BIOGRAPHIES AND ABSTRACTS

6th International Conference on

WOODFIBER-PLASTIC

Composites

May 15-16, 2001
The Madison Concourse Hotel
Madison, Wisconsin, USA

Sponsored by the USDA Forest Service in cooperation with the ACS Cellulose, Paper and Textile Division, the American Plastics Council, the Market Development Alliance of the FRP Composites Industry, the University of Wisconsin, the University of Toronto, and the Forest Products Society.

Hosted by the USDA Forest Service, Forest Products Laboratory.

PLANNING COMMITTEE, SESSION CHAIR, AND SESSION MODERATOR BIOGRAPHIES

CONFERENCE GENERAL CHAIR

Craig M. Clemons
Research General Engineer
Forest Products Laboratory
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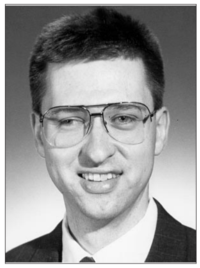
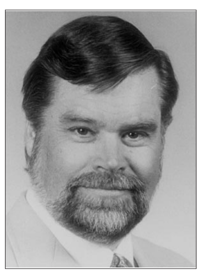


Craig Clemons is a Research General Engineer in the Performance-Designed Composites Group at the USDA Forest Products Laboratory (FPL) in Madison, Wisconsin. He received a BS degree in Chemical Engineering, an MS degree in Forestry, and a PhD degree in Materials Science, all from the University of Wisconsin-Madison. For the past 10 years he has worked at FPL developing composite materials from wood/paper fibers and thermoplastics. His areas of interest lie both in the materials science and processing technologies of these natural-fiber reinforced thermoplastics. Current areas of emphasis are processing-structure-property relationships, fungal durability, and impact performance of natural-fiber reinforced thermoplastics.

Arthur B. Brauner
Executive Vice President
Forest Products Society
Madison, WI, USA



Art Brauner received BS and MS degrees in Wood Science and Technology from the University of Michigan. He has been Executive Vice President of the Forest Products Society since 1976. He came to the Society in 1968 as Editor of Publications and Director of the Society's computerized information retrieval system. Previously, he was on the staff of West Virginia University's School of Forestry as a Research Assistant and Assistant Professor.

Daniel F. Caulfield
Research Chemist
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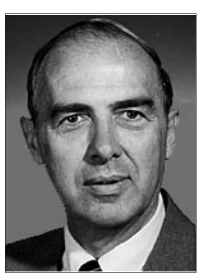

Dan Caulfield received a PhD degree in Physical/Polymer Chemistry from the Polytechnic Institute of Brooklyn (now Polytechnic University of New York). He has been a Research Chemist at the USDA Forest Products Laboratory for over 30 years. His fields of research interest are structure/properties relationships in composites and paper. He has authored or coauthored over 75 technical articles, primarily in the area of moisture interaction with cellulose and paper. In 1982, he was elected as a Fellow in the International Academy of Wood Science. He currently serves as an Associate Technical Editor of the *Journal of Pulp and Paper Science*.

Brent English
Sales & Engineering Manager
Goldtooth, Inc.
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Brent English is Sales & Engineering Manager at Goldtooth, Inc., which specializes in extrusion dies and downstream decorating solutions for woodfiber-plastic composite materials. He has been involved in woodfiber-plastic composite materials for more than 12 years, starting as Program Manager of the Secondary Fiber Utilization Project at the University of Wisconsin-Stout. He later conducted industrial research at the USDA Forest Products Laboratory, Madison, Wisconsin, where he specialized in woodfiber-plastic composite materials and processes. Midway through his career, he partnered with a custom compounder to produce wood-filled pelletized feedstocks for a variety of custom applications. Striking out on his own, he worked as a consultant, helping a number of clients develop composite formulations, improve processes, conduct market research, and resolve intellectual property issues. He joined the Goldtooth team late in 2000 first as a consultant. At Goldtooth, he has developed free flow die designs specifically for woodfiber-plastic composite materials. He received a Bachelor's degree in Manufacturing Engineering and a Master's degree in Industrial Technology. He writes and speaks frequently on woodfiber-plastic composite issues.

Robert H. Falk
Research Engineer
Forest Products Laboratory
USDA Forest Service
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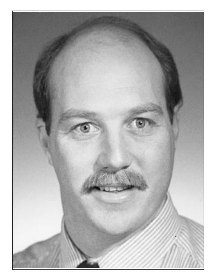

Bob Falk is a Research Engineer at the USDA Forest Products Laboratory in Madison, Wisconsin. He currently performs research on the development of value-added building products from wood waste materials. This work includes the development of reuse options for salvaged lumber and timber as well as the development of composites from waste natural fibers and waste thermoplastics. In addition to developing a basic understanding of the engineering properties of these materials, Dr. Falk is active in helping develop the engineering property and engineering design standards necessary to facilitate their widespread use in construction applications. He is a professionally registered engineer and received a BS degree in Civil Engineering from California Polytechnic State University, an MS degree in Civil Engineering from Michigan Technological University, and a PhD degree in Structural Engineering from Washington State University.

Mark T. Kortschot
Professor/Associate Chair
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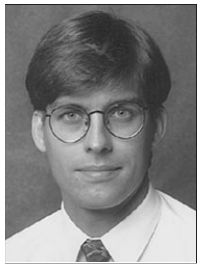

Mark Kortschot is a Professor and Associate Chair of the Department of Chemical Engineering & Applied Chemistry at the University of Toronto. He obtained his BASc (1984) and MASc (1985) degrees in the Faculty of Applied Science & Engineering at the University of Toronto, specializing in mechanics and materials science. He then went to Cambridge University as a Commonwealth Scholar and obtained his PhD in 1989. Dr. Kortschot is interested in the relationship between microstructure and material properties, with particular emphasis on the strength fracture toughness of fibrous materials such as long and short fiber reinforced polymers and paper. He is also interested in engineered wood panels such as OSB, MDF, and particleboard. His research is a mixture of experimental and theoretical approaches. He has published 28 papers in refereed journals, and has given many conference presentations and other scholarly addresses.

Kristiina Oksman
Project Manager, Natural Fibre Composites
Swedish Institute of Composites
Piteå, Sweden

Kristiina Oksman is Project Manager, Natural Fibre Composites with the Swedish Institute of Composites in Piteå, Sweden. She received an MS degree in Material Science and Engineering and a PhD degree in Wood Technology from Luleå University of Technology in Skellefteå, Sweden. Previously, she worked as a Research Scientist with the Department of Wood Technology at Luleå University of Technology conducting research with woodfiber-thermoplastic composites.

Roger M. Rowell
Project Leader
Forest Products Laboratory
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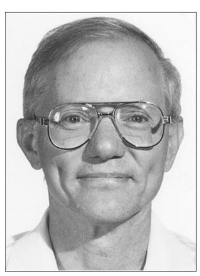

Roger Rowell is a Research Chemist and Project Leader at the USDA Forest Products Laboratory in Madison, Wisconsin. He is also currently a Professor in the Department of Forestry, the Department of Biological Systems Engineering, and the Engineering Research Center for Plasma-Aided Manufacturing at the University of Wisconsin-Madison. His research interests include carbohydrate synthesis, chemical modification of lignocellulosics for property enhanced composites, materials science of natural fibers, composites from sustainable agro-resources, cold plasma modification of carbohydrate polymers, and fiber/thermoplastic composites. Previously, he was a United Nations Development Project Mission Leader for composites in India; Guest Scholar at Kyoto University, Kyoto, Japan; Guest Research Fellow at the Forest Research Institute, Rotorua, New Zealand; Guest Professor at the University College of North Wales, Bangor, United Kingdom; a National Science Foundation Exchange Professor at the Wood Research Institute, Kyoto University, Uji, Japan; and a Guest Professor at Beijing Forestry University, Beijing, China. He received a BS degree in Chemistry/Math from Southwestern College, and MS and PhD degrees in Biochemistry from Purdue University. He is the author of over 300 publications, has edited 9 books, and holds 22 patents.

Nicole M. Stark
Chemical Engineer
Forest Products Laboratory
USDA Forest Service
Madison, Wisconsin, USA

Nicole Stark is a Chemical Engineer at the USDA Forest Products Laboratory (FPL) in Madison, Wisconsin. She received her degree from the University of Wisconsin-Madison, and started her career at FPL. Her initial assignment was with the Fire Performance Group, and she is now a member of the Performance-Designed Composites Group. Nicole has been involved with the research and development of natural fiber/thermoplastic composites for 5 years. Her research focus has been to examine the influence of raw materials on mechanical properties and is currently moving towards understanding the durability of these composites.

John A. Youngquist
Retired
Forest Products Laboratory
USDA Forest Service
Madison, Wisconsin, USA

John Youngquist has been at the USDA Forest Products Laboratory (FPL) for more than 20 years. He received a BS degree in Chemical Engineering from the University of Wisconsin-Madison, followed by 2 years of law school. Following military service, he completed course work in statistics and advanced mathematics at Rutgers University. Prior to joining the staff at FPL, he worked as an industrial research manager and plant manager for 12 years. He is a Past President of the Forest Products Society and has been a member for over 20 years. He has served on the Board of Directors of the Society of Wood Science and Technology and has been chairperson for many national and international conferences on wood-based composites. In 1993, he was recognized as the Forest Service Engineering Manager of the Year, and in 1994 and 1995, was the recipient of USDA Honor Awards. In 1996, he was elected as a Fellow in the International Academy of Wood Science. He has authored or coauthored over 100 publications in the area of wood-based composites. He has been a member of the International Union of Forestry Research Organizations' (IUFRO) Board of Directors from 1990 through 2000, and has served as the Coordinator of IUFRO Division 5 on Wood Products from 1997 through 2000. He retired from FPL in July of 1999.

SPEAKER BIOGRAPHIES

Beckry Abdel-Magid
Professor
Dept. of Composite Materials Engineering
Winona State Univ.
Winona, Minnesota, USA

Beckry Abdel-Magid is a Professor of Composite Materials Engineering at Winona State University in Winona, Minnesota. He is responsible for teaching and research in composite materials, and research in durability and structural applications of composites. His current research projects include using DMA Analysis to predict long-term creep and fatigue behavior of glass-reinforced composites; durability of fiber-reinforced polymers in pedestrian and vehicular bridge applications; and fatigue behavior of glass/phenolic composites. Dr. Abdel-Magid has written numerous papers for various publications. He received a BS degree in Civil Engineering from the University of Khartoum, and an MS degree in Structural Engineering, an MS degree in Engineering Mechanics, and a PhD degree in Civil Engineering from the University of Wisconsin-Madison.

Chris Anderson
Sales Manager
North Wood Plastics, Inc.
Baraboo, Wisconsin, USA

Chris Anderson is Sales Manager at North Wood Plastics, Inc. in Baraboo, Wisconsin. Previously, he was President of Natural Fiber Composites. He received BA and BBA (Bachelor, Business Administration) degrees from the University of Wisconsin-Madison.

Mirta I. Aranguren
Associate Professor
Facultad de Ingeniería / INTEMA
Universidad Nacional de Mar del Plata
Mar del Plata, Argentina

Mirta Aranguren is an Associate Professor in the Departments of Chemical and Materials Engineering at the Universidad Nacional de Mar del Plata in Mar del Plata, Argentina. Dr. Aranguren is responsible for the undergraduate course, Mass Transfer Unit Operations, and partly for Heat Transfer Unit Operations in the Department of Chemical Engineering. Dr. Aranguren also lectures Viscoelastic Properties of Polymeric Materials, a graduate course, for the Doctoral Program in the Department of Materials Engineering. Since 1992, she has been the Director of a small group working in the area of polymer composites using vegetable fibers in the Polymer Division of the Institute of Research in Materials Science and Technology, the Universidad Nacional de Mar del Plata, and the National Scientific and Technical Research Council. Her other research interests include thermosets, structure properties, and modifications. She is the author of 30 papers in refereed international journals and has presented her work at more than 40 national and international scientific meetings. Dr. Aranguren received a BS degree in Chemical Engineering from the Universidad Nacional de Mar del Plata and a PhD degree in Chemical Engineering from the University of Minnesota.

Robert H. Bessemer
Product Manager, Extrusion
The Conair Group, Inc.
Pittsburgh, Pennsylvania, USA

Bob Bessemer works for The Conair Group, Inc. based in Pittsburgh, Pennsylvania, as Product Manager, Extrusion. He is a senior member of the Society of Plastics Engineers with over 16 years in the plastics extrusion industry, and he has a Bachelor of Business Administration degree from Pennsylvania State University. He has been awarded several patents involving vacuum sizing, cutting equipment, and process. His responsibilities include: developing innovative ideas for new downstream extrusion related products based on customer input, design and engineering interface with the entire product line, and direct sales and training. He has been involved in extrusion training programs and has delivered numerous programs to the extrusion industry. These included subjects involving cutting-pulling technology, drives innovations, vacuum sizing techniques, taper tubing technology, and cooling techniques.

Debes Bhattacharyya
Professor/Head, Dept. of Mechanical Engineering
Univ. of Auckland
Auckland, New Zealand

Debes Bhattacharyya holds a Personal Chair in Mechanical Engineering, University of Auckland, New Zealand, and is currently the Head of the Department. Dr. Bhattacharyya's research interests include the mechanics of manufacturing using fiber-reinforced composites. He has had visiting professorships at various universities in Australia, Canada, Germany, and the United States. He was awarded the German Science Foundation Fellowship in 1996 and received the Testimonial of Excellence from the Institute for Composite Materials (Germany) for his research and teaching contributions. He has given lectures by invitation in numerous countries and has more than 150 scientific/technical publications, including a book, *Composite Sheet Forming*, and several book chapters. He also holds three patents in the composites area. He is a Fellow of the Royal Society of New Zealand and the Institution of Professional Engineers NZ, and serves on the Mechanical Engineering Group Committee of IPENZ. He is the current Vice President of the Executive Council of Asian-Australasian Association of Composite Materials and is a member of the American Society of Mechanical Engineers.

Urs Buehlmann
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Dept. of Wood & Paper Science
North Carolina State Univ.
Raleigh, North Carolina, USA

Urs Buehlmann is an Assistant Professor and Extension Specialist in the Department of Wood & Paper Science at North Carolina State University in Raleigh, North Carolina. Dr. Buehlmann received a Vocational degree from Cabinet Maker in Thun, Switzerland; a Business degree from the Rischik Business School in Bern, Switzerland; a Wood Engineering degree from the Swiss Institute of Wood Technology; and an MBA degree in Finance & Management and a PhD degree in Wood Processing from Virginia Tech. Previously, he was an Assistant Professor of Industrial Engineering at the University of British Columbia.

Maureen Dever
Research Associate Professor
Textiles & Nonwovens Development Center
Univ. of Tennessee
Knoxville, Tennessee, USA

Molly Dever is a Research Associate Professor in the Textiles and Nonwovens Development Center at the University of Tennessee in Knoxville. She received her degrees in Textiles from the University of Vermont, University of Illinois, and Kansas State University. For the past 12 years she has conducted research on the process-structure-property relationships of melt-spun nonwoven textiles. She has expertise in textile chemical finishing and filtration material for removal of vapors, solids, liquids, and live microorganisms. Her current area of research is in lyocell, which is an environmentally friendly, regenerated, manufactured cellulose, generic fiber type made from undervalued cellulose sources.

Guillaume G. Dijon
Ph.D. Student
Dept. of Materials
Imperial College of Science, Technology & Medicine
London, United Kingdom

Guillaume Dijon is a third-year PhD Student in the Department of Materials at Imperial College of Science, Technology & Medicine in London, United Kingdom. He received a degree in Physics and Chemistry, and a Master's degree in Materials from the Université de Rouen, Rouen, Normandie, France.

Carl H. Eckert
Senior Vice President
Kline & Company, Inc.
Little Falls, New Jersey, USA

Carl Eckert is a Senior Vice President with Kline & Company, Inc. in Little Falls, New Jersey. In this capacity, he is responsible for all materials-related projects. In the course of his 24 years at Kline & Company, Mr. Eckert has planned, assisted in, and directed numerous marketing and strategic studies for a variety of clients ranging from relatively small industrial suppliers to multi-billion dollar producers. This work has emphasized market analysis, strategic planning, technology assessment, and diversification opportunities. Mr. Eckert managed Kline's recent market study, Opportunities for Natural Fibers in Plastic Composites, 2000. In recent years, he has also managed dozens of strategic studies on opportunities for various plastic reinforcements and filler materials. Prior to joining Kline & Company, Mr. Eckert was employed by Allegheny Ludlum Industries for 7 years as a Powder Metallurgist and eventually Technical Service Manager for the company's Carmet Division. He graduated from Stevens Institute of Technology with a BE in Metallurgy. In addition, he received his MBA from Rutgers University.

Alan Franc
Development Manager
Clariant Additive Masterbatches
Winchester, Virginia, USA

Alan Franc is Development Manager at Clariant Additive Masterbatches in Winchester, Virginia. He is responsible for the product development and technical service for the Center of Excellence in Winchester. Previously, he was Development Engineer for B.I. Chemicals, Specialty Products Division, and Development Engineer for Adell Plastics. He received a BS degree in Chemical Engineering from Pennsylvania State University. He is currently pursuing his MBA degree.

Steven M. Jackson
Manager, Process Engineering
Coperion Corp.
Ramsey, New Jersey, USA

Steven Jackson is the Manager of Process Engineering at Coperion Corporation, where he has worked since 1987. He is responsible for process development and machine specification for a variety of twin-screw processes. He is also responsible for the technical and operational issues associated with their five-line Compounding Pilot Facility in Ramsey, New Jersey. His work experience includes scaleup of twin-screw compounding processes and process development for reactive extrusion, engineering resin compounding, and continuous devolatilization. He has published several papers including coauthoring a 1999 Antec paper titled "New Twin-Screw Element Design for Elastomer Compounding." He received a BS degree in Chemical Engineering from Rensselaer Polytechnic University and an MS degree in Chemical Engineering from Rutgers University. He is a member of the Society of Plastics Engineers.

Rodney Jacobson
President
A-J Engineering Company, LLC
Madison, Wisconsin, USA

Rod Jacobson is President of A-J Engineering Company, LLC in Madison, Wisconsin. He received BS and MS degrees in Material Science & Engineering from Washington State University, Pullman, Washington. From 1994 to 1998, he worked at the USDA Forest Products Laboratory (FPL) as a term employee in the field of cellulose polymer composites. In 1998, he entered into a "Business Enterprise Zone" at FPL as a preferred contractor under the name AJ-Engineering Company, LLC.

Philip Jacoby
Senior Research Associate
BP Amoco Polymers
Alpharetta, Georgia, USA

Philip Jacoby is currently a Product Development Scientist in the Polypropylene Business Unit of BP Amoco Polymers in Alpharetta, Georgia. His responsibilities include developing new products and improving existing products in the consumer and industrial market areas. One of his current projects is the development of a wood-filled polypropylene product for use in extruded composite lumber for outdoor decking applications. Dr. Jacoby has worked at Amoco and then BP Amoco for the past 25 years in Polymer R&D, including Product Development and Polymer Characterization. He holds 10 U.S. patents and 9 foreign patents. He received a BS degree in Chemistry from the City University of New York and a PhD degree in Physical Chemistry from the University of Wisconsin-Madison. He is a member of the Society of Plastics Engineers (SPE) and is on the Board of Directors of the Southern Section of SPE.

Mike R. Kearney
Manager, Process Laboratory
Farrel Corp.
Ansonia, Connecticut, USA

As Manager of the Process Laboratory, Mike Kearney is responsible for demonstrations of continuous processing machinery for prospective Farrel customers, and field service troubleshooting of existing continuous lines and startup of new lines. He received an AAS degree in Chemical Engineering from Waterbury State Technical College, Waterbury, Connecticut, a BA degree in Chemistry from the University of Bridgeport, Bridgeport, Connecticut, and an MS degree in Chemistry from Southern Connecticut State University, New Haven, Connecticut.

José M. Kenny
Professor
Materials Engineering Center
Univ. of Perugia
Terni, Italy

José Kenny is a Professor of Materials Science and Technology, Materials Engineering Center, Department of Civil & Environmental Engineering, University of Perugia, Terni, Italy. His research interests include processing and recycling of polymers and polymeric-based composites; materials and computational engineering; materials for aeronautical and automotive applications; mathematical modeling of reactive processes; polymer reaction and crystallization kinetics; rheology of thermosets and thermoplastics; and processing and characterization of thin films. He received a BS degree in Chemistry (Industrial Chemistry) from the Universidad Nacional de Buenos Aires, Argentina; and a PhD degree in Chemical Engineering from the Universidad Nacional del Sud, Bahia Blanca, Argentina. He has over 150 publications in international journals, books, and proceedings of international conferences. He is involved in several scientific societies including the Materials Research Society, American Chemical Society, Society of Polymer Engineers, Polymer Processing Society, Associazione Italiana di Macromolecole, Associazione Italiana di Materiali, and he is President of the European Chapter of the Society for the Advancement of Material and Process Engineering.

Ellen C. Lee
Technical Specialist, Plastics Research
Ford Motor Co.
Dearborn, Michigan, USA

Ellen Lee is a Technical Specialist, Plastics Research, at Ford Motor Company's research laboratory in Dearborn, Michigan. Her research at Ford is in the areas of thermoplastics, thermosets, and novel filler composite materials for interior, exterior, trim, and underhood automotive components. She has studied aspects of material development as well as the effects of processing conditions on material mechanical properties. She is also interested in the effect of fillers on the structure property relationships in several types of composite materials. She received a BS degree in Chemical Engineering from Northwestern University. She completed her PhD from the Department of Chemical Engineering at the University of California-Berkeley, where she made fundamental measurements of single-chain polymer dynamics using flow light scattering techniques. These measurements, along with rheological behavior of bulk systems, allow better modeling and understanding of complex processing conditions. After completing her graduate work at the University of California-Berkeley in 1998, she joined the research laboratory at Ford Motor Company.

Sang Yeob Lee
Research Assistant/PhD Candidate
Dept. of Forest Products
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Moscow, Idaho, USA

Sang Yeob Lee is currently a Research Assistant and PhD Candidate majoring in Wood Composites in the Department of Forest Products at the University of Idaho. He is developing current fundamental research in the influence of material properties combined with thermoplastic polymers and applying the findings to a woodfiber-plastic composite system from the material modifications. All usable wood materials need to be collected and delivered to a wood composite production system in a manner that maintains the raw material qualification, thereby maximizing material utilization and minimizing additional and unnecessary work in the production line. Controlling the woodfiber length and a mixing combination of wood flour and length controlled fibers could be a possible research project for the application of virgin and recyclable woodfibers to an extruder system. He received a BS degree in Forest Resources/Products, and an MS degree in Forest Resources/Production, major in Forest Products from Yeungnam University, Kyongsan, Kyungbuk, Korea.

Thomas Lundin
Research Assistant
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Thomas Lundin is a Research Assistant in the Department of Civil & Environmental Engineering at the University of Wisconsin in Madison, Wisconsin.

Gloria A. Manarpaac
PhD Student
Faculty of Forestry
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Serdang, Selangor, Malaysia

Gloria Manarpaac is a PhD Student in the Faculty of Forestry at the Universiti Putra Malaysia in Serdang, Selangor, Malaysia. Previously, she was an Instructor/Lecturer at Mindanao State University in Marawi City, Philippines. She received a BS degree in Forest Products Engineering, and an MS degree in Forestry (Wood Science & Technology) from the University of the Philippines Los Banos, Laguna, Philippines.

Amar K. Mohanty
Research Associate
Composite Materials & Structures Center
Michigan State Univ.
East Lansing, Michigan, USA

Amar Mohanty is a Research Associate in the Composite Materials & Structures Center at Michigan State University in East Lansing, Michigan. Dr. Mohanty has 10 years of teaching experience in the field of "Polymer Science and Chemistry" and 15 years of research experience in the field of polymers, fibers, and polymer composites. He received a PhD degree in Polymer Chemistry from Utkal University, India. He was an Alexander von Humboldt Fellow at the Technical University of Berlin, Germany, and a Post-Doctoral Research Associate at Iowa State University, Ames, Iowa, USA. He has published 95 papers in various refereed journals, conference papers/presentations, and articles and books.

Jeffrey J. Morrell
Professor
Dept. of Forest Products
Oregon State Univ.
Corvallis, Oregon, USA

Jeff Morrell is a Professor in the Department of Forest Products at Oregon State University in Corvallis, Oregon. Dr. Morrell's expertise is in wood preservation and biodeterioration. His current programs include: effect of incisions on preservative fluid flow and wood strength; feasibility of using biological control against wood staining fungi; improving the performance of wood poles; evaluation of remedial treatments for U.S. species; and performance of surface treatments and high-pressure wood treatments. He is the author of numerous publications. He received a BS degree from the State University of New York, College of Environmental Science & Forestry; an MS degree from Pennsylvania State University; and a PhD degree from State University of New York, College of Environmental Science & Forestry.

Dave Murdock
Business Area Manager, Building Products
Davis-Standard Corp.
Pawcatuck, Connecticut, USA

As Business Area Manager, Building Products, Dave Murdock is responsible for sales, engineering, and product development management at Davis-Standard Corporation. Previously, he was President of Michigan Roll Form and Product Manager at Cincinnati Milacron. He received a BS degree in Mechanical Engineering Technology from the University of Dayton, Dayton, Ohio, and an MBA degree from Rensselaer Polytechnic University, Hartford, Connecticut.

Tim A. Osswald
Professor/Director
Polymer Engineering Center
Univ. of Wisconsin
Madison, Wisconsin, USA

Tim Osswald is a Professor of Mechanical Engineering and Director of the Polymer Engineering Center at the University of Wisconsin-Madison. Originally from Cucuta, Colombia, he received BS and MS degrees in Mechanical Engineering from the South Dakota School of Mines and Technology, and a PhD degree in Mechanical Engineering from the University of Illinois at Urbana-Champaign in the field of Polymer Processing. He spent 2-1/2 years at the Institute for Plastics Processing in Aachen, Germany, as an Alexander von Humboldt Fellow. He received the National Foundation's Presidential Young Investigator Award. Currently, he teaches polymer processing and designing with polymers, and his current research projects include mixing, extrusion, compression molding, thermomechanical behavior of fiber-reinforced parts, boundary element simulation of the non-isothermal, and non-Newtonian flow of polymer melts. He has published over 100 papers, the books *Materials Science of Polymers for Engineers*, *Polymer Processing Fundamentals*, and *Injection Molding Handbook*, as well as many book chapters. He also teaches a yearly course on Modeling in Polymer Processing at the University of Nuremberg-Erlangen. He has also been consulted by several industries and is one of the co-founders of The Madison Group - Polymer Processing Research Corporation.

Ton Peijs
Associate Professor
Dept. of Materials
Queen Mary Univ. of London
London, United Kingdom

Ton Peijs joined Queen Mary University of London as an Associate Professor in 1999 after having worked at Eindhoven University of Technology (The Netherlands) since 1991, where he also received his PhD and still holds a part-time position. His research areas include failure and damage of composites, interfaces in composites, recycling, and natural fiber composites. He has published over 100 papers in the area of polymer composites and is the co-chair of the next European Conference on Composite Materials (ECCM-10) to be held in Brugge in 2002, and EcoComp to be held in London in September 2001.

Anand R. Sanadi
Madison, Wisconsin, USA

Anand Sanadi has worked in research in the area of natural fiber composites for over 10 years, and research in composites for over 15 years. He is the chief inventor of the process to produce highly filled natural fiber composites, where fiber loadings of over 80 percent by weight is possible. His interests include structure-property relationships in polymers and composites, and adhesion and interfaces in nonsimilar materials. Previously, he was an Assistant Scientist in the Department of Biological Systems Engineering at the University of Wisconsin-Madison. He received a Bachelor's degree in Textile Technology from the Indian Institute of Technology, New Delhi, India; an MS degree in Chemical Engineering from the University of Toronto , Toronto, Canada; and a PhD degree in Engineering Science from Washington State University, Pullman, Washington.

Karl D. Sears
Principal Scientist, Specialty Fibers
Rayonier Inc.
Jesup, Georgia, USA

Karl Sears is Principal Scientist, Specialty Fibers, at the Performance Fibers Division of Rayonier Inc. His current responsibilities and areas of focus are to develop new and improved performance fibers with commercial utility. This includes investigating new applications for Rayonier's existing wood-cellulose fibers as well as custom designing fibers for new applications. In addition to helping identify and develop useful fibers for the plastic composites industry, other new modified fibers are currently under development for other specialty fiber markets (e.g., in absorbent product and chemical cellulose derivative applications). He has worked for Rayonier for his entire 33-year career. He received a BA degree in Chemistry from the University of Iowa, Iowa City, Iowa, and a PhD degree in Organic Chemistry from the University of Washington, Seattle, Washington.

Jose Antonio Silva Guzmán
Graduate Research Assistant
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Jose Antonio Silva Guzmán is a Graduate Research Assistant in the Department of Forest Products at Oregon State University in Corvallis, Oregon. Previously, he was Assistant Researcher in the Department of Wood, Cellulose, and Paper at the University of Guadalajara, Guadalajara, Jalisco, Mexico. He has been involved in research activities related to wood structure and quality and composites from nonwood materials. He received a Bachelor's degree in Engineering in Wood Technology from the University of Michoacan, Morelia, Michoacan, Mexico, and an MS degree in Forest Products from University of Guadalajara, Guadalajara, Jalisco, Mexico.

Paul M. Smith
Professor
School of Forest Resources
Pennsylvania State Univ.
University Park, Pennsylvania, USA

Paul Smith is a Professor of Industrial Marketing, Forest Industry Specialist, at Pennsylvania State University. His activities include teaching and advising both undergraduate and graduate students, conducting research, and consulting. He received a PhD degree from Virginia Tech, an MS degree from the University of Idaho, and a BS degree from the University of Montana. His current research projects include Trade Show Use and Effectiveness, Electronic Commerce in Channels, Value-Added Opportunities for Pennsylvania Hardwoods, and Woodfiber-Plastic Composite Product/Market Development.

Wayne Song
Technical Director
Futuresoft Technologies Inc.
Mississauga, Ontario, Canada

Wayne Song is Technical Director at Futuresoft Technologies Inc. (FTI), a Toronto company specializing in extruder screw and die design and manufacture, especially profile dies, extrusion processing, and die simulation software development and marketing. FTI also makes breakthrough extensional flow mixers for polymer blends and alloys, including woodfiber-plastic composites. Previously, he was a Consultant at Macro Engineering & Technologies Inc.; Vice President of Engineering, and one of the founders, of Dura Products International Inc.; R&D Manager, Macro Engineering & Technology Inc.; and Senior Engineer, SRP Industries Ltd. He received a PhD degree from the Department of Chemical Engineering at McMaster University of Canada, where he worked on extrusion die design and simulation. He went on to post-doctoral research at the University of Toronto, where he worked on woodfiber-plastic technology. His Master's and Bachelor's studies were in mechanical engineering and engineering mechanics.

Edward L. Steward
Director of Process Technology
American Kuhne, Inc.
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Ed Steward has been employed at American Kuhne for 4 years as the Director of Process Technology. Prior to that he was employed at the Davis Standard Corporation for 24 years as the Chief Process Consultant. His responsibilities include screw design and application along with processing related tasks that insure extrusion systems will meet the designated performance goals. Educational experience includes a BS degree in Mechanical Engineering from the University of Connecticut. Mr. Steward has written numerous papers for various extrusion societies and publications on screw design and related topics. These include general screw performance, data acquisition for screw design, screw wear, coextrusion articles, vented extrusion, and grooved feed extrusion.

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Doug Stokke received his BS degree in Forest Products with a minor in Industrial Engineering from Iowa State University in 1980. In 1982, he received his MS degree from the University of Minnesota in Forest Products/Industrial Engineering – Operations Research. His PhD degree is in Forest Biology/Wood Science from Iowa State University, received in 1986. Following his graduate studies, Dr. Stokke served 5 years as an Assistant Professor in the School of Forestry & Wood Products at Michigan Technological University and then for 6 years as a Forest Products Technologist with the USDA Forest Service, North Central and Northeastern Forest Experiment Stations. He joined Iowa State University's Forestry Department as an Associate Scientist in 1998. He was appointed as an Assistant Professor in 1999. His areas of responsibility are split equally between forest products research and extension.

William T.Y. Tze
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William Tai-Yin Tze is a Graduate Research Assistant in the Department of Forest Management at the University of Maine. He is pursuing his PhD degree and performs research on adhesion and polymer science in the Advanced Engineered Wood Composites Center. Mr. Tze's research experience includes: physical and chemical characterization of wood and fiber surfaces; evaluation of fiber/polymer interfacial bonding in composites; pulping and bleaching studies of agricultural fibers; and evaluation of sawing and woodworking properties of tropical wood. He is a member of the Forest Products Society, Society of Wood Science & Technology, and the American Chemical Society. He was the recipient of the International Tropical Timber Organization Fellowship in 1994. He performed his fellowship at the University of Reading and Oxford University, United Kingdom, for enhancing his experience in managing statistical data and formulating research in forestry. He previously held positions as a Guest Researcher in the Polymers Division, National Institute of Standards & Technology, Gaithersburg, Maryland; Graduate Research Assistant in the School of Forestry & Wood Products at Michigan Technological University; Wood Science & Utilization Research Officer in the Sepilok Forest Research Center of Malaysia; and Shift-in-Charge of the pulp and paper mill chemical recovery plant in Sabah Forest Industry, Malaysia. He received a Bachelor of Forestry Science degree (Wood Industry Concentration) from the Universiti Putra Malaysia; an MS Forestry degree (Wood Science) from Michigan Technological University; and an Advanced Certificate in Pulp & Paper Management from the College of Engineering, University of Maine.

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Magnus Wålinder is a Post-Doctoral Research Associate in the Advanced Engineered Wood Composites Center at the University of Maine, Orono, Maine. Dr. Wålinder's research work is focused on surface energy characterization of wood, woodfibers, and different polymers. This is particularly important for the interface and bonding properties between these materials in, for instance, woodfiber-plastic composites. In addition to this, he is also involved in a project regarding manufacturing and testing of extruded woodfiber-plastic lumber. He received an MS degree in Mechanical Engineering, a Licentiate in Engineering degree, and a PhD degree in Wood Technology & Processing from KTH-Royal Institute of Technology, Stockholm, Sweden.

Chris Weinrich
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Chris Weinrich has been working in the extrusion industry for the past 12 years as an employee of Milacron, Inc. He is currently Product Manager and Engineering Manager for Extrusion Tek Milacron. His past experience includes engineering design and technical service. He received a BS degree in Mechanical Engineering from the University of Cincinnati, Cincinnati, Ohio, and a Master's degree in Business Administration from Xavier University, Cincinnati, Ohio.

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As General Sales Manager at K-Tron America, John Winski manages sales and systems sales for the central U.S. region. His territories include western Pennsylvania, northern Ohio, Illinois, Wisconsin, eastern Iowa, Tennessee, Arkansas, and northern Mississippi. Previous positions he held at K-Tron include Technical Sales Support Manager, Project Engineer, and Field Service Engineer. He received a degree in Electrical Engineering Technology from Temple University, Philadelphia, Pennsylvania.

Michael P. Wolcott
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Mike Wolcott is Research Director and the Louisiana-Pacific Professor of Wood Materials and Engineering at Washington State University (WSU). He received a PhD in Materials Engineering Science from Virginia Tech in 1989. Before coming to WSU, Dr. Wolcott was an Associate Professor of Wood Science at West Virginia University. His research emphases include wood composites design, woodfiber-plastic composites, wood-polymer interaction, viscoelasticity, and adhesion. Dr. Wolcott has received numerous honors including two George Marra Awards for excellence in wood research, the Wood Award for excellence in wood graduate research, and the Cahn Award for research in dynamic contact angle analysis. He has served on the Board of Directors for the Forest Products Society and the Society of Wood Science and Technology, Chair of the National Planning Committee for Forest Products Research, and Program Manager for the USDA National Research Initiative. Dr. Wolcott's research is published in over 60 manuscripts appearing in journals, books, and proceedings, and he regularly presents his work internationally. He has served as Principal Investigator on over 30 academic research projects totaling more than US$ 7.5 million. He has managed over 75 industrial product research and development projects with more than 30 companies. In addition to research, Dr. Wolcott teaches undergraduate and graduate courses in the Department of Civil and Environmental Engineering. These courses include wood composites design and production, dynamics, and remedial and advanced mechanics of materials. Annually, Dr. Wolcott serves as Co-Chair of the International Particleboard/Composite Materials Symposium, sponsored by the Wood Materials and Engineering Laboratory at Washington State University.

Raymond A. Young
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Raymond Young is a Professor in the Department of Forest Ecology & Management and the Center for Plasma-Aided Manufacturing at the University of Wisconsin-Madison. His fields of interest include plasma modification of natural and synthetic materials, bonding and adhesion in composite materials, new wood pulping methods, and chemistry of natural products. He is the author of numerous publications. He received a PhD degree from the University of Washington, Seattle, Washington.

TUESDAY MORNING, MAY 15

OPENING PLENARY SESSION

An Automotive Industry Viewpoint

Ellen C. Lee, Technical Specialist, Plastics Research, Materials Science Dept., Ford Research Lab., Ford Motor Co., Dearborn, Mich., USA

The automotive industry is an end user of a variety of materials ranging from metals to ceramics to plastics. As gasoline prices continue to rise, the search for lighter-weight materials to improve fuel economy intensifies. Natural fiber reinforced thermoplastics hold promise for lightweight automotive parts that are both economical as well as dimensionally and structurally sound. In addition to providing such composite materials with a decrease in density and weight, natural fibers are a renewable resource, are less abrasive to tooling, can help decrease processing cycle times, and are less harmful to operators than glass fiber fillers. Automotive applications, however, have several more stringent and unique requirements that are not typical of other commercial applications. These requirements include NVH (noise, vibration, and harshness) performance, dramatic temperature cycling, and corrosive environments, among others. This presentation will focus on the unique material metrics for the automotive industry, current plastics and composites usage, and future trends.

Natural Fiber Composites in the European Automotive Industry

José M. Kenny, Professor, Materials Engineering Center, Univ. of Perugia, Terni, Italy

The use of natural fiber composites for European automotive components has developed mainly during the last 5 years and takes advantage of the important potential of re-planting and sustainable industrial crops, as well as the suitability of flax and hemp to European agricultural production. In fact, the principal fibers now being used for this purpose are flax and hemp, grown mainly in Western Europe, and the subtropical fibers, jute and kenaf, mainly imported from Asia and South America. The main objective of this study is to analyze the current status of knowledge, research, and commercial applications of natural fibers in the European automotive industry. The content of this study is mainly based on the activities under development in the European Research Program ECOFINA and on a recent report by E.P. Eddleston et al. to the U.K. Ministry of Agriculture, Fisheries and Food. The study comprises an analysis of the European automotive components market and its supply chain in relation to the use of natural fibers. It also covers current attitudes towards the use of natural fiber composites in the automotive components industry, including the important role of providers of processing and textile technologies. The main factors analyzed in this study are: 1) comparative physical and performance properties of natural fibers used in the automotive industry; 2) the suitability of natural fiber composites for current automotive process technology; 3) current and potential applications of natural fiber composites for the production of automotive components; 4) performance specifications and requirements for the European automotive industry; 5) current market opportunities and constraints for natural fibers in the European automotive sector; 6) estimated European market size and characteristics, and analysis of current commercial usage and supply chain in each country; and 7) technical status and research priorities, including publicly funded research projects, and reports from research institutes, universities, and companies operating in the sector.

U.S. Woodfiber-Plastic Composite Decking Market

Paul M. Smith, Professor, School of Forest Resources, Pennsylvania State Univ., University Park, Penn., USA

The use of woodfiber-plastic composites (WPCs) in North America is not new. The automobile and door industries have used composites of wood and plastic for decades. However, extruded woodfiber-plastic composites are a relatively new product whose market growth has been rapid. This presentation addresses the predominant residential application for WPCs in the United States, that is, outdoor decking products (e.g., deck boards and guardrails). The sudden rise in popularity for WPC decking products has been driven by two factors: consumer fears regarding the perceived health and environmental risks of pressure-treated wood products, and consumer dissatisfaction with several performance attributes of treated lumber. A demand also exists for strong, cost-effective, durable, and environmentally benign materials for weather-exposed infrastructure applications. Specifically, this paper also examines a potential high-growth, high-value industrial product/market opportunity in WPC decking products for civilian and military waterfront applications.

TUESDAY AFTERNOON, MAY 15

SESSION 1A: MATERIALS - NATURAL FIBERS

A Study of the Structural and the Mechanical Properties of Flax Fiber and Its Composites

Guillaume G. Dijon, Ph.D. Student, and *Caroline Baillie*, Lecturer, Dept. of Materials, and *Richard Murphy*, Senior Lecturer, Dept. of Biology, Imperial College of Science, Technology & Medicine, London, United Kingdom

In this presentation, both the structure and the mechanical behavior of flax single fibers are investigated. Despite many papers published on flax, very little has been done on characterizing the structure of flax single fibers. A better knowledge of the intimate structure of flax fiber will enable a better understanding of its mechanical behavior. The three types of flax used (respectively, Duralin, green, and dew retted fibers) were kindly provided by Ceres BV. The structure of flax fibers has been studied by microscopy of cross sections of pulled-out fibers and while performing tensile tests inside the chamber of an electron microscope. A wide range of results was observed for both tensile and shear strengths; because single fibers are biological materials, they can vary in maturity. It was discovered that the secondary wall of the single fibers was made of several layers of lamellae. The cross sections showed that the number of lamellae varies from one fiber to another. Therefore, it may account for the variability in the mechanical properties, in particular the tensile strength.

Reinforcement of Engineering Thermoplastics with High-Purity Wood Cellulose Fibers

Karl D. Sears, Principal Scientist, Specialty Fibers, Rayonier Inc., Performance Fibers Div., Jesup, Ga., USA; *Rodney Jacobson*, President, A-J Engineering Co., LLC, Madison, Wis., USA; *Daniel F. Caulfield*, Research Chemist, USDA Forest Products Laboratory, Madison, Wis., USA; *John H. Underwood*, Director, Market Development, Rayonier Inc., Performance Fibers Div., Jesup, Ga., USA

High-purity wood cellulose fibers ($\geq$ 95% α-cellulose content) can provide good reinforcement properties for engineering plastics melting above 200°C, such as nylon 6, to yield mechanical properties that are intermediate between glass fiber and mineral materials such as wollastonite. Composite discoloration and decomposition are minimized using such high-purity wood pulp fibers. At the levels employed (30-33% by weight), processing temperatures in both compounding and injection molding can be substantially lowered. Of six wood pulps studied, two with α-cellulose contents greater than 97 percent gave the best overall results with one appearing superior (a hardwood kraft pulp). In this study, pulp fibers were granulated with a rotary knife cutter prior to compounding them with nylon 6; this step reduced fiber length. It was later found that pelletizing the fibers helps preserve original fiber length, improves processing, and leads to better mechanical properties (at times exceeding those for glass fibers). Mercerization of the hardwood kraft fibers results in additional processing and mechanical property improvements. These studies with nylon 6 will be presented and discussed, along with some limited results obtained using certain process additives as well as other engineering plastics.

Kudzu Fiber-Reinforced Polypropylene Composites

Kevin M. Kit, Assistant Professor, and *Roberto S. Benson*, Professor, Materials Science & Engineering, *Maureen Dever*, Research Associate Professor, Textile Science, and *Xiaoyu Luo*, Graduate Assistant, Materials Science & Engineering, Univ. of Tennessee, Knoxville, Tenn., USA

Reinforcing polymers with cellulosic fibers is often an inexpensive route to increasing mechanical properties and reducing cost. The sources of cellulosic fibers are often waste by-products. These sources include wood flour, nut shells, and fibers from various plants (vegetables, kute, flax, hemp, pineapple, bamboo, etc.) The mechanical properties of these cellulose/polymer composites (i.e., strength, modulus, toughness) are almost always further improved if the fiber and/or polymer matrix are modified such that fiber/matrix adhesion is enhanced. Cellulose reinforced composites have recently found commercial applications in the automotive and agricultural industries. Here we report on the behavior of kudzu fiber-reinforced polypropylene. Kudzu is a noxious weed that grows in the southeastern United States. Previously in our laboratory we have optimized pulping procedures for kudzu fibers and produced kudzu paper with properties comparable to that of softwood kraft. In the current work, kudzu pulp has been melt blended with polypropylene (PP) and maleic anhydride-grafted polypropylene (MAPP). Modest increases (18%) in tensile strength were measured when 30 percent kudzu pulp was blended with PP. However, when 10 and 23 percent MAPP was also blended with PP and 30 percent kudzu pulp, tensile strengths increased by 29 and 52 percent, respectively, compared with unfilled PP. Significant increases in tensile modulus were also found for 30 to 40 percent fiber loadings. The melt blending conditions (mixing time, melt temperature, and strain rate) also had an effect on the tensile properties for these composites. The effects of these conditions on the dispersion of the fibers in the PP matrix were characterized by optimal and scanning electron microscopy. These results are correlated with the mechanical properties. Also, the effect of MAPP content on the nature of the interaction between fiber and matrix was determined via Fourier transform infrared spectroscopy.

Grassland Fiber/Polyethylene Composites

Douglas D. Stokke, Assistant Professor, *Monlin Kuo*, Associate Professor, *Daniel G. Curry*, Laboratory Manager, and *Heath Gieselman*, Research Associate, Dept. of Forestry, Iowa State Univ., Ames, Iowa, USA

In an effort to seek new markets for grassland fiber grown in the state of Iowa, two types of grass, switchgrass and fescue, were investigated as potential fillers or reinforcements for high-density polyethylene (HDPE). The project consisted of two stages: 1) laboratory extrusion, injection molding, and properties testing; and 2) initial industrial scale-up. In the laboratory work, an injection molding grade HDPE (Chevron HiD 9006) was compounded with either switchgrass or fescue flour in a Leistritz micro 18 twin-screw extruder. Grass flour of varying screen fractions was added at 20/80, 30/70, and 40/60 flour/HDPE (w/w) ratios. Commercial pine wood flour was also extruded with HDPE at the same ratios. Extruded material was pelletized. Pellets were used to produce test coupons in a 20-ton Boy Machines injection molder. Samples were tested for tensile and flexural properties, specific gravity, melt flow index, mold shrinkage, and Izod notched and unnotched impact. In general, switchgrass-blended materials were comparable in properties to HDPE containing the pine wood. Fescue blends tended to have lowered properties. The industrial scaleup was anticipated to be complete by October 31, 2000. Approximately 1,000 pounds (combined) of switchgrass and fescue flour has been prepared for us by the American Wood Fibers company. We are negotiating with a company to conduct the extrusion blending of the grassland fiber with HDPE, after which we will test the blends on industrial injection molders in the factory of a cooperating company. Completion of this initial demonstration trial will bring this particular project to a close. We expect to be able to report on the entire project at the 2001 conference.

Oil Palm Empty Fruit Bunch Fibers/Polypropylene Composites: The Effects of Electron Beam Radiation and Some Reactive Additives

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Oil palm (*Elaeis guineensis*) empty fruit bunch (EFB) fibers are abundant in tremendous volumes in palm oil producing countries, but their commercial use is limited to those of lower technological products such as mulch, mattresses, and car seat cushions. Considerable research and development efforts have been undertaken to develop value-added products. Recently, thermoplastic composites were the focus of research in this area, but the properties of the resultant composites were not so promising due to the incompatibility of the two components. Thus, efforts have been made to enhance their properties by using coupling agents or treating the fibers. This study aims to evaluate the effects of electron beam (EB) radiation and some reactive additives (RA) on the properties of EFB-PP composites. Different modes of irradiation and some monomers and oligomers were evaluated. PP was irradiated at room temperature with a 3 MeV electron-beam machine with a beam current of 1 mA and a dose of 10 kGY before melt mixing with EFB fibers. EFB fibers 0.5 to 1 mm and with approximately 5 percent moisture content were used in the preparation of 50:50 ratio by weight (EFB fibers:PP) composites. Compounding was done at 180ºC for 15 minutes using a Plastic Corder PL2000-6 measuring mixer type W50E at a screw speed of 30 rpm. The compounded materials were then hot- and cold-compression molded at 180ºC and 18ºC, consecutively. The effects of irradiation on tensile strength and modulus, Izod impact strength, Rockwell hardness, elongation at break, and water absorption were evaluated in accordance with ASTM standards. Improvement of mechanical properties for EFB fibers and PP composites were achieved by radiation treatment and can be further improved with the addition of reactive additives.

SESSION 1B: DURABILITY

Mechanical and Creep Behavior of Polypropylene/Wood-flour Composites

Mirta I. Aranguren, Associate Professor, *María M. Reboredo*, Professor/Researcher, Facultad de Ingeniería / INTEMA, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina; *José M. Kenny*, Professor, Materials Engineering Center, Univ. of Perugia, Terni, Italy; *Norma E. Marcovich*, Research Associate, and *Adrián Nuñez*, Student, Facultad de Ingeniería / INTEMA, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina

The incorporation of woodfibers in thermoplastics leads to poor dispersion of the fibers due to strong interfiber hydrogen bonding, which holds the fibers together. Although there have been various studies on the mechanical performance of lignocellulosic composites in the last decade, limited experimental results are available in creep. Creep and creep rupture considerations are essential if woodfiber-thermoplastics composites will be applied to long-term loading applications. This work focuses on the study of the creep behavior of PP/wood-flour composites. The compatibility between filler and matrix was modified by the addition of PPMAN (from University of Simon Bolivar, Venezuela) to the mixture. Filler content was varied from 0 to 60 percent by weight. Melt blended mixtures were molded by compression (10 min. at 180ºC followed by slow cooling). Short-term creep data (0 to 30 min.) were obtained using in a Perkin Elmer dynamic mechanical analyzer (DMA7) in the creep mode at 10 MPa, and temperatures of 20º and 50ºC. Three-point bending geometry on rectangular bars of 3-mm thickness was used for the tests. Creep strain was reduced with wood flour addition (from 1 to 0.5% for the unfilled sample and the 50% by weight filled composite, respectively). The incorporation of PPMAN induced the decrease of the creep strain with respect to the behavior of the composite prepared without the additive. The creep deformation of the 40 percent by weight composites is reduced from 0.7 to 0.55 percent by the addition of 5 percent PPMAN. Mathematical analysis of the creep behavior is currently being carried out. Acknowledgements: International Foundation for Sciences (IFS), D/2813-1.

Effect of Woodfiber/Plastic Ratio and Biocide Addition on Durability of Woodfiber-Plastic Composites

John Simonsen, Associate Professor, *Jeffrey J. Morrell*, Professor, and *Camille Freitag*, Senior Research Scientist, Dept. of Forest Products, Oregon State Univ., Corvallis, Oreg., USA

Woodfiber-plastic composites have received increasing attention as possible alternatives to conventional wood decking. The addition of a wood filler markedly increases the stiffness of the resulting composite; however, the inclusion of a biological material also creates the potential for biodeterioration. Initially, many manufacturers presumed that the plastic would coat and protect the wood, but several recent reports have highlighted the potential for degradation of the wood component in these materials. Susceptibility to biodeterioration is probably a function of the durability of the wood species used, the relative proportion of wood to plastic, and the potential for water ingress to the wood particles, which is, in turn, a function of particle size and shape. While woodfiber-plastic composites have been the subject of much research, there are relatively few reports on the effects of wood content on durability. In addition, most wood durability research has utilized weight loss to determine biodeterioration. Since the amount of wood filler in woodfiber-plastic composites is closely related to stiffness in these systems, stiffness might be a more appropriate measure of the extent of biodeterioration. In this report, we will describe a series of tests on the durability of woodfiber-plastic composites containing four woodfiber-plastic ratios using weight loss and stiffness tests to assess decay resistance against *Gloeophyllum trabeum*, a brown rot fungus. Weight losses ranged from 0 percent for the plastic alone to 7 percent for the 60/40 woodfiber-plastic sample. Weight losses of untreated control blocks ranged from 50 to 60 percent. The results highlight the need for further research on the durability of the wood component in these composites.

Effect of Fungal Attack on Creep Behavior and Strength of Woodfiber-Plastic Composites

Jose Antonio Silva Guzmán, Graduate Research Assistant, *Barbara L. Gartner*, Associate Professor, *Jeffrey J. Morrell*, Professor, and *Camille Freitag*, Senior Research Scientist, Dept. of Forest Products, Oregon State Univ., Corvallis, Oreg., USA

Zinc borate is increasingly used to protect a variety of wood-based composites from biodeterioration. Zinc borate has a much lower water solubility than other borates, making it more leach resistant and able to withstand the elevated temperatures associated with the manufacturing of these materials. Zinc borate has proven especially useful for woodfiber-plastic composites, where its presence dramatically improves decay resistance of the wood in these materials. The effect of this chemical on the colonization of woodfiber-plastic composites by various wood inhabiting fungi remains poorly understood. In this report, we will describe tests on the resistance of woodfiber-plastic panels to colonization by mold and decay fungi under controlled laboratory conditions using visual assessments, weight loss, and scanning electron microscopic examination to better understand the nature of microbial attack of panels with and without zinc borate. While zinc borate clearly inhibited fungal decay, its ability to inhibit growth by mold and stain fungi was far more limited.

The Effect of Composition on the Decay Resistance of Woodfiber-Thermoplastic Composites

Steven A. Verhey, Ph.D. Student, *Peter E. Laks*, Professor, and *Dana L. Richter*, Research Scientist II, School of Forestry & Wood Products, Michigan Tech Univ., Houghton, Mich., USA

Woodfiber-thermoplastic composites are finding increasing use in exterior applications, e.g., siding and decking. There have been reports of fungal attack on these materials in both field and laboratory situations. Model composites generated from woodfibers and polypropylene were tested by laboratory soil block tests, field exposure in Hawaii, and in a fungal cellar. Experiments were carried out to determine the effects of wood loading on decay susceptibility, how outdoor weathering in a high-humidity/high-temperature environment affects physical properties, and correlation of wood particle size with decay susceptibility of composites made from hard and softwoods. Weight loss (in the soil blocks) and strength properties loss (MOE and MOR) were monitored as evidence of decay. Soil block experiments have shown that the composites were increasingly susceptible to degradation proportional to wood loading. Strength properties loss in the field exposure samples was due primarily to the effects of moisture cycling, although sterile isolations from the interior of the stakes revealed the presence of fungi. Zinc borate was incorporated as a preservative into the soil block and field exposure samples at loadings of 1, 3, or 5 percent, based on the ovendry weight of wood in the composite. The preservative was found to be effective at inhibiting weight loss in the soil block samples at all loadings.

Engineering Property Durability of Natural Fiber-Thermoplastic Composites Exposed to Ultra-Violet (UV) Light

Robert H. Falk, Research Engineer, USDA Forest Products Laboratory, Madison, Wis., USA; *Thomas Lundin*, Research Assistant, Dept. of Civil & Environmental Engineering, Univ. of Wisconsin, Madison, Wis., USA; *Colin Felton*, Technical Manager, Teel - Global Resource Technologies, Madison, Wis., USA

This presentation overviews research conducted at the USDA Forest Products Laboratory to evaluate the durability performance of natural fiber-thermoplastic composites intended for use in outdoor applications. The degradation of the composite due to various accelerated aging techniques has been shown to adversely affect both the physical and flexural properties and ultimately the composite's intended service life. The degree of degradation due to UV exposure and its impact on flexural properties for thermoplastic natural fiber composites has not been well documented, nor has any quantifiable correlation between exposure and degradation of physical and mechanical properties been made. Four different specimen formulations were studied. Injection-molded high-density polyethylene (HDPE) served as the polymer base for all formulations. Additives consisted of an antioxidant and a UV stabilizer. Two lignocellulose fillers, wood flour, and kenaf fiber were added at 50 percent by weight. Specimens were exposed in a laboratory WeatherOmeter to high levels of ultraviolet radiation, elevated temperatures, and moisture cycling to simulate the effects of sunlight and rain. Various properties, including color loss (fading), bending stiffness (modulus of elasticity), and strength (modulus of rupture) were measured both prior to and after specific periods of exposure. All specimen formulations exhibited a reduction in properties in response to accelerated aging.

WEDNESDAY MORNING, MAY 16

SESSION 2A: MATRIX EFFECTS

A Comparison of Wood-Filled High-Crystallinity Polypropylene with Other Wood-Filled Polyolefins

Philip Jacoby, Senior Research Associate, *William Crostic*, Market Development Manager, and *Richard Sullivan*, Technical Service Engineer, BP Amoco Polymers, Alpharetta, Ga., USA

Over the past decade, wood-filled polyolefins have become accepted as a replacement for lumber in high-value outdoor applications such as decks. Most of the products offered have used polyethylene as the polymer matrix, with wood flour as the typical filler. It is well known that polypropylene offers certain benefits over polyethylene in terms of higher stiffness, strength, heat deflection temperature (HDT), and high-temperature creep performance. In this presentation, we will present physical property data for wood flour levels ranging from 20 to 60 percent in both polypropylene and high-density polyethylene matrices. The PP resins studied included standard homopolymer, high-crystallinity homopolymer (ACCPRO), and impact copolymer. The effect of different levels of a maleated polyolefin coupling agent will also be examined. The ACCPRO-based composites showed a significant improvement in stiffness, strength, and HDT over that of the standard homopolymer PP, with no loss of impact. All of the filled PP materials were substantially stiffer and stronger than that of the filled HDPE, especially at elevated temperatures. The homopolymer and ACCPRO materials also had much better creep resistance compared to the HDPE at both ambient and elevated temperatures. The water absorption characteristics absorbed less moisture than that of the comparable HDPE based materials, and the loss of strength and stiffness with water pick-up was also less pronounced for the wood-filled PP. These results indicate that wood-filled PP, and especially high-crystallinity-filled PP, will provide better mechanical performance in structural applications such as outdoor decks, as compared to that of wood-filled HDPE.

Influence of Surface Characteristics of TMP Fibers to the Growth of TCL on the Linear Fiber Surface (I): Aspect in the Surface Roughness

Sang Yeob Lee, Research Assistant/Ph.D. Candidate, and *Thomas M. Gorman*, Professor/Head, Dept. of Forest Products, Univ. of Idaho, Moscow, Idaho, USA; *Michael P. Wolcott*, Research Director/ Louisiana-Pacific Professor, Wood Materials & Engineering Lab., Washington State Univ., Pullman, Wash., USA

This research focused on the influence of surface characteristics of thermomechanical pulp (TMP) fibers to define the correlation of both surface properties to crystallinity of the polymers and to interfacial strength resulting from the increased crystallinity. For this study, the fiber roughness was analyzed using atomic force microscopy (AFM). The three scan sizes were 5 µm, 2.5 µm, and 1.25 µm. Differential scanning calorimetry (DSC) and dynamic mechanical analysis (DMA) for the thermal analysis, and polarize optimum microscopy (POM) to observe the crystallization process were used. Six TMP fibers, which were produced with two different wood sources (mature and juvenile) and three pressures (4, 8, and 12 bar), were used for this study with 100 percent PP, 99 percent PP/1 percent MAPP, 95 percent PP/5 percent MAPP, and 100 percent MAPP at 150º ± 1ºC. The highest crystallinity was achieved when the highest surface roughness of 8 bar juvenile fibers placed with 100 percent MAPP. Enhanced MAPP also increased transcrystallinity on the woodfiber surfaces, and nucleation density also associated with the amount of MAPP. Transcrystalline layers (TCL) were formed on the TMP fiber surfaces with 100 percent PP resulting from the increased surface roughness. The DMA and DSC results showed decreased crystallization temperature with increased surface roughness. The increased interfacial strength was also achieved using the highest surface roughness with the fiber failure from lap shear test samples. Consequently, opened functional groups by a mechanical pulping process with an optimized pressure is an efficient way to obtain increased crystallinity and interfacial strength.

Performance Evaluation of Woodfiber-Biodegradable Polymer Composites

Debes Bhattacharyya, Professor/Head, Dept. of Mechanical Engineering, and *Krishnan Jayaraman*, Senior Lecturer, and *Sharlene Peterson*, Post-Graduate Student, Centre for Composites Research, School of Engineering, Univ. of Auckland, Auckland, New Zealand

The desire for lighter, stronger, and stiffer materials has been the driving force behind the increasing usage of fiber-reinforced polymer composites. This expansion in synthetic polymer usage has also led to increasing problems of recycling and resource identification. The use of natural fibers in essentially nonloadbearing applications has seen a rapid growth in the past few years due to their renewability and likely abundance in nature. However, the limited recyclability of the matrix material can often compromise the composite's overall eco-friendliness. The primary objective of this presentation is to evaluate the manufacture and performance of high-temperature mechanical pulp (HTMP) woodfiber- (*Pinus radiata*) biodegradable polymer composites in sheet form, suitable for use in moulded product forms. A thermoplastic polyester, Biopol™ (a polyhydroxybutyrate/polyhydroxyvalerate copolymer (PHBV) manufactured by Monsanto), has been selected for this research due to its possible manufacturing applicability and relatively short degradation period. A Taguchi approach has been adopted to reduce the number of actual experiments and to make both the forming and property analyses of the product insensitive to variation in uncontrolled factors. A four-factor, multi-level experimental design is utilized and the interaction effects are studied. The four chosen manufacturing parameters are consolidation temperature, time, pressure, and the point of time at which pressure is applied. For simplifying the experimental design, the fiber mass fraction has initially been kept constant at 18 percent. The effects of different parameters on mechanical properties and the formability of the composite sheets will be presented and discussed in the context of product manufacturing.

High-Fiber/Low-Matrix Composites: Kenaf Fiber/Polypropylene

Anand R. Sanadi, Dept. of Biosystems Engineering, Univ. of Wisconsin, Madison, Wis., USA; *J.F. Hunt*, *G. Kovacsvolgyi*, and *Daniel F. Caulfield*, Research Chemist, USDA Forest Products Laboratory, Madison, Wis., USA; *B. Destree*, Dept. of Chemical Engineering, Univ. of Wisconsin, Madison, Wis., USA

Considerable interest has been generated in the use of lignocellulosic fibers and wastes (both agricultural and wood based) as fillers and reinforcements in thermoplastics. In general, present technologies limit fiber loading in thermoplastics to about 60 percent by weight of fiber. Producing high fiber content composites for commercial use while maintaining adequate mechanical properties requires innovative processing techniques. A new technique has been developed that allows very high fiber loading. We have processed composites up to about 95 percent by weight of fiber in polypropylene (PP). The process involves some additional processing steps, in addition to conventional compounding techniques, to achieve such high fiber content in PP. Studies on composites made from about 85 percent kenaf-PP indicate that the properties such as flexural modulus and strength of these composites are superior to most types of wood particleboards and low- and medium-density hardboards. The fiber orientation is predominantly two dimensionally random for the kenaf-PP composite. The range for the flexural strength (MOR) of medium-density fiberboards (MDF) using phenol-formaldehyde as the binding system is typically from 13 MPa to 42 MPa. The flexural stiffness (MOE) range for MDF boards is from 2.24 GPa to about 4.9 GPa. The high range for flexural strength of high-density fiberboards is typically about 70 MPa and the flexural stiffness about 7.58 GPa. The high-density kenaf-PP composite, with an MOR of 75 MPa and an MOE of 6.4 GPa has comparable properties to conventional formaldehyde-based fiberboards. Thermal analysis of the kenaf composites indicates that the crystallinity of the PP in the composites is not affected by the processing.

Processing, Properties, and Applications of Flax Fiber-Reinforced Composites

Ton Peijs, Associate Professor, Dept. of Materials, Queen Mary Univ. of London, London, United Kingdom; *Jayamol George*, *Sanjeev Garkhail*, and *Edwin Klompen*, Eindhoven Univ. of Technology, Eindhoven, The Netherlands

Environmental legislation as well as consumer pressure are all increasing the pressure on manufacturers of materials and end products to consider the environmental impact of their products at all stages of their life cycle, including ultimate disposal, a 'cradle-to-grave' approach. These environmental issues in combination with the low cost of plant fibers such as flax, hemp, kenaf, and sisal have generated considerable interest as reinforcements in engineering composites. Plant fibers are currently being evaluated as environmentally friendly and low-cost alternatives for glass fibers. Natural fibers have a number of advantages over E-glass fibers; they are renewable, cheap, lightweight, biodegradable, non-abrasive, and CO_2 neutral. Also, natural fibers can be incinerated with energy recovery, there is less concern with safety and health, and they have good mechanical properties. The combination of interesting mechanical and physical properties with their environmentally friendly character has triggered various activities in the area of ‘green composites’, and many European universities and institutes are starting activities in this area through various ‘eco-driven’ R&D programs. The European automotive industry is especially looking into the possibility of using natural fiber-reinforced thermoplastics to serve the environment while saving weight and cost. Although natural fibers have a number of ecological advantages over glass fibers, they also possess a number of disadvantages. As far as mechanical properties, natural fibers can easily compete with glass fibers in terms of stiffness. However, the tensile strength, compressive strength, and especially impact strength of natural fiber composites are relatively low compared to glass fiber composites. Another area of concern is the poor moisture resistance (rotting) and dimensional stability (swelling) of natural fibers, which can lead to debonding and microcracking in the composite. However, a potentially more serious problem is related to processing because natural fibers tend to degrade near the processing temperature of most thermoplastics. Thermal degradation during processing not only limits the number of polymers that can serve as a matrix system, but causes additional concern with respect to reprocessing and recycling. Although one may get away with the narrow processing window for natural fiber composites in a single-step process, it may cause problems in reprocessing and mechanical recycling. Currently natural fibers are pushed because of their 'green' image, mainly because they are renewable and can be incinerated at the end of the material’s lifetime. However, the recycling issue will be key in answering the question: How green are natural fibers? On the other hand, since car manufacturers are aiming to make every part either recyclable or biodegradable, there still seems to be room for biocomposites based on biopolymers and natural fibers. Such biodegradable composites may, from a cradle-to-grave point-of-view, have some advantages over traditional composites for certain applications. Similarly, the upgrading of recycled plastics, which are close to the end of their lifetime, with natural fibers is a sound option because of the clear advantages with respect to end-of-lime time disposal by incineration. This presentation will give an overview of ongoing research at Queen Mary University of London (United Kingdom), and Eindhoven University of Technology (The Netherlands) in the area of flax fiber-reinforced composites and will discuss issues related to properties, processing, and applications.

Low-Temperature Processing of Cellulose Pulp Fibers into Nylon 6 and Other Engineering Thermoplastics

Rodney Jacobson, President, A-J Engineering Co., LLC, Madison, Wis., USA; *Daniel F. Caulfield*, Research Chemist, USDA Forest Products Laboratory, Madison, Wis., USA; *Karl D. Sears*, Principal Scientist, Specialty Fibers, and *John Underwood*, Director of Marketing Development, Rayonier Inc., Jesup, Ga., USA

Techniques for compounding and injection molding ultra pure cellulose pulp fibers into nylon 6 and other engineering thermoplastics will be described. Low Temperature Compounding (LTC) is a technique that provides a processing route to utilize cellulose pulp fiber as a reinforcement in resins with melting points greater than 220ºC. In particular, nylon 6 has a melting point of 221ºC, which is well above the commonly stated belief that cellulose should not be compounded above the 200ºC benchmark. By understanding and utilizing the viscosity shear heating effects of cellulose/nylon 6 composite systems, the LTC method provides high-quality composite pellets for injection molding. Low Temperature Injection Molding (LTIM) techniques will be described that provide a means of producing ASTM Standard test samples for evaluation. The discussion will focus on LTC and LTIM methods of producing cellulose/nylon 6 composites. A limited number of injection molded parts will be demonstrated and representative composite mechanical properties will be presented.

SESSION 2B: PROCESSING I

Feeding Solutions for Woodfