TECHNICAL FORUM AND STUDENT POSTER COMPETITION ABSTRACTS

SUNDAY, JUNE 25
4:00 pm - 5:30 pm

WOOD ANATOMY & QUALITY

POSTER 1

An Assessment of Veneer Log Quality Attributes

Delton Alderman, Research Scientist, Northeastern Research Station, USDA Forest Service, Princeton, WV; and *David Brinberg*, R.O. Goodykoontz Prof. of Marketing, R.B. Pamplin College of Business, Alfred P. Sloan Forest Industries Center, Virginia Tech, Blacksburg, VA

Veneer logs constitute less than 1% of the hardwood forest resource in the U.S.; yet veneer log prices, in some instances, can be 10 times greater than the value of Grade 1 sawlogs. Color, ring density/count, ring texture, defects, and figure characteristics singularly or in combination, affect how a buyer perceives log quality and ultimately determines the value of a log. Many studies have identified attributes and defects; however, which attributes/defects or combination thereof have not been quantitatively identified. This is not a non-trivial matter as the consequences have implications for both business economics and forest management. For example, veneer manufacturers and their customers have discrete wood quality parameters that are understood among differing entities, but are poorly defined among those same entities. In order to better understand and to discern the salient quality attributes that differentiate veneer logs from sawlogs and high-end from low-end veneer logs, we conducted a series of studies in which veneer log attribute data was collected from veneer log buyers and veneer manufacturers. The relative importance of veneer log quality attributes were examined for each of the following species: cherry, red oak and white oak, white ash, and sugar maple. We utilized Brunswik's (1935) Lens Model to assess veneer attributes and defects. The focus of this research was to detail veneer log attributes via buyer cues, analyze, and develop veneer log quality metrics. Buyer guidelines for assessing the potential of high-quality veneer trees grown under different hardwood management regimes can be based on the attribute metrics derived from this study.

POSTER 2

Bulk Density of Nine Oak Species in Arkansas

David W. Patterson, Prof., *Paul F. Doruska*, Associate Prof., Biometrics/Inventory, *Jonathan Hartley*, Program Technician, and *Matthew Hurd*, Grad. Research Assistant, Univ. of Arkansas-Monticello, Monticello, AR

As the hardwood industry in Arkansas changes from stick scaling to weight as a means of economic exchange, the need arises for information on the bulk density or weight scaling factors of the various trees. The objective of this study was to determine the bulk density values of the different oak species and how they compare. Data was collected from three sites: Felsenthal Wildlife Refuge (elevation 65 to 75 feet), private land near Hamburg (elevation 135 to 145 feet), and the Ozark National Forest (elevation 1700 to 1800 feet). A total of nine species of oak (black, cherrybark, northern red, nuttall, overcup, southern red, water, white, and willow oak) were measured and weighed. The average bulk density value for all of the oaks was 79.6 lbs/ft^3. The values varied by species from 77 lbs/ft^3 for white oak to 85 lbs/ft^3 for southern red oak. Tree size was a significant variable with 12 inch DBH having an average value of 82.6 lbs/ft^3 and 28 inch DBH and larger having an average of 77.0 lbs/ft^3.

POSTER 3

Developing a Model System in Vitro to Understand Secondary Cell Wall Formation in Douglas-fir (*Pseudostuga menziesii*)

Karthik V. Pillai, Grad. Student Research Assistant, and *Armando G. McDonald*, Associate Prof., Dept. of Forest Products, Univ. of Idaho, Moscow, ID

Wood is formed by the secondary cell wall formation and lignification of xylem cells derived from the cambial initials. The difference in properties of different woods can be traced on a micro level to the cell wall chemistry and architecture, which in turn is controlled by the genetic make up of the particular species. Is it possible to customize or tailor-make a wood for specific end use? To answer that question we would first need an artificial system to try out the various possibilities by introducing specific genes of interest. To do this on a whole plant basis would mean a big investment in terms of time and labor. In this study, a tissue culture system is being investigated. Cambial strips obtained from young Douglas-fir trees were inoculated on a solidified nutrient media. Profuse production of callus tissue or undifferentriated cells were observed in MS (Murashige and Skoog, 1962) medium supplemented with 2 mgl-1 2, 4-dichlorophenoxy acetic acid (2,4D) and 2 mgl-1 6-benzylaminopurine (BA). The callus cells could be sustained on the same medium when sub-cultured in 5-6 week intervals. The cells formed were spherical to elongated and had no secondary cell walls. When the media was supplemented with activated carbon (AC) the proliferation of the cells stopped and production of lignin was noted histochemically by phloroglucinol-HCl treatment. The presence of lignin was confirmed when isolated cell wall samples were subject to pyrolysis gas chromatography mass spectrometry and fourier transform infra-red spectroscopy. The percentage of lignin in the cell wall samples was assessed by lignothioglycolic acid assay. Other cell wall components like polysaccharides and uronic acids will be quantified by ion chromatography and high-pressure liquid chromatography, respectively. When subsequent subcultures were subject to activate charcoal treatment cells with secondary thickened cell walls were observed on a very rare basis and further experiments are being carried out to arrive at a conclusion. In a separate experiment suspension cultures of the callus cells obtained on solidified media were successfully initiated and maintained in liquid MS medium supplemented with 2mg/l 2, 4-D, 2mg/l naphthalene acetic acid (NAA) and 2 mg/l 2, 4-D and BA. The possibility of inducing secondary cell wall formation with suspension cultures is currently under investigation.

