
- Do not write down everything that is said, word-for-word, that would be transcribing, which is an altogether different skill. Concentrate on the key points, remain alert and attentive and listen to what is being said.
- Write in your own style and use your own words, you don't need to worry too much about spelling, grammar, punctuation or neatness as long as you can read your notes later and they make sense to you. Your personal note-writing system will evolve and improve with practice.
- Try to use short concise points, single words or phrases or short sentences, use bullet or numbered lists if necessary. If you are using a pen and paper then it is easy to add linking lines to join ideas and concepts.
- Write down in full, key information that can't be shortened: names, contact details, dates, URL's, references, book titles, formulas etc.
- Use abbreviations to help you – just note what they mean!
- Use underlining, indentation, circle words or phrases, use highlighter pens – whatever system works for you to emphasis the most important points and add some structure to your notes.
- Use some sort of shorthand system that you will understand later – develop this system as you become more skilled at note-taking.
- Don't panic if you miss something. You can usually ask the speaker to repeat a point or ask a colleague or peer after the event. Note down that you have missed something to remind you to do this.

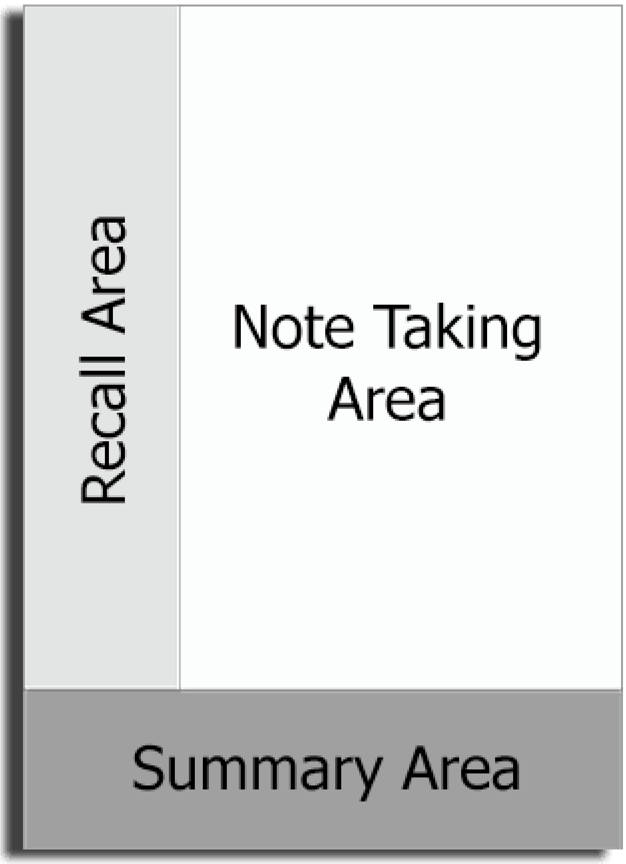
Once the event has finished:

- As soon as possible, after the event, you should review and, where necessary, rework your notes. Fill in any gaps, adding content and further research to your notes. If your notes are handwritten you may want to type them into a computer. The more you interact with your notes the more you will remember and ultimately learn.
- If possible share and/or compare your notes with a colleague or peer. Discuss your understandings and fill in any gaps together.

The Cornell Method

The Cornell Method of note-taking is highly effective, see if it works for you.

- Divide your sheet of paper, as the diagram, so you have a wide left margin (the recall area) and a deep (summary area) at the bottom. Leaving the rest of the sheet for the notes you take while attending the class or meeting.
- Write notes in the 'note taking area'. After the event fill in any gaps in your notes, try to leave some white space between points. For each major point or idea covered in your notes write a 'cue word' or 'keyword' in the recall area of your sheet.



- For example: If your notes were about 'note taking methods' and you had a section describing the Cornell Method then you would probably write 'Cornell' or 'Cornell Method' in your recall area aligned with the specific notes.
- Use the summary area to write a brief summary of what your sheet contains – it may be useful to colour code this area. The summary will help you to find relevant notes later when you need to review them – this is especially useful for students when revising for exams or writing an assignment.

The Cornell Method of note-taking can be used as a powerful aid to recalling information.

Test your memory and knowledge by putting another sheet of paper over the 'note taking area' so just the 'recall area' is visible. Use the phases in your recall area as your cue and recite as much information about each point as you can remember – check what you have remembered with your main notes. You will quickly find where the gaps in your knowledge are.

PAPERmaking!
FROM THE PUBLISHERS OF PAPER TECHNOLOGY
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10 Steps To Effective Listening

Dianne Schilling

Listening properly involves concentrating carefully on what is being said, and not trying to multitask. Learn more about this important skill with this short article.

Dianne Schilling is a writer, editor, graphic artist and instructional designer who specializes in the development of educational materials and customized training programs for business and industry. She holds a masters degree in counselling and is a founding partner of WomensMedia.com.

www.forbes.com

In today's high-tech, high-speed, high-stress world, communication is more important then ever, yet we seem to devote less and less time to really listening to one another. Genuine listening has become a rare gift—the gift of time. It helps build relationships, solve problems, ensure understanding, resolve conflicts, and improve accuracy. At work, effective listening means fewer errors and less wasted time. At home, it helps develop resourceful, self-reliant kids who can solve their own problems. Listening builds friendships and careers. It saves money and marriages.

Here are 10 tips to help you develop effective listening skills.

Step 1: Face the speaker and maintain eye contact.
Talking to someone while they scan the room, study a computer screen, or gaze out the window is like trying to hit a moving target. How much of the person's divided attention you are actually getting? Fifty percent? Five percent? If the person were your child you might demand, "Look at me when I'm talking to you," but that's not the sort of thing we say to a lover, friend or colleague.

In most Western cultures, eye contact is considered a basic ingredient of effective communication. When we talk, we look each other in the eye. That doesn't mean that you can't carry on a conversation from across the room, or from another room, but if the conversation continues for any length of time, you (or the other person) will get up and move. The desire for better communication pulls you together.

Do your conversational partners the courtesy of turning to face them. Put aside papers, books, the phone and other distractions. Look at them, even if they don't look at you. Shyness, uncertainty, shame, guilt, or other emotions, along with cultural taboos, can inhibit eye contact in some people under some circumstances. Excuse the other guy, but stay focused yourself.

Step 2: Be attentive, but relaxed.
Now that you've made eye contact, relax. You don't have to stare fixedly at the other person. You can look away now and then and carry on like a normal person. The important thing is to be attentive. The dictionary says that to "attend" another person means to:

- be present
- give attention
- apply or direct yourself
- pay attention
- remain ready to serve

Mentally screen out distractions, like background activity and noise. In addition, try not to focus on the speaker's accent or speech mannerisms to the point where they become distractions. Finally, don't be distracted by your own thoughts, feelings, or biases.

Step 3: Keep an open mind.
Listen without judging the other person or mentally criticizing the things she tells you. If what she says alarms you, go ahead and feel alarmed, but don't say to yourself, "Well, that was a stupid move." As soon as you indulge in judgmental bemusements, you've compromised your effectiveness as a listener.

Listen without jumping to conclusions. Remember that the speaker is using language to represent the thoughts and feelings inside her brain. You don't know what those thoughts and feelings are and the only way you'll find out is by listening.

Don't be a sentence-grabber. Occasionally my partner can't slow his mental pace enough to listen effectively, so he tries to speed up mine by interrupting and finishing my sentences. This usually lands him way off base, because he is following his own train of thought and doesn't learn where my thoughts are headed. After a couple of rounds of this, I usually ask, "Do you want to have this conversation by yourself, or do you want to hear what I have to say?" I wouldn't do that with everyone, but it works with him.

Step 4: Listen to the words and try to picture what the speaker is saying.
Allow your mind to create a mental model of the information being communicated. Whether a literal picture, or an arrangement of abstract concepts, your brain will do the necessary work if you stay focused, with senses fully alert. When listening for long stretches, concentrate on, and remember, key words and phrases.

When it's your turn to listen, don’t spend the time planning what to say next. You can't rehearse and listen at the same time. Think only about what the other person is saying.

Finally, concentrate on what is being said, even if it bores you. If your thoughts start to wander, immediately force yourself to refocus.

Step 5: Don't interrupt and don't impose your "solutions."
Children used to be taught that it's rude to interrupt. I'm not sure that message is getting across anymore. Certainly the opposite is being modelled on the majority of talk shows and reality programs, where loud, aggressive, in-your-face behaviour is condoned, if not encouraged.

Interrupting sends a variety of messages. It says:

"I'm more important than you are."
"What I have to say is more interesting, accurate or relevant."
"I don't really care what you think."
"I don't have time for your opinion."
"This isn't a conversation, it's a contest, and I'm going to win."

We all think and speak at different rates. If you are a quick thinker and an agile talker, the burden is on you to relax your pace for the slower, more thoughtful communicator—or for the guy who has trouble expressing himself.

When listening to someone talk about a problem, refrain from suggesting solutions. Most of us don't want your advice anyway. If we do, we'll ask for it. Most of us prefer to figure out our own solutions. We need you to listen and help us do that. Somewhere way down the line, if you are absolutely bursting with a brilliant solution, at least get the speaker's permission. Ask, "Would you like to hear my ideas?"

Step 6: Wait for the speaker to pause to ask clarifying questions.
When you don't understand something, of course you should ask the speaker to explain it to you. But rather than interrupt, wait until the speaker pauses. Then say something like, "Back up a second. I didn't understand what you just said about…"

Step 7: Ask questions only to ensure understanding.
At lunch, a colleague is excitedly telling you about her trip to Vermont and all the wonderful things she did and saw. In the course of this chronicle, she mentions that she spent some time with a mutual friend. You jump in with, "Oh, I haven't heard from Alice in ages. How is she?" and, just like that, discussion shifts to Alice and her divorce, and the poor kids, which leads to a comparison of custody laws, and before you know it an hour is gone and Vermont is a distant memory.

This particular conversational affront happens all the time. Our questions lead people in directions that have nothing to do with where they thought they were going. Sometimes we work our way back to the original topic, but very often we don't.

When you notice that your question has led the speaker astray, take responsibility for getting the conversation back on track by saying something like, "It was great to hear about Alice, but tell me more about your adventure in Vermont."

Step 8: Try to feel what the speaker is feeling.
If you feel sad when the person with whom you are talking expresses sadness, joyful when she expresses joy, fearful when she describes her fears—and convey those feelings through your facial expressions and words—then your effectiveness as a listener is assured. Empathy is the heart and soul of good listening.

To experience empathy, you have to put yourself in the other person's place and allow yourself to feel what it is like to be her at that moment. This is not an easy thing to do. It takes energy and concentration. But it is a generous and helpful thing to do, and it facilitates communication like nothing else does.

Step 9: Give the speaker regular feedback.
Show that you understand where the speaker is coming from by reflecting the speaker's feelings. "You must be thrilled!" "What a terrible ordeal for you." "I can see that you are confused." If the speaker's feelings are hidden or unclear, then occasionally paraphrase the content of the message. Or just nod and show your understanding through appropriate facial expressions and an occasional well-timed "hmmm" or "uh huh."

The idea is to give the speaker some proof that you are listening, and that you are following her train of thought—not off indulging in your own fantasies while she talks to the ether.

In task situations, regardless of whether at work or home, always restate instructions and messages to be sure you understand correctly.

Step 10: Pay attention to what isn't said—to nonverbal cues.
If you exclude email, the majority of direct communication is probably nonverbal. We glean a great deal of information about each other without saying a word. Even over the telephone, you can learn almost as much about a person from the tone and cadence of her voice than from anything she says. When I talk to my best friend, it doesn't matter what we chat about, if I hear a lilt and laughter in her voice, I feel reassured that she's doing well.

Face to face with a person, you can detect enthusiasm, boredom, or irritation very quickly in the expression around the eyes, the set of the mouth, the slope of the shoulders. These are clues you can't ignore. When listening, remember that words convey only a fraction of the message.

Listening Skills Exercise: Summarize, Summarize, Summarize!
For at least one week, at the end of every conversation in which information is exchanged, conclude with a summary statement. In conversations that result in agreements about future obligations or activities, summarizing will not only ensure accurate follow-through, it will feel perfectly natural. In conversations that do not include agreements, if summarizing feels awkward just explain that you are doing it as an exercise.

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How to Be a Successful Change Leader

Change is an inevitable part of life, especially in the modern business world. Navigating change requires effective leadership, as described in this short article.

www.ccl.org/articles/

Successful change is one of biggest problems that modern organizations face. In our fast-changing world, the strategic imperative to change is often clear: Without doing things differently, our company is unlikely to continue doing anything at all.

But change management research has demonstrated time after time that organizational change initiatives fail more often than they succeed, despite the resources put into creating change management processes.

We know that effective leadership is essential to successful change. But we wanted to understand the differences in leadership between successful and unsuccessful change efforts. That's why we recently conducted a study where we asked 275 senior executives to reflect on successful and unsuccessful change efforts they had led.

Our goal was to characterize "change-capable leadership," define the key leadership competencies necessary for change, and better understand leadership behaviours that could contribute to change failures.

Our study, the full results of which are available in a new white paper, revealed 9 critical leadership competencies that characterized successful change efforts. The 9 change competencies can be further divided into 3 main categories — leading the process, leading people, and what we call "the 3 C's of change."

The 3 C's

These 3 C's are the most common themes that united effective change leadership:

Communicate. Unsuccessful leaders tended to focus on the "what" behind the change; successful leaders communicated the "what" and the "why." Leaders who explained the purpose of the change and connected it to the organization's values or explained the benefits created stronger buy-in and urgency for the change.

Collaborate. Bringing people together to plan and execute change is critical. Successful leaders worked across boundaries, encouraged employees to break out of their silos and refused to tolerate competition. They also included employees in decision-making early on, strengthening their commitment to change. Unsuccessful change leaders failed to engage employees early and often in the change process.

Commit. Successful leaders made sure their own beliefs and behaviours supported change, too. Change is difficult, but leaders who negotiated it successfully were resilient and persistent, and willing to step outside their comfort zone. They also devoted more of their own time to the change effort and focused on the big picture. Unsuccessful leaders failed to adapt to challenges, expressed negativity, and were impatient with a lack of results.

Leading the Process

Strategic change doesn't happen on its own. Effective leaders guide the process from start to finish.

Initiate. Effective change leaders begin by making the case for the change they seek. This can include evaluating the business context, understanding the purpose of the change, developing a clear vision and desired outcome, and identifying a common goal. Unsuccessful leaders say they didn't focus on these tasks enough to reach a common understanding of the goal.

Strategize. Successful leaders developed a strategy and a clear action plan, including priorities, timelines, tasks, structures, behaviours, and resources. They identified what would change, but also what would stay the same. Leaders who weren't successful said they failed to listen enough to questions and concerns, and failed to define success from the beginning.

Execute. Translating strategy into execution is one of the most important things leaders can do. In our study, successful change leaders focused on getting key people into key positions (or removing them, in some cases). They also broke big projects down into small wins to get early victories and build momentum. And they developed metrics and monitoring systems to measure progress. Unsuccessful change leaders sometimes began micromanaging, got mired in implementation details, and failed to consider the bigger picture.

Leading People

While change processes are well understood, too many leaders neglect the all-important human side of change. The most effective leaders devoted considerable effort to engaging everyone involved in the change effort.

Support. Successful change projects were characterized by leaders removing barriers to employee success. These include personal barriers such as wounded egos and a sense of loss as well as professional barriers such as the time and resources necessary to carry out a change plan. Leaders of unsuccessful change focused exclusively on results, so employees didn't get the support they needed for the change.

Sway. Effective leaders identified key stakeholders — including board members, C-suite executives, clients, and others — and communicated their vision of successful change to them. Unsuccessful leaders told us they were more likely to avoid certain stakeholders rather than try to influence them.

Learn. Finally, successful change leaders never assumed they had all the answers. They asked lots of questions and gathered formal and informal feedback. The input and feedback allowed them to make continual adjustments during the change. In the case of unsuccessful changes, leaders didn't ask as many questions or gather accurate information, which left them without the knowledge they needed to make appropriate adjustments along the way.

The executives we surveyed were all participants in our Leadership at the Peak program, which targets executives with more than 15 years of management experience, responsibility for 500 or more people, and decision-making authority as members of top management teams. All of them were seasoned leaders.

Besides the 9 change-capable leadership competencies, our study also identified leadership traps and change derailers that characterized failed change efforts. For more information about those, and our overall change-capable leadership model, download the white paper, "Change-Capable Leadership: The Real Power Propelling Successful Change."

https://www.ccl.org/articles/white-papers/change-capable-leadership-propel-success/

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Products & Services

APG GWR200 FLOW LEVEL SENSOR

Bell Flow Systems are pleased to introduce the new GWR200 flow sensor from APG, which promises to take the problems and frustration out of your level measurement.

The Systems True Echo™ Communication Tool, which provides a Modbus-to-USB connection for communication with True Echo™ Software allows for advanced configuration and monitoring of multiple True Echo™ sensors.

Specifications includes an auto calibration for easy setup with the True Echo™ software, a robust IP65 ingress protection housing, innovative signal processing and disturbance signal suppression and featuring a range up to 10 feet with SS rod, 80 feet with cable. Additionally, the sensors are unaffected by foam, vapours or dust.

The Sensor NEMA 6 housing comes as standard, and its 316 SS or PFTE-coated 316 SS probes can operate in process temperatures from -40° to 203°C. Robust and reliable, the GWR200 sensor makes difficult level measurements easy.

With a programmable 4-20 mA or RS-485 Modbus outputs, and innovative signal processing, the GWR200 can accurately provide measurement of solids, liquids, and slurries at depths up to 25 metres.

www.bellflowsystems.co.uk

AQUEOUS CLEANING MACHINE FROM TURBEX

One of the world's largest paper making machinery manufacturers has installed a Turbex aqueous cleaning machine to remove grease and oil from more than 30 different components during refurbishment. The machine is also assisting renovation of selected parts from rolling mills, which accounts for 25 per cent of turnover.

With the company's previous aqueous washer, it was awkward to load components as they had to be lowered in from the top. Additionally, larger parts were coming in to be processed which did not fit in the washing machine at all, so it was time for a replacement.

Several different makes of equipment were reviewed, including from the incumbent supplier. The refurbishment centre eventually decided in favour of a Turbex AC 1.7 two-stage industrial cleaning machine in which the load table is able to support up to two tonnes.

Apart from the spray-wash machine's larger size and greater weight-carrying capacity, the front-loading design makes it easier to handle steel and cast iron bearing housings and other components in and out by overhead crane.

Although the Turbex cleaning solution cost a little more than some on the market, the stainless steel construction of the process chamber and of the rotating spray bars was considered to be superior to others that were considered.

Safety features for protecting the heating system and pump as well as the electrically operated, automatic lifting door were additional positive features. Another useful design point is that the immersion heaters are fitted from the top, so are easy to exchange. The water filter is also simple to replace in a unit at the side of the machine.

Some larger components are placed singly in the Turbex AC 1.7, which has a chamber measuring 1.4 metres cube, while multiple smaller parts can be washed in a single program. Five different cycles, each of which lasts from 20 to 60 minutes according to the level of contamination, have been stored to suit the components being processed.

Detergent is dosed into the hot water to speed the removal of soils. It is followed by a rinse stage to achieve a high level of cleanliness. At each stage, the liquid is filtered before entering the tank and is then re-circulated.

As a footnote, it was pointed out that as the wash cycle is a hot process, it can assist reassembly of refurbished machine parts. Roll shop staff simply allow some components to cool completely while others, due to expansion, are fitted around them more easily if left warm.

www.turbex.co.uk

CHOOSING THE RIGHT PALLET TRUCK

The world of pallet trucks can seem confusing – but with PalletTrucksUK, it doesn't have to be. The experts in all things materials handling has offered business leaders and managers advice on choosing the correct pallet truck to suit their needs.

With so many options available, it's all about planning ahead – according to the experts. Thinking about what companies will need not just in the immediate, but the future, will ensure they choose the ideal pallet truck for them. Whether it be plans to expand, increase their offering, or indeed change direction, looking to the future will ensure the pallet truck/s they choose will serve them well for years to come.

When it comes to picking the correct model for the job in hand however, it can be more complex. Regular hand pallet trucks are the most universal model and can aid with moving items swiftly from one point to another. A staple in workplaces all over the world, they make light work of manoeuvring heavy and large objects.

