PAPERmaking!
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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 abstracts contained in this report show the most recently published items likely to prove of interest to our readership, arranged as follows:

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 International* 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*.

COATING

Application of Some Polymer latexes in Preventing Paper Documents Forgery, *Egyptian Journal of Chemistry*, 62 (1), 2019, pp.1-14. The main objective of this research is to improve ink printability of papers via their modification with various types of water-based polymer latexes during paper manufacturing process. In order to achieve this target, various types of styrene-acrylate polymer latexes were used for modification of different types of papers. Styrene-acrylate latexes were prepared via emulsion polymerization of styrene with various acrylate monomers using emulsion polymerization technique. The effect of different emulsifying agents on the properties of the prepared emulsions was studied. The obtained results showed a significant improvement in degree of gloss and ink density on the polymer-coated papers which positively affect the ink ability, and ink holding properties of the modified paper. In addition, ink gloss and ink density of the coated papers improved with increasing the concentration of modifying latexes containing Texapon®P as emulsifier. These promising results open the way to use polymer latexes in treatment of documented value which can be used in stabilization of disappearing ink on paper leading to prevent forgery.

Water vapour and grease resistance properties of paper coating based starch-bentonite clay Khairuddin et al, *Journal of Physics: Conference Series*, 1153, conference 1. In the present study, the water vapour and grease resistance properties of paper coating based starch – bentonite clay has been investigated. The clay concentration was 0%, 10%, 15%, 23%, 30%, 40% and 50% w/w. The composites were prepared by solution casting and coated on the surface of the paper, and analysed using Payne cup method (water vapour transmitter rate-WVTR), grease resistance test and X-Ray diffraction (XRD). The WVTR results showed that the addition of clay improved water vapour barrier properties and the most optimal improvement was obtained at clay concentration in the range of 10 - 23 wt %. However, the opposite trend was observed for grease resistance properties which showed that the grease resistance decreased with increasing clay concentration. XRD results showed that starch entered clay gallery and formed intercalated bilayer structure both at clay concentration of 10 and 23 wt % wt. The clay/starch composite (23 wt%) was more ordered and higher amount of starch chains entered gallery than than those of clay/starch (10 wt%) supporting better water barrier properties at high clay concentration.

Effect of coating with novel bio nanocomposites of cationic starch/cellulose nanocrystals on the fundamental properties of the packaging paper, Khashayar Vaezi et al, *Polymer Testing*, 80, 2019, online. In this research, an environmentally friendly and biodegradable cationic starch (CS)/nanocrystalline cellulose (NCC) nanocomposite coating was produced and it was applied to improve the mechanical, barrier and physical properties of packaging kraft paper via surface coating. The mechanical and barrier properties of the paper were affected by the CS/NCC nanocomposite coating and it was the subject of investigation. CS/NCC nanocomposites were prepared by the solvent method. Structural and morphological properties of the nanocomposite were studied by FESEM and TEM observation. Results showed that the increased NCC nanoparticles loading, increased the tensile strength, oil resistance and air resistance of the coated paper. Also, the water absorption of the coated paper decreased 50% at 5 wt% NCC concentration. In our study it was concluded that the optimized amount for the NCC nanoparticles (among, 3 wt%, 5 wt%, and 7 wt%), is 5 wt%. The CS/NCC nanocomposite coatings are then proposed as a favorable booster which intensifies the mechanical and barrier properties of the paper in the food packaging application.

Influence of Nano-silica on Inkjet Paper Coating, Huanmei Wang et al*, Advances in Graphic Communication, Printing and Packaging*, Springer Verlag, pp.689-696. The influence of nano-silica with different particle sizes on inkjet paper coating was investigated. Laboratory self-made silica sol with particle size of 16 and 100 nm was employed as the pigment, and Polyvinyl Alcohol (PVA) was used as the binder. In order to study how nano-silica influences the properties of the inkjet paper coating, four groups of coating were prepared by variation of the dosage for two types of silica sol particle sizes. The viscosity of coating, the microstructure, physical properties, inkjet printing quality and dynamic permeability were characterized. The results showed that 16 nm silica sol could increase the viscosity of coating and reduce coating liquidity. Meanwhile, it did not contribute to the improvement of the physical properties and permeability of the coated paper. When the ratio between 16 and 100 nm silica sol was 30:70, the coated paper exhibited the best glossiness, smoothness and the solid density. In addition, it was found that the microstructure of the coating demonstrated good correlation with the performance of the coated paper.

Characterization of the Interface Between Coating and Fibrous Layers of Paper, H. Aslannejad et al, *Transport in Porous Media*, 127 (1), pp.143–155. Coated paper is an example of a multi-layer porous medium, involving a coating layer along the two surfaces of the paper and a fibrous layer in the interior of the paper. The interface between these two media needs to be characterized in order to develop relevant modeling tools. After careful cutting of the paper, a cross section was imaged using focused ion beam scanning electron microscopy. The resulting image was analyzed to characterize the coating layer and its transition to the fibrous layer. Such image analysis showed that the coating layer thickness is highly variable, with a significant fraction of it being thinner than a minimum thickness required to keep ink from invading into the fibrous layer. The overall structure of the coating and fibrous layers observed in this analysis provide insights into how the system should be modeled, with the resulting conclusion pointing to a specific kind of multi-scale modeling approach.

ENERGY / ENVIRONMENT

Exploring external and internal pressures on the environmental behavior of paper enterprises in China: A qualitative study, Zhengxia He et al, *Business Strategy and the Environment*, 28 (6), pp.951-969. As one of the typical high-polluting and high-energy-consuming industries in China, the paper industry's environmental behavior has become the focus of a range of stakeholders, policy makers, and the whole society because the industry's business activities are a main source of environmental pollution and contribute to massive energy consumption. This study used a qualitative approach to examine the relative importance of external and internal pressures (EP and IP) in driving the environmental behavior of paper enterprises in China. Based on grounded theory, this study aimed to examine the EP and IP on the environmental behavior of paper enterprises to create a comprehensive theoretical model based on grounded theory code analysis. It was found that government pressure, economic pressure, social pressure, and IP have direct and significant positive effects on the corporate environmental behavior (CEB) of paper enterprises in China. Furthermore, government, economic, and social pressures have indirect and significant positive effects on CEB through other pressures. Finally, the paper concludes with a discussion of these four pressures and provides policy implications.