POSTER 4

Correlative Microscopy of Wood Products Using Environmental Scanning Electron Microscopy, Confocal Microscopy, and Image Analysis

James Drummond, Principal Technical Specialist, *Ho Fan Jang*, and *Val Lawrence*, Paprican, Vancouver, BC, Canada

Environmental scanning electron microscopy (ESEM) enables imaging of biological materials such as wood and woodfiber-based products without the need for a conductive coating on the sample. Thus, samples can subsequently be examined using other techniques since there is no coating to interfere. We have taken advantage of this by using state-of-the-art ESEM and confocal microscopes to analyze identical samples and sample areas of various wood-based materials. We have employed image analysis to derive quantitative morphological data where appropriate. Examples of this approach applied to wood and woodfiber-based products are shown, including wood, wood composites, and paper.

CHEMISTRY / CHEMICAL & MECHANICAL MODIFICATION

POSTER 5

Ponderosa Pine Wood Enhancement by Resin Treatment

Ayiguli Keyoumu, Ph.D. Student Research Assistant, *Armando G. McDonald*, Associate Prof., and *Thomas M. Gorman*, Prof. and Head, Dept. of Forest Products, Univ. of Idaho, Moscow, ID

This study is aimed at adding value to small-diameter ponderosa pine by enhancing its properties for several solid wood markets. A series of experiments were carried out to enhance dimensional stability and hardness of lumber by impregnating a thermosetting low molecular resin system followed by a curing step. Treatment included using short-term vacuum treatment and long-term immersion, respectively. Various resin systems (urea formaldehyde (UF), melamine formaldehyde (MF), and phenol-formaldehyde (PF), etc.) were examined. Process parameters (vacuum-pressure cycle, kiln drying temperatures) were optimized and the mechanical properties determined relative to matched controls. This process shows potential for raising the value and uses of low-value ponderosa pine.

POSTER 6

Supercritical Methanol Treatment of Bark

Juan Andres Soria, Research Associate, and *Armando G. McDonald*, Associate Prof., Dept. of Forest Products, Univ. of Idaho, Moscow, ID

The Northwestern States are faced with the task of minimizing standing forest biomass, stemming from a century of forest fire suppression practices. The challenge now lies in creating economic opportunity in the use of the removed biomass and in the process; create novel ways of producing value-added products. This project involves the use of supercritical methanol (SCM) technologies as a means of converting waste biomass into usable fuels and chemicals. Small-diameter ponderosa pine, common in Northern Idaho, was harvested and the bark collected and treated. SCM treatment above 238°C and 1200 psig were employed to depolymerize bark and yields measured. Analytical tools such as GC-MS, FTIR, and pyro-GCMS were employed to characterize the depolymerized materials and solid residues after treatment. Data shows that the degradation of bark in supercritical methanol is capable of achieving above 70% conversion of solid biomass into a methanol soluble fraction, with varying composition. This novel approach to generate bio-oil and valuable chemicals from tree residues offers a potential source of renewable chemical building blocks, which parallels petroleum and thus reduces our dependency on fossil reserves.

POSTER 7

Chemical Changes that Occur During Hot Pressing of Hybrid Poplar

Noridah Osman, Ph.D. Student Research Assistant, and *Armando G. McDonald*, Associate Prof., Dept. of Forest Products, Univ. of Idaho, Moscow, ID; and *Marie-Pierre G. Laborie*, Assistant Prof., Wood Materials & Engineering Lab., Washington State Univ., Pullman, WA

This study aims at understanding what changes (chemical and viscoelastic) occur in wood during hot pressing of hybrid poplar and determine what traits are suitable for composites. Hybrid poplar veneers were obtained and conditioned (0, 12, and 100% moisture content) prior to pressing (180-200°C for 10 minutes). The control and pressed veneers were analyzed for organic soluble and water soluble extractable components. In addition, the veneers were analyzed by Fourier transform infrared (FTIR) spectroscopy to monitor chemical changes that occur during pressing. The effect of moisture content on chemical changes that occur during hot pressing will be discussed.

POSTER 8

Plasticization of Wood Fiber by Benzylation

Lina Ma, Grad. Student Research Assistant, and *Armando G. McDonald*, Associate Prof., Dept. of Forest Products, Univ. of Idaho, Moscow, ID

Pine wood flour was chemically modified with benzyl chloride under alkaline conditions at various mole ratios of benzylchloride to wood hydroxyl groups (0.5, 1, and 2). The modified wood fiber was exhaustively extracted with acetone to remove any reagents and dried. The extent of benzylation was assessed by weight gain and by FTIR spectroscopy. FTIR spectroscopy revealed the reduction of wood hydroxyl groups bands (3400-3500 cm^{-1}) consistent with etherification. The thermal properties of the benzylated wood fiber were assessed by dynamic parallel plate rheometry on pressed discs. Viscous flow (complex viscosity) was observed in benzylated wood fiber between 120 and 160°C. Results have also shown that the benzylated wood thermal properties can be controlled by the extent of benzylation. The mechanical and processing properties of these modified wood fibers will be further discussed.

POSTER 9

Nano-Mechanical Properties of Biodegradable Cellulose Diacetate-Graft-Poly(L-lactide)s by Nanoindentation

Seung-Hwan Lee, Research Associate, and *Siqun Wang*, Assistant Prof., Tennessee Forest Products Center, Univ. of Tennessee, Knoxville, TN; *Yoshikuni Teramoto*, Biomass Research Center, National Inst. of Advanced Industrial Science & Technology, Hiroshima, Japan; and *George M. Pharr*, ORNL Collaborating Scientist, Dept. of Materials Science & Engineering, Univ. of Tennessee, Knoxville, TN

Effect of the molar substitution (MS) of lactyl unit and crystallization of PLLA side chains on nano-hardness, elastic modulus, and creep behavior of cellulose diacetate-graft-poly(L-lactide) (CDA-g-PLLA) was investigated using a continuous nanoindentation technique. Cellulose diacetate with an acetyl substitution (DS) of 2.15, pure PLLA, and two CDA-g-PLLAs with MS of 7 and 58 were used. Crystallization of pure PLA and CDA-g-PLLA with MS of 58 was conducted under isothermal conditions at 130°C for 48 hours. A smooth surface for nanoindentation was obtained by solvent casting method in an oven at 220°C under nitrogen atmosphere. A continuous measurement that involves a progressive series of loading and partial unloading cycles were conducted until a final indentation depth, generating series of hardness and modulus values as a function of the indentation depth. Indentation creep experiment with different loads and loading time was also conducted to investigate the dependency of crystallization on creep behavior.

POSTER 10

Wood Modification for Composite Manufacture

John O'Connor, Grad. Research Assistant, and *Frederick A. Kamke*, JELD-WEN Professor of Wood Composite Science, Dept. of Wood Science & Engineering, Oregon State Univ., Corvallis, OR

Mechanical compression perpendicular-to-the-grain was used to increase the density of wood. The compression was accomplished after the wood was softened in a pressurized steam environment. Actual compression occurred after steam pressure was released and the specimen was undergoing desorption. This produces a mechanosorptive affect that reduces the force required to perform the compression. Density was increased from 100 to 200% with a corresponding increase of MOE and maximum bending stress. Wood species investigated included sweetgum, and eastern cottonwood. The densified laminas are easily bonded with conventional adhesives. The purpose of this research is to develop a wood modification process that will increase the strength and stiffness of low-density wood materials for use as components in structural composites.

WOOD PHYSICS / MOISTURE RELATIONS

POSTER 11

Behavior of Safranine Penetration in Main Wood Species of Pinacea Grown in Korea Observed by Camscope

Su Kyoung Chun, Prof., *Sheikh Ali Ahmed*, Grad. Student, and *Sun Kyo Yoon*, Lab. Technician, Dept. of Wood Science & Engineering, Kangwon National Univ., Chunchon, South Korea

In camscope observation, sap and heartwood of *P. koraiensis* conducted safranine in higher depth in radial direction. On the other hand, the lowest depth was traveled by *L. kaempferi*. Penetration rate was found to be highest within 5 seconds and gradually decreased with the increase of time. In longitudinal penetration, depth was dependent upon the longitudinal tracheid length and it was found to be highest in both sap and heartwood of *L. kaempferi*. Besides sapwood penetration, pit aperture diameter was found to be another factor regarding the

variation of penetration depth in different wood species. Sapwood penetration was found to be higher than heartwood penetration. Due to the difference in air pressure and total pressure of safranine just above and below the air-safranine interface, respectively, curved meniscus was formed in the lumen of longitudinal tracheid and flat air-safranine meniscus was found for the equal pressure. Lumen diameter of tracheid determined the capillary pressure of safranine. Finally, it can be concluded that safranine impregnation in different wood species depends on several factors; such as species, anatomical features, soaking time, and moisture content. But at a given condition, permeability of liquid in wood can be increased by prolonging the soaking time.

POSTER 12

Microwave Moisture Sensors for Kiln Drying

William W. Moschler, Research Associate, Tennessee Forest Products Center, Univ. of Tennessee, Knoxville, TN; and *Gregory R. Hanson*, Principle Scientist, Oak Ridge National Lab., Oak Ridge, TN

The goal of this project was to develop a prototype microwave- based moisture sensor system to be used in a hardwood dry kiln. Moisture sensors are battery powered and are capable of being linked with the host kiln control system via spread spectrum wireless communications. We have developed two separate designs of launchers working at 4.5 GHz to 6 GHz that give a linear response to moisture content (MC) over a range of 90% MC to 6% MC. These launchers allow us to make a swept frequency transmission measurement through a small area of a board. We have developed electronic circuit boards that provide the microwave excitation and read and store the microwave signal returned through the wood. We are currently testing the "second generation" prototype electronics to go into the kiln mated with these launchers to produce a prototype MC measurement system design to be tested in kilns.

POSTER 13

Modeling Moisture Absorption Process of Wood-Based Composites Under Over-Saturated Moisture Conditions Using Two-Part Equations

Sheldon Q. Shi, Assistant Prof., Dept. of Forest Products, and *Dongfeng Wu*, Assistant Prof., Dept. of Mathematics, Mississippi State Univ., Mississippi State, MS

The objective of this study was to investigate the moisture absorption process for wood-based composites subjected to over-saturated moisture conditions, consisting of both a moisture diffusion process (bound water transfer) and free water movement. A model was developed based on two-part equations to describe the process, from which three parameters in the equations (K_1, K_{21}, and K_{22}) can be used to quantitatively describe the moisture transfer process under the conditions. Two different wood-based composites, wood fiberboard and wood fiber/polymer composites (polymer content: 30%), were used in this study. By applying this model, the effects of material types and temperature on the moisture absorption process were investigated. Four different temperatures (30, 45, 62, and 80ºC) were evaluated in the experiment. It is shown in this study that the developed two-part moisture absorption model can accurately describe the moisture absorption process under over-saturated moisture conditions. The temperature has significant effect on the moisture absorption process for both the bound water transfer and free water movement in wood-based composites. Incorporation of polymers into wood fiberboard also has effect on the moisture absorption process.

SWST STUDENT POSTER COMPETITION

POSTER 14

Effect of Termite Collection Method and Geographic Location on the Variability of Control Samples Used in the AWPA E1-97 Jar Test

Jay P. Curole, Research Associate, *Todd F. Shupe*, Associate Prof., Forest Products, and *Qinglin Wu*, Prof., Louisiana Forest Products Development Center, School of Renewable Natural Resources, LSU AgCenter, Baton Rouge, LA; and *W. Ramsay Smith*, Global Research Mgr., Arch Wood Protection, Inc., Conley, GA

The AWPA E-1 97 test (Standard Method for Laboratory Evaluation to Determine Resistance to Subterranean Termites) is an important test to determine the resistance of cellulosic material to subterranean termites. This test is of particular interest to companies developing new wood preservatives for various market sectors in the U.S. South, which is an inherently high deterioration risk zone. The Formosan subterranean termite (*Coptotermes Formosanus*, Shiraki) has been introduced in the Gulf South and has led to renewed interest in wood durability, particularly for housing applications. The E-1 test can be affected by numerous factors that are not accounted for, and perhaps may or may not need to be, in the current test protocol. Two particular factors of interest that may influence Formosan subterranean termite vigor include the geographic region in which the termites were collected and the method used to collect the termites. This study was therefore initiated to determine effects of these variables on termite performance as measured using untreated southern yellow pine solid wood samples to determine mortality, sample weight loss and sample rating (0-10) after 28 days of testing. This presentation will provide an update of this ongoing research at the Louisiana Forest Products Development Center.

POSTER 15

Chemical Characterization of Accelerated Weathered Wood-Plastic Composites

James S. Fabiyi, Ph.D. Student Research Assistant, and *Armando G. McDonald*, Associate Prof., Dept. of Forest Products, Univ. of Idaho, Moscow, ID; and *Michael P. Wolcott*, Prof. and Research Dir., Wood Materials & Engineering Lab., Washington State Univ., Pullman, WA

Wood-plastic composites (WPC) have emerged as a new decking and siding material. However, the durability performance of WPC has been of a great concern. Several researchers have studied the effects of weathering on WPC's mechanical, physical, and chemical properties. Unfortunately, there is limited detail information on the chemical change that occurs to weathered WPC relative to its material compositions. Also, the relationships between chemical and color change in weathered WPC has not been established. This study aimed at getting a better understanding of the chemical changes that occur to weathered WPC relative to its material compositions (wood and plastic). Understanding the contributions of WPC's individual component to overall degradation would enhance further research that will provide the right solution needed for the production of WPC with improved weathering performance. High-density polyethylene based WPC were subjected to accelerated (xenon-arc) weathering. Color change, chromophores generation, and the extent of oxidation on the surface of weathered WPC were monitored using colorimetery, UV-VIS spectroscopy, and Fourier transform infrared spectroscopy, respectively. Pyrolysis gas chromatograph mass spectrometry was employed to determine the compositional changes that occur on the WPC surface. The study showed that longer exposure time caused more chromophores generation, higher oxidation, lower wood lignin, and higher plastic content on weathered WPC surface. From this study, the relationships between chemical and color changes were established. It is therefore suggested that maybe the modification of wood lignin and plastic, might minimize changes in color fade of WPC used as outdoor material.

POSTER 16

Morphology of Wood Species Affecting Wood-Plastic Interaction. Part 1: Mechanical Interlocking

William Gacitua E., Ph.D. Student, and *Michael P. Wolcott*, Prof. and Research Dir., Wood Materials & Engineering Lab., Washington State Univ., Pullman, WA

The surface topography of the solid phase is important in providing physical interactions between wood and thermoplastics. Despite the wide coverage of chemical interactions, the physical aspect has not been well addressed in the scientific literature. The primary objective of this research is to quantify anatomical features in the wood cell wall that could relate to the interaction with molten thermoplastics. Using a vacuum bagging process and scanning electron microscopy (SEM), the mechanical interlocking between different wood species and high-density polyethylene (HDPE), without coupling agent and additives, has been studied. The vacuum and pressure cycles at high temperatures help for melting and flowing of the HDPE mainly through the radial face (tangential direction) in small softwood samples. This flow process generates a 3D interpenetration of the thermoplastic into the cell wood structure, resulting in a significant increase in the interfacial contact area. Interpretation of SEM micrographs suggests that the number, size, and distribution of open pits in the cell wall strongly influence the potential path for the transverse movement of HDPE into the wood structure. Also, the collapse of cell walls under pressure dur-

ing the vacuum bagging experiment was identified as a competing phenomenon with the potential to interrupt the free flow of the molten thermoplastic. Empirical models based on the main effects and interactions were constructed to estimate the wood-thermoplastic interaction. Penetration and interface area are significant affected by the percentage of earlywood or latewood. The wood specie Grand fir (*Abies grandis*) presented the highest interfacial area, which represent a potential for stress transfer in a composite. The second major factor was the interaction between the location from which the wood specimen was sampled (i.e. near or distal from the pith) and the wood specie. The vacuum bagging process used here, combined with the morphological analysis with SEM, was deemed a good method to compare the physical interaction of a thermoplastic with different wood species.

POSTER 17

Antioxidant Activity of Extracts from the Wood and Bark of Port-Orford-Cedar

Heng Gao, Grad. Research Assistant, and *Todd F. Shupe*, Associate Prof., Forest Products, Louisiana Forest Products Development Center, School of Renewable Natural Resources, LSU AgCenter, Baton Rouge, LA; and *Thomas L. Eberhardt*, Research Scientist, and *Chung-Yun Hse*, Principal Wood Scientist, Southern Research Station, USDA Forest Service, Pineville, LA

In this study, heartwood, sapwood, inner bark, and outer bark of Port-Orford cedar (POC) were extracted with methanol and the resultant extracts evaluated for antioxidant activities. The total phenol content (TPC) of the extracts was determined by the Folin-Ciocalteu method and expressed as Gallic Acid Equivalent (GAE). Butylated hydroxytoluene (BHT) was used as a positive control in the free radical scavenging activity tests and Ethylenediaminetetraacetic acid dihydtrate, disodium salt (EDTA-Na2·2H2O) served as a positive control in the metal chelating activity assay. All the wood extracts showed significant free radical scavenging activity. In the ABTS+· assay, the inner bark extracts exhibited the strongest free radical scavenging activity followed by the outer bark, sapwood, and heartwood extracts. The IC_{50} value (DPPH•) of the heartwood, sapwood, inner bark, and outer bark extracts were 64.77μg·mL^{-1}, 29.03μg·mL^{-1}, 10.31μg·mL^{-1}, 19.87μg·mL^{-1}, respectively. In the metal chelating activity system, the sapwood extract demonstrated significant activity. The greatest TPC, 537.5 mg GAE per gram of dry extract was detected in the inner bark and the second was found in the outer bark. The lowest TPC of 136.9 mg GAE•g^{-1} extract was observed in the heartwood extract. The results indicate that the extracts of antioxidant activity is in accordance with the amount of phenolics present in these extracts, and the inner bark and outer bark of POC are rich in phenolics and may provide a good source of antioxidants.

POSTER 18

Line Extension Opportunities in Manufacturing Wood Products

Emmanuel T. Kodzi Jr., Ph.D. Candidate, and *Rado Gazo*, Associate Prof., Dept. of Forestry & Natural Resources, Purdue Univ., W. Lafayette, IN; and *Richard P. Vlosky*, Prof., Forest Products Marketing, and Dir., Louisiana Forest Products Development Center, School of Renewable Natural Resources, LSU AgCenter, Baton Rouge, LA

Comparative analyses of wood products manufacturing groups based on machinery and equipment is important to the growth of U.S. wood products manufacturers. For companies considering horizontal diversification, information about the degree of machine center commonality between industry and product segments will guide capital investment decisions, based on exploitable opportunities. This will ensure that the choice and acquisition of woodworking machines is integrated into existing business in such a way as to create additional value. We examined the extent of machine usage commonality between six industry segments and, within the segments, across four sales classes in the Louisiana wood products industry in 2005. We also analyzed the strength of association between machine usage and economic outcomes within industry segments. We found that eight specific machines were listed as the most commonly-used across product categories. We, however, discovered a disparity between a ranking of most commonly-used machines and those that emerged as having the greatest potential to impact sales within industry segments. We found links between this disparity and competitive indicators for the Louisiana wood products industry, based on the 2002 Economic Census. This formed a basis for redefining which machine centers are most critical to the economic outcomes of specific product categories. Through this study, we also gained insights into how training and development programs for the value-added industry sector might be structured for effectiveness.

POSTER 19

Facilitating Cultural Acceptance of Advanced Manufacturing – The Case of Effective Instruction

Emmanuel T. Kodzi Jr., Ph.D. Candidate, and *Rado Gazo*, Associate Prof., Dept. of Forestry & Natural Resources, Purdue Univ., W. Lafayette, IN

Competitive trends in the secondary wood products manufacturing industry mandate the examination of advanced manufacturing techniques as a means to increase spontaneity in manufacturers' response to changes in the marketplace. Higher order learning outcomes based on Bloom's Taxonomy are required for students being groomed for industry positions to internalize the principles of advanced manufacturing. Based on this focus, instruction was crafted, for a "Design for CNC Manufacturing" course at Purdue University, employing an effective interplay of objectives, activities, and assessment. Using a project-based approach and a CNC router as the major tool, the instruction design was aimed at helping students acquire a working knowledge of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) as applied to secondary wood products manufacturing within one semester. For different cohorts, an emphasis on analysis and application helped students to synthesize concepts relating to the advanced manufacturing of wood products through a rigorous design process. Learning outcomes were evidenced by unique products that cannot be easily replicated using conventional methods; by the perceived commercial value of class outputs; and by student presentations and evaluations indicating greater appreciation of the subject matter compared with early semester feedback. Given that there was an expressed demand for follow-up independent studies to further explore the field of contemporary manufacturing concepts, it is expected that students trained through this class may be agents of change in favor of advanced manufacturing in the secondary wood products industry.

POSTER 20

Interfacial and Fracture Properties of Maleated Polypropylene Film and Wood Fiber Handsheet Laminates

Sangyeob Lee, Grad. Research Assistant, Forest Products, and *Todd F. Shupe*, Associate Prof., Forest Products, Louisiana Forest Products Development Center, School of Renewable Natural Resources, LSU AgCenter, Baton Rouge, LA; and *Leslie H. Groom*, Project Leader, and *Chung-Yun Hse*, Principal Wood Scientist, Southern Research Station, USDA Forest Service, Pineville, LA

The grafting effect of maleic anhydride (MA) as an interfacial bonding agent and its influence on the tensile strength properties of thermomechanical pulp (TMP) handsheet-polypropylene (PP) film laminates (TPL) was studied. This study included the effect of different levels of MA and benzoyl peroxide (BPO) on TMP fiber and PP film interactions. Optical equipment was used to examine the nature of the fracture surfaces of tensile test specimens. The number of fibers exposed at the fracture surfaces interface was determined and correlated with the tensile strength properties of the TPL. The effect of grafting level of maleic anhydride (MA), material preparation, and number of fibers at the fracture surface were studied on interfacial and tensile strength properties of TPL. For the MA treated with BPO as an initiator, tensile strength properties increased 76% with PP film over untreated laminates. The optimal strength properties were obtained with a MA and BPO ratio of 2:1. A strong correlation was observed between the number of fibers in the web and tensile strength properties for both handsheet drying conditions. The R^2 values were 0.95 for air-dry conditions and 0.94 from oven-dry conditions. Scanning electron microscopy (SEM) images also showed the effectiveness of MA loading on the surface of TMP fibers due to increased fiber failure which occurred without fiber being pulled out from the PP matrixes. Crystallinity and heat flow were determined using differential scanning calorimetery (DSC), and increased as expected with the ratio of 2:1. These results were also in accordance with the morphological observations at the fracture surface, FTIR spectra, and thermal analysis.

POSTER 21

Improving the Performance of Boron Compounds in Outdoor Wood Durability Applications

Diana N. Obanda, Ph.D. Grad. Research Assistant, and *Todd F. Shupe*, Associate Prof., Forest Products, Louisiana Forest Products Development Center, School of Renewable Natural Resources, LSU AgCenter, Baton Rouge, LA; and *W. Ramsay Smith*, Global Research Mgr., Arch Wood Protection, Inc., Conley, GA

Despite the many advantages of boron wood preservatives such as broad spectrum of insecticidal and fungicidal activities, low mammalian toxicity and low-cost of production, boron does not adequately protect wood in ground contact and exterior applications. Current research is directed towards developing methods that enable the combination of the diffusibility and environmental benefits of boron with the benefits of a fixed preservative for a long time. Strategies that have been tried include painting and coating, using non-toxic monomers or polymers such as proteins as water repellents, and use of fixed borates via chemistry. The objective of this study was to separately prepare and determine the performance of borosilicate compounds prepared *in situ* from boric acid, diphenyl silane diol, and sodium silicate. The compounds were characterized by MNR and mass spectrometry. Southern yellow pine sapwood was pressure treated separately with each of the test compounds and subjected to biological tests against test organisms in laboratory tests. Test organisms used were a brown rot fungi (*Gloeophyllum trabeum*), white rot fungi (*Trametes versicolor*), and *Coptotermes formosanus* termites. Separate blocks were leached and weathered to determine resistance to depletion. The performance of the compounds was compared to that of boric acid. Work currently in progress involves statistically determining which silicon compound is more effective in reducing boron leaching out of wood. The results are expected to contribute new information significant in the development of leach resistant borate-based preservatives.

POSTER 22

Effects of Liquefaction Conditions on Liquefied Wood Residues

Hui Pan, Grad. Research Assistant and Ph.D. Candidate, and *Todd F. Shupe*, Associate Prof., Forest Products, Louisiana Forest Products Development Center, School of Renewable Natural Resources, LSU AgCenter, Baton Rouge, LA; and *Chung-Yun Hse*, Principal Wood Scientist, Southern Research Station, USDA Forest Service, Pineville, LA

The amount of liquefied wood residues is commonly used to measure the extent of wood liquefaction. Characterization of the liquefied wood residue provides a new approach to understand some fundamental aspects of wood liquefaction. Phenol to wood (P/W) ratio, liquefaction temperature, and cooking method (i.e., atmospheric and sealed) were the three variables chosen in the study. Residues were characterized by chemical analysis, Fourier transform infrared (FT-IR) spectroscopy, x-ray diffraction (XRD) analysis, and scanning electron microscopy (SEM). The lignin content of the residues decreased while the holocellulose and α-cellulose increased as the P/W increased. A peak at 1735 cm^{-1}, which is attributed to the ester carbonyl group in xylan, disappeared in the FT-IR spectra of the residues from liquefied wood under a sealed reaction system, indicating the significant different effects of atmospheric vs. sealed liquefaction. The crystallinity indexes of the residues performed by XRD were higher than that of the virgin wood fiber and slightly increased with an increase in the P/W ratio. The SEM images of the residues showed that the fiber bundles decomposed to small size bundles or even single fibers as the P/W ratio increased from 1/1 to 3/1, which indicated that the lignin in the middle lamella had been dissolved in liquefaction prior to that of the cellulose.

POSTER 23

A Business Model for a Small-Diameter Processing Facility in Southwest Virginia

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Utilization of small-diameter timber (SDT) has emerged as a nationwide dilemma for various reasons, including decades of fire suppression and high grading, decreased pulping capacity, and paradigm shifts in forest management. The classifications and characteristics of SDT vary from region to region based on utilization capabilities and forest cover type and tree species, age, site class, stand history and silvicultural treatments, respectively. Due to pulpwood demand disparity, the widespread impact of catastrophic wildfires, a large portion of SDT utilization research has focused on western softwood species. Eastern hardwood utilization research has concentrated on adding value to low-grade logs and lumber through manufacturing and marketing solutions. Previous research on converting SDT into lumber focused on volume and value yield and didn't assess economic feasibility. The objectives of this research project are: 1) Determine the economic feasibility of a SDT processing facility located in Southwest Virginia; 2) Determine the volume and value yield of lumber, pallet parts, bark, chips, and sawdust from SDT and the market potential for these products; and 3) Develop a business plan for a SDT processing facility located in Southwest Virginia. The methods for this research project will consist of three distinct sections: 1) Resource analysis, 2) feasibility study, and 3) business planning. The resource analysis is necessary to determine the species and volume of SDT available in Southwest Virginia. The feasibility study is required to determine whether a processing facility can operate economically. The business planning will use data generated from the feasibility study to construct a business plan for an economically viable SDT processing facility.

POSTER 24

Identifying and Analyzing the Spatial Clustering of the Value-Added Forest Products Sub-Cluster in Indiana

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Industrial clusters are defined as localized concentrations of networked sectors and enterprises along with supporting non-business organizations and programs. A recent report by Bio-crossroads on agricultural economy identified the forest products cluster as one of the five major industrial clusters in Indiana in terms of employment and revenue to the state. The manufacturing strengths for these clusters in the state are manufactured and mobile homes, wood containers and pallets, wood office furniture, and wood kitchen cabinets, which are value-added products. To date, there appears to be little empirical research that analyzes the contribution and competitiveness of value-added forest products manufacturing clusters. This study is intended to develop insights into geographic location, proximity to raw materials, availability of other resources, industry specialization, firm-specific competencies, and the availability of support services of this sub-cluster. The specific objectives of this study are to: 1) Identify clusters of value-added forest products manufacturers in Indiana; 2) Develop a spatial map of these clusters based on their geographic location; 3) Identify factors that contribute to cluster development that support the forest products manufacturing clusters; and 4) Provide a set of suggestions to assist local economic development groups to identify local clusters and assess their competitive advantages.

POSTER 25

Characterization of Cure Kinetics of a Phenol-Formaldehyde Resin

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In traditional wood-based composites bonded with thermosetting resins such as phenol-formaldehyde resins (PF), the degree of cure of the resin largely determines the composite performance. In this perspective, understanding and modeling the cure development of PF resins can largely contribute to optimizing hot-pressing processes. As a result, PF resins have been the subject of many cure kinetic studies utilizing both model-fitting and model-free kinetics. Yet the best model for predicting both PF dynamic and isothermal cure has not been established. The objective of this research is to compare and contrast several available kinetic models, and then recommend the best model for predicting degree of cure and cure rate of PF resins. Toward this objective, the cure behavior of a PF resin is characterized by differential scanning calorimetry. The cure development of the PF resin is evaluated with both model-free and model-fitting kinetics. The model-free kinetic procedure relies on the Kissinger-Akahira-Sunose algorithm; model-fitting techniques for first order, n^{th} order and autocatalytic reactions are assessed using the ASTM E698, ASTM E2041 Borchardt-Daniels procedures, and a modified autocatalytic model, respectively. The results show that model-free kinetics gives more

accurate predictions of cure behavior. However, the simplicity and accuracy of the n^{th} order model with the Borchardt-Daniels procedure make it the cure kinetics model of choice for incorporation of PF cure development into hot-pressing models.

POSTER 26

Suitability of Gold Particles as a High Contrast Agent for X-ray CT Scanning of Wood-Plastic Composites (WPC)

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Wood-plastic composites (WPC) are typically composed of wood particles, thermoplastic polymers, and a small amount of modifying additives. Further improvement of WPCs requires better understanding of the micro-mechanical performance and durability of their internal structure. X-ray computed tomography (CT) scanning techniques can be applied for visualization and nondestructive quantification of the internal structure, deformation, and damage accumulation in WPC materials under degrading loads and environmental exposure. However, both wood and thermoplastics used in WPCs are weakly attenuating materials for x-ray and it is hard to obtain a good contrast between the phases. Chemically inert material, gold nano- and micro-particles are considered to improve x-ray attenuation of thermoplastics, however a surfactant is usually added to help the particles disperse well in the composite. It was observed that such doping impairs the mechanical properties of the composites. In this study, the effect of addition of 1% gold nano- and micro-particles on the tensile properties of wood-HDPE (high-density polyethylene) composite samples is examined. Samples with and without surfactant were tested. It was concluded that the addition of gold particles alone did not impair the WPC tensile properties. However, the tensile properties were significantly affected if the surfactant was added to the formulations. Addition of the surfactant had also a negative effect on the properties of the reference neat polymer samples. The gold micro-particles were shown to disperse well without surfactant and significantly increase the x-ray contrast of the polymer, while the nano-particles did not disperse well.

POSTER 27

Equivalent Circuit Modeling of Southern Pine

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Electrochemical impedance spectroscopy (EIS) shows promise in its ability to rapidly evaluate the corrosion of metals in contact with wood. Unfortunately, while EIS data give information about the corrosion reaction on the surface of the metal, this information is convoluted with information about the electrical and ionic transport through the wood to the other electrode(s), making interpretation of the corrosion data very difficult. This study models the electrical and ionic transport in wood so that EIS can become a viable experimental technique for monitoring corrosion of metals in wood. Impedance spectra were collected from Southern Pine (*Pinus spp.*) equilibrated at two different moisture contents. Cylindrical graphite electrodes were embedded in the wood so that they were aligned parallel to the grain, and the impedance properties were characterized as functions of electrode spacing and electrode contact pressure at frequencies between 1×10^{-1} and 3×10^{5} Hz. High-frequency data shows a narrow distribution of relaxation times, which were fit using a constant phase element (CPE) in parallel with a resistor. Furthermore, the high-moisture content data exhibit a low-frequency tail that can be fit by adding a Warburg element, indicative of a diffusive motion of charge carriers. Strong correlation was found between the Warburg impedances and previously published data on the molar conductivities of endogenous mineral ions in wood. This original analysis strongly indicates that at low frequencies, mineral ions are the main mechanism by which wood conducts electricity.

POSTER 28

Seating Furniture for Plus-Size Population

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The focus of this project is customization of furniture for the plus-size population in the U.S., which currently makes up 64.5% of the adult population (*Trust for America's Health Report*, 2005). Production of customized goods is a challenge as well as an opportunity for the furniture industry. The goal of the study is to develop a method for appropriate design and product development. This study describes the distribution of plus-size people among total population; demonstrates the common problems caused by incorrectly sized furniture for them; demonstrates the 5 step methodology in furniture design and customization for plus-size people; analyzes feasible manufacturing process for customization; arranges the furniture customization workflow; and develops a "Design Aid Ergonomic Tester" device for plus-size seating customization. The Design Aid device will facilitate measurement collection such as basic chair dimensions, angles, chair interfaces, and consideration of comfort levels. One of the functions of the ergonomic device is to get real-time data from a plus-size customer for his/her customized product based on a selected standard design. Engineering design principles will be applied determining the acting load, estimating the product member sizes, analyzing the magnitude and distribution of internal forces, and designing the correct joints. After data collection and adjustments, the selected chair will be designed and manufactured.