Wide hand pallet trucks on the other hand may look just like traditional pallet trucks, but they provide much more stability for larger items. Designed with larger pallets in mind, they are tough and robust for workplaces that handle large items.

Phil Chesworth, Managing Director of PalletTrucksUK, said, "There's a common misconception that pallet trucks are all the same, but this is simply not the case. Pallet trucks are designed to make life infinitely easier, and with that comes options in order to meet unique requirements. It really is all about being armed with knowledge."

Heavy duty hand pallet trucks are another variant. Designed for heavy items, they are smooth and quiet, ensuring items are stable at all times – and of course are able to be moved with ease.

Long pallet trucks are not as common as the above, but are often missed by those companies who don't invest in one. Longer than traditional pallet trucks, they make it easy to move long items, such as leisure equipment and other machinery – without fear of damage or injury.

Other models include, mini pallet trucks, pallet trucks with a brake, and easy roller pallet trucks. "All coming with their own unique benefits, it really is down to leaders to think about that they need, why, and of course when, to ensure they are prepared," added Phil.

To find out more about Pallet Trucks UK's expertise and browse their first-class equipment available to purchase online, visit the website: **www.midlandpallettrucks.com**

CLOG RESISTENT TANK CLEANING MEANS LESS DOWNTIME

The Problem

In certain tank cleaning applications in the food and beverage industry a common problem can be clogged tank cleaning heads. The result is unwanted process downtime and increased maintenance costs. Clogging is usually caused by particles within the recycled cleaning fluid blocking the small holes in traditional spray balls and even more seriously, these can clog the bearings or gears on rotary devices. As a consequence, pre-determined cleaning patterns fail, cycles are incomplete resulting in missed areas. Often a secondary manual cleaning operation is then required to complete the cleaning process.

The solution

The HYDROCLAW™ is a new design of tank cleaning head which has been introduced by THE SPRAY NOZZLE PEOPLE offering the important benefit of being clog resistant. Traditional cleaning heads typically have multiple small orifices which form a 360º cleaning pattern. However, the new Hydroclaw impacts a jet of water on a claw like plate which shatters the fluid into a 360º pattern. As there is only a single orifice for the cleaning fluid to pass through the overall free passage is dramatically increased (between 3 to 5 times higher) allowing for high particle content liquid (for particles over 7.6mm in diameter) to be used as the cleaning media. The shape of the 'claw' is designed to ensure that the fluid shatters into a genuine 360º pattern effectively covering the whole tank. Initially developed for wine producers, the HydroClaw has applications for the wider brewing and distilling industry as well as for other non-food tank cleaning systems where clogging is a problem.

Features

The HydroClaw is made from FDA compliant 316L stainless steel so is ideal for food grade and aseptic clean-in-place (CIP) applications. In addition to its innovative design it has no moving parts and is self-draining, self-flushing and is laser welded for optimum durability.

It provides with low pressure / high flow to enable quick cleaning of tank walls and helps to reduce water consumption compared to a static spray ball. The HydroClaw is designed to fit through a 76mm opening and is available with a variety of connection types such as 1"female NPT or G threads, 1½" or DN40 tube clip-on.

www.spray-nozzle.co.uk

COMPRESSIVE YIELD STENGTH TESTER

The L&W S-Tester is based on a new, quick test method for determining the quality of fluting medium in corrugated packaging material. It expands ABB's laboratory quality measurement offering to help paper producers improve quality and reduce costs.

The S-test method was developed by a group of fluting producers (CCB-CEPI) to provide a more reliable and easy measurement method than the time-consuming flat crush of corrugating medium CMT test (Concora Medium Test). This new test method can be fully automated.

The new S-test method correlates well with the compressive yield strength potential of fluting medium in a CMT test. This yield strength is more relevant than standard CMT when predicting the ability of fluting medium to keep the liners apart, without losing its own strength in a corrugated board construction.

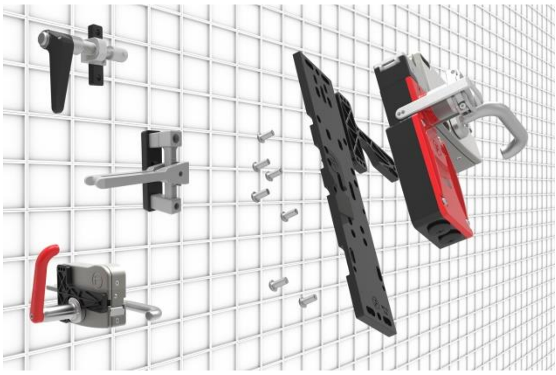
The L&W S-Tester will provide quick and accurate feedback; it can also perform automated S-tests in L&W Autoline (complete paper quality measuring system) to add even more impact to mills producing fluting-medium when it comes to saving production costs. These measurements will help to reduce energy consumption through the elimination of over-refining, optimize the use of starch additives, and improve overall quality by generating a uniform paper product.

Benefits/Features

- Quicker and easier method (s-test) for strength classification of fluting medium (than standard CMT measurements)
- No need of corrugating and taping of test pieces
- Reports test results within some seconds
- Designed and produced using long experience of manufacturing measuring units for L&W Compressive Strength Tester STFI
- Ease of use:
  - Auto-start, a photocell detects the presence of a sample and automatically initiates a measurement sequence, thus allowing hands-free operation measurements
  - Large touch screen for good overview
  - Intuitive user interface

http://new.abb.com

FITTING SAFETY SWITCHES TO MACHINE GUARDING



Configuring a mounting plate for an interlock is easy with Fortress Interlock's new Eazi-fit mounting system, which allows any amGardpro interlock safety switch to be easily fitted to machine guarding.

Suitable for both hinged and sliding guards, the robust Eazi-fit is easy to select using Fortress' unique online configurator, which provides 2D and 3D images and models, together with part numbers to simplify ordering.

There are two configuration options:

1. Need to configure a new interlock

If you configure a new amGardpro interlock switch using the online configurator and choose to add a mounting plate, the configurator will automatically select the appropriate plate, which is then pre-fitted to the interlock for easy installation.

2. Already have an interlock but need a mounting plate

If you already have an amGardpro interlock switch but need a mounting plate, it is easy to select one using the online configurator, which will automatically select the appropriate Eazi-fit combination.

The die cast mounting plates are extremely robust and can withstand a force of 10KN. They can accommodate all amGardpro configurations and are ideal for indoor or outdoor use. Available in a choice of colours, the plates are pre-fitted to the interlock when ordered together, or can be ordered separately.

www.fortressinterlocks.com

GESPASA OVAL GEAR FLOW METERS FOR ADBLUE®

Spanish manufacturer Gespasa have released the MGE-110 BLUE - an electronic flow meter designed for the measurement AdBlue® but also suitable for various other liquids such as water, fuel and light chemicals. The meter contains a PVC measuring chamber with high accuracy oval gears and features an enclosed front casing which prevents the ingress of liquid.

The MGE-110 BLUE features an integral battery powered LCD display with a five digit flow total displayed in large easy to read numerals. A low battery warning alert and easily removable facia for battery replacement ensure that servicing is quick and easy.

A major advantage of these new electronic meters is that they can be fitted outdoors due to their IP66 protection rated enclosure. The meters feature a flow rate of 10 to 110 litres/min and offer high accuracy of +/- 0.8%. The MGE-110 BLUE has a pulse output for retransmission of data to fluid management and control systems and has BSP connection threads with PA material adaptors, as standard.

Bell Flow Systems are the representatives for Gespasa in the UK, if you would like more information on Gespasa products we provide, visit our dedicated website **www.gespasa.co.uk.**

GUIDANCE FOR INDUSTRIAL STEAM BOILERS

Following the withdrawal of HSE's PM60 the CEA have created BG03; Blowdown Systems, Guidance for Industrial Steam Boilers, and we are proud to announce the launch of BG03 as part of the ongoing production of guidance in the Boiler Guidance (BG) series.

This comprehensive guide deals with all aspects of steam boiler blowdown for industrial steam boilers and why it is necessary to carry out the function of “blowing down” the boiler. We trust that by studying the contents and following this advice your boiler plant will operate safely and more efficiently, and provide you with a trouble-free system. If in any doubt contact the supplier, the system designer or your boiler water treatment specialist for advice.

It is aimed at the Owner, Operator, Engineer and Manager of the boiler plant to help them understand all aspects that affect the boilers and why blowing down is necessary, both from a practical operational performance view and for the legal requirements.

It covers who is responsible for the safe and efficient operation of steam boiler plant, and who is responsible for managing the safe operation of this type of equipment. Ultimately the responsibility lies with the most senior person on site; however, they can delegate the responsibility for daily operations, but only to a suitably trained and competent person on site.

With other HSE guidance being withdrawn, and having taken all factors into consideration, The Combustion Engineering Association (CEA) agreed to write this guide with the help of its members.

Within this Guide there are a significant number of legal requirements, regulations and standards highlighted; these regulations and standards are periodically reviewed and they can and do change, but they are as accurate as possible at the time of publication.

CEA cannot accept any liability for the information provided herein; however, be assured that we have consulted widely with our member companies during the compilation of this guide.

The guide has been written to provide advice to designers, specifiers, manufacturers, installers and those responsible for the management and operation of steam plant as well as Competent Persons. It is applicable to both new and existing installations of steam boilers and addresses the following issues:

- The safe discharge of blowdown from boilers;
- The safe use and operation of blowdown vessels;
- Proper maintenance and inspection of blowdown vessels and pits including requirements for regular inspection by a Competent Person in accordance with the Written Scheme of Examination (WSE)

Advice was previously provided by Health and Safety Executive (HSE) Guidance Note PM60 Steam boiler blowdown systems 2nd edition 1998, which has been withdrawn.

Ideally we would like you to attend the next seminars where a hard copy will be included free of charge as part of the delegate pack. However, if you wish to purchase your copy of BG03 for RRP £40.00 + £2 p&p   Tel: **01740 625538** or email: **info@cea.org.uk**

HYSTER LOWERS HANDLING COSTS FOR PAPER RECYCLERS

In 2015, collection and recycling in Europe increased by almost one million tonnes of paper in just 5 years. As the industry continues to grow, Hyster Europe claims that it can help even the most intensive paper recycling operations reduce cost and maximise efficiency.

“Paper recycling applications present many particular materials handling challenges,” says David Reeve, Industry Manager for Hyster Europe. “Operations need high quality trucks that are tough enough to avoid downtime and unplanned maintenance costs.”

Materials handling equipment used in the paper recycling industry is often required to operate on uneven ground, for long hours and in dirty and dusty environments indoors and outdoors, all at optimal efficiency. Furthermore, specialised attachments are often required to handle the paper bales which can absorb rain water resulting in additional weight.

“Recycling businesses are no longer restricted to only using tough ICE trucks,” says David. “Hyster® electric trucks are tough enough for most recycling operations, but as with any application, the choice depends on how the trucks will be used.”

Choose Tough Electric Trucks

Switching to electric trucks can ensure zero-emissions and reduce energy costs, something that interests many recycling firms with a focus on sustainability. With fewer required maintenance intervals and less wear, it may also reduce maintenance costs.

“While electric trucks can have an acquisition price of up to 20% more than ICE trucks, the reduced operating costs delivered means that the investment can be recovered over a contract period,” adds David.

Hyster is well known for producing tough trucks and the electric forklift range is no exception. Built for both indoor and outdoor use, a weatherproof all-steel cab provides operator comfort even in the dirty, dusty environment of a paper recycling application.

“Operators frequently have to chisel loads out from tightly packed bales on a vehicle,” says David. “These trucks are built for such operations which can cause massive shock loadings to the attachment, mast rollers and carriage. We can even add built in load weight indicators to give the operator reassurance when lifting uncertain load weights.

“In some cases, however, lead-acid or lithium-ion battery options may be quickly discounted as there simply may not be enough power to provide the necessary operating hours each day,” David continues. “Therefore, diesel or LPG options may achieve a lower total cost of ownership compared to electric trucks.”

Choose ICE Cool Trucks

Some of main problems of using a standard ICE truck in a recycling application include engines overheating and radiators getting clogged up due to dust, dirt and debris in the environment. Indoor waste paper stores also tend to have poor air circulation and are often confined spaces. The heavy-duty banding wire is another common issue if not carefully disposed of. It can be picked up and transferred to the transmission and axle of the fork lift truck during travel risking damage to exposed truck components. This costs businesses money in downtime and regular maintenance.

The Hyster® 'Cool Truck' is a lift truck option specially designed to overcome these challenges, enhancing efficiency and reducing costs. Oil immersed brakes also help keep brakes and tyres cool in short shuttle or long run applications whilst preventing the ingress of paper debris into the braking system.

"The Cool Truck is designed to enhance efficiency and reduce unnecessary expenditure specifically in the difficult environments of paper and recycling plants," explains David.

Options include a fully enclosed frame and vented hoods, side panels and radiator covers to reduce the vacuuming of dirt and debris from the floor into the engine. The 'Cool Truck', which is available as a modification both on Hyster® Fortens® lift trucks and heavy duty forklifts, has also been developed for use with a wide range of attachments, so can be tailored to suit specific applications.

The Hyster® Duramatch transmission assists bulldozing applications. Its integrated Auto Deceleration System can reduce brake and tyre wear by up to 50% and Controlled Power Reversal reduces shocks through the transmission and helps prolong tyre life. The Hyster® DuraMatch transmission electronically controls braking, direction changes and ensures the truck operates smoothly.

Choose Hyster Quality

Hyster® electric counterbalance trucks from 1.3 - 3.5 tonne capacity, and ICE counterbalance lift trucks from 1.6 - 5.5 tonne capacity are built by Hyster in its factory in Craigavon, Northern Ireland to the highest quality standards. Strict quality measures and testing help to ensure durability in the most demanding paper recycling operations, with, for instance, more durable paintwork, highly tested components and robust tyres.

Extensive research and testing with paper recycling industry customers also helps to feed the design objectives of Hyster® trucks, ensuring the focus is on what owners and operators want and need. Quality service and maintenance support from the global network of local distribution partners is also key to a low cost of ownership.

Choose for your application

"Intelligently designed Hyster® forklift trucks are tough enough to support operational demands while delivering a low cost of operation," adds David. "However, for maximum efficiency, we can help businesses identify which truck is the right choice to meet their specific application needs."

For more information about the extensive range of Hyster® trucks and solutions to support paper recycling operations visit **www.hyster.eu.**

MOSCA LAUNCHES HIGH-TECH TRAINING ACADEMY

Strapping specialist Mosca D irect Ltd has opened a new high-tech customer training facility, The Mosca UK Training Academy, as part of its recently-completed refurbished head office in Cotgrave, Nottingham.

The £500,000 investment has created additional space in response to the company's impressive year-on-year success since it was established as a dedicated UK sales and service facility in 2000, and to allow for future growth. As part of this, it was imperative that the redeveloped site should include a modern training facility to further enhance Mosca's service offering to customers as well as provide better capacity to train its own sales and engineering staff in new machine developments.

Mosca has offered customer training for many years at two levels - basic Operator Level, which covers the fundamentals of machine operation and daily/weekly housekeeping; and a second, more advanced Engineer Level, which teaches in-depth dismantling and reassembly of the strapping heads for fault-finding, repairs, maintenance and cleaning.

The Mosca UK Training Academy consists of a classroom area with TV and white boards, plus a fully-operational workshop which is home to several pieces of key training equipment. The training machines - a SoniXs standard strap way 6 test rig and head, a KSR test rig and head, SoniXs test rig and head, and a MCB head – have been specially commissioned for this purpose and are free from machine housing, allowing working mechanisms to be visible and accessible. This ensures that trainees gain an in-depth understanding of the four key procedures of a strapping machine: magazine, feed, retraction and tension, and cut and seal.

In addition, the opening has enabled Mosca Direct to offer additional training options. The Mosca UK Training Academy can accommodate up to four people for a full day of training which can be tailored to whatever the customer needs, for example focusing more on the electrical or mechanical side. For Operator Level training, one full day is required. For Engineer Level, one full day is also required depending on the experience level of engineers attending and the type of machine. At the end of the course, each participant is awarded with a certificate to verify their level of training. This is required by employers for Health & Safety reasons before a machine can be safely operated. Depending on each company's own Health & Safety Policy, customers may also request refresher courses.

Throughout the year, Mosca will also have different machine models situated in a new demo area. This allows customers to see machines in action and they can bring along their own products to test the various strap tensions and see the pack sizes that can be accommodated.

Based in Nottingham, Mosca Direct Ltd supplies top of the range manufactured strapping machinery, based on modular design to fit easily into existing lines or as part of a new project.
www.mosca.com/en-uk

NEW COLOUR FINDER TOOL

Archroma, a global leader in colour and specialty chemicals, has launched a free online tool that allows paper and packaging industry customers to search for products within the company's entire range of colorants.

Already known for its pioneering colour management services for the textile industry, Archroma launches the *Color Finder* aimed to packaging, paper and tissue applications. This publicly available, web-based tool can quickly search Archroma's global range of colours, plus selected local shades, to help spur inspiration in the most practical way possible. Customers can use it to search the company's core range of colourant products and first see useful technical and application information. Developed using responsive design technology, the tool is easy to use on computers and mobile devices alike.

For each colourant, Archroma shows the CIELAB values, product performance (such as water-fastness, light-fastness, backwater, etc.), food-contact approvals, application recommendations, eco-label status, and offers shade card downloads.

Features and benefits include:

- An innovative, user-friendly search tool;
- A broad colourants range for packaging and paper applications;
- Extensive technical information that draws on Archroma's deep knowledge and expertise;
- Eco label and food contact data that demonstrates the company's commitment to sustainability and leadership in this realm.

A good example of the final point relates to Archroma's work to ensure compliance with the three major eco-labels – EU Ecolabel, Nordic Swan and Blue Angel.

"We have undertaken considerable efforts in recent years to enhance our products further and to make them ever kinder for people and the environment and ensure regulatory compliance. Already, more than 80% of Archroma paper colourants included in the *Color Finder* today, fulfil the requirements of at least one eco-label. In addition we have invested in a continuing R&D program to ensure our products are fully compliant with the latest EU/BfR food contact regulations. As an example we have recently launched four new colourants which were reformulated to remove restricted additives such as DEA and TEA. These additions enhance our already extensive food contact range," comments Simon Boyd, Product Manager Colourants, Packaging & Paper Specialties.

With a dedicated R&D team, Archroma is a leading company in developing patented and REACH-registered chemistries of anionic direct, cationic direct and modified basic liquid dyes, especially designed for paper applications. It remains one of the few companies with a complete range of colourants and an own manufacturing network in Europe, Asia, North and South America.

"We believe the *Color Finder* to be a unique tool in the packaging and paper industry with regards to the depth of technical data and breadth of different colourants offered," adds Boyd.

Learn more at **colorfinder.archroma.com**.

NEW "COOL TRUCK" PACKAGE FOR HYSTER TRUCKS

Hyster Europe announces a new 'Cool Truck' package for the H2.0-3.5FT lift truck series. This package helps extend run time, enhancing dependability in extreme operating environments such as paper bale handling and recycling.

"When operating standard forklift trucks in the paper industry, the radiators can easily get clogged up causing unnecessary downtime," says David Reeve, Industry Manager, Counterbalance Solutions. "This is not only frustrating, but it also costs businesses money in lost production, and can lead to other problems."

The launch of the new 'Cool Truck' package for 2-3.5 tonne capacity lift trucks follows the successful introduction on the H4.0-5.5FT Cool Truck in 2015. It features an innovative automatically reversing fan that significantly extends radiator cleaning intervals compared to a H2.0-3.5FT. By minimising radiator clogging caused by debris build up operations can increase productivity and maximise return on investment.

"The package is designed to reduce the amount of debris entering the engine compartment and getting stuck on the transmission or in the radiator," says Reeve, explaining that tilt and steer cylinder gaiters also minimise the risk of damage to cylinders from debris. Tough rubber guards over the drive axle also minimise ingress of paper under the floorplates.

Venting on side panels helps to minimise the vacuuming effect of debris on the ground and a solid multi-piece belly pan under the engine compartment reduces the amount of loose debris entering the underside of the truck.

Based on the current Hyster® H2.0-3.5FT range, with capacities from 2-3.5 tonnes, the Cool Truck is built for recycling centres or paper mills where there may be large areas full of recycled paper bales ready for pulping. A number of options are available to meet particular application needs.

"To challenge the dependability of our system, we have conducted extended field trials in some of the harshest paper production applications worldwide," Reeve confirms. "For example, we found that conventional trucks required engine compartment cleanouts much more frequently to prevent overheating."

"Chiselling loads out from tightly packed bales on a vehicle can also cause massive shock loadings to the attachment, mast rollers and carriage," says Reeve, explaining that the risk in this instance is serious damage to transmissions and front-end equipment, whilst potentially overloading the forklift's engine and cooling system.

The Hyster® Duramatch™ transmission, with its Controlled Power Reversal, reduces shocks through the transmission and helps prolong tyre life, again adding to the dependability of these tough trucks.

“The Cool Truck is designed to keep going in tough paper and recycling applications, offering the reliability and durability that end users in these tough operations need from their equipment,” Reeve adds.

For more information, visit **www.hyster.eu**

NEW SERIES OF REVERSIBLE AIR MOTORS

Parker Hannifin, a global leader in motion and control technologies, has extended its range of P1V-A Series reversible air motors with additional power ratings, including models with ATEX certification suited to use in explosive environment applications.

The new extended family of P1V-A Series of air motors features painted cast iron motor housings and sealed components to enable reliable operation in challenging, damp, dirty environments. The range contains six different sizes with power ratings ranging from 1,600 to 18,000 Watts.

The motors can be supplied either in basic form or with built-in gearboxes. Three types of gearboxes – planetary, helical or worm gears – are available for selection depending on the type of rotation and torque required in the application. A combination of face and base mounting options offer additional flexibility to system designers.

All of Parker's P1V-A pneumatic air motors are equipped with spring loaded vanes as standard; this supports very good starting and low speed running characteristics. The simple, rugged construction of the motors makes them vibration, heat and impact resistant as well as enhancing reliability and speed and ease of servicing.

Air motors are better suited to some rotary power transmission applications than electric motors, especially when operating in harsh industrial environments. With their comparatively small dimensions and fewer moving parts, air motors are self-cooling and do not pose a sparking hazard. Unlike their electrical counterparts, they can be stopped and started repeatedly and even loaded until they stall without incurring any damage.

ATEX-certified versions for use in environments with an explosive atmosphere are available for four basic models without gearboxes: 1600, 3200, 5000 and 6000 Watts. The ATEX-certified motors can operate at ambient temperatures in explosive environments ranging from -20 to +40 °C and can withstand pressures spanning four to six bar.

Image Caption: Parker has extended its range of P1V-A Series reversible air motors with additional power ratings, including models with ATEX certification.

www.parker.com

ONLINE SYSTEM FOR MONITORING FIBER PROPERTIES

• L&W Fiber Online expands ABB's offering for pulp measurements to help improve quality and reduce costs for paper producers

• Compared with other traditional indirect measurements, L&W Fiber Online provides paper makers with complete information on fibre properties, refining effect and fibre mix, to help them monitor and control pulp quality

ABB has launched L&W Fiber Online – a reliable, repeatable and cost-effective online system for measuring, monitoring and controlling significant fibre quality variables in paper stock preparation and pulp production. This helps pulp and paper customers to save production costs by optimizing fibre usage, as well as reducing energy consumption through elimination of over-refining, and to improve quality by generating uniform pulp furnish for the paper, board or tissue machine.

Compared with traditional indirect measurements such as Canadian Standard Freeness (CSF) and Schopper-Riegler (SR), the measurements based on fibre images provided by L&W Fiber Online provide a more detailed and accurate information on the status of pulp quality. Fibre properties are categorized and presented as mean values and statistical distributions of width, length, shape factor, two classes of fines (P and S) and macro fibrillation.

L&W Fiber Online mitigates the problem of detecting late in the production process quality issues caused by fibre variations. By discovering variations earlier in the process, and as early as in stock preparation, it becomes feasible to take corrective actions in time to produce paper, board or tissue that meets the specifications. This system is based on ABB's well-known L&W Fiber Tester Plus, a laboratory instrument which is used by hundreds of papermakers to track their pulp quality, and is a preferred tool by research centres and universities around the world. The system also allows for multiple sampling points with a single instrument, reducing initial investment and ongoing maintenance costs. For mixed furnishes, the optional Blend software analyzes the ratio of reference fibre species in a fibre mix, making it possible to save raw materials when switching grades or during start-up.

“We can now offer a robust unit that tells the complete story of the fibres in real time, which gives our customers an easy way to pinpoint and follow trends on furnish quality, and at the same time help them to reduce variations in stock preparation or pulp production, as well as saving energy” says Anna Schärman, Global Product Manager, ABB Pulp & Paper products.

http://new.abb.com

OPTICAL CONSISTENCY TRANSMITTERS

Valmet Optical Consistency Transmitter (Valmet OC) has gained a deserved reputation for accuracy, reliability and ease of installation since its introduction four years ago. Now Valmet introduces three new models for applications that have been particularly challenging for inline optical consistency transmitters in the past. This includes measurement of eucalyptus pulp, recycled fibre and chemical pulps.

"Valmet's continuous development expands reliable consistency measurement applications. Sharing the same basic components and modules, each new transmitter has a probe and total consistency measurement method optimized for use in special process environment i.e. recycled fibre," says **Heikki Föhr**, Product Manager, Valmet.

Eucalyptus pulp applications

Eucalyptus pulp has different optical properties compared to other pulps; which has led to the design of the special optical sensor and measurement method of the Valmet OCE. Results with the new transmitter in several commercial installations have already been successful in applications where competing inline optical transmitters have failed. A typical application is the control of LC-refiner feed consistency, where improved refiner freeness results and reduced specific energy consumption have been reported.

OCC and RCF applications

OCC and RCF processes are a challenge for any measuring device, where sand, metal and other contaminants as well as non-organic fillers are present. The Valmet OCR features a robust probe to survive the harsh physical environment and a measurement that tolerates the ash variations that prevent the use of other inline optical consistency transmitters. Installations in OCC processes before coarse screening have proved the probe's robustness and the total consistency measurement accuracy is excellent throughout the stock preparation area even with wide ash variations.

http://www.valmet.com/valmetoc/

SKF MODULAR ELECTROMECHANICAL ACTUATOR

New CASM 100 electromechnical actuator offers exceptional flexibility for a broad range of applications

SKF has launched the versatile CASM 100 electromechanical actuator with a variety of different modules, making it exceptionally adaptable to satisfy a range of applications in a variety of sectors.

This problem-solving technology can, for example, be used in the automation sector on applications including servo presses, test benches, plastic injection moulding, dosing machinery and conveyors. In the metals sector, it can be used for continuous casting, steel bar handling, the regulation of foundry processes. It also has sawing and other applications in the woodworking sector, and roll adjustment in pulp and paper mills.

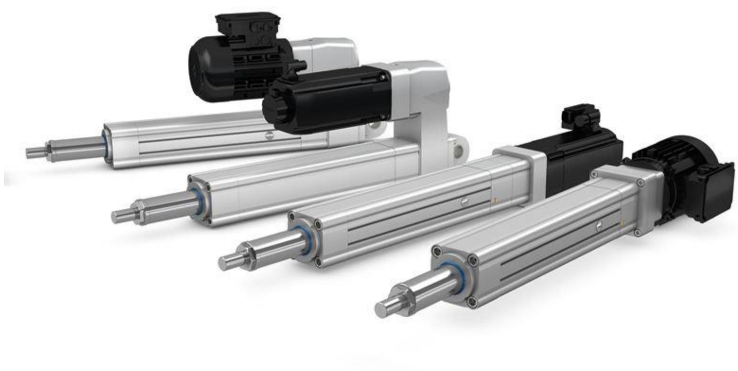
The product's modular design offers a base platform with new modules planned for release over time to cater for future needs. The standardised interface between modules – similar to the concept of LEGO bricks – increases the unit's flexibility and makes it backward compatible. This modularity design also offers the benefit of easy integration and fast assembly.

The CASM 100 actuator has a range of applications including the control of robots, handling and packaging machines, sorting systems and cutting machines. The availability of different modules also allows customers to change the CASM 100 to suit their own specific application needs, selecting the optimum combination of performance and cost.

The actuator consumes up to 80% less energy than pneumatic alternatives and 50% compared to hydraulic solutions. It also uses fewer consumables because, in many applications, is virtually maintenance-free, only requiring re-lubrication using standard grease. There is also no need to change hydraulic fluids and seals so it is remarkably clean, leak-free, cost-effective and environmentally-friendly.

Featuring a linear design that will withstand the harshest conditions, the CASM 100 is manufactured from high-grade materials, boasts a long service life and offers an outstanding level of precision and repeatability. The actuator has a force range up to 82kN and linear speed up to 890 mm/s, and will support OEMs and machine builders migrating to the latest Industry 4.0 technology.

The CASM 100 also benefits from a wide assortment of accessories, outstandingly long stroke lengths (up to 2m) to fit an array of applications, and an inline and parallel gearbox, the latter with spur gear technology and manual override available as standard for an extra safety in operations in case of power losses.



www.skf.com

SMART SENSOR FOR LOW VOLTAGE MOTORS ARRIVES IN THE UK

A new smart sensing solution from ABB can reduce downtimes of low-voltage motors by up to 70 percent, extend motor lifetime by as much as 30 percent and cut energy consumption by up to 10 percent.

A device that cost efficiently monitors the condition of low voltage (LV) motors to increase their performance, efficiency, reliability and lifespan is now available in the UK.

The ABB AbilityTM Smart Sensor for motors is a pocket-sized device that is retrofitted to the frame of LV induction motors. Installation of the sensor module is made easy as no additional wiring is required. The sensors are available not only for motors made by ABB but also for non-ABB motors.

The device picks up data on vibration, temperature and other parameters. On-board algorithms, based on ABB's decades of motor expertise, interpret these parameters and relays information about the motor's health, via a smartphone and over the internet, to a secure, cloud-based server. By providing meaningful information on motor condition and performance, the service will enable users to plan their maintenance according to actual needs rather than on the basis of time intervals or operating hours alone. This will reduce maintenance costs and enable the plant to cut or even eliminate unplanned stops.

By converting regular LV motors into intelligent, connected machines, the solution enables advanced maintenance planning that will help businesses to cut costs and boost productivity. Predictive analytics based on data from the solution can reduce downtime by up to 70 percent, extend motor lifetime by as much as 30 percent and cut energy consumption by up to 10 percent.

"This solution is truly a quantum leap for millions of LV motors," says Derek Robinson of ABB's UK motors business. "It enables plant operators to deliver effective maintenance planning for their motors, assess the efficiency of their operation and prevent costly downtimes. We are confident that this solution will not only transform the maintenance approaches but also create added operational value for our customers."

The smart sensor is available to purchase from ABB direct or from one of its ABB authorised value providers. Once purchased, users can use the app, which is available for iOS or Android, to track and monitor the motor. It also gives access to the portal, the scope of which depends on whether the maintenance package (which contains everything needed for normal plant upkeep) or the analyst package (offers everything required to optimize a plant) is purchased.

The smart sensor condition monitoring solution is part of ABB Ability, which brings together all of ABB's digital solutions and services, each built from a combination of sector knowledge, technology leadership and digital expertise.
www.abb.com

TFX ULTRA PROVIDES RELIABLE LEAKAGE DETECTION

Bell Flow Systems were recently approached by a customer looking for a reliable solution to remotely monitor a fire hydrant for flow detection and leakage purposes.

The site, located remotely, required a clamp-on measurement solution to provide flow measurement without breaking into the pipeline. Information from the site also need to be available remotely, as well as providing visual alarms to operators at the site office.

Bell Flow Systems supplied the TFX Ultra flow meter and provided a local Modbus output to a third party telemetry system. Data From the telemetry system will be stored onto a web portal providing a visual indication of the current flow, total flow and diagnostic information from the flow meter. Information on the data portal will also show visual alarms so the operators can respond to leakage or flow events at the site office.

TFX Ultra has inherent advantages over traditional devices including clamping onto the outside of pipes and not contacting the internal liquid. Advantages of the TFX Ultra non-invasive flow meter include measurement of a range of liquids with small amounts of suspended solids or aeration, a bi-directional flow measurement and a wide variety of communications including Modbus RTU over RS485 communications; Ethernet connection options includes BACnet/IP, EtherNet/IP and Modbus TCP/IP protocols.

Meters include a large easy-to-read digital display and a rugged aluminium enclosure for use in harsh environments. For more information see **www.bellflowsystems.co.uk**

THE CARDBOARD BOX-ING MATCH

Card, board and paper based products are critically dependent on vapour permeability for their strength, integrity and printability. Packaging also controls the contamination of food and pharmaceutical products. Tiny changes in composition or coatings can make a major difference to these physical characteristics.

Versaperm's latest of permeability measurement system is designed to measure this, not just for coatings and materials, but also for the complete finished package. This is often critical as manufacturing processes, such as forming, folding and adhering, can change, substantially, the package's vapour permeability.

The most important factor is often water vapour but the system can measure permeability for carbon dioxide, oxygen, hydrocarbons, aromatics and almost any other gas in commercial use. The system is ideal for product and coating developments as well as for quality control.

The Versaperm system is fast, reliable and easy to use - producing results that are accurate in the PPM (parts per million range), PPB ranges and for some materials, and can take as little as 30 minutes. Where desired the system can produce results under environmental controlled conditions including temperature, pressure and relative humidity.

Multi-chamber systems allow measurements to be produced on several samples at the same time and different designs and clamping systems cater for varying sample types.

As well as manufacturing the instruments, Versaperm offers a technical consultancy plus a permeability testing service for companies.

www.versaperm.co.uk

VALMET'S POLARIZED FORMING FABRICS

Forming fabrics have an essential role in water drainage in the wire section of a paper machine. By introducing the new generation's polarized forming fabrics, Valmet revolutionized water drainage in the wire section.

"Our polarized forming fabrics have been piloted in paper-machines for over a year now. After the polarized technology entered the market in 2016, we have seen its advantages through our customers' performance. The machines run cleaner, number of breaks is reduced, retention is higher, just to mention a few. The unique polarized structure makes a big difference in the fabric performance compared to what we have seen before," says Pekka Kortelainen, Product Technology Manager at Valmet.

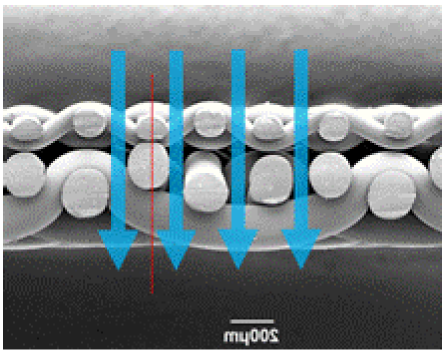
Polarized structure improves the machine runnability and performance
Traditionally, all SSB (sheet support binding) fabrics have had direct drainage channels. In the polarized structure, the machine direction yarns on both the paper side and the roll side are shifted to form an off-stacked structure. This special structure removes the direct drainage channels traditionally used in forming fabrics.

"The unique polarized structure allows controlled initial drainage in the paper-making process. That improves retention and helps keeping the machine clean. Good runnability and cleanliness reduce breaks and therefore increase production capacity remarkably. Cost-savings are created by for example being able to use less chemicals," explains Kortelainen.

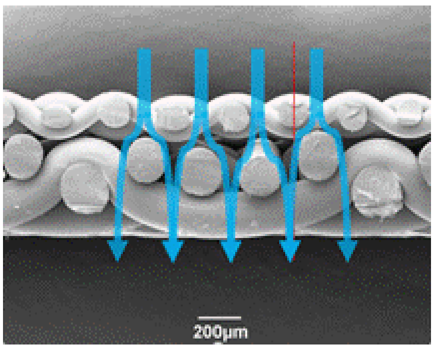
Customer satisfaction on an excellent level
To this date Valmet has sold about 300 polarized Valmet Forming Fabrics and over 90% of the customers who have tested the new fabric type have seen its benefits and continued to run it on their machines.

"Our target was to further improve formation without losing our good dewatering, and already the first trials proved the advantages of the polarized structures. We were able to significantly improve formation as we wanted, but the cleanliness and runnability were also good, and the dry content remained excellent. Since that first trial, those polarized fabrics have become our standard Valmet design fabrics. Valmet has been Parenco's key partner in paper machine clothing for over 30 years, and we truly appreciate their support and excellent services," says Yan Vassart, Operations Manager at Parenco in Netherlands.

The polarized structure can be utilized in all SSB forming fabric types, which makes it suitable for all paper machines.



Drainage with standard SSB fabric



Diffuse drainage with polarized fabric

http://www.valmet.com/

VIBRATION SENSING SOLUTIONS WITH TRANSMITTER INTERFACE

Machine Protection and Condition monitoring specialists SENSONICS has developed its range of 4-20mA sensing devices to a level which now represents one of the most comprehensive sets of vibration sensing solutions available for critical items of plant and equipment, such as motors, fans, pumps and compressors. The sensor range includes the PZDC piezoelectric and VEL/GDC electrodynamic, absolute velocity vibration transmitters and the DNX80 relative shaft vibration, thrust position and speed proximity probe transmitters.

The VEL/GDC has been introduced to compliment the widely used PZDC velocity vibration transmitter to ensure the Sensonics product line can cater for all machine types and industrial environments. Whilst the PZDC piezoelectric based sensor meets with the requirements of ISO 10816 for absolute vibration measurements there is recognition for the need for a sensor which can meet heavy industrial demands and be utilised on a wide range of plant; particularly where the earth regimes are not ideal and high immunity to interference from auxiliary systems is key.

The electro dynamic VEL/GDC sensor provides a 4-20mA loop powered output proportional to velocity vibration and offers the advantage of dual case isolation in conjunction with a low impedance circuit, so is ideal for high noise environments. Due to the electro dynamic nature of the sensor assembly, both high and low frequency events are filtered mechanically and since no integration (from acceleration to velocity) is required the arrangement is immune to the saturation that can be seen in piezoelectric devices.

Absolute bearing vibration is only part of the requirement for measuring the dynamic behaviour of a machine and shaft vibration measurements in fluid film bearings are equally critical. The cost effective Sensonics solution for this requirement is the DNX80 series of processed output drivers used in conjunction with the Senturion X range of proximity probes. The DNX80 not only provides peak to peak vibration measurements but also shaft position, thrust wear and speed measurement options through a straightforward 4 to 20mA loop.

Industrial fans, pumps and compressors will particularly benefit from the DN803X series. When combined with Sensonics range of compact machine mounted housings it provides a particularly cost effective solution for critical operational measurements, with a straightforward interface that requires no local power supply. Ideal for OEM applications, the driver also provides a raw buffered output of the vibration signal that can be utilised through portable analysis equipment for a more detailed picture of the dynamic performance of the machine.

The 4-20mA loop powered modules provide easy integration with either the local machine PLC or a plant wide DCS since it is powered through the safety barrier measurement loop. All signal processing is carried out within the unit providing an output current proportional to either peak-to-peak shaft vibration or relative position or speed.

Sensonics can provide expert advice on sensor selection based on your specific application and have over 40 years of experience in providing effective condition monitoring solutions. **www.sensonics.co.uk**

VORTEX FLOW METERS FROM BADGER METER

The new VN2000 vortex flow meters from Badger Meter are available from Bell Flow Systems and offer an ideal solution for a range of applications for measuring volumetric or mass flow of liquids, gases and steam. As a robust and reliable meter and with a large turn-down ratio these meters are an ideal solution for a range of applications.

The vortex meter technology lends itself well to harsh environments due to the lack of mechanical parts and solid construction. The VN2000 model is no exception and with its solid stainless steel construction and non-wetted sensors it takes this further offering a heavy-duty option with an exceptionally long life span, maintaining accuracy for many years and reducing maintenance costs over time in comparison to other metering technologies.

The VN2000 meters have the option of an integrated RTD temperature sensor, which is used for mass flow calculations and can also have a second external RTD connected to calculate energy transfer across a heat exchanger. The benefit of a high 204°C process temperature rating and a large flow range lends the meter to more applications especially where flow rates may span from low to high.

Two models are available in the range; a compact and a Hot Tap insertion model. As an insertion meter, flow in large pipes can be measured and the Hot Tap model can be used to measure pipes from 2 to 24” (50 to 1200mm). This hot-tap model also allows installation during high pressure applications without a system shut down, reducing costs and inconvenience involved when the meter needs to be removed and reinstalled.

When installing electronic flow meters there is always the possibility of incorrect wiring, having to open up the meter to fit wires into hard to reach terminal blocks can create errors and can also be time consuming. The VN2000 models are provided with a Power Plug, which eliminates wiring errors in the field. The plug connects to the enclosure meaning all wiring is done externally allowing for quick and easy connections. This includes wiring for the analogue output, Modbus and external RTD when used for energy calculations.

www.bellflowsystems.co.uk

WARNING TO WAREHOUSES OVER DRIVERLESS VEHICLES

With the news that warehouses are trying out driverless vehicles for more and more tasks including driverless pallet trucks and driverless fork lifts, Midlands Pallet Trucks has warned companies not to discount human involvement entirely.

“Though we’ve seen statistics suggesting that 45% of manufacturing tasks will be done by robots by 2025, that still leaves 55% of tasks to be done by humans,” said Phil Chesworth, Managing Director at Midland Pallet Trucks. “Companies who rely on robotics to do all their work should remember how often computers can go wrong.”

Midlands Pallet Trucks sell pallet trucks and other heavy-duty machinery to everyone from builders to warehouse managers. Their main range of pallet trucks start at lightweight trucks for smaller loads all the way to 4-way trucks capable of carrying extremely heavy items.

The news comes as Spanish firm, Asti, is building a range of driverless forklifts, stackers and pallet trucks. If driverless vehicles get it wrong, no human will be around to fix the problem quickly. This could leave businesses in financial trouble, dealing with destroyed stock as well as a broken and expensive machine to get fixed.

Keeping humans around makes sense for the foreseeable future, so although robotics and driverless vehicles may happen in a number of years, for now they are in no danger of taking over the manufacturing sector. Trained humans will always know what to do with a pallet truck; a programmed robot can forget if water leaks onto it or they miscalculate a distance.

Midlands Pallet Trucks is selling products that suit their customer’s needs in the UK now, and not basing their information on a bank’s predictions that may or may not come true.

To find out more about Midland Pallet Trucks and their extensive range of strong and dependable pallet trucks, lift tables and other valuable equipment, visit the website:

www.midlandpallettrucks.com

WATER HAMMER & THERMAL EXPANSION THREAT TO BOILERS

In the run-up to the heating season, start-up dangers are a serious problem for many heating systems using steam as a source of heat, largely due to the fact that they have been lying dormant over the summer.

John Pickering, an expert in safe procedures for steam distribution systems at Spirax Sarco, warns boilerhouse operators that they must therefore be wary of the threat posed by water hammer and thermal pipework expansion when restarting their boilers this autumn.

With the heating season just around the corner, John explains that new operators of steam systems may underestimate the care and time required for steam system start-ups following an extended period of shut down.

“After a long, dormant period over the summer, both water hammer and thermal expansion pose a real threat to steam pipework when systems are fired back up again,” says John.

He continues: “Water hammer may be viewed largely as an acoustic problem, but the consequences can be much worse. The entry of steam into a pipe that already has a build-up of water can lead to condensation, which results in a vacuum forming. This will mean water rushes through the pipe, and its momentum is capable of causing extensive mechanical damage to pipework and fittings.”

According to John, thermal expansion is an equally serious issue. “Expansion occurs when the steam system is heated too quickly, and the pipework quite literally buckles under the pressure of the steam as it hits the weakest point in the distribution line. I have seen instances where pipework has bent and expansion bellows have become twisted and distorted – all of which could have been avoided if the correct procedures had been followed.”

Spirax Sarco recommends an 11-point procedure for warming pipework from cold, which is outlined by the National Industrial Fuel Efficiency Service (NIFES) in the organisation’s handbook.

“The Boiler Operator’s Handbook outlines a clear procedure that includes checks to the boiler and valves and that, crucially, stresses the need for the gradual warming of the system pipework to increase the pressure and purge it of air and condensate,” John says. “I cannot stress enough how important it is to open the steam valve incrementally.”

Steam valves should be opened very slowly. If there is any indication of water hammer in the surrounding pipes, the steam isolating valve should be shut immediately and kept closed until the pipes have been drained. The start-up procedures for steam pipework are complex and require an experienced operator. Those with any doubts over the correct procedure to follow should call an expert.

www.spiraxsarco.com/global/uk/Pages/home.aspx

YELLOW FOOD-COMPLIANT DYE

Archroma, a global leader in colour and specialty chemicals, has extended its Cartasol® range by introducing a new, improved bright yellow dye called Cartasol® Yellow 6GFC liq. that has no added diethanolamine (DEA) or triethanolamine (TEA, and also called TAN).

New European regulations have come into force that greatly lower the limits for DEA and TEA contents in paper and board intended for food-contact applications. Dye makers have used those auxiliaries in the past to help maintain storage stability and prevent deposits forming over time. However, these amines are under scrutiny as they are potentially mutagenic, meaning they may lose their ISEGA certificates, and no longer be considered suitable for food-contact applications." (Germany's ISEGA GmbH provides independent testing and certification for food-contact and other materials.)

Archroma's new, food-compliant yellow formulation is butyldiglycol free, and will completely replace its existing Cartasol® Yellow 6GFN liquid product by the end of this calendar year.

In 2015 the company began introducing a new palette of food contact grades that will help tissue paper makers create the exciting colours that the consumers desire. Since then it has rolled out the following new grades in the range:

- Cartasol® Blue GDFC liq
- Cartasol® Yellow 2GFC liq
- Cartasol® Red 7BFC liq
- Cartasol® Blue 3RFC liq

"At the time," Simon Boyd, Archroma's Head of Global Product Management, Colourants, Packaging & Paper Specialties Business, says: "We were already able to cover most colour needs for food-contact applications with our existing dyes. Now by developing additional ones to extend our range we can fully meet our customers' requirements."

The company's continuing active dye-reformulation program has led to the latest launch of Cartasol® Yellow 6GFC liq. The new dye has been designed to have the same strength, shade and properties as its predecessor, but with the added advantage of being fully compliant with the food contact requirements. In addition, the new grades are REACH-compliant and fulfill the requirements of most major eco labels.

"Importantly, the bright greenish yellow colour of Cartasol® Yellow 6GFC liq. is attractive and adds a vibrant new colour option to those producing bright yellow and green tissue and related packaging, thereby further supporting design creativity", Boyd adds.

www.archroma.com

PAPERmaking!

FROM THE PUBLISHERS OF PAPER TECHNOLOGY

Volume 3, Number 2, 2017

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Installations

The following pages contain a summary of the various installations and orders from around the world of papermaking, wood panel and saw mills, and bio-power generation, received between April 2017 and November 2017. Also includes new announcements about plans to build new mills or install new machinery (in which case the supplier will be noted as 'TBA').

COMPANY, SITE	SUPPLIER	DESCRIPTION	START-UP
Alas Doradas, El Salvador	Valmet	To rebuild tissue machine (PM4) by installation of an Advantage ViscoNip press combined with an Advantage ReDry web heater	End 2017
Anhui Shanying Paper Industry Co., Ltd., Maanshan City, Anhui province, China	Papcel Group	To supply a new Shoe press for refurbishment of PM1	Q3 2018
Anon, noteworthy pulp mill in the southern United States	Fitnir	To upgrade measurement technology, by additing an online FT-NIR analyzer to replace a Modo-Chemetics auto-titrator for digester control	Late 2017
AO Knauf Petroboard, Kommunar, Russia	Andritz	To rebuild the KM2 board machine	Q4 2018
Ariete Srl, Cava dei Tirreni, near Salerno, Southern Italy	Toscotec	To replace tissue machine with a new TM capacity up to 30,000tpy	2017
August Koehler, Kehl facility, Germany	TBA	To install a new 100,000tpy paper machine for the production of flexible packaging paper	
Australian Paper, Morwell, Australia	PMP	To supply an Intelli-Jet V® hydraulic headbox for PM2	
BillerudKorsnäs Gävle Mill, Sweden	Procemex	To deliver production wide integrated web inspection (WIS) and web monitoring systems (WMS) for BM4	Q4 2017
BillerudKorsnäs, Gruvön Mill, Sweden	AFT (Aikawa Fiber Technologies)	To supply a compact POM System for all three layers of the new 550,000tpy board machine	Q1 2019
BillerudKorsnäs, Gruvön Mill, Sweden	Andritz	To supply a new brown stock washing sideline for fibreline upgrade	Q1 2019
BillerudKorsnäs, Gruvön Mill, Sweden	Procemex	To deliver production wide integrated web inspection (WIS) and web monitoring systems (WMS) for BM7	2019
BillerudKorsnäs, Gruvön Mill, Sweden	Valmet	To deliver dewatering equipment and an automatic pulper feed system, including bale storage, destacking and dewiring for baled pulp	Q1 2019
Blue Paper, Strasbourg, France	Valmet	To supply a Valmet DNA Control System for the new Solid Recovered Fuels (SRF) boiler	Spring 2018
Bohui Paper Group, Dafeng, Jiangsu province, China	Voith	To supply a new folding boxboard machine (BM4)	Late 2018
Canfor Pulp, Prince George, British Columbia, Canada	TBA	To install a new 32MW condensing turbo-generator, and upgrade the refining line	
Cartiere Modesto Cardella, Italy	Toscotec	To rebuild the dryer sections of PM3 and PM4 with TT SteelDryers	Q4 2017
Cartulinas CMPC, Valdivia Mill, Valdivia, Chile	KPA Unicon	To deliver biomass-fired steam boiler plant (30tph)	Q4 2018
Cenibra, Pulp Mill, Belo Oriente, Brazil	Valmet	To supply a new bleaching plant (capacity 500,000tpy)	

COMPANY, SITE	SUPPLIER	DESCRIPTION	START-UP
Chiping County Senqiang	Valmet	To deliver an EVO-56 Defibrator system (30tph) for MDF line	Q2 2018
CMPC Celulosa, Santa Fe, Chile	Valmet	To supply a new Valmet Brown Stock Quality Analyzer for fibre line 1 (ECF bleached eucalyptus pulp)	
Copel S.A., Bolivia	GapCon Tissue S.r.l	To supply a new tissue paper machine (85tpd)	H2 2018
Currenta GmbH & Co. OHG, Bürrig, Germany	Andritz	To deliver a SCR DeNOx plant (SCR: Selective Catalytic Reduction) for the hazardous waste incineration plant to treat the flue gases from the sewage sludge incineration line with multiple-hearth furnace VA3 and the two lime kilns VA1 and VA2	H2 2018
Daio Paper, Japan	Voith	To supply a new XcelLine tissue machine (54,000tpy)	
Delfort, Feurstein Mill, Austria	Savcor Roest OY	To deliver Wedge Process Diagnostic System	2017
Delfort, Olšany, Czech Republic	TBA	To install a new paper machine to manufacture thin speciality papers	Next two years
DONG Energy, Asnaes Power Station, Kalundborg, Denmark	Valmet	To supply a biomass power plant and an automation system	Late 2019
Eurovast, Villa Basilica Tissue Mill	Toscotec	To supply new 30,000tpy tissue machine	
First Quality Tissue (FQT), USA	Valmet	To supply a complete Advantage ThruAir 70,000tpy tissue line	Q2 2018
Georgia-Pacific, Palatka, Florida, USA	TBA	To install a new TAD tissue machine	2019
Glatfelter, Ober-Schmitten, near Frankfurt am Main, Germany	TBA	To upgrade production capabilities for the electrical and glassine paper markets	
Grupo Gondi, Mexico	TBA	To build new 350,000tpy containerboard mill	
Hangzhou Dongda Paper Co. Ltd, China	Bekaert Solaronics	To install three infrared drying systems	
Hansol Paper, Shintanjin, South Korea	Valmet	To supply an off-machine coater rebuild to convert the paper mill for thermal paper	2018
Harmac Pacific, Nanaimo, BC, Canada	Fitnir Analyzers	To supply online Ft-Nir Analyzer to analyze seven recovery and recaust streams	2017
Hauni Primary GmbH, Gudang Garam paper mill, Indonesia	GapCon tissue S.r.l.	To deliver equipment and machinery for the stock preparation line, which operates a paper machine producing reconstituted tobacco	
Hayat Kimya, Yelabuga, Tartaristan, Russia	Valmet	To supply a 70,000tpy Advantage DCT machine (TM7) including the flexible ViscoNip press and an extensive automation package	

COMPANY, SITE	SUPPLIER	DESCRIPTION	START-UP
Heinzel Group, Pöls Mill, Austria	TBA	To build a second paper machine, capacity 120,000tpy of bleached kraft papers (MG papers)	Q1 2019
Hunton Fiber AS, Gjørvik, Norway	Andritz	To supply chip handling, pressurized refining equipment (capacity of 5 bdmt/h), and the chemical dosing system to this new greenfield wood processing mill	Q2 2018
ICT Iberica, Spain	Valmet	To supply a complete tissue production line with an extensive automation package	Q3 2018
Iggesund Paperboard AB, Sweden	Andritz	To supply a new 7-effect high dry solids evaporation plant will have a capacity of 350 t/h evaporated water	Q2 2019
Indonesian Infrastructure Partnership, Kalimantan, Indonesia	Matthis-Morrison	Awarded a contract for construction of a new harbour for the country's expanding pulp and paper industry	
Irving Consumer Products, Macon, Georgia	Valmet	Construction of a new state-of-the-art 75,000tpy TAD tissue plant	2018
Ittihad International Investment L.L.C., Abu Dhabi, United Arab Emirates	Valmet	To supply a fine paper line (7.1m) for high-quality printing and writing paper grades	
Jiangxi Taison, greenfield mill in Jiujiang, Jiangxi Province, China	Valmet	To supply Valmet DNA automation systems and Valmet IQ quality control systems to four new tissue machines, TM7, TM8, TM9 and TM10	
Jianhui Paper, China	Voith	To rebuild the headboxes and shoe presses of Jianhui PM3 and PM4	
Jinzhou Paper, China	Voith	To rebuild the headboxes and shoe presses of Jinzhou PM3 and PM4	
Kimberly-Clark Corporation, Mobile, Alabama, USA	TBA	To construct a new on-site CHP plant at this tissue mill	Q1 2019
Kipaş Kağıt, Söke, Turkey	Voith	To build the PM1, a 700,000tpy board and packaging machine	
Knauf Petroboard, Kommunar, Russia	Andritz	To rebuild KM2 board machine	Q4 2018
Kyiv Cardboard and Paper Mill, Ukraine	A.Celli	To upgrade TM2 and deliver a new Pope Reel with central cut unit, web stabilizing system, shaft puller, spool storage, core lifter and finished reel lifting table	Q4 2017
Kyiv Cardboard & Paper Mill, Ukraine	Bekaert Solaronics	To supply UniDryer® V3 infrared drying systems and air bar dryers to as part of coater machine upgrade	H1 2018
Kyiv Cardboard & Paper Mill, Ukraine	Bellmer	To supply coating machine upgrade, including installation of IR dryer and new coating unit	Q2 2018
Lucart, two locations, Italy	GE Oil & Gas	To supply two NovaLT12 gas turbines	H1 2020

COMPANY, SITE	SUPPLIER	DESCRIPTION	START-UP
Lucart, various sites	Kadant Lamort	To install 6 Boostek™ screening units to various mill sin the group	
Metsa Group, Äänekoski bioproduct mill, Finland	ABB	To connect ABB electrical systems installed at the mill to the ABB Ability Collaborative Operations solution portfolio	
Metsä Tissue, Düren mill, Germany	TBA	To rebuild (and increase capacity by 10,000tpy) of PM5 which produces cooking and baking grades	Q4 2018
MMK Eerbeek Mill, The Netherlands	TBA	Installation of a film press	2017
Monalisa Co. Ltd., Seoul, South Korea	Andritz	To supply a sludge handling system	End 2017
Mondi SCP, Ružomberok, Slovakia	TBA	To install new 300,000tpy containerboard machine	Q2 2019
Naini Group paper mill , India	Pasaban	To add two new paper sheeters	
Navigator Company S.A., District of Aveiro, Portugal	A.Celli	To supply a latest-generation rewinder model E-WIND® T200	Q3 2018
Navigator Company, Cacia, Portugal	Voith	To supply a new XcelLine tissue machine, 70,000tpy	H2 2018
Nine Dragons Paper, Taicang, Quanzhou, Yongxin, Chongqing, and Dongguan Mills, China	Andritz	To supply five circulating fluidized bed boilers for utilization of in-house residual materials	H2 2018
Nine Dragons, China	Valmet	A repeat order of two more containerboard machines (PM41 & PM42). Also, steam and condensate systems for these new lines and for the previous board making lines (PM39 & PM40)	H2 2018 / H1 2019
OOO Mayak-Technocell (MTC), Penza, Russia	UMV	To supply coater units for new PM6 (décor- and non-woven wallpaper base)	Q1 2018
Orora Limited, Botany Mill, New South Wales, Australia	Valmet	Renewal of maintenance agreement for B9	
Papelera Samseng S.A., Buenos Aires, Argentina	GapCon Tissue S.r.l.	To supply an EconSOFTTM energy and resources saving (ERS) tissue machine	
Papeles Y Cartones De Europa, SA	Cellwood	To upgrade stock preparation line MP1 with a 200 Tpd – Krima Dispersing Unit	2017
Paper Mill Investment (PMI), Algeria	Andritz	To supply a tissue machine with steel Yankee and shoe press, capacity 135tpd	Q1 2018
Pro-Gest, Mantova, Italy	Kemira	Start-up chemicals contract for green field containerboard machine in Europe	2017
PT Aspex Kumbong, West Java, Indonesia	ABK Groupe & PapcelL	To supply a complete tissue machine (60tpd) including approach flow system, Crescent former, winder and auxiliary equipment	Q4 2018

COMPANY, SITE	SUPPLIER	DESCRIPTION	START-UP
S. Kijchai Enterprise PCL, Huay-Yang, Rayong, Thailand	Andritz	To supply another pressurized refining system for MDF production line II	Q2 2018
SAICA Paper, El Burgo de Ebro mill, near Zaragoza, Spain	Pesmel	To supply rack type automated roll warehouse (ARW)	Q1 2019
Sappi Lanaken,	Valmet	To supply a grade conversion rebuild for PM8, to go from LWC grades to produce lightweight and high-quality woodfree coated paper grades	2019
Sappi North America, Cloquet, Minnesota, USA	PMP	To supply an Intelli-Jet V® hydraulic headbox for PM12	2017
Sappi, Saiccor, South Africa	Andritz	To supply a baling line with bale tracking	2018
SCA, Östrand Pulp Mill, Timrå, Sweden	ABB	To provide overall process control for the world's most digitized mill	H2 2018
Schumacher Poledno, Bukowiec, Poland	Valmet	To supply a moisturizer system for a corrugated line	2017
SFT Group, Russia	Papcel	To supply two stations for preparation of starch (enzymatic, cationic) and working station for size press	
Shandong Sun Paper, China	Cellwood	To supply four Krima hot dispersing units for the PM36 and PM37 project	2018
Smurfit Kappa, Nettingsdorf Paper Mill, Austria	TBA	A new recovery boiler and steam turbine	2020 / 2022
Smurfit Kappa, Roermond Papier, The Netherlands	Pöyry	Awarded with the detail engineering services assignment for the modification of PM1. The assignment includes process engineering, mechanical engineering, electrical, automation and instrumentation engineering	
Sofidel, Buñuel, Navarra, Spain	A.Celli	To install a latest-generation rewinder model E-WIND®	Q3 2018
Sofidel, Ibertissue Mill, Buñuel, Navarra, Spain	Valmet	To supply an Advantage NTT tissue production line	Q3 2018
Stora Enso, Heinola Mill, Finland	Valmet	To supply an upgrade of the washing process area with a TwinRoll Evolution wash press (TRPE) on the Neutral-Sulfite Semi-Chemical (NSSC) line	Q1 2018
Stora Enso, Skutskär Pulp Mill, Sweden	Bellmer	To convert pulp dryer DM7 from bale-based market pulp into softwood fluff pulp, which is delivered in rolls to customers	
Thai Paper Co., Ltd., Wangsala Pulp Mill, Kanchanaburi, Thailand	Andritz	To upgrade the wet lap plant twin wire press	H2 2017
Twin Rivers Paper Company, Madawaska Mill, USA	Bekaert Solaronics	To supply Infrared system to improve moisture profile on PM5	

COMPANY, SITE	SUPPLIER	DESCRIPTION	START-UP
UPM, Kaukas Pulp Mill, Lappeenranta, Finland	TBA	Upgrade targeting fibre lines, recovery boiler, evaporation, bailing and wood handling	Q1 2018
Vajda Papír, Dunaföldvár, Hungary	Andritz	To supply a complete 2.7m tissue production line	Q1 2018
Yuen Foong Yu, Ching Shui Mill, Taiwan	PMP	To rebuild TM7 including steel Intelli-YD®, Intelli-Hood® and Steam & Condensate system	
ZAO Kartontol, Russia	OOO PAPCEL Saint Petersburg	To supply equipment and machinery for the stock preparation line (waste paper processing), line output 100 tpd	

PAPERmaking!
FROM THE PUBLISHERS OF PAPER TECHNOLOGY
Volume 3, Number 2, 2017

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Research Articles

Most journals and magazines devoted to the paper industry contain a mixture of news, features and some technical articles. However, very few contain research items, and even fewer of these are peer-reviewed.

This listing contains the most recent articles from the five main journals that publish original research:

- *APPITA JOURNAL*
- *IPPTA JOURNAL*
- *J-FOR*
- *NORDIC PULP & PAPER RESEARCH JOURNAL*
- *TAPPI JOURNAL*

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.

APPITA JOURNAL, Vol.70, No.2, Apr-June 2017

1. Preflocculated PCC to improve paper strength
2. Chitosan as a wet-end additive to enhance paper properties
3. The early history of the Australian paper industry and the use of Eucalypts
4. Early pulping advances developed by Australian scientist with NSSC and AQ pulping
5. Early studies by New Zealand scientist to use *Pinus radiata*

APPITA JOURNAL, Vol.70, No.3, Jul-Sep 2017

1. The characterization of biobased latex dispersions by serum replacement
2. Efficacy of different commercial cellulases to improve reactivity of mixed hardwood kraft pulp
3. Influence of fibre morphology on paper properties Part 1-fibre length
4. Rapid measurement of variation in tracheids transverse dimensions in a radiata pine tree
5. Handsheet property prediction from kraft-fibre and wood tracheid properties in eleven radiata pine clones

IPPTA JOURNAL, Vol.29, No.1, Jan-Mar 2017

1. Energy savings in paper machine vacuum system - how to utilize modern vacuum and nip dewatering technology
2. Learning from data - sustainable plant optimization at dip 4 Holmen paper, Madrid
3. Performance improvements and sustainability through advance process controls and remote monitoring services
4. Sustenance of business & conservation of resources by adopting clean and green methodology
5. Green and clean best practices in paper & board manufacturing at Emami
6. Sustainability in competitive market through innovation & creativity-quality up-gradation and operational excellence
7. The promise of new biobased and compostable polymer materials in harmony with emerging “circular economy”
8. Utilization of lime sludge as a filler in paper making - an innovative approach to cost reduction and zero environmental impact
9. Emission intensity reduction through enhanced recovery cogen performance and implementation of advanced energy efficient schemes in Seshasayee paper
10. Practices and technologies adopted by international pulp and paper mills to enhance environmental sustainability
11. Pulping and bleaching of *Melia dubia* clone k10: a short rotation pulp wood clone to improve environmental and economical performance
12. An integrated approach for utilization of rice straw for production of various grades of paper
13. Production of fungal xylanase and laccase enzymes for enzymatic pre-bleaching application
14. Green approach for synthesis of optical brightening agents and their application in wet end of papermaking
15. Pulp & paper mill enhancements for green productivity benefits
16. Stickies and pitch control with superior enzymatic formulations
17. Selectivity of commercial biocides on control of microbial contamination
18. Plastic waste disposal in paper industries - a new approach

J-FOR, Vol.6, No.3, 2017

1. On-line Biomass Moisture Content Measurement Using Near-infrared Spectroscopy
2. New and Upgraded Electrostatic Precipitators for Recovery Boilers
3. Variability in Lime-mud Feed Rate Induced in the Lime-mud Filter: Consequences and Action
4. Kiln Infra-red Cameras for Abnormal Situation Detection and Residual Carbonate Control
5. Release of Carbon and Nitrogen During Pyrolysis of Reduced Lignin Black Liquors - Experimental Results

J-FOR, Vol.6, No.4, 2017

1. Wrapped by Bacteria: Biofilm Detection and Removal in Paper Mills
2. Advanced Applications or HDPE Pipe with New PE-RT Material
3. An Approach to Application of Statistical Methodology for Calculation of Standard Working Time in Wood Processing
4. Development of Method for Rapid Prediction of Chemical Components of Dhaincha using FT-NIR Spectroscopy and Chemometrics
5. Production of Lactic Acid from Mixed Feed of Paper Mill Sludge and Hemp Hurd by Simultaneous Saccharification and Co-fermentation

NORDIC PULP & PAPER RESEARCH JOURNAL, Vol.32, No.2, 2017

1. PRINTING - The Evaluation of Experimental Cationic Polyvinyl Alcohol Containing Inkjet Coating Colors replaced by Calcium Carbonate
2. BIOREFINERY - Characterization of cellulose nanocrystal obtained from electron beam treated cellulose fiber
3. PAPER PHYSICS - Viability and properties of roll-to-roll coating of cellulose nanofibrils on recycled paperboard
4. MECHANICAL PULPING - The use of TAED in the last phase of CMP peroxide bleaching
5. COATING - The effect of different wear on superhydrophobic wax coatings - OPEN ACCESS
6. MECHANICAL PULPING - Mill evaluation of an intensified mechanical pulping process - OPEN ACCESS
7. COATING - Improving the optical performance of the nanostructured starch-calcium carbonate hybrid pigments
8. PRINTING - Roll-to-roll manufacturing of disposable surface-enhanced Raman scattering (SERS) sensors on paper based substrates
9. PAPER PHYSICS - Effect of the ratio of softwood kraft pulp to recycled pulp on formation and strength efficiency in twin-wire roll forming - OPEN ACCESS
10. PRINTING - Development of a paper-based sensor for the qualitative and quantitative detection of Cu2+ in water
11. PAPER CHEMISTRY - Improved microscopy method for morphological characterisation of pulp fines
12. MECHANICAL PULPING - CTMP Process Optimization Part II: Reliability in Pulp and Handsheet Measurements
13. MECHANICAL PULPING - CTMP Process Optimization Part III: On the Prediction of Scott-Bond, Z-strength and Tensile index
14. BIOREFINERY - Miniaturized determination of ash content in kraft lignin samples using oxidative thermogravimetric analysis
15. RECYCLING - Using phospholipase to control natural stickies in old newspaper pulp and the reaction mechanism therein

16. PRINTING - Biodegradation of thermochromic offset prints
17. CHEMICAL PULPING - The Effect of Bulk Crystals on Sodium Salt Scaling in Black Liquor Evaporators
18. PAPER CHEMISTRY - Effect of salt concentration in polyelectrolyte multilayering on properties of modified GCC and filled paper - OPEN ACCESS

NORDIC PULP & PAPER RESEARCH JOURNAL, Vol.32 No.3, 2017

1. CHEMICAL PULPING - The effect of increased pulp yield using additives in the softwood kraft cook on the physical properties of low-grammage handsheets
2. PAPER CHEMISTRY - The effect of chemical additives on the strength, stiffness and elongation potential of paper - OPEN ACCESS
3. PAPER PHYSICS - The effects of different types of wet-end added microfibrillated celluloses on the properties of paper made from bleached kraft pulp
4. RECYCLING - Evaluation of fly ash as a potential alkali for old newspaper de-inking
5. PRINTING - Influence of moist-heat accelerated ageing on yellow ElectroInk screen elements
6. BIOREFINERY - Cultivation and domestication of micro-aerobic magnetic activated sludge for pentachlorophenol (PCP) degradation
7. PAPER PHYSICS - Use of papermaking pulps in foam-formed thermal insulation materials
8. BIOREFINERY - Universal industrial sectors integrated solutions module for the pulp and paper industry - OPEN ACCESS
9. MECHANICAL PULPING - Effect of LC refining intensity on fractionated and unfractionated mechanical pulp - OPEN ACCESS
10. COATING - Visualization of latex and starch in paper coatings by tagging with fluorescent dyes
11. PAPER PHYSICS - One-sided versus two-sided roll forming of never-dried softwood kraft pulp - effects on formation and strength efficiency
12. PAPER CHEMISTRY - The role of fire retardant-polyvinyl alcohol systems on enhancing the performance of paper sheets toward ageing and counterfeiting
13. CHEMICAL PULPING - The effect of reaction wood on bleached eucalypt kraft pulp production - Part I
14. CHEMICAL PULPING - The effect of reaction wood on the properties of eucalyptus kraft pulp - Part II
15. PRINTING - Impact of fountain solution addition level on tack and optical properties of the print of a mechanically distributed water-in-oil thin film emulsion
16. BLEACHING - The use of calcium hydroxide as alkali source in peroxide bleaching of kraft pulp
17. COATING - Active-antimicrobial coatings based on silver nano-particles and natural polymers for paper packaging functionalization
18. CHEMICAL PULPING - Optimization of eucalyptus pretreatment by NH_4Cl using response surface methodology
19. PAPER CHEMISTRY - Cellulose-fiber-based insulation materials with improved reaction-to-fire properties
20. PAPER PHYSICS - Characterization of micro-fibrillated cellulose fiber suspension flow using multi scale velocity profile measurements

TAPPI JOURNAL, March 2017

1. Lignin carbon fiber: The path for quality
2. Melt-blown compostable polyester films with lignin
3. Accelerated aging of bio-oil from lignin conversion in subcritical water
4. An easy and reliable method for syringyl:guaiacyl ratio measurement
5. Formation mechanisms of "jellyroll" smelt in kraft recovery boilers

TAPPI JOURNAL, April 2017

1. TAPPI Journal 2016 Best Research Paper Award: Mining Big Data to improve pulping and papermaking operations
2. Novel thin functional coatings for paper by foam coating
3. Recent advances in lignin-based polyurethanes
4. Toward valorization of lignin: characterization and fast pyrolysis of lignin recovered from hot-water extracts of electron-beam irradiated sugar maple
5. Decision-making process for the identification of preferred lignin-based biorefinery strategies

TAPPI JOURNAL, May 2017

1. Impact of dissolved matter in the oxygen delignifcation stage

TAPPI JOURNAL, June 2017

1. Editorial: Coating & Graphic Arts, Process Control papers honored at PaperCon
2. Kinetics of sulfur dioxide-alcohol-water (SAW) pulping of sugarcane straw (SCS)
3. Improving the efficiency of hydrogen peroxide bleaching of chemimechanical pulp by continuous replenishment of bleaching chemicals
4. Finite element analysis of the thermal bending of a chilled cast thermo roll
5. Pulping and bleaching of Malaysian oil palm empty fruit bunches

TAPPI JOURNAL, July 2017

1. Editorial: The Laboratory of Soft Materials & Green Chemistry at North Carolina State University
2. Reduction of alkali loss in an ash leaching system
3. How old are fibers in paper for recycling and what is their life expectancy? A contribution to the life cycle assessment of wood fiber-based products
4. Evaluation of the particle size of organosolv lignin in the synthesis of resol resins for plywood and their performance on fire spreading
5. Low consistency refining of mechanical pulp - system design

TAPPI JOURNAL, August 2017

1. Guest Editorial: The next act for nonwovens
2. Visual discrimination of hygiene tissue softness in the absence of haptic feedback
3. Operating parameters affecting the thermal performance of biomass boilers
4. Drying characteristics of biosludge from pulp and paper mills
5. Modeling the influence of forming fabric structure on vacuum box dewatering

TAPPI JOURNAL, September 2017

1. Editorial: Multifaceted research at the University of Maine
2. Addition of corn stover arabinoxylan into hardwood during pulping for improved physical properties,
3. Oil absorption and desorption by polypropylene fibers
4. Effect of surface treatment with biodegradable materials on properties of linerboard made from old corrugated containers (OCC)

TAPPI JOURNAL, October 2017

1. Editorial: To paper and beyond at the University of Minnesota
2. Lignin value prior to pulping (LVPP): An advanced pulping concept
3. Degradation of 2,4-dichlorophenol by melamine amine cellulose - immobilized lacasses
4. Effect of conductivity on paper and board machine performance - a review and new experiences,
5. Techno-economic analysis of ECF bleaching and TCF bleaching for a bleached eucalyptus kraft pulp mill
6. Formation mechanisms of “jellyroll” smelt in kraft recovery boilers

PAPERmaking!

FROM THE PUBLISHERS OF PAPER TECHNOLOGY

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Technical Abstracts

The general peer-reviewed scientific and engineering press consists of several thousand journals, conference proceedings and books published annually. In among the multitude of articles, presentations and chapters is a small but select number of items that relate to papermaking, environmental and waste processing, packaging, moulded pulp and wood panel manufacture. The edited abstracts contained in this report show the most recent items likely to prove of interest to our readership, arranged as follows:

Those marked OPEN ACCESS can be downloaded from the internet in their entirety, free of charge.

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.

ENVIRONMENT

Life cycle assessment of paper production from treated wood, Asmae Ismaili *et al*, *Energy Procedia*, 128. Chemically treated wood waste has several physical and chemical properties which makes it usable for the manufacture of another product to multiple use, among which the production of paper and fuel. This paper presents the initial life cycle assessment (LCA) study on wood waste used for paper production. The results of the analysis demonstrate competitiveness of the waste wood use for paper production vs. raw wood in such environmental categories as human health and ecosystem quality.

Green Net Value Added as a sustainability metric based on life cycle assessment: An application to Bounty® paper towel, Bayou Demeke *et al*, *Journal of Cleaner Production*, 170. Sustainability measurement in economics includes assessment of environmental and economic effects in an integrated manner. In this study, system level economic data are integrated with environmental impacts determined from a life cycle assessment (LCA) of a common product. Green Net Value Added (GNVA) is a type of full cost accounting that incorporates total revenue, the cost of production, depreciation, and environmental externalities. We present externality costs disaggregated by upstream sectors, full cost of production, and GNVA to evaluate the relative sustainability of Bounty® paper towels manufactured at two production facilities. We found that the longer running, more established line had a higher GNVA. The predominant components contributing to externality costs come from the stationary sources in the supply chain: electricity generation (27–35%), refineries (20–21%), pulp and paper making (15–23%). Health-related externalities from Particulate Matter (PM2.5) and Carbon Dioxide equivalent (CO2e) emissions are to a great extent driven by electricity usage and emissions by the facilities, followed by pulp processing and transport.

Investigating external and internal pressures on corporate environmental behavior in papermaking enterprises of China, Zheng-Xia He *et al*, *Journal of Cleaner Production*, 172. As China's ecological environmental problem becomes severe, corporate environmental behaviour (CEB) has become the focus of a range of stakeholders, policy makers and the whole society since the operating activities of companies is the main source of environmental pollution. This study used a questionnaire survey and structural equation model (SEM) to examine the relative importance of external and internal pressures (EIP) on driving CEB. Data was obtained from 702 papermaking companies in China. The results showed that government pressure, economic pressure and internal pressure played significant positive roles in environmental behaviour of papermaking companies in China. Economic pressure was the most important factor on environmental behaviours (including defensive, accommodative and proactive behaviours) of papermaking companies. By comparison, the role of social pressure, which was imposed by general public and environmental Non-Governmental Organizations (NGOs), was not significant.

Environmental performance of straw-based pulp making: A life cycle perspective, Mingxing Sun *et al*, *Science of The Total Environment*, online. Agricultural straw-based pulp making plays a vital role in pulp and paper industry, especially in forest deficient countries such as China. However, the environmental performance of straw-based pulp has scarcely been studied. A life cycle assessment on wheat straw-based pulp making in China was conducted to fill of the gaps in comprehensive environmental assessments of agricultural straw-based pulp making. The dominant factors contributing to environmental impacts are coal consumption, electricity consumption, and chemical (NaOH, ClO2) input. Compared with wood-based and recycled pulp making, wheat straw-based pulp making has higher environmental impacts, which are mainly due to higher energy and chemical requirements. However, the environmental impacts of wheat straw-based pulp making are lower than hemp and flax based pulp making from previous studies. If carbon sequestration is taken into account in pulp making industry, wheat straw-based pulp making is a net emitter rather than a net absorber of carbon dioxide.

NANO-SCIENCE

Mechanical and chemical dispersion of nanocelluloses to improve their reinforcing effect on recycled paper, Cristina Campano *et al*, *Cellulose*, online. The use of nanocelluloses as strength-enhancing additives in papermaking is widely known since both cellulose nanofibers (CNF) and nanocrystals (CNC) present similar composition than paper but their exceptional properties in the nanometre scale confers a paper quality enhancement. However, some agglomeration problems in CNF and CNC through hydrogen bonding cause a lower improvement of mechanical properties of paper. Therefore, a better dispersion of both nanocelluloses can maximize their effect on paper properties, thus reducing the required dose to get the same increment in tensile strength and then reducing material costs. This study can be of great interest of those researchers trying to implement the use of nanocelluloses as strength additive in papermaking.

Nanofibrillation of deep eutectic solvent-treated paper and board cellulose pulps, Terhi Suopajärvi *et al*, *Carbohydrate Polymers*, 169. In this work, several cellulose board grades, including waste board, fluting, and waste milk container board, were pretreated with green choline chloride-urea deep eutectic solvent (DES) and nanofibrillated using a Masuko grinder. The properties of the nanofibrils after disc grinding were compared with those obtained through microfluidization. Overall, the choline chloride-urea DES pretreatment significantly enhanced the nanofibrillation of the board pulps in both nanofibrillation methods. Consequently, the DES chemical pretreatment appears to be a promising route to obtain cellulose nanofibrils from waste board and paper.

Biocompatible microcrystalline cellulose particles from cotton wool and magnetization via a simple in situ co-precipitation method, Mehnaz Rashid *et al*, *Carbohydrate Polymers*, 170. This investigation describes the preparation of magnetically doped degradable microcrystalline cellulose (MCC) nanocomposite particles with application potential in biotechnology, solid support for biomolecule/water purification, oil recovery from water and beyond. The nanocomposite dispersion was colloidally stable and the particles responded when external magnetic field was applied. It was possible to control the magnetic property by regulating the content of iron oxide.

Hydrophobization and smoothing of cellulose nanofibril films by cellulose ester coatings, Pia Willberg-Keyriläinen *et al*, *Carbohydrate Polymers*, 170. Cellulose nanofibril (CNF) films may find new applications, for example in printed electronics, if the surface smoothness of CNF films can be improved. One way to improve surface smoothness is to use thin coating solutions with zero porosity, such as molar mass controlled cellulose ester coatings. In this study, we have coated CNF films using molar mass controlled cellulose esters with different side chain lengths forming 3-layer film (ester-CNF-ester). These coatings improved significantly the smoothness of CNF films. The 3-layer films have also good water vapor barrier and mechanical properties and the films are heat-sealable, which enable various new applications in the future.

A new quality index for benchmarking of different cellulose nanofibrils, Johanna Desmaisons *et al*, *Carbohydrate Polymers*, 174. From a single plant source, a wide range of mechanically-deconstructed cellulose nanomaterials can be obtained due to the large number of possible combinations of pre-treatments, mechanical disintegration process, and post-treatments. It leads to the existence of a variety of cellulose nanofibrils with different shapes, morphologies, and properties on the market. This method also allows for the benchmarking of different commercial nanocellulose products.

NOVEL PRODUCTS

Simple and green fabrication of AgCl/Ag-cellulose paper with antibacterial and photocatalytic activity, Lin Dai *et al*, *Carbohydrate Polymers*, 174. A green in situ technique to prepare a kind of multifunctional hybrid paper, AgCl/Ag particles hybrid cellulose-paper (AgCl/Ag-paper), was established. The AgCl/Ag-paper was obtained from a facile ultrasound agitation procedure. Overall, this work provided a simple and green approach for the preparation of a new paper-based material with effectively antibacterial, photocatalytic activity, and biocompatibility for various applications and also showed the potential of scale-up production.

Combination of microsized mineral particles and rosin as a basis for converting cellulosic fibers into "sticky" superhydrophobic paper, Xiaoyan Yu *et al*, *Carbohydrate Polymers*, 174. In the paper industry, microsized mineral particles are widely used in the production of printing/writing paper grades, while rosin derived from trees is the earliest internal sizing agent for paper hydrophobication. Internal filling of cellulosic networks with mineral particles was basically used to hold out the mineral particles added at the surface, and the delicate integration of wet-end/surface applications of mineral particles with paper surface engineering with rosin/alum led to the development of "sticky" superhydrophobicity, i.e., ultrahigh water-repellency and strong adhesion to water. This proposed concept may provide valuable implications for expanding the use of paper-based products to unconventional applications, e.g., ultrahigh-performance ink jet printing paper for mitigating the "coffee-ring effect" and paper-based microfluidic devices for biomedical testing.

Magnetic cellulose nanocrystal nanocomposites for the development of green functional materials, E. Lizundia *et al*, *Carbohydrate Polymers*, 175. A magnetic cellulosic material composed of cellulose nanocrystals (CNC) and cobalt ferrite ($CoFe_2O_4$) nanoparticles was developed through evaporation-induced self-assembly (EISA). Those features obtained in a non-petroleum-based composite provide insight into the development of the next generation of functional materials from natural origin.

Comparative study of ultra-lightweight pulp foams obtained from various fibers and reinforced by MFC, Y. Liu *et al*, *Carbohydrate Polymers*, 182. A range of cellulose-based, ultra-lightweight pulp foams with different morphologies were prepared and reinforced with microfibrillated cellulose (MFC). By careful design of the pulp foam forming process, free-standing ultra-lightweight pulp foams were obtained through high velocity mixing and air/oven drying from cellulose fibre in the presence of surfactant, MFC, and retention aid. The effects of different types of fibres and surfactants on the air uptake volumes and mechanical properties of the foam were systematically investigated. The process developed in this work provides a cost effective approach to fabricate the strong and ultra-lightweight pulp foam, with a density lower than 0.02 g/cm3, using a standard handsheet former.

Dielectric Losses of Paper in the THz Domain: Literature Review, Needs for Future Research, and Prospective Solutions, Patrick Huber *et al*, *physica status solidi (a)*, online. High frequency paper-based electronics is developing fast, with smart yet low cost applications in view. However, the dielectric losses of paper remain a difficult hurdle to overcome. First, the literature on the topic is reviewed and the contributions from moisture, air, mineral filler, and wood constituents to dielectric losses are highlighted. Then, the guidelines for future research are defined, including the need for systematic comparisons in controlled moisture conditions.

PACKAGING

Rice stubble as a new biopolymer source to produce carboxymethyl cellulose-blended films, Pattrathip Rodsamran & Rungsinee Sothornvit, *Carbohydrate Polymers*, 171. Rice stubble is agricultural waste consisting of cellulose which can be converted to carboxymethyl cellulose from rice stubble (CMCr) as a potential biomaterial. Plasticizer types (glycerol and olive oil) and their contents were investigated to provide flexibility for use as food packaging material. Overall, results suggest that CMCr can be used to form edible film and coating as a renewable environmentally friendly packaging material.

Effect of silver contents in cellulose nanocrystal/silver nanohybrids on PHBV crystallization and property improvements, Heng Zhang *et al*, *Carbohydrate Polymers*, 173. Ternary nanocomposites including cellulose nanocrystals/silver nanohybrids (CNC-Ag) and biodegradable poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) were prepared by using solution casting. The effect of different AgNPs contents in the nanohybrids on crystallization ability and properties of PHBV was comprehensively investigated. Overall, the good barrier property and lower migration levels in food simulants, high antibacterial ratio of 99.9% and biocompatibility to human MG-63 cells, suggesting its potential application in food packaging related materials.

Understanding the mechanisms of oxygen diffusion through surface functionalized nanocellulose films, Maria Soledad Peresin *et al*, *Carbohydrate Polymers*, 174. A concept for direct surface modification on self-standing films of cellulose nanofibrils (CNF) is demonstrated using an aminosilane group in cellulose compatible solvent (dimethyl acetamide, DMA). The chemically modified structure efficiently prevents the oxygen molecules from interacting with the nanocellulose film in the presence of water molecules. Experimental evidence on the importance of interfacial processes that hinder the water-cellulose interactions while keeping film’s low affinity towards oxygen is demonstrated.

Propolis and chitosan as antimicrobial and polyphenols retainer for the development of paper based active packaging materials, Manuela Rollinia *et al*, *Food Packaging and Shelf Life*, 14 (Part B). The research investigates the potential combination of propolis and chitosan to develop a completely bio-based active food packaging material. Propolis glycolic extract was used as antioxidant and antimicrobial, due to its polyphenols content. Two commercial chitosans with different molecular weights were comparatively used as antimicrobial, wet strength additive substitute and polyphenols retainer. Paper antimicrobial activity was confirmed on thinly sliced raw veal meat, where a decrease of intentionally inoculated *L. innocua* of around 1 log cycle was achieved in 48 h at 4 °C.

Moulded Pulp Manufacturing: Overview and Prospects for the Process Technology, Mattia Didone *et al*, *Packaging Technology and Science*, 30 (6). Eco-friendly packaging such as moulded pulp products have gained commercial importance in the recent years. However, it remains a greatly under-researched area, and there is an arising need to consolidate the best practices from research and industry in order to increase its implementation. The goal of this paper is to give an overview of the main aspects involved in the manufacture of moulded pulp products. This includes a classification of moulded pulp products, historical and current applications, production processes, materials, mechanical properties and environmental sustainability. Moreover, based on the latest research in the field, an innovative drying technique that utilizes concepts derived from impulse drying is presented, and the implementation of this process technology is discussed.

Experimental investigation of novel curdlan/chitosan coatings on packaging paper, Urška Vrabič Brodnjak, Progress in Organic Coatings, 112. In the research, paper was successfully coated with curdlan and chitosan (CR/CH) coating solutions at different ratios (CR/CH ≈ 10:0, 8:2, 6:4, 5:5, 2:8, 4:6, 0:10% w/w). The novelty of this paper is in the use of combination of curdlan and chitosan, which led to a positive effect on the mechanical and water barrier properties. The resulting blend curdlan/chitosan coatings exhibited good water barrier and mechanical properties and could be used in many fields.

PAPERMAKING

The performance of chitosan with bentonite microparticles as wet-end additive system for paper reinforcement, Mehdi Rahmaninia *et al*, *Carbohydrate Polymers*, 179. In this research, the effect of bentonite micro-particles on the performance of chitosan as a new additive system for improving the dry strengths of acidic papermaking was studied. The application of bentonite in combination with chitosan had a significant impact on chitosan performance in mechanical properties. The best results were obtained with 0.3% bentonite consumption. Visual formation ranking had a proper correlation with this obtained results.

Synergies between cellulose nanofibers and retention additives to improve recycled paper properties and the drainage process, Noemi Merayo *et al*, *Cellulose*, 24 (7). Cellulose nanofibers (CNF) have increasing relevance in different applications, for instance, in the paper industry as a sustainable strength additive. This application is especially beneficial for recycled paper, which reaches higher product quality despite its limitations. CNF change paper properties and also can affect the production process, especially the drainage stage, in which retention additives (RA) are commonly used to promote interaction of cellulose fibres. However, these interactions vary depending on the type and flocculation mechanism of RA. This research is aimed at establishing possible synergies between CNF and RA to improve paper strength, while avoiding negative effects on the drainage process.

Effect of enzyme beating on grinding method for microfibrillated cellulose preparation as a paper strength enhancer, Kang-Jae Kim *et al*, *Cellulose*, 24 (8). Hardwood bleached Kraft pulp was treated with an endoglucanase prior to Valley beating. The Valley-beaten pulp slurry was further ground with a particle grinder in order to evaluate the effect of enzyme beating on preparation of microfibrillated cellulose (MFC). The time required to make 100 mL Canadian Standard Freeness pulp slurry was greatly reduced by enzyme pre-treatment. Thus, the mechanical energy for MFC manufacturing can be greatly reduced with enzyme beating.

Chemically modified cellulose micro- and nanofibrils as paper-strength additives, Rebecca Hollertz *et al*, *Cellulose*, 24 (9). Chemically modified cellulose micro- and nanofibrils were successfully used as paper strength additives. Three different kinds of cellulose nanofibrils (CNFs) were studied: carboxymethylated CNFs, periodate-oxidised carboxymethylated CNFs and dopamine-grafted carboxymethylated CNFs, all prepared from bleached chemical fibres of dissolving grade, and one microfibrillated cellulose from unbleached kraft fibres. In addition to mechanical characterization of the final paper sheets the fibril retention, sheet density and sheet morphology were also studied as a function of addition of the four different cellulose fibrils.

The effect of PVA foaming characteristics on foam forming, Qiupeng Hou & Xiwen Wang, *Cellulose*, 24 (11). Foam forming is a promising papermaking technology, which can reduce water and energy consumption while saving raw material. It can be used to produce low quantity thick special products such as non-woven fabrics and filter papers with high porosity and smooth surfaces. This study mainly introduced the effect of polyvinyl alcohol (PVA) foaming properties on foam forming, including foam generation rate, liquid drainage rate, properties of the suspension and foam stability.

Charge reversal system with cationized cellulose nanocrystals to promote dewatering of a cellulosic fiber suspension, Allison C. Brockman & Martin A. Hubbe, *Cellulose*, 24 (11). A surface-modified form of cellulose nanocrystals (CNC) was employed to explore mechanisms related to the release of water from cellulosic fibre suspensions during papermaking. The CNC surface was rendered partly cationic (forming CCNC) by adsorption of poly-DADMAC, a high charge density cationic polymer. Meanwhile, a suspension of cellulosic fibres and calcium carbonate particles was prepared from recycled copy paper, which was treated sequentially with poly-DADMAC and a very-high-mass anionic acrylamide copolymer (aPAM). Results were consistent with a model of nanoparticle-enabled bridging, based on an assumption of non-equilibrium or slowly equilibrating processes of adsorption.

Reusing tissue paper mill effluent water as corrugated paper mill intake water: Case study of a new clean production measure, Jinsong Tao *et al*, *Environmental Progress & Sustainable Energy*, online. To relief the water shortage crisis in China, the Chinese government has initiated a series of clean production (CP) measures to reduce the freshwater consumption and wastewater discharge from paper industry. In this study, a new CP technology was introduced in the paper industry to reuse tissue paper mill effluent water as intake water of corrugated paper mill. The feasibility and impact of the new CP technology was investigated in three different scales, laboratory experiments, pilot-scale testing, and long-term implementation. Results show that the water quality of treated tissue paper mill effluent water is competitive with that of freshwater and some water quality indexes are even better, indicating that treated tissue paper mill effluent water is a suitable alternative to replace the freshwater as intake water for the corrugated paper mill.

High performance of hydrophilic polymers on the crosslinked polystyrene spheres for controlling contaminants in white water, He Xiao *et al*, *Journal of Applied Polymer Science*, 134 (31). The accumulation of dissolved and colloidal substances (DCS) and inorganic salts in the white water of papermaking circulation system will result in the abnormal runnability of paper machine and low quality of products. Contaminant adsorption on a solid adsorbent in a fluidized bed reactor has been applied for white water treatment.

Unique alkyl ketene dimer Pickering-based dispersions: Preparation and application to paper sizing, Qi Zhao *et al*, *Journal of Applied Polymer Science*, 135 (4). Particle-stabilized alkyl ketene dimer (AKD) dispersions were prepared using dodecyl trimethyl ammonium chloride (DTAC)-modified laponite as the stabilizer, and sodium alginate (SA) as the protective colloid. The modification of laponite particles with DTAC, which was characterized by transmission electron microscopy, infrared spectroscopy, and X-ray diffraction technique. The effect of these particles on paper properties, particularly sizing, was measured.

Numerical investigation of three-dimensional fiber suspension flow by using finite volume method, Yue Mu *et al*, *Polymer Bulletin*, 74 (11). Fibre suspension flow is common in many industrial processes like papermaking and fibre-reinforcing polymer-based material forming. The investigation of the mechanism of fibre suspension flow is of significant importance, since the orientation distribution of fibres directly influences the mechanical and physical properties of the final products. The mathematical model and numerical method proposed in the study can be successfully adopted to predict fibre suspension flow patterns and hence to reveal the fibre orientation mechanism.

Multilayer assembly of ionic starches on old corrugated container recycled cellulosic fibers, Hamidreza Rud *et al*, *Polymer International*, online. In this study, old corrugated container recycled fibres were treated with polyelectrolyte multilayers consisting of biopolymer cationic starch with two degrees of substitution (DS) each in combination with one anionic starch. Pulp zeta potential, paper strength and the thin layer ellipsometry technique were applied to examine the influence of cationic starch DS on the formation of polyelectrolyte multilayers. The results indicated a significant interaction between the DS of cationic starch and the number of ionic starch layers formed, with strength increase being a function of the number of starch layers.

PULPING

Utilization of cotton waste for regenerated cellulose fibres: Influence of degree of polymerization on mechanical properties, Rasike De Silva & Nolene Byrne, *Carbohydrate Polymers*, 174. Cotton accounts for 30% of total fibre production worldwide with over 50% of cotton being used for apparel. In the process from cotton bud to finished textile product many steps are required, and significant cotton waste is generated. Typically only 30% of pre consumer cotton is recycled. Here we use cotton waste lint to produce regenerated cellulose fibres (RCF). The properties of the RCF are characterized and compared to wood pulp RCF.

Ultra-high pressure modified cellulosic fibres with antimicrobial properties, Ana M. Salgueiro *et al*, *Carbohydrate Polymers*, 175. In this work bleached *E. globulus* kraft pulp was doped with polyhexamethylene biguanide (PHMB) from an aqueous solution or from a suspension of silica capsules (PHMB@silica) by impregnation under atmospheric or ultra-high pressure (UHP) conditions (500MPa). The antimicrobial properties of pulps were evaluated towards gram-negative *E. coli* and gram-positive *L. innocua* bacteria.

Hydrogen bonds and twist in cellulose microfibrils, Sridhar Kumar Kannam *et al*, *Carbohydrate Polymers*, 175. There is increasing experimental and computational evidence that cellulose microfibrils can exist in a stable twisted form. In this study, atomistic molecular dynamics (MD) simulations are performed to investigate the importance of intrachain hydrogen bonds on the twist in cellulose microfibrils.

Lignocellulosic micro/nanofibers from wood sawdust applied to recycled fibers for the production of paper bags, Quim Tarrés *et al*, International Journal of Biological Macromolecules, 105 (1). In the present work, lignocellulosic micro/nanofibers (LCMNF) were produced from pine sawdust. For that, pine sawdust was submitted to alkali treatment and subsequent bleaching stages, tailoring its chemical composition with the purpose of obtaining effective LCMNF. The obtained LCMNF were characterized and incorporated to recycled cardboard boxes with the purpose of producing recycled paper. Overall, the studied strategies could allow a significant reduction of paper basis weight, with the consequent material saving and, thus, contribution to the environment.

STARCHES

Interaction of industrially relevant cationic starches with cellulose, Katrin Niegelhell *et al*, *Carbohydrate Polymers*, 179. Industrially relevant, commercially available cationic starches have been investigated towards their interaction capacity with cellulose thin films derived from trimethylsilyl cellulose (TMSC). The starches used in this study stem from different sources (potato, pea, corn) and featured rather low degrees of substitution ranging from 0.030 to 0.062. The interaction of those starches with cellulose thin films was studied by surface plasmon resonance spectroscopy under different flow conditions.

Properties of heated aqueous starch dispersions dependent on the preparation conditions, Marco Ulbrich and Eckhard Flöter, *Starch – Stärke*, 69 (9-10). The solution state of starch was investigated depending on several factors. Impacts on the preparation of aqueous starch pastes were examined with respect to solubility and molecular characteristics of the starch existent in the two phases. Different initial molecular states of the starch (native potato and three acid-thinned [AT] products), different disintegration temperatures (95, 125, and 155°C) as well as a high-shear after-treatment of the dispersion using an Ultra-Turrax were tested systematically.

TESTING

Measurement of the flexibility of wet cellulose fibres using atomic force microscopy, Torbjörn Pettersson *et al*, *Cellulose*, 24 (10). Flexibility and modulus of elasticity data for two types of wet cellulose fibres using a direct force–displacement method by means of AFM are reported for never dried wet fibres immersed in water. For BSW the modulus of elasticity ranges from 1 to 12 MPa and for TMP between 15–190 MPa. These data are lower than most other available pulp fibre data and comparable to a soft rubber band. Reasons for the difference can be that our measurements with a direct method were performed using never dried fibres immersed in water while other groups have employed indirect methods using pulp with different treatments.

Long-chain ionic liquid based mixed hemimicelles and magnetic dispersed solid-phase extraction for the extraction of fluorescent whitening agents in paper materials, Qing Wang *et al*, *Journal of Separation Science*, 40 (11). A novel mixed hemimicelles and magnetic dispersive solid-phase extraction method based on long-chain ionic liquids for the extraction of five fluorescent whitening agents was established. The present method was applied to extract the fluorescent whitening agents in two kinds of paper samples, obtaining satisfactory results. All showed results illustrate that the detection sensitivity was improved and the proposed method was a good choice for the enriching and monitoring of trace fluorescent whitening agents.

Optical measurement of the hydrophobic properties of paper products, Konrad Olejnik *et al*, *Measurement*, 115. Hydrophobic properties belong to the most important factors which determine functional properties of paper products. A number of methods related to the measurement of the interaction between water and paper are already used but most of them give results after specific period of time whereas many unit operations in modern industrial processes (e.g. printing) last usually less than one second. As a result, most of the existing methods are not corresponding to today's requirements. The aim of the presented research was to develop the method based on image analysis for measuring the dynamics of penetration and permeation of liquid through paper. Special device named eXtended Liquid Penetration Analyser (XLPA) was built for this purpose. The proposed method fully replaces the method implemented in the PLG Sizing Tester, which estimated the time of a 50% decrease in brightness of a tested paper sample permeated by ink. Presented method offers the possibility of quantitative measurement of changes in liquid absorption with time resolution of 1/60 s.

A simplified compression test for the estimation of the Poisson's ratio of viscoelastic foams, Paolo Bonfiglio & Francesco Pompoli, *Polymer Testing*, 61. This paper describes a simplified procedure for determining the Poisson's ratio of homogeneous and isotropic viscoelastic materials. A cylindrical shaped material is axially excited by an electromagnetic shaker and consequent displacement waves are investigated. The results are presented and discussed for different materials and compared to well-established quasi-static and finite element simulations.

WASTE TREATMENT

Effect of Feedstock Concentration on Biogas Production by Inoculating Rumen Microorganisms in Biomass Solid Waste, Na Li *et al*, *Applied Biochemistry and Biotechnology*. A methane production system with continuous stirred-tank reactor, rumen liquid as inoculate microorganisms, and paper mill excess sludge (PES) as feedstock was studied. The work mainly focused on revealing the effect of feedstock concentration on the biogas production, which was seldom reported previously for the current system. The findings of this work have a significant effect on promoting the application of digesting PES by rumen microorganisms and further identified the technical parameter.

Converting wastewater sludge and lime-treated sugarcane bagasse to mixed carboxylic acids – a potential pathway to ethanol biofuel production, Hema Rughoonundun & Mark T. Holtzapple, *Biomass and Bioenergy*, 105. Sludge is the solids recovered from wastewater treatment. Its high content of organic matter makes it a potential biomass resource for renewable energy production. In this study, batch and continuous counter-current fermentations were performed with a 60:40 mixture (dry weight basis) of lime-treated bagasse:sludge. This study shows that wastewater sludge is a valuable resource for liquid transportation fuels, and provides an attractive replacement for fossil fuels.

Effects of papermaking sludge-based polymer on coagulation behavior in the disperse and reactive dyes wastewater treatment, Ruihua Li *et al*, *Bioresource Technology*, 240. In this study, papermaking sludge was used as the raw biomass material to produce the lignin-based flocculant (LBF) by grafting quaternary ammonium groups and acrylamide. LBF was used as a coagulant aid with polyaluminum chloride (PAC) to treat reactive and disperse dyes wastewater. Effects of dosing method, pH, hardness and stirring speed on the coagulation behavior and floc properties were studied.

Modeling and simulation of the industrial sequencing batch reactor wastewater treatment process for cleaner production in pulp and paper mills, Yi Man *et al*, *Journal of Cleaner Production*, 167. Being an internationally accepted standard for the activated sludge modelling, the Activated Sludge Model No.1 (ASM1) was used to simulate the treatment of paper mills effluent in an industrial full-scale sequencing batch reactor (SBR). The results showed that the ASM1 could be reasonably used in the papermaking wastewater treatment simulation.

WOOD PANEL

Isolation of lignocellulose nanofibrils (LCNF) and application as adhesive replacement in wood composites: example of fiberboard, Cherif Ibrahima *et al*, *Cellulose*, 24 (7). Thermomechanical pulp (TMP) produced using atmospheric refining was ground to isolate lignocellulose nanofibrils (LCNF). Forty minutes and a specific energy of about 1300 kWh/t were necessary to reach the end-point of the process defined by the presence of 95% fines in the slurry. The effect of using LCNF as adhesive replacement in fibreboard has been assessed. A maximum modulus of rupture of 12.1 MPa comparable to that of commercial fibreboards and high modulus of elasticity, was obtained at 20% LCNF content for panels produced at 180 °C. The binding ability of LCNF and its effect on the mechanical properties of fibreboards were more perceptible when a less refined TMP with lower fine content and longer fibres was used in the process.

Comparison between two different pretreatment technologies of rice straw fibers prior to fiberboard manufacturing: Twin-screw extrusion and digestion plus defibration, Dyna Theng *et al*, Industrial Crops and Products, 107. The present work compares two different pretreatment technologies, i.e. twin-screw extrusion, and steaming digestion plus defibration, for producing a thermo-mechanical pulp from rice straw for fibreboard manufacturing. The results showed that liquid/solid ratio had influence on energy consumption of the equipment for both defibrating methods For the twin-screw extrusion method, a lower liquid/solid ratio required more energy while for the digestion plus defibration the effect was the opposite. The corresponding total specific energy consumption ranged from 0.668 kW h/kg to 0.946 kW h/kg dry matter for twin-screw extrusion, and from 6.176 kW h/kg to 8.52 kW h/kg dry matter for digestion plus defibration. Thus, the pulping method consumed about nine times more energy than that of the twin-screw extrusion. In addition, for twin-screw extrusion, the liquid/solid ratio did not have a substantial effect on fibre characteristics with similar chemical compositions and thermal properties.

Approaching a new generation of fiberboards taking advantage of self lignin as green adhesive, Juan Domínguez-Robles *et al*, *International Journal of Biological Macromolecules*, online. This study describes the use of lignin as natural adhesive for the production high density fibreboards (HDF) made from wheat straw. In the present work, this agricultural residue was used to produce thermomechanical pulp and the used lignin was obtained from the spent liquors generated in the same process. A hot pressing process was conducted to manufacture these fibreboards and different percentages of this green adhesive were targeted. Physical and mechanical properties were assessed and the results revealed that the panels made only with wheat straw fibres had a flexural strength value (52.79 MPa) even above the value corresponding to the commercial HDF (41.70 MPa). Also, results showed that the incorporation of soda-lignin lead to lignocellulosic composites that, as lignin content was increased (from 0 to 15%), mechanical properties were enhanced.

Synthesis of bromo-cardanol novolac resins and evaluation of their effectiveness as flame retardants and adhesives for particleboard, Oleg Shishlov *et al*, *Journal of Applied Polymer Science*, online. The synthesis of bromo derivatives cardanolic novolac resins (BCNR) using infrared, thermogravimetric analysis, differential scanning calorimetry, gel permeation chromatography, nuclear magnetic resonance 1H and 13C methods was studied. The mechanism of thermal degradation of BCNR is proposed. It is shown, that particleboards manufactured using PU-(BCNR) as an adhesive are materials with enhanced flame retardant properties, meeting the requirements of P7 class to EN 312 (especially durable moisture-resistant particleboards) and the requirements of the emission class Super E0. The bromine in the structure of the cardanol-containing polyurethane binder allows achieving both high physical and mechanical characteristics of the particleboards and resistance to flame.

Improving Water Resistance of Soy-Based Adhesive by Vegetable Tannin, Saman Ghahri *et al*, *Journal of Polymers and the Environment*, online. In this research tannic acid was used to prepare soy-based adhesives for making plywood and fibre board. The different resin formulations were analyzed by Differential scanning calorimetry (DSC), thermogravimetric analysis (TGA) and its derivative as a function of temperature (DTG) and Fourier Transform Infra-red (FTIR) spectroscopy. The results showed that the addition of tannic acid to soy-based adhesive decreased soy-based adhesive viscosity and its pH. The mechanical and physical properties such as MOR, MOE, IB, and water resistance of fiberboard were improved, by adding tannic acid to the soy-based adhesive.

PAPERmaking!
FROM THE PUBLISHERS OF PAPER TECHNOLOGY
Volume 3, Number 2, 2017

Paper Industry Technical Association
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Events

Details of selected forthcoming world events along with the latest copy of the PITA Calendar of World Events.

In this edition:

INTERNATIONAL SEMINAR 2017

TECHNOLOGIEKRING Paper & Board Industry

'The paper-/board machine and paper-/board products'

Location: Van der Valk Hotel Apeldoorn-De Cantharel

Van Golsteinlaan 20 7339 GT Apeldoorn

November 22nd (Wednesday afternoon) | November 23rd (Thursday morning)

Preliminary program

November 22th (Afternoon, Day 1)

13:00	Welcome by Mr. J. Pille, Projectmanager VNP (Human Talent Agenda)
	A. General
13:10	Opening by chairman of the day – Mr. M. Maessen, Smurfit Kappa PPT
13:30	Techniques paper restauration, Mr. B. van Velzen, Paper Gnomon
13:50	Sludge reduction – Mr. B. Güres, Episome Biotechnologies
	B. Additives
14:10	Dry Strenght – Mr. F. Burkhard, Solenis
14:30	EDT/Enzym applications in paper industry - Mr. J. Polster, EDT-Enzymes
14:50	Dry strength systems - Mr. V. Grigoriev, Kemira
15:10	**Break & Telsell → Education moment Human Factory**
15:40	Recyclable Water Based Barrier Solutions for Paper and Board and cost efficient printability improvements by VAcA-binders - Mr. T. Niskanen, CH-Polymers
16:00	Vegetable oil asa sizing agent – Mrs. E. Lackinger-Csarmann, Kemira
16:20	Adhesives for packaging, tissues and corrugated cardboard – Mr. A. van Dongen, Wellchem
	C. Z-direction masterclass/workshop
16:40	From CMT to S-test (ABB) New development, Mr. P. Gerards, Smurfit kappa
17:05	**Break & Snack**
17:20 *Workshop*	Short overview Paper properties and up-date Z-direction testing - Mr. A. de Brouwer, ABB With practical peeling issues – Mr. H. Mulder, Coldenhove Practice cases Z-direction of a number of companies: Teijin Aramid – Mr. JC Tiecken IGT – Mr. F. Zuijdewijk, Mr. de Groot The importance of tensile Z for Eska – Mr. B. Uil, Eska Graphic Board Z-direction issues in multilayered solid board - Mr. J. de Jongh, Smart Packaging Solutions Headboxes in relation to z-direction properties – Mr. M. Maessen, Smurfit Kappa Paper Production
18:35	**Networking at the technology market**
19:30	**Dinner and official ceremony Technologie Kring Award November 2017**

We❤Papertechnology
Technologie Kring

November 23th (Morning, Day 2)

8:45	Opening by chairman of the day, Mr. L. Joore, MD Millvision BV
	D. Paper machine developments
9:00	MindSphere, application in P & P - Mr. H. de Ruysscher, Siemens
9:20	Braincube Manufacturing Intelligence end-to-end solution in Industry 4.0 technologies - Mr. D. Kaban, Braincube
9:40	Trim squirt nozzle applications in paper production – Mr. L. G. Fabiny, Fabiny GmbH
10.00	Forming fabrics/dry fabrics and cleanbelts - Filcon Europe
10:20	FlexoDirect – Mr. A. Jagodowski, AS Drives
10:40	Contact less drying and IR profiling (Coaters and Paper machine) – Mr. P. Hallberg, Ircon Drying Systems AB
11:00	**Break & Telsell**
11:15	Spreading cylinders – Mr. J. Lehtonen, Logistic
	E. Safety and inspiration by other sectors
11:35	Safety concept ABB, Mr. N. Lahtinen, ABB Paper Machine Drives
11:55	Voith ProTect system, Mr. K. Aengeneyndt, Voith
11:15	The latest tail threading solutions for the safety part (hands off from paper machines) – Mr. A. Schumann, Valmet, Via T. Zapf
12:35	Air drying technologies – Mr. R. Banecki, Valmet
12:55	Non woven compared to paper and machine speeds in relation to intermediate materials – Mr. BJ Hudepohl, Le Moine Holland
	End of seminar and take away lunch

Program updates: www.technologiekring.nl
Program is subject to changes

“COLLABORATING. NETWORKING. SHAPING TOGETHER … OUR FUTURE”

44th INTERNATIONAL ANNUAL SYMPOSIUM DITP

Wednesday, 22nd November, 2017 - AFTERNOON SESSION

15.00 –16.30 - FUTURE PROCESSES AND PRODUCTS (parallel section)

• DRY DEFIBRATION – A NEW PULPING METHOD AS A PREREQUISITE FOR NOVEL PAPER & BOARD PRODUCTION TECHNOLOGIES
Thomas Schrinner; Technische Universität Dresden, Dresden (DE)

• CAVITATION – ADVANCED TECHNOLOGY FOR THE CONTROL OF MICROBIOLOGICAL FACTORS IN PAPER INDUSTRY
Matej Šuštaršič1, Martin Petkovšek2; 1Pulp and Paper Institute, Ljubljana, 2 Faculty of Mechanical Engineering Ljubljana, Laboratory for Water and Turbomachinery, Ljubljana (SI)

• POTENTIAL APPLICATION OF ENZYMATICALLY MODIFIED LIGNOSULFONATES AS COATING
Karin Hofer3, Andreas Ortner2, Gibson S. Nyanhongo2, Heribert Winter3, Kai Mahler3, Georg Gübitz2, Wolfgang Bauer1;
1Institute of Paper, Pulp and Fiber Technology Graz, 2University of Natural Resources and Life Sciences Vienna, 3Sappi Paper Holding (AT)

15.00 –16.30 - NETWORKING FOR EFFICIENT MANAGEMENT”

• THE SUPPLY CHAIN PRINCIPLE IN A BUSINESS WORLD
Alenka Knez; DS Smith Packaging Divison, Brestanica (SI)

• PHYSICAL ASSET MANAGEMENT PRACTICES: A CASE STUDY IN A PAPER MILL VEVČE d.o.o.
Viktor Lovrenčič; C&G d.o.o. Ljubljana, Ljubljana (SI)

• INCREASING ENERGY EFFICIENCY WITH ACTIVE ENERGY MANAGEMENT
Dejan Papež; Kolektor Sisteh d.o.o., Ljubljana (SI)

16.30 – 17.00
Coffe break

"COLLABORATING. NETWORKING. SHAPING TOGETHER … OUR FUTURE"

17.00 – 19.00 - FUTURE PROCESSES AND PRODUCTS (parallel section)

- PRINT QUALITY OF MFC BASED PAPERS PRINTED BY FLEXOGRAPHY
Igor Karlovits, Gregor Lavrič, Tanja Pleša; Pulp and Paper Institute Ljubljana, Ljubljana (SI)

- NEW SECURITY PAPER PRODUCTS UNDER DEVELOPMENT FROM CEPROHART
Mihaela Daniela Dumitran, Constantin Secară; CEPROHART SA, Braila (RO)

- ANALYSIS OF PAPER MATERIALS USING MODERN FIB-SEM ELECTRON MICROSCOPE
1Gregor Kapun, 2Andrej Šinkovec; 1National Institute of Chemistry, Ljubljana, 2Pulp and Paper Institute Ljubljana, Ljubljana (SI)

- INFLUENCE OF MASS DISTRIBUTION ON ELECTRIC BREAKDOWN STRENGTH OF INSULATING PRESSBOARD
Michael Vogel; Siemens Insulation Center GmbH & Co. KG, Zwönitz (DE)

17.00 – 19.00 - SHAPING THE CIRCULAR ECONOMY

- CONCERNS ON VALORISATION OF BIOLOGICAL SLUDGE FROM RECYCLING PAPERS WASTEWATER TREATMENT PLANT
Petronela Nechita1, Violeta Negreanu2; 1Dunărea de Jos University of Galaţi, 2Pulp and Paper Research and Development Institute Braila, Braila (RO)

- THE USE OF RECYCLED MATERIALS FROM PAPER PRODUCTION IN CIVIL ENGINEERING: THE EU PROJECT PAPERCHAIN
1Karmen Fifer Bizjak1, Justina Šepetavc2, Ana Mladenovič1, Stanislav Lenart1; 1Institute for Construction of Slovenia, Ljubljana, 2Vipap Videm Krško d.d., Krško (SI)

- ENERGY SAVING HIGH EFFICIENCY SCREENING FOR RECYCLED FIBER
Winfried Wolf; Andritz AG Pulp @ Paper, Raaba (AT)

- NETWORKING – AND MODERN PREPARATION AND CLEANING OF RECYCLED FIBERS
Edmund Grebien; Grebien Qualifiber GmbH, St. Stefan (AT)

20.00
Dinner

"COLLABORATING. NETWORKING. SHAPING TOGETHER … OUR FUTURE"

Thursday, 23rd November 2017 - MORNING SESSION

09.00 – 10.30 - COLLABORATION IN ADVANCED PAPERMAKING

• FROM WOOD LOG TO THE FINAL REEL OUT OF ONE HAND!
Thomas Schiffer; ANDRITZ AG Andritz Pulp & Paper, Graz (AT)

• TECHNICAL HIGHLIGHTS OF CONVERSION OF A FINE PAPER MACHINE INTO A SPECIALTY BOARD MACHINE
Jürgen Bihler; BELLMER GmbH Maschinenfabrik, Niefern-Öschelbronn (DE)

• LATEST TECHNOLOGY FOR BOARD MACHINE KM3 IN ARNSBERG
Martin Lehrner; Voith Paper Rolls GmbH & Co KG, St. Pölten (AT)

10.30 – 12.00 - SHAPING THE FUTURE OF PAPERMAING – poster session

Introductory paper

NANOCELLULOSE IN PAPERMAKING
Janja Juhant Grkman1, Matjaž Kunaver2, Primož Oven3, David Ravnjak4,Milena Resnik5, Andrej Kovič6;
1Pulp and Paper Institute, Ljubljana, 2National Institute of Chemistry, Ljubljana, 3University of Ljubljana, Biotechnical Faculty, Ljubljana, 4Paper Mill Vevče, Ljubljana, 5Vipap Videm Krško, Krško, 6Količevo Karton, Količevo (SI)

Poster Introduction (15')
POSTER presentation and coffee break (45')

12.00 – 13.00 - COLLABORATION IN ADVANCED PAPERMAKING

• MODERN OIL CIRCULATION LUBRICATION SYSTEMS HELP REDUCE ENERGY CONSUMPTION
Hans Georg Weber; SKF-Lubrication Systems Germany GmbH, Hopckenheim (DE)

• FLEXODIRECT® – A REVOLUTION IN THE PAPER MACHINE-DRIVE TECHNOLOGY
Ramazan Ataman; AS Drives & Services GmbH, Reken (DE)

13.00 – 14.30
Lunch

14.30 – 16.30 - DIGITIZING THE PAPER INDUSTRY

• OPTIMIZED PAPER MANUFACTURING PROCESSES USING THE INTERNET OF THINGS – PAPERMAKING 4.0
Matthias Schmitt; VOITH GmbH, Heidenheim (DE)

• ESTIMATING STRENGTH PROPERTIES ONLINE WITH A SOFT SENSOR
Mikko Viitamaeki; Valmet Technologies OY, Tampere (FIN)

• THE BEST-IN-CLASS MILL OPERATIONS
Robert Mihalyi; ABB AG, Wien (AT)

• DIGITALIZATION AND NEW ECOSYSTEMS
Rok Koren; Siemens d.o.o., RC-SI PD, Ljubljana (SI)

16.30 – 16.45 - FINAL WORD
Marko Jagodič, President of the Pulp and Paper Engineers and Technicians Association (DITP), Ljubljana (SI)

SLO “Papir – vedno vznemirljiva zgodba”

14.30 – 16.00 - NAPREDNE MERILNE METODE
Predsedujoči:
Matej Šuštaršič; Inštitut za celulozo in papir, Ljubljana (SI)

• HITRO IN NATANČNO NAPOVEDOVANJE REZULTATOV TISKA Z METODO OPTIČNE TOPOGRAFIJE
Hakan R. Osterholm; Lorentzen & Wettre ABB AB, (SE)

• UPORABA VIZUALNE TEHNOLOGIJE V INDUSTRIJI PAPIRJA, KARTONA, TISSUE PAPIRJA IN CELULOZE
mag. SeppoToivonen; PAPERTECH Inc., Lohja (FI)

• MERJENJE TRDOTE ZVITKOV - ONLINE MERJENJE POROZNOSTI
Jyrky Laari; ACA RoQ Roll Hardness Profiler, Sotkuma (FI)

16.00 – 16.45
ZAKLJUČEK SIMPOZIJA
Marko Jagodič, predsednik Društva inženirjev in tehnikov papirništva(DITP), Ljubljana (SI)

Seznam predstavljenih posterjev:
1.) LAVA VOJVODINE KRANJSKE 1689: ANALIZA PAPIRJA OB KONSERVATORSKO-RESTAVRATORSKEM POSEGU
Prof. dr. Jedert Vodopivec; Arhiv R Slovenije, Ljubljana (SI)

2.) VPLIV TEMPERATURE NA NEKATERE OPTIČNE IN POVRŠINSKE LASTNOSTI ARHIVSKIH, SITETIČNIH IN SPECIALNIH PAPIRJEV
Barbara Blaznik; Katedra za info.in grafično tehnologijo, Ljubljana (SI)

3.) VPLIV RAZLIČNIH NAČINOV PREDOBDELAVE SUROVE CELULOZE NA UČINKOVITOST ENCIMSKE HIDROLIZE
Maša Iršič; Univerza v Mariboru, Fakulteta za kemijo in kemijsko inženirstvo, Maribor (SI)

4.) UPORABA TEHNIČNIH LIGNINOV ZA RAZVOJ PREMAZOV ZA POVRŠINSKO KLJEJENJE EMBALAŽNIH PAPIRJEV
Samir Kopacic1, Andreas Ortner2, Georg Gübitz2, Wolfgang Bauer1; 1Institute of Paper, Pulp and Fiber Technology; 2University of Natural Resources and Life Sciences, Dunaj (AT)

5.) PROIZVODNHJA BIO-OSNOVANIH SPOJIN S PRETVORBO LIGNINA IZ ODPADNE LIGN-CELULOZNE BIOMASE: KEMIJSKO INŽENIRSKI PRISTOP
Bernhard Nellessen, AchimSchenker; Nopco Paper Technology GmbH,Düsseldorf (DE)

6.) PROIZVODNHJA BIO-OSNOVANIH SPOJIN S PRETVORBO LIGNINA IZ ODPADNE LIGN-CELULOZNE BIOMASE: KEMIJSKO INŽENIRSKI PRISTOP ADDED BIO-BASED CHEMICALS BY VALORIZATION OF WASTE BIOMASS LIGNIN: CHEMICAL ENGINEERING APPROACH
Ana Bjelić, Miha Grilc, Blaž Likozar; Kemijski inštitut, Ljubljana (SI)

7.) OPTIMIZACIJA POTISKANE POVRŠINE
Helena Peuranen, KEMIRA Oyj; Espoo (FI)

8. ELECTROCHEMICAL SYSTEM FOR WASTEWATER TREATMENT IN PAPER INDUSTRY
Karlo Nađ1, Robert Kollar1, Oliver Kurdija1

Povzetki posterjev bodo objavljeni v Zborniku predavanj.

OPUS TRUST MARKETING

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THE CHANGING FACE OF CUSTOMER COMMUNICATIONS

THURSDAY 23rd NOVEMBER 2017

Opus Trust Marketing Limited, 133-137 Scudamore Road, Leicester, LE3 1UQ

AGENDA

9:30 - 10:00 Arrival and coffee

10:00 - 10:15 Strength through flexibility
Technology has shifted the way information can be consumed.
Channel choice is now greater than ever. So how does the supply chain keep up?
Paul Brough, Chief Executive Officer, Opus Trust Marketing

10:15 - 10:45 Keynote: We know where your mail is!
How innovative technology ensures accountability, in an industry where integrity is everything.
Stephen Agar, Managing Director,
Consumer and Network Access, Royal Mail

10:45 - 11:30 Digital transformation in the world of customer communications
Introducing new channels to drive customer engagement. See it, hear it, interact with it.
Keith Dear, Strategic Account Director, Pitney Bowes Software

BREAK

11:45 - 12:30 Your Epic journey starts here
Integrity is at the heart of everything we do. Get up close and personal
with our high speed multi-format inserter.
Opus Trust Marketing Production Team

12:30 - 1:30 Lunch, networking and mini exhibition showcasing Print Management, On Demand, E-services, Hybrid Mail, Postal Services and Core Operations
Your chance to engage with experts from across the organisation.

1:30 - 2:30 Long term customer engagement demands intelligent channel choices
Balance efficiency with effectiveness to achieve the best communications mix for your business.
A collaborative session to stimulate thinking and fuel your communications channel strategy.
Hosted by the Opus Trust Marketing Board of Directors

2:30 Summary and close

Expertly Delivered

SENSE THE FUTURE

European Paper Week

28-30 November 2017
Brussels, Belgium

This year is a special one for CEPI as we celebrate our 25th anniversary, making this year's European Paper Week an even more memorable occasion. We invite you to join us on a journey of discovery as we experience paper through the five senses – sight, sound, smell, taste, and touch. We will also partner up with RISI for the PPI Awards which will be held at CEPI's special 25th anniversary dinner. All this and much more in store for you at this year's European Paper Week.

REGISTER NOW!

To see the detailed programme, register and book your hotel accommodation, go to **www.cepi.org/epw**

#CEPI25

HIGHLIGHTS

- 25th anniversary dinner in conjuction with the PPI Awards at Brussels' famous Royal Museum of Art & History
- Gunther Pauli, prolific TED speaker and serial entrepreneur, addresses this year's High-Level Session
- **NEW THIS YEAR!** The International Council of Forest and Paper Associations (ICFPA) comes together to discuss global challenges ahead
- **NEW THIS YEAR!** For the first time ever, a European edition of the Blue Sky Young Researcher's Award

REGISTRATION (excluding VAT)

€ 590 – 3 day access to all public sessions!

CEPI 25th anniversary dinner and PPI Awards: € 100

EU officials and journalists are welcome to participate free of charge.
NEW THIS YEAR! Limited amount of free spaces available to students.
Please contact mail@cepi.org for more information.

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PITA Meet - North

Dear Member,

We are extremely pleased to announce a mill tour and festive lunch at **Preston Board & Packaging, Romiley Mill** on **Thursday, 7th December 2017**, commencing at 14:00 hrs.

Romiley Board Mill has manufactured cardboard for well over 100 years throughout various ownership and was acquired by Preston Board and Packaging in 1994 under the Directorship of David Hardman and Charles Ingham, since then the business has seen a dramatic surge in technological development, production techniques and product quality improvements, making Romiley Board Mill almost unique in the British Paper Industry.

Our thanks go to John Johnson and all at Romiley Board for inviting PITA Members to visit their historic site. Numbers for this visit will be limited, in order to secure a place contact the PITA Office.

For further details or to book your place, please contact Helen in the PITA Office (0300 3020 150) or e-mail helen@pita.org.uk

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PITA Training & Conferences

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Kate Leach presents . . . .

"Energy Optimisation"

Essential Cost Saving Knowledge for All involved in the Paper Industry

13th & 14th February 2018 / Venue: TBA

This Two Day course will focus on Energy Optimisation in Paper Production but is also relevant to other energy heavy industries.

This course is essential training for anyone (manufacturer or supplier) who wishes to get a better understanding of how to optimise energy usage in the work place.

Kate is an effective and entertaining trainer with a thorough and grounded knowledge of papermaking processes with good insight into the world of soft tissue manufacture.

I can honestly say that after 38 years in the paper industry and having attended a large number of courses this was truly one of the best both in terms of content and supporting material.

Day One:

- ***Energy & Trends:*** *A look at energy trends locally and globally.*
- ***Motors:*** *Understanding how motors work, to make them work more efficiently in our mills.*
- ***Context & Scale:*** *Looking at energy use in the Home, Office and Industry.*
- ***Processing & Pumping Efficiency****: Learning how to spot process inefficiencies in pumps.*

Day Two:

- ***Dewatering:*** *Relative costs of water removal throughout the papermaking process, how small changes can bring about big savings.*
- ***Employee Engagement:*** *The importance of involving the whole workforce in energy optimisation and some tools to do this.*
- ***Compressed Air:*** *How to ensure one of the largest single energy users in the mill is working optimally.*
- ***Refining:*** *A background to refining leading on to an understanding of how to optimise refining results whilst minimising energy requirements.*
- ***Energy Generation:*** *Generation options for the paper industry (including: heat exchangers and steam systems).*

Only £575 (plus VAT) per person for the two day course, including full course notes, refreshments & six months complimentary membership of PITA

**For further details &
to book your place on this course,
contact Helen in the PITA Office
(0300 3020 150 / helen@pita.org.uk)**

5 Frecheville Court
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PITA Training & Conferences

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Kate Leach presents . . . .

"An Introduction to Tissue Manufacture"

Essential Background Knowledge for Anyone involved in the Tissue Sector

13th – 15th March 2018 / Venue TBA

This Three Day Introductory course provides an insight into the modern tissue mill and the peculiarities of tissue when compared with conventional paper products.

Kate will lead attendees through the process of manufacturing tissue from fibres to finishing and explore key aspects of the 'Tissue Machine' including the Yankee Cylinder, Tissue Properties, Costs, Quality and, perhaps most mysterious of all, Softness.

This course is essential training for anyone (manufacturer or supplier) new to the Tissue Sector or those wishing to broaden their understanding of this fascinating paper product.

Kate is an effective and entertaining trainer with a thorough and grounded knowledge of papermaking processes with good insight into the world of soft tissue manufacture.

I can honestly say that after 38 years in the paper industry and having attended a large number of courses this was truly one of the best both in terms of content and supporting material.

Day One:

Day One will look at the full tissue production process, from fibre to shelf

- ***Fibres:*** *the basics, the different types, how they impact on final sheet properties*
- ***Pulping****: a look at the major types of virgin fibre pulping techniques, & secondary fibre treatments*
- ***Papermaking:*** *a guide through the papermaking process, from pulp preparation & approach flow through to the end of the paper machine*
- ***Chemical Additives****: talking through the most common categories of chemical additives used through the tissue making process*
- ***Finishing & Converting****: from the parent reel-up to the customer - what processes are likely to be involved in turning a parent reel into saleable tissue*

Day Two:

Building on the knowledge gained, Day Two looks at tissue properties & process costs

- ***Tissue Properties*** – *identifying what properties are desirable in different types of hygienic paper, looking at how our manufacturing processes impact on these. Is it possible to enhance all our properties together? Or are there trade-offs to be considered?*
- ***Considering Quality*** - *What does "quality" mean to each of your customers throughout the process? How can we influence final sheet properties right from the start of the process? Look at root cause issues of quality defects*

Day Three:

Day Three consolidates earlier learnings & focuses on the importance of the Yankee Cylinder

- ***Focus on the Yankee Cylinder*** *–A look at Yankee performance & operation. Where to look when trying to trouble shoot the root cause of issues that may be seen & experienced at the Yankee*
- ***Measurement Methods*** - *Making sure there is a common language for quality standards between customer & supplier. An overview of the type of measurements that are taken in tissue manufacture, & the equipment used*
- ***Softness*** – *looking at softness in a logical progression, from the definition of softness, through to how it is measured & finally looking at ways to enhance softness perception through papermaking processes*

Only £699 (plus VAT) per person for the three day course, including full course notes, refreshments & six months complimentary membership of PITA

For further details & to book your place on this course, contact Helen in the PITA Office (0300 3020 150 / helen@pita.org.uk)

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PITA Training & Conferences

"Pumping Systems Energy Efficiency Workshop"

Essential Knowledge for Everyone Working with Pumps

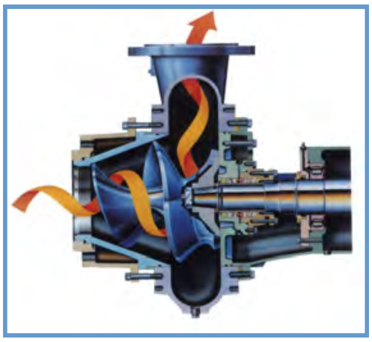
17th April 2018 / Venue TBA

Paper
Industry
Technical
Association

Who should attend:

Energy Managers & Coordinators
Operations Supervisors & Managers
Plant & Process Engineers
Maintenance Personnel

Energy efficiency of pumping systems is important in that energy efficiency is one of the most important factors in determining pump reliability and maintenance costs. Consequently, energy inefficiency in pump systems increases operating costs due to:



- Higher energy use and cost
- Increased maintenance costs
- Failure (reduced reliability affecting production schedules)

There are many reasons for low energy efficiency of pump systems. Several of these can be identified by simple measurements such as flow, power consumption and total pump head. Other reasons for low efficiency may require a detailed analysis of the pump system to identify specific issues and what steps to take to resolve these issues.

This course is designed to show how to measure pump efficiency so that pump systems are operated at high efficiency following remedial action when the data shows that there is a cost benefit from this action.

Contents

- The relationship between Energy Efficiency and Reliability
- How to assess Pump System Efficiency; what measurements need to be taken and the possible problems in taking these
- How to use the data generated
- What surveys show in terms of Pump System Efficiency - typical efficiency in pump systems
- Options to improve efficiency after finding that a system is inefficient
- The pros and cons of Variable Speed Drives
- How to measure pump failure rates, so that improvements can be tracked

Only **£399 per person** including full course notes, refreshments and six months complimentary subscription to Paper Technology

For further details or to book your place on this course, contact Helen in the PITA Office
(0300 3020 150 / info@pita.co.uk)

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www.paper-biorefinery.com

November 2017

CALL FOR PAPERS

Dear ladies and gentlemen!

The annual "Paper Conference" has been taking place in Graz (Austria) for more than 60 years. About 450 representatives from industry and research get together each year to exchange knowledge and to strengthen their networks.

PAPER & BIOREFINERY CONFERENCE

From **16 – 17 May 2018**, the conference will prove yet again that it is a premier event, where the latest trends and industry developments are discussed: With its **extended focus and international format** it sets the trend, highlighting the innovative move of the pulp and paper sector as an increasingly successful operator in the biorefinery segment.
Of course the conference will continue to address current topics in the pulp and paper industry presented by distinguished speakers. The Messecongress Graz offers again the ideal surroundings.

INVITATION / CALL FOR PAPERS

The APV (Association of Academic Paper Engineers Graz) together with the Austrian industry associations ÖZEPA and AUSTROPAPIER invites **experts active in industry and research** to present current results of their work at the PAPER & BIOREFINERY CONFERENCE 2018.

DEADLINE: 12 JANUARY 2018

When handing in a paper please use the enclosed **Abstract Submission Form** and observe the information and **deadlines** listed on the following page. From all submitted papers the conference's program committee will prepare the final program with about 30 presentations, which will be divided in two parallel sessions.

Please note:

You are kindly asked to give your presentation in ENGLISH, as no simultaneous translation will be offered.

Main topic 2018: **DISRUPTION**

PREFERRED TOPICS OF PRESENTATIONS:

- **Innovative fiber based products and novel applications** for pulp, paper and board (e.g. nanocelluloses, viscose fibers, super hydrophobic papers, barrier materials, novel packaging solutions, paper based sensors ...)
- **Wood based biorefinery concepts** including **potential applications, realized projects** and **research results** pertaining **pulp & paper industry** (e.g. wood based chemicals, bioenergy, biofuels...)
- **Industry 4.0 / IOT applications**
- Advances in **chemical pulping**, **mechanical pulping** and **stock preparation**
- **Recycled Fiber**: new production processes, raw material input, product innovations
- **Advances in research** in all pulp and paper related fields
- Projects, ideas and initiatives to **strengthen collaboration** along the entire **wood based value-added chain**
- **Practical experience reports by pulp-, paper- and board mill professionals** (modernizations, rebuilds, optimization, energy projects...)
- **Improved energy efficiency** in the whole pulp and paper production chain
- Technological innovations in **paper and coating machinery** (including machine clothing, process and quality control...)
- New and improved **raw materials and chemical additives** and their optimal use in the furnish and in coatings
- Current developments in **measurement and control systems** in the pulp and paper industry
- **Innovative analysis routines** and **testing methods** in the pulp and paper industry
- **Innovative concepts** in the field of **human resource management** and **education** in the pulp and paper industry (staff recruitment, novel modes of working, workforce of the future)
- Occupational **health and safety** issues

PAPER & BIOREFINERY

CONFERENCE **16-17 May 2018, Graz** TRADE SHOW

PLEASE OBSERVE THE FOLLOWING DEADLINES:

12 January 2018:................ **Send your proposal per E-Mail to: office@paper-biorefinery.com**.
Suggestion of topic/title, including an informative abstract and all authors.
Please use the **enclosed Abstract Submission Form** and add – if desired – a separate abstract (max. 1 page in **English**, an additional German version is optional).

9 February 2018: .... **Notice** of acceptance to the authors.

20 April 2018:........................ **Final short version (abstract)** due.
1-2 pages A4, Word-document; English (an additional German version is optional).

11 May 2018:......................... **Presentation** due as PPT- and PDF-File.
All presentations will be published online in PDF-format on the conference homepage, which is only accessible for participants of the conference.
If you do not want your presentation to be published online, please let us know.

We are looking forward to your contribution!

APV – Association of Academic Paper Engineers
at Graz University of Technology

Institute of Paper, Pulp and Fiber Technology
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ABSTRACT SUBMISSION FORM

PAPER & BIOREFINERY
CONFERENCE 16-17 May 2018, Graz TRADE SHOW

TITLE OF THE PRESENTATION:	
INFORMATIVE ABSTRACT:	❐ Please see enclosure.
AUTHOR(S):	For <u>all</u> authors: Full name, company and postal address
SPEAKER: (One speaker per lecture gets free access to the conference, not including social program)	Full name, company, postal address, e-mail and telephone number
CONTACT PERSON:	<u>If different from "SPEAKER"</u>: Full name, company, postal address, e-mail and telephone number
YOUR COMMENTS:	

Print the form

Please submit the completed sheet <u>by 12 January 2018</u> at the latest to: office@paper-biorefinery.com – Thank you!

Send the form

IMPC 2018
International Mechanical Pulping Conference
28-30 May 2018, Trondheim, Norway

FIRST ANNOUNCEMENT

Organiser
The Technical Association of The Norwegian Pulp and Paper Industry,
www.ptf.no

Welcome to Trondheim and IMPC 28-30 May 2018

Conference Venue

The conference will take place at Scandic Nidelven.

Tentative Program

The program will cover all aspects of mechanical pulping including new prosesses and new equipment, quality considerations and new applications. The program will last from May 28 through May 30.

A poster session will be arranged.

Conference Language

The official conference language is English.

Call for Papers

An invitation to lectures and preliminary outline of the program will be issued Summer 2017.

Suggestions regarding papers may be sent to our office from now on.

Who Should Attend

The program will be planned for an international audience. It will cover topics of interest both to people working in research and development and to people working in the mills. It should also be of interest to papermakers, since various applications of high – yield pulp will be described and discussed.

Social Program

An enjoyable social program will be offered during the evenings for the delegates and their accompanying persons. Various cultural and leisure activities will also be offered to accompanying persons during daytime.

Hotels

In addition to Scandic Nidelven, reservations will be made available at hotels in various price categories.

Program Committee

Lars Johansson, RISE PFI AS, Norway, Chairman
Antti Fredriksson, PI, Finland
Per Engstrand, SPCI, Sweden
Reza Amiri, PAPTAC, Canada
Representative of APPITA, Australia
Representative of TAPPI, USA
Kjell-Arve Kure, Norske Skog Saugsbrugs, Norway
Peter Dahlbom, Norske Skog Skogn, Norway
Philip Reme, RISE PFI AS, Norway

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The Norwegian University of Science and Technology, the largest university in Norway, is located in **Trondheim**. The city is home to 554 technology companies employing over 10,000 people, generating more than NOK 14.4bn (USD $1.9bn).

(By: NTNU – Norwegian University of Science and Technology)

PITA Calendar of World Events

November 2017		
21 - 22	Third meeting of the 'Union Papetière 2017' (ATIP) @ Grenoble, France	www.atip.asso.fr
22 - 23	DITP @ Bled, Slovenia	www.danpapirnistva.si
22 - 23	Technologie Kring @ Apeldorn, The Netherlands	www.technologiekring.nl
23	The Changing Face of Customer Communications @ Leicester, UK	ruth@themarketingpod.co.uk
28 - 30	European Paper Week @ Brussels, Belgium	www.cepi.org/EPW
28 - 29	PTS Faserstoff (Fibres) Symposium @ Dresden, Germany	www.faserstoff-symposium.de
29 - 30	Zellcheming Tech. Com. 'Mechanical Pulping' @ tba, Germany	reiner.ohrnberger@t-online.de
December 2017		
5 - 7	Digital Print for Packaging Europe 2017 @ Berlin, Germany	www.smitherspira.com
7	PITA Meet North 2017 @ Romiley Board Mill, Near Stockport, UK	info@pita.co.uk
11 - 13	Paper One Show @ Sharjah, UAE	www.paperoneshow.net
12 - 14	Paper Arabia 2017 @ Dubai, UAE	www.paperarabia.com
February 2018		
13 - 14	PITA Energy Optimisation Course @ PITA Office, Bury, UK	info@pita.co.uk
28 - 1 Mar	Packaging Innovations @ NEC, Birmingham, UK	www.easyfairs.com
March 2018		
7 - 9	27th International Munich Paper Symposium @ Munich, Germany	www.paper-online.de
13 - 15	PITA 'An Introduction to Tissue Manufacture' @ PITA Office, Bury, UK	info@pita.co.uk
21 - 23	Tissue World America @ Miami, USA	www.tissueworld.com
April 2018		
15 - 18	PaperCon 2018 @ Charlotte, NC, USA	http://papercon.org
17	PITA Pump Efficiency Course @ PITA Office, Bury, UK	info@pita.co.uk
18 - 20	IMFA 21st Annual Molded Fiber Seminar @ San Diego, USA	www.imfa.org
19 - 20	Zellcheming Tech. Com. 'Plant Engineering & Energy' @ Schwedt, Germany	h.wald@pkvarel.de
23 - 25	Specialty Papers Europe 2018 @ Cologne, Germany	www.specialtypaperconference.com
May 2018		
13 - 17	Paper & Biorefinery @ Graz, Austria	www.paper-biorefinery.com
28 - 30	International Mechanical Pulping Conference 2018 @ Trondheim, Norway	www.ptf.no
29 - 31	PulPaper 2018 @ Helsinki, Finland	http://pulpaper.messukeskus.com
June 2018		
6 - 8	Asian Paper @ Bangkok, Thailand	www.asianpapershow.com
6 - 8	Tissue World Bangkok @ Bangkok, Thailand	www.tissueworld.com
13 - 15	Paper Vietnam @ Hanoi, Vietnam	www.paper-vietnam.com
25 - 29	It's Tissue 2018 @ Lucca, Italy	www.edipap.com
26 - 28	Zellcheming Expo @ Frankfurt, Germany	www.zellcheming-expo.de
September 2018		
4 - 6	Tissue World Istanbul @ Istanbul, Turkey	www.tissueworld.com
19 - 23	International Paper Historians Biennial Congress @ Gent, Belgium	www.paperhistory.org
20 - 21	Zellcheming Tech. Com. 'Plant Engineering & Energy' @ Varel, Germany	h.wald@pkvarel.de
23 - 27	Progress in Paper Physics Seminar 2018 @ Lodz, Poland	https://ppps.p.lodz.pl
October 2018		
10 - 12	MIAC 2018 @ Lucca, Italy	www.miac.info
23 - 25	Nordic Wood Biorefinery Conference @ Helsinki, Finland	NWBC2018@vtt.fi
November 2018		
14 - 15	PAP-FOR Business Forum 2018 @ St. Petersburg, Russia	www.papfor.com
March 2019		
25 - 27	Tissue World Europe @ Milan, Italy	www.tissueworld.com