Industrial verification of energy saving for the single-tier cylinder based paper drying process, Xiaobin Chen et al, *Energy*, 170, pp.261-272. The paper drying process has the highest level of energy consumption in the pulp and paper production process. Analysis and optimization of the energy system during the paper drying process is critical for improving the energy efficiency of the entire paper mill. In the existing model for the paper drying process, the solution requires accurate boundary conditions such as the air temperature and humidity of the pocket area and the cylinder surface temperature, which are very difficult to obtain in the papermaking process. This can result in significant deviations between the model solution and the actual production process. This paper focuses on the single-tier dryer cylinder-based paper drying process that has been widely used with high-speed papermaking machines in recent years. A mathematical model is proposed based on real-time data. The verification via industrial production demonstrates that the proposed model is reliable for the paper drying process. Based on the simulation results, two optimization operations have been proposed. The energy consumption decreases from 1.51 t steam/t paper to 1.44 t steam/t paper, 4.6% of the steam and 1.26×10^6 RMB can be saved for a medium-scale paper mill with the annual production capacity of 10^5 t paper.

Life cycle analyses of alternative fibers for paper, Alice Favero et al, *Journal of Advanced Manufacturing and Processing*, 1 (3), e10023. This study provides a quantitative and qualitative review of life cycle analyses of alternative fibers for paper production. Alternative fibers include both virgin fibers from rapidly renewable sources (hemp, flax, *Arundo donax*, bamboo, kenaf) and agricultural residues (wheat straw and bagasse). A comparison is made with conventional wood fibers, including northern and southern softwood and eucalyptus, and with recycled fiber. The evaluation characterizes the major environmental impacts of alternative fibers that have been identified in previous studies. The assessment of the literature indicates that a substantial portion of the environmental impacts of paper products is associated with the pulping and paper-making processes across all fiber types. Alternative fibers may have somewhat different pulping impacts, although the differences are generally not large in the overall impacts of the life cycle.

Resource value flow analysis of paper-making enterprises: A Chinese case study, Zhen Li et al, *Journal of Cleaner Production*, 213, pp.577-587. Papermaking enterprises are currently under both environmental pressure and economic pressure for sustainable development in China. Thus, the efficiency, effectiveness, and benefits of resource utilization need to be improved. High-consumption and high-pollution companies should manufacture paper using sustainable methods. This study highlights a resource value flow analysis from the circular economy perspective, developing an extension of material flow cost accounting and modifying it by accounting for environmental damage as well as economic benefits. With reference to the Plan-Do-Check-Act cycle, this specific case study was conducted to verify the comprehensive utility of resource value flow analysis by establishing decision-making prioritization according to the dualistic diagnosis of “internal resource loss–external environmental damage costs.” In general, applying a resource value flow analysis can both reduce resource consumption and minimize environmental damage, enhancing the sustainable development of a process industry with limited resources.

ENZYMES

Cellulases Production and Application of Cellulases and Accessory Enzymes in Pulp and Paper Industry: A Review, Muhammad Imran et al, *PSM Biological Research*, 4 (1), 2019. Cellulases are produced from a variety of microorganisms; include both bacteria and fungi. Solid-state fermentation, liquid-state fermentation, and fed-batch fermentation techniques are utilized for the manufacture of cellulases. Cellulases have vast applications in almost every industry and are extensively used in fabric manufacturing. Enzymes have been used in the pulp for juice making, food processing, paper manufacturing, and pharmaceutical applications. The process of recycling in the paper industry had great importance and its value increased day by day in writing and printing papers. Many manufacturing services in the paper industry were integrated. Paper mills start with wood chipping at first, followed by pulping, bleaching, papermaking, and recycling of the past consumer products. Reduction of energy by cellulase enzyme and chemicals has been used to improve the quality of the paper and help to decrease the environmental influence of pulp production. In the near future, the need for cellulases will be strongly recommended for the commercial production of biofuels and bioenergy.

MOULDED PULP

Production of Unitary Moulded Pulp Products Using Rapid-Köthen Apparatus, Monika Sikora & Dariusz Danielewicz, *BioResources*, 14 (4), pp.9781-9785. This study shows that it is possible to manufacture moulded products from fibrous pulp at the laboratory scale using the Rapid-Köthen apparatus (found in almost every paper laboratory) and a special sieve form set. This process includes the design of elements of the mould forming sets by special software, production of these elements using a numerically controlled tool machine, the assembly of the sieve form, its installation in the Rapid-Köthen apparatus, and the forming and drying of the pulp product.

On the drying process of molded pulp products: Experiments and numerical modelling, Didone, Mattia et al, *Drying Technology (an International Journal)*, 2019, online. Molded pulp products are experiencing increased importance due to their environment-friendly characteristics with regards to both production and disposal. In this study, the thermoforming process for the production of molded pulp products was examined by means of two experimental campaigns, with the scope of distinguishing between the water removal due to only compression (better known as cold pressing) and the water removal under additional thermal conditions. The underlying multiphysics of the processes were identified by comparison with similar manufacturing processes found in available literature, and then implemented using a 1-dimensional finite element model in COMSOL software. This fast, simple model was able to predict the water removal for a specific set of process conditions and the results were supported by corresponding experimental observations. Within a process time of up to 15 s, temperatures ranging from 80 °C to 120 °C, and a final dryness between 40% and 65%, the simulations gave accurate estimates, with a difference in prediction down to 0.3%. The paper thus documents the first combined experimental-simulation study for thermoforming of molded pulp products.

Moulded pulp products manufacturing with thermoforming, Mattia Didone & Guido Tosello, *Packaging Science & Technology*, 32 (1), pp.7-22. Over the past years, eco-friendly packaging solutions such as moulded pulp have resonated with a growing number of consumers. Among all of them, the thermoformed products make use of the most recent manufacturing approach that produces high-quality, thin-walled items. However, it remains an underresearched area, and the development of an efficient and precise manufacturing process is fundamental in order to increase the implementation of sustainable packaging.

With the purpose of setting a step towards in the standardization of design and testing practices of eco-friendly packaging, this work focused on the characterization of the thermoforming process of moulded pulp products and their characteristics. Three different analyses were carried out for this purpose, covering the dewatering efficiency of the process, a quantification of the moulding geometrical accuracy, and an analysis of the internal microstructure of the parts. Experimental results and statistical analysis show that the dewatering efficiency is mainly governed by the mould's temperature while the duration of the contact time is not influential. In the second investigation, the geometrical accuracy of the mouldability of microfeatures was assessed. The process appeared to be dependently related to the pulp type employed. Finally, the internal microstructure was documented using X-ray computed tomography. The analysis shows an increase in the internal void fraction linked with an increase in the mould's temperature. The role of the water change of phase in the thermoforming process is also discussed by reference to the work conducted on impulse drying.

NANO-SCIENCE

Cellulose nanofiber (CNF) as a versatile filler for the preparation of bamboo pulp based tissue paper handsheets, Min Guan et al, *Cellulose*, 26 (4), pp.2613–2624. Tissue paper that is prepared from bamboo has a very promising future in the world, especially in China, thanks to the various merits of bamboo fibers. However, the water absorption behavior and mechanical properties of bamboo pulp based tissue paper need to be improved due to the inherent drawbacks of bamboo fiber, such as high stiffness, weak interaction between bamboo fibers etc. Hence, cellulose nanofibers (CNFs) were combined with bamboo fibers before the tissue paper-making process, to improve the water absorption behavior and mechanical properties of tissue paper. The hypotheses are that: (1) CNFs themselves possess large specific surface area and abundant hydroxyl groups as well, thus enhancing the hydrophilicity of tissue paper; and (2) the added CNFs can form 3D structures in tissue paper, thus providing abundant pores with uniform small size, which would facilitate the capillary effect for water absorption; and (3) more hydrogen bonds will be formed between CNF and bamboo fibers, thus improving the strength properties of tissue paper, thanks to the excellent mechanical and physical properties of CNF. The results from water absorption and tensile strength tests of bamboo handsheets indicated that the addition of CNFs can increase the water absorption capacity from 6.6 to 8.7 g/g when the CNF dosage was 10 wt% (based on the dried pulp). The water retention value of prepared bamboo fibers increased from 163 to 190% at the same CNF dosage, the tensile index increased from 18.5 to 24.5 N m/g as well. The results from the bulk and pore size analyses, FTIR, as well as SEM images of tissue paper also evidenced the conclusions above.

Carboxymethylated cellulose nanofibrils in papermaking: influence on filler retention and paper properties, Ana F. Lourenço et al, *Cellulose*, 26 (5), pp.3489–3502. The papermaking industry competitiveness has been exponentially increasing. In order to improve the paper properties, processes have to be optimized in such a way that new horizons, such as the synthesis of new materials, are in sight. The present paper deals with the production of cellulose nanofibrils (CNF) from bleached *Eucalyptus* kraft pulp by carboxymethylation and TEMPO-mediated oxidation, followed by high pressure homogenisation. The main purpose of the work was to increase the filler retention and mechanical strength of printing and writing paper grades. Mineral fillers are of utmost importance in papermaking and therefore a thorough study of the CNF influence in filler-containing handsheets is mandatory. In this sense, flocculation studies revealed the extraordinary ability of CNF to flocculate calcium carbonate, which was translated into high

filler retentions in the paper matrix. Moreover, the interactions between bleached pulp, CNF, mineral fillers and common paper additives, such as cationic starch, alkenyl succinic anhydride and cationic polyacrylamide, were investigated. The results allowed concluding that, depending on the materials applied, CNF are able to promote an adequate bonding between fibres and filler aggregates, reducing the requirements for the additives. The addition of carboxymethylated or TEMPO-oxidised CNF to the fibrous matrix led to handsheets with better structural, mechanical and optical properties than those of reference handsheets (without CNF and with additives).

Bacterial nanocellulose in papermaking, Matej Skočaj, *Cellulose*, 26 (11), pp.6477–6488. Bacterial nanocellulose (BNC) is a unique natural nanomaterial that shares very few similarities with other natural or industrially produced nanomaterials. BNC can be produced by a variety of bacteria, as a survival aid in different ecological niches. BNC is traditionally produced by static or shaking culture methods, and the 'mother vinegar', or biofilm, is a typical example of this product after static vinegar fermentation. BNC has great potential in biomedicine, and recent studies have also demonstrated its use in the papermaking industry. It has nanoscale fiber size and large numbers of free hydroxyl groups, which ensure high inter-fiber hydrogen bonding. Thus, BNC has great potential as a reinforcing material, and is especially applicable for recycled paper and for paper made of nonwoody cellulose fiber. As well as enhancing the strength and durability of paper, modified BNC shows great potential for production of fire resistant and specialized papers. However, the biotechnological aspects of BNC need to be improved to minimize the cost of its production, and to thus make this process economically feasible.

Isolation of lignocellulose nanofiber from recycled old corrugated container and its interaction with cationic starch–nanosilica combination to make paperboard, Seyed Mehdi Yousefhashemi et al, *Cellulose*, 26 (12), pp.7207–7221. In recent years, many studies have been carried out on the use of cellulose nanofiber (CNF) produced from virgin fiber as a strengthening agent for improving the physical and mechanical properties of paper, while the use of CNF isolated from bleached virgin fiber is not necessary or reasonable for many recycled/impure products. In this due, novel lignocellulose nanofiber (LCNF) was produced from inexpensive recycled old corrugated container pulp by the ultra-fine grinding technique. The diameter of the resulted LCNF was in the range of 10–80 nm, while the cellulose crystallinity index and crystallite size reduced during the process to 49% and 4 nm, respectively. Regarding the chemical composition of LCNF, no significant change was observed in comparison to OCC fiber. But, an obstacle for the application of nanofibers, especially for paperboards, is dewatering problem. Accordingly, it was tried to evaluate the potential of cationic starch–anionic nanosilica combination as a drainage/retention aid to compensate for the negative effects of applying nanofibers in the pulp suspension, meanwhile the combination enhances the gains of LCNF application. The evaluation of pulp freeness showed that the addition of 3% nanofibers reduced dewatering ability about 100 ml CSF (around 33% loss). But, interaction of the nanosilica–starch system with the furnish containing LCNF not only compensated for the freeness reduction, but also caused a 32% or 57% increase in tensile index, in comparison to sample containing LCNF or control pulp respectively. Moreover, the addition of starch–nanosilica system with LCNF to pulp suspension, improved the retention of fine materials. Also, LCNF caused a reduction in thickness, bulk and bending resistance index of paperboard, while employment of the starch–nanosilica combination somehow off-set these negative effects. In addition, as a result of the cationic starch–anionic nanosilica system, the tear index was improved.

Processing nanocellulose to bulk materials: a review, Qianqian Wang et al, *Cellulose,* 26 (13–14), pp.7585–7617. Various types of nanocellulose have been isolated from the cellulosic feedstock. It was expected that nanocellulose could be used to replace fossil-based plastic in certain areas because it is biodegradable, biocompatible, environment-friendly, and has outstanding performance. Unlike conventional plastic processing, nanocellulose is generally isolated and processed in aqueous environments. Therefore, dewatering and drying are essential unit operations for nanocellulose processing. Different drying methods for colloidal nanocellulose suspension mediated different self-assembly behaviors and thus resulted in different nanocellulose morphology and physical properties. The most utilized techniques for nanocellulose processing, such as spinning, vacuum/pressurized filtration, solvent casting and roll to roll casting, coating and roll to roll coating, and additive manufacturing are investigated. Process parameters such as temperature, pH, ion species, concentration, and external electrical field, affect the orientation and assembly behavior of nanocellulose, which in turn influence the properties of the prepared materials. Therefore, the method for assembling nanocellulose into bulk materials in a controlled way is vital for the properties of the fabricated nanocellulose composites. Here, some of the recent advances in the processing of nanocellulose for bulk materials are reviewed.

Nanocellulose Applications in Papermaking, Carlos Salas et al, *Production of Materials from Sustainable Biomass Resources*, pp.61-96. (Part of the *Biofuels and Biorefineries* book series, BIOBIO, volume 9). Research on the utilization of biomass feedstocks has evolved rapidly in the past decades. Key developments include the production of materials with a more sustainable footprint than those derived from petrochemicals. Among associated materials, nanocelluloses have been produced from different sources and routes, such as high shear fibrillation and hydrolysis (chemical or enzymatic) or their combinations. The unique properties of nanocelluloses have sparked a myriad of uses including those related to the fields of oil and gas, adhesion, film formation, coating, packaging, food and composite processing. High end uses include the development of advanced lightweight materials, biosensors and energy harvesting systems; however, central to this review are uses closer to the source itself, namely fiber processing and, in particular, papermaking. In this chapter, the literature in these latter applications is discussed with emphasis on the use of nanocellulose to achieve favorable strength and barrier properties as well as in coating and paper sheet-forming.

NOVEL PRODUCTS

Lignin as a Wood-Inspired Binder Enabled Strong, Water Stable, and Biodegradable Paper for Plastic Replacement, Bo Jiang et al, *Advanced Functional Materials*, Wiley, online. Plastic waste has been increasingly transferred from land into the ocean and has accumulated within the food chain, causing a great threat to the environment and human health, indicating that fabricating an eco-friendly and biodegradable replacement is urgent. Paper made of cellulose is attractive in terms of its favorable biodegradability, resource abundance, large manufacturing scale, and low material cost, but is usually hindered by its inferior stability against water and poor mechanical strength for plastic replacement. Here, inspired by the reinforcement principle of cellulose and lignin in natural wood, a strong and hydrostable cellulosic material is developed by integrating lignin into the cellulose. Lignin as a reinforced matrix is incorporated to the cellulose fiber scaffold by successive infiltration and mechanical hot-pressing treatments. The resulting lignin-cellulose composite exhibits an outstanding isotropic tensile strength of 200 MPa, which is significantly higher than that of conventional cellulose paper (40 MPa) and some commercial petroleum-based plastics. Additionally, the composite demonstrates a superior

wet strength of 50 MPa. Adding lignin also improves the thermostability and UV-blocking performance of cellulose paper. The demonstrated lignin-cellulose composite is biodegradable and eco-friendly with both components from natural wood, which represents a promising alternative that can potentially replace the nonbiodegradable plastics.

Poly(lactic acid) composites reinforced with kraft pulp fibres: Production by a papermaking process and characterisation, Sónia Sousa et al, *Composites Part A: Applied Science and Manufacturing*, 121, pp.273-282. Four different pulp fibres, representing short and long cellulose fibres and chemically modified fibres, were tested as reinforcements for poly(lactic acid) composites. A simple papermaking method was used to form the composite sheets, which were further compression moulded. The effects of morphological, chemical, and mechanical characteristics of kraft pulp fibres and their contents on the PLA composite characteristics were investigated. The incorporation of kraft pulp fibres provided composites with 16–24% and 36–39% higher tensile strength and Young's modulus values, respectively, than those of neat PLA. Unbleached pulp fibres, which had higher intrinsic strength than that of the corresponding bleached pulp, provided composites with higher tensile properties. In the tested range, the effect of the cellulose fibre length was not significant. Compared to those of neat PLA, barrier properties for water vapour and oxygen were slightly superior for composites incorporating up to 30% (wt) of kraft pulp.

PACKAGING TECHNOLOGY

Measurement of thermal conductivity of paper and corrugated fibreboard with prediction of thermal performance for design applications, E. M. Gray-Stuart et al, *Cellulose*, 26 (9), pp.5695–5705. Understanding heat transfer in corrugated fibreboard is important to the design of more effective packaging for industries which involve the freezing and chilling of food. In this work the thermal conductivity of papers which compose corrugated fibreboard were measured and used to validate finite element models of heat transfer in fibreboard. The results showed paper to be highly anisotropic, with thermal conductivity in the machine and cross machine directions being almost an order of magnitude larger than in the thickness direction. The finite element models showed good agreement with experimental results and demonstrated that the majority of heat transfer in corrugated fibreboard is though the fluted medium. Based on the finite element models, simple models for the prediction of the thermal performance of corrugated board were evaluated and shown to be very effective in reproducing the results of the more complex finite element methods. These simple methods can be used to perform corrugated fibreboard design calculations, and the models with and without radiation can be used to provide estimates of the lower and upper bounds of the thermal resistance for a given board design.

An overview of paper and paper based food packaging materials: health safety and environmental concerns, Gaurav Kr Deshwal et al, *Journal of Food Science and Technology*, 56 (10), pp.4391–4403. Pulp and paper industry is one of the major sector in every country of the globe contributing not only to Gross Domestic Product but surprisingly to environmental pollution and health hazards also. Paper and paperboard based material is the one of the earliest and largest used packaging form for food products like milk and milk based products, beverages, dry powders, confectionary, bakery products etc. owing to its eco-friendly hallmark. Various toxic chemicals like printing inks, phthalates, surfactants, bleaching agents, hydrocarbons etc. are incorporated in the paper during its development process which leaches into the food chain during paper production, food consumption and recycling through water discharges. Recycling is considered the best

option for replenishing the loss to environment but paper can be recycled maximum six to seven times and paper industry waste is very diverse in nature and composition. Various paper disposal methods like incineration, landfilling, pyrolysis and composting are available but their process optimization becomes a barrier. This review article aims at discussing in detail the use of paper and paper based packaging materials for food applications and painting a wide picture of various health and environmental issues related to the usage of paper and paper based packaging material in food industry. A brief comparison of the environmental aspects of paper production, recycling and its disposal options (incineration and land filling) had also been discussed.

Pla-zno nanocomposite paper for antimicrobial packaging application, *Journal Polimesin*. 17 (2), pp.1-6. Many food packages (plastic wrappers) today cannot be broken down by the environment; therefore, it is necessary to add natural substances that can make the food package decompose and be resistant to contamination with bacteria. Development of biodegradable polymers from renewable sources is highly desirable for food preservation and packaging, provided they can be effective as plastics or paper that are currently used in packaging, protecting food against microbial contamination, physical damage and chemical reactions (eg oxidation). Poly lactic acid (PLA) is one of the natural polymers produced by several bacteria that grow in crops rich in carbohydrates (such as sugar beets, corn and others). This research aims to insert ZnO nanoparticles and chitosan into a plastic layer of PLA (poly lactic acid) which can improve the antibacterial properties of the resulting packaging. The method used in making PLA-ZnO-chitosan nanocomposite is the precipitation method and the heating method. PLA-ZnO nanocomposites were obtained by varying ZnO nanoparticles 0.5% by weight, 2% by weight, and 3.5% by weight. The results obtained in SEM images show that nanoparticles are homogeneously distributed on the plastic surface. Antimicrobial tests show nanocomposites work effectively in deactivating E. coli and S. aureus. where it was found that E. coli was more susceptible to this type of nanocomposite, where there was a reduction of 3.4 logs to 3.5% ZnO loading in the PLA layer.

PAPERMAKING

Highly Filled Papers, on their Manufacturing, Processing, and Applications, Benjamin Dermeik et al, *Advanced Engineering Materials*, 21 (6), 1900180. Since more than a decade ago, the research on highly filled papers, as well as paper-derived inorganic materials, has greatly intensified. As presented in this review, highly filled papers as preforms allow for the design of porous or dense, multilayered, and geometrically complex structures. These paper-derived ceramic- or metal-based materials are generated by the heat-treatment of highly filled papers. Paper-derived materials are potential materials of choice for applications in transportation, energy-generation, environmental conservation, support structures, medical uses, and electronic components. Due to the adjustability of the filler content and the good machinability of highly filled papers, paper-derived sheets or multilayers may include intricate structures and tailored gradients in phase structure or porosity. Paper-derived multilayers also may contain cast ceramic tapes or other functionalized layers, as presented in some examples. Computer-aided manufacturing processes for paper-derived materials can be supplemented by prediction models for the sintering shrinkage in order to identify optimal post-processing steps, stacking orders and orientations for highly filled paper layers within multilayer green bodies. The accuracy of established component-level sintering models can be significantly increased by microstructure models of the highly filled paper.

Enzymatic nanocellulose in papermaking – The key role as filler flocculant and strengthening agent, Ana F.Lourenço et al, *Carbohydrate Polymers*, 224, 115200. Nanocelluloses have been increasingly used in composites since their reduced size, high aspect ratio and stiffness confer great strength to the materials. In papermaking, it has been proved that harsh and expensive chemical pre-treatments to generate nanofibrils, such as TEMPO-mediated oxidation, are not the most favourable and therefore the use of cellulose microfibrils (CMF) have gained extra attention, especially those produced with the aid of enzymatic hydrolysis. In the present work, strategies to improve filler flocculation and the papermaking properties, by using enzymatic CMF, are provided. The CMF degree of polymerization was found to be directly related to precipitated calcium carbonate flocculation, leading to higher retentions in the fibre matrix. Besides, the paper dry and wet strengths were much improved, allowing in return the production of high-filler loaded handsheets with reduced requirements for common paper additives.

The mechanism of alkyl ketene dimer (AKD) sizing on cellulose model films studied by sum frequency generation vibrational spectroscopy, Lei Li et al, *Cellulose*, 26 (5), pp.3415–3435. Sum frequency generation vibrational spectroscopy (SFS) was employed to study the alkyl ketene dimer (AKD) sizing mechanism employed in the papermaking industry for hydrophobization of cellulose. The AKD was spun coat onto model cellulose films, which resulted in ≈2.6 nm thick AKD layers. The chain orientation of AKD molecules during the sizing process was measured at different temperatures. It was demonstrated that the chain orientation and conformation of AKD do not correlate with observed changes in sizing. The distribution of AKD molecules on model cellulose surfaces as a function of time and temperature was imaged via fluorescence microscopy to complement SFS measurements. It was concluded that the distribution of AKD plays a major role in the sizing effect.

Environment-friendly packaging material: banana fiber/cowdung composite paperboard, M. Vishnuvarthanan et al, *Environmental Chemistry Letters*, 17 (3), pp.1429–1434. Wood is the main raw material for paper production, which in turn contributes to the decrease of forest resources. There is therefore a need of finding alternate sources for the production of paper. Here we prepared paperboard from the cowdung and banana fibers by chemical pulping. Banana fibers provide cellulose fibers, and lignin is removed. Pectin was added finely to the suspended pulp for binding fibers. Hydrogen peroxide was added to improve pulp brightness. The paper was tested for physical and mechanical properties. Results show that incorporation of cowdung increased the tensile and burst strength from 1 to 5 MPa and 10 to 50 kPa. The porosity was also decreased from 5 to 1 mL/min. The efficient water absorption (COBB) value was obtained for 50% of cowdung. The barrier properties such as oxygen transmission rate and water vapor transmission rate were gradually decreased to 1000 cc/m^2 day atm and 5 g/m^2 day. The antimicrobial properties of the prepared paperboard were tested against the *Escherichia coli* and *Staphylococcus aureus*, and it showed efficient activity against both the microorganisms.

Investigation of the effect of para-amino benzoic acid (PABA) added starch-coated chemicals on the printability properties of paper, Arif Ozcan, *Journal of Applied Biomaterials & Functional Materials*, Jan-March 2019, pp.1-5. Paper is the most important material of the printing industry and is being improved due to the increasing needs of industry. The most important process to improve the optical and physical properties of paper is the surface coating. Paper has a smoother and opaquer surface with surface coating. In addition, brightness, whiteness, and yellowness values are improved

with surface coating. Ultraviolet (UV) light in sunlight causes changes in the structure of the paper and coating chemicals and accordingly causes yellowing. Para-amino benzoic acid (PABA), due to its chemical structure, is a UV-blocking agent used in sunscreen creams.

CO2 capture and preparation of spindle-like CaCO3 crystals for papermaking using calcium carbide residue waste via an atomizing approach, Liang Ma et al, *Korean Journal of Chemical Engineering*, 36 (9), pp.1432–1440. Spindle-like $CaCO_3$ crystals with controllable sizes for papermaking were successfully prepared using CO_2 (8% CO_2/N_2 mixture gas) and calcium carbide residue (CCR) waste, a by-product of acetylene gas and polyvinyl chloride production, as the raw materials by an atomization method at room temperature. The influences of solution concentration, reaction temperature, and gas/liquid flow rate ratios on the properties of the $CaCO_3$ crystal were systematically investigated, and a possible atomization mechanism was proposed. The size of the as-prepared $CaCO_3$ crystal with pure calcite phase was turned from 4.71×4.02 μm to 1.82×1.12 μm by adjusting the reaction conditions. The application of the as-prepared $CaCO_3$ crystals from CCR waste as a filler for papermaking was explored. The R475 blue light whiteness of paper was increased from 77.3 to 80.6 with 11.4% $CaCO_3$ crystals.

Nanocellulose in the Paper Making, Elaine Cristina Lengowski et al, *Sustainable Polymer Composites and Nanocomposites*, Springer, pp.1027-1066. In recent times, nanotechnology, which has been one of the main novelties to be developed in the 21st century, has been applied to many sectors, particularly to various industrial sectors including forest-based industry. An output of this is the development of nanomaterials of which nanocelluloses have been studied as high technology biopolymers for application in various materials through the development of films and as reinforcement in papers. With this background, the main objective of this Chapter is to present the use of nanocellulose in the paper making. Accordingly, the Chapter presents characteristics of the most used wood in the world for pulp and paper production, main methods of obtaining cellulose in nature, process of bleaching of pulp, paper making, processes to obtain different types of nanocellulose (microfibrillar nanofiber and cellulose nanocrystals), applications of nanocellulose in the paper making through coating and films as well as by nanocellulose-reinforced pulp and the resulting effects of the use of nanocellulose in paper production. These include increased tensile and burst strengths, weight loss, improved barrier properties for oils, oxygen and moisture, better printing surface, etc. In the end, marketing aspects, possible future opportunities and finally concluding remarks are given. These briefly mention the use of nanocelluloses in papermaking presenting interesting possibilities, which offer improvements in cost-benefit, energy efficiency and biocompatibility, in addition to generating new products with uses are not available today.

PULP / PULPING

A structural fibrillation parameter from small angle X-ray scattering to quantify pulp refining, Jia Mao et al, *Cellulose*, 26 (7), pp.4265–4277. Pulp fibrillation results from refining and is of prime importance for papermaking. Yet a structural parameter reflecting the extent of fibrillation remains elusive. In this work, we demonstrate that in refined pulps, the interfibrillar distance at water saturated state (L_s), as derived from the interference factor from small angle X-ray scattering, structurally reflects fibrillation degree. Interestingly, the minimal L obtained at low water content is close to the crystal thickness derived from wide angle X-ray scattering. For a series of refined pulp samples, significant regressions are established between L_s and equilibrium moisture content, transmittance (T%), surface energy components (γ_{LW}, γ_{AB}), and the normalized crystallinity index (CrI_n).

These regressions establish L_s as a unique structural parameter for quantifying the fibrillation degree and derived properties of refined pulps without the need of a multi-parameter and time-consuming analyses.

Impact of modifying conventional chlorine dioxide stage to hot chlorine dioxide during rice straw pulp bleaching on pulp, paper and effluent characteristics, Daljeet Kaur et al, *Cellulose*, 26 (12), pp.7469–7482. Paper industry being a mature mega-scale industry is focusing on process oriented technical modifications to reduce dependency on wood fibers and resource utilization. In this research study, conventional chlorine dioxide (D_0) bleaching method was modified to hot chlorine dioxide (D_{HT}) with an aim of reducing the effluent load with special concern to chlorolignin compounds. These compounds were measured by gas chromatograph equipped with ECD detector. The chlorophenols, chlorocatechols, chloroguaiacols, chlorovanillins, chlorosyringols and bromophenols were reduced by 9%, 50%, 34%, 47%, 17% and 31%, respectively under D_{HT} based sequence at same dose of chemicals. The general environmental parameters i.e. COD, BOD, TS, colour, lignin and AOX also got reduced in D_{HT} based sequence. The modification of D_0 to D_{HT} was found to be effective as effluent quality was enhanced without compromising the optical and strength properties of cellulosic paper even at low dose of chlorine dioxide.

Dewatering parameters in a screw press and their influence on the screw press outputs, Bouchaib El idrissi et al, *Chemical Engineering Research and Design*, 152, pp.300-308. A Thune SP23 screw press dewatering parameters were studied. The dewatering efficiency was affected more by the rotational speed and the pulp properties. The counter-pressure affects dewatering near the discharge end, and it was observed to influence the outlet consistency and filtrate flow rate of Kraft, which has much longer fibres and fewer fines compared to TMP and BCTMP. The feed stock freeness and consistency are very important variables to consider in the screw press performance. The freeness reflects the degree of drainage, which is an important parameter to consider when optimising the screw press, while the feed consistency is a parameter of the fibre-fibre contact degree. The pulp properties, especially the fines content and fibre flexibility are also two very important parameters that affect the screw press performance. This study was to provide an insight of the screw press performance and to show the complex effect of the operational parameters on the dewatering characteristics. Using three different pulps, Kraft and TMP softwood fibres and a BCTMP hardwood fibres, we have shown that the fines content and fibre properties are two dominant properties that should be highly considered when operating a screw press.

Anatomical and chemical properties of wood and their practical implications in pulp and paper production: a review, J.T.B. Riki et al, *Journal of Research in Forestry, Wildlife and Environment*, 11 (3), pp.358-368. Wood is a highly variable and complex material that has different chemical, physical and anatomical properties that influence its commercial value. This review therefore, explains the wide variability between anatomical and chemical properties of wood and their practical implication in pulp and paper production. In papermaking, fibres are the cell elements that impart strength to the paper sheet. The function of the vessel element is to conduct water and dissolved minerals from the roots to the higher parts of the plant. Generally, lingnocellulose materials from wood and non-wood plant consist of lignin, hemicelluloses, extractive and some inorganic matter. Information on the chemical composition is important in deciding the techno-commercial suitability, pulping method and paper strength of a particular wood material.

RECYCLING

Macroscopic and microscopic properties of fibers after enzymatic deinking of mixed office waste paper, Jinran Wang et al, *Cellulose*, 2019, online. The deinking of mixed office waste paper by cellulase, M/Las (modification of laccase aspartic acid system), and C-M/Las (cellulase synergistic modification of laccase aspartic acid system) was investigated. The fiber morphology parameters, hydrogen bond patterns, cellulose crystallinity, and fiber microstructure were observed via fiber quality analyzer (FQA), Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscopy (SEM). The results showed that the effective residual ink concentration of enzyme deinked pulp decreased compared with blank pulp (pulp without enzymatic treatment). The deinking efficiencies of C-M/Las, cellulase, and M/Las were 18.17%, 14.01%, and 12.31%, respectively. FQA analysis indicated that the fiber length and curl index decreased, while the fiber width slightly increased. FTIR analysis revealed that after cellulase, M/Las, and C-M/Las treatment, the content of intermolecular hydrogen bonds increased by 14.65%, 13.37%, and 19.80%, respectively. This indicates that there is a synergistic effect between cellulase and M/Las. XRD showed that the cellulose crystallinity decreased after enzymatic deinking. SEM micrographs of fibers treated with enzymes revealed that the fiber surface became rough and more fibrils appeared. The water retention value was increased after enzymatic deinking.

TESTING

Quantitative non-destructive analysis of paper fillers using ATR-FT-IR spectroscopy with PLS method, Signe Vahur et al, *Analytical and Bioanalytical Chemistry*, 411 (20), pp.5127–5138. A quantitative non-destructive express method of determining fillers —kaolin and chalk— in paper was created using attenuated total reflectance Fourier transform infrared (ATR-FT-IR) spectroscopy in the mid-IR and far-IR region (3800–245 cm^{-1}) combined with partial least squares (PLS) data analysis. Altogether, 30 two-component (cellulose pulp + kaolin and cellulose pulp + chalk) reference paper samples with known different filler concentrations and one reference paper sample without any fillers were prepared for calibration and validation. The reference values of filler concentrations in the prepared papers were determined by gravimetric analysis via dry ashing (for establishing accurate concentrations of fillers in paper) and ATR-FT-IR microspectroscopy (for evaluating homogeneity of the papers). Two-component (cellulose pulp + kaolin or cellulose pulp + chalk) PLS models were created with papers of different cellulose types and containing different amounts of fillers. The best model had root mean square errors of prediction (RMSEP) for determining the kaolin or chalk content in the two-component papers of 2.0 and 2.1 g/100 g, respectively. The performance indices were 90.4% and 92.9%, respectively. As a demonstration of practical applicability of the method, different papers from books, journals, etc. were analysed. It was concluded that the developed quantitative method is suitable for non-destructive express analysis of kaolin or chalk in paper.

Moisture adsorption in palletised corrugated fibreboard cartons under shipping conditions: A CFD modelling approach, T.M.Berry et al, *Food and Bioproducts Processing*, 114, pp.43-59. Corrugated fibreboard packages (cartons) must support considerable mechanical loads during long term transport of fresh produce in refrigerated freight containers (RFCs). Fresh produce are transported under high relative humidity to reduce fruit moisture loss and preserve quality. However, these conditions can progressively reduce carton mechanical strength over time as a result of mechano-sorptive creep. Little is known regarding the actual moisture dynamics in stacked cartons in RFCs, which is important for mechanical strength assessments. To this end, a portion of a fully

loaded RFC was investigated using a computational fluid dynamics (CFD) model, with respect to moisture transport in the air and the corrugated fibreboard. Simulations included the effects of loading, defrost cycles, fruit respiration and transpiration. Results showed relatively low moisture content gradients in fibreboards through the stacked cartons under optimal shipping conditions. However, the initial activation of the RFC considerably accelerated the development of moisture content gradients in the cartons. Additionally, the most significant factor influencing spatial moisture gradients through the cartons was heat conduction from outside through the container wall.

A technique to quantify morphological damage of the flute profile in the midplane of corrugated fibreboard, Mohamad Aiman Jamsari et al, *Packaging Technology & Science*, 32 (5), pp.213-226. This research presents a technique to quantify morphological damage to flutes in corrugated fibreboard (CFB). The method involves laser cutting thin samples and analysing digital images of the flute profiles. The surface profiles of creased CFB before and after laser cutting were measured using fringe projection and showed that the sample preparation does not significantly affect the flute profile. After imaging the laser cut samples, skeleton analysis was used to derive a digitised profile of the flute shape. To characterise the level of damage to the flute profile, a similarity factor (SF) was introduced to quantify the relative difference between test sample and reference flute profiles. Validation of this analysis technique was done by generating known images of flute profile with variations that include distortions that could occur to CFB. These images were then fed into the skeleton analysis, and the results were compared with the original profile. This comparison showed good agreement between the initial and skeleton-analysed flutes. A demonstration of the skeleton analysis on purposefully damaged actual CFB flute profiles shows that the SF reduces as the level of crushing increases, showing that the technique could be used to enumerate morphological damage to CFB during manufacture, conversion, and use.

Experimental and numerical performance of corrugated fibreboard at different orientations under four-point bending test, Mohamad Aiman Jamsari et al, *Packaging Technology and Science*, 32 (11), pp.555-565. This paper presents experimental work, finite element (FE) model, and analytical solution for predicting the four-point bending on C-flute corrugated fibreboard (CFB) when oriented at different angles. The angles of the CFB samples used in this research study were 0° (cross-machine direction) and 30°, 45°, 60°, and 90° (machine direction). The CFB was assumed as an orthotropic shell element in the FE model and was validated by comparing the bending stiffness, maximum bending force, and failure formation from the experimental test. It was found in the experiment that the 90° sample had the highest bending stiffness with the lowest maximum bending force while the 0° sample had the opposite. An interesting finding was that the 30° and 45° samples improve the bending stiffness than does 0° without significantly affecting the maximum bending force. Both the FE model and analytical solution predicted the bending stiffness trend of the board from 0° to 90° with good agreement compared with experimental results. The maximum bending force in the FE model showed reasonable agreement with the experimental findings. The failure regions on the samples showed similar patterns in both experiments and the FE model. The accurate response in the FE model justify that it is a good tool to predict the bending behaviour of CFB.

WASTE TREATMENT

The effect of dried paper-mill sludge on cement hydration, Jurgita Malaiškienė et al, *Journal of Thermal Analysis and Calorimetry*, 2019, online. In the paper, the impact of paper-mill sludge dried at 75 °C (PS) on cement hydration is being analysed. The used specimens were made of CEM I 42.5 R cement and the added PS replaced 0%, 5%, 10% and 15% by mass of cement. The results of calorimetric measurements of the mixtures and the compressive strength were analysed (W/(C + PS) = 0.35). SEM and XRD tests were carried out after 3, 14, 28 and 56 days of curing W/(C + PS) = 1. PS was found to extend the induction period of the cement hydration and delay the time of the secondary heat release effect, especially in specimens with the highest content of the PS. The total heat release (after 96 h) measurement results showed that the highest total heat evolved from specimens without the PS. The total liberated heat gradually increased with the increase in the PS content in the cement paste mixture. In the specimens with 15% of PS, the total heat release decreased by 20%, as compared to the control specimen without the additive. XRD test results revealed that the standard minerals listed below were formed in cement stone: ettringite, calcite, portlandite, and calcium aluminium silicate hydrate. SEM tests revealed significant changes in cement stone microstructure caused by the increase in the PS in cement paste. The compressive strength of specimens with PS waste was found to be considerably lower in the initial stage of hardening; however, when samples hardening time is increased up to 56 days, the difference between the values of compressive strength for specimens 5% of PS and the control specimens decreases.

Technical Feasibility of Zero Waste for Paper and Plastic Wastes, Deepak K. Sharma et al, *Waste and Biomass Valorization*, 10 (5), pp.1355–1363. Complete material recovery followed by recycling of paper and plastic waste streams is crucial for the success or failure of achieving zero waste targets. The highest recovery of material from paper and plastic waste streams reported in the U.S. and Europe are 85 and 73% respectively. However, this means there is still a remaining 15 and 27% of paper and plastic waste which is not recycled or reused indicating it is not possible to completely recycle all paper and plastic. Investigating the limitations that impede recovery and recycle identifies other avenues for engineering a zero-waste process. This study discusses the effects of various properties of paper and plastics on their quality and recycling rates. Furthermore, we present a thorough analysis of the estimated recovery for paper and plastic wastes in processing facilities. The results show that the recovery rate obtained from a traditional material recovery facility (MRF) is lower than that obtained from a combined MRF and a modern mixed-waste processing facility (MWPF). However, the MWPF is still being commercialized, posing a practical limitation in recycling operation. This paper focuses on delineating major technical issues underlying the limited recycle of paper and plastic as well as the limitations to collection systems. For example, in the U.S. the state-of-the-art recycling equipment used for paper had a stagnant recovery rate (~ 46,000 tonnes) from 2008 to 2013 of 66.4% although the amount of paper available for recycle is near 70,000 tonnes. Plastic recycling is a similar case where nearly 79% can be technically recovered due to problems associated with specific property requirements for final recycled products. Importantly, these limitations are independent of the actual market available for the recycled material.

WOOD PANEL

Gypsum-Based Boards Made from Mixtures of Waste Cellulosic Sources: Part 1. Physical and Mechanical Properties, Halil Şahin & İlkhan Demir, *European Journal of Science and Technology*, Issue 16, 2019, pp.567-576. It was realized that post-consumer waste paper, old corrugated container (OCC) and secondary fiber addition (cellulosic additives) to gypsum in panel structure negative impact on Thickness Swelling (TS) values in water. However, highest TS values of 23.32% (A6) in A-type, 12.76 (B6) in B-type and 7.79% (C6) in C-type experimental boards found at similar proportions (50:50 w/w) of gypsum and cellulosic additives while the lowest with control sample that was only 1.88%. Moreover, the boards produced by secondary fiber/gypsum mixture (C type boards) under similar ratios (w/w) were found to higher IB strength than others. The highest IB strength value of 0.60 N/mm^2 found for C3 board while the ratio of the secondary fiber in the mixture to be more than 20% negative effects on IB values to a certain extent. The addition of all three cellulosic sources to the gypsum structure increases the bending strength properties some level. At 10% (A2: 6.59 N/mm^2) and 50% (A6: 6.44 N/mm^2) proportion levels, A-type boards show higher bending strengths than the B- and C-type boards. In all manufacturing conditions and board types, the natural weathered boards have always shown lower hardness properties than counterpart control samples.

Thermomechanical surface instability at the origin of surface fissure patterns on heated circular MDF samples, Andrea Ferrantelli et al, *Fire & Materials*, 43 (6), pp.707-716. When a flat sample of medium density fibreboard (MDF) is exposed to radiant heat in an inert atmosphere, primary crack patterns suddenly start to appear over the entire surface before pyrolysis and any charring occurs. Contrary to common belief that crack formation is due to drying and shrinkage, it was demonstrated for square samples that this results from thermomechanical instability. In the present paper, new experimental data are presented for circular samples of the same MDF material. The sample was exposed to radiant heating at 20 or 50 kW/m^2, and completely different crack patterns with independent eigenmodes were observed at the two heat fluxes. We show that the two patterns can be reproduced with a full 3-D thermomechanical surface instability model of a hot layer adhered to an elastic colder foundation in an axisymmetric domain. Analytical and numerical solutions of a simplified 2-D formulation of the same problem provide excellent qualitative agreement between observed and calculated patterns. Previous data for square samples, together with the results reported in the present paper for circular samples, confirm the validity of the model for qualitative predictions and indicate that further refinements can be made to improve its quantitative predictive capability.

Tailoring of oxidized starch's adhesion using crosslinker and adhesion promotor for the recycling of fiberboards, Muhammad Adly Rahandi Lubis et al, *Journal of Applied Polymer Science*, 136 (38), article 47966. The growing interest in recycling waste medium density fiberboards (MDFs) is driving the development of new adhesives that provide sufficient adhesion, and allow disintegration of the waste MDFs. Described in here is the preparation of adhesives based on oxidized starch (OS) in combination with blocked-polymeric 4-4 diphenylmethane diisocyanate (B-pMDI) as a crosslinker and poly(vinyl alcohol) (PVA) as an adhesion promotor for the recycling of waste MDFs. The –COOH groups of OS were reacted with –NCO groups of B-pMDI to form amide linkages, and the –CHO groups were reacted with –OH groups of PVA through hydrogen bonding. Further, when applied as an adhesive, the OS formed ester linkages with –OH of MDF fibers. As the results, MDF bonded with 1% B-pMDI/15% PVA/OS adhesive had an internal bonding strength of 0.13 MPa, 0.01 mg L^{-1} of formaldehyde emission (FE), and

12% of degree of fiber disintegration. These results demonstrate that the B-pMDI/PVA/OS adhesive is a possible alternative to the current urea–formaldehyde resins for the recycling of waste MDFs into recycled MDFs without FE.

A Modified Glue for Producing Particle Boards and Boards Based on Waste of Annual Plants, S. A. Ugryumov et al, *Polymer Science*, Series D, 12 (3), pp.251–253. This paper proposes a water-soluble phenol-formaldehyde resin modified by an alkyd oligomer for reducing the surface tension of an adhesive composition and improving its distribution over wood particles or particles of annual plants during the production of compressed board materials for construction purposes. It was found that the physical and mechanical characteristics of boards increase when produced with the use of the modified glue obtained with a small change in its production technology.

A Technology for Production of Fiberboards Based on Cotton Stalks, V. E. Tsvetkov et al, *Polymer Science*, Series D, 12 (3), pp.328–330. This paper considers a technique for producing raw materials and grinding of fiber from cotton stalks, as well as its properties. The properties of medium-density boards obtained in the laboratory using the dry process under various technological conditions are investigated. The results of comparative tests of wood fiber and cotton fiber boards are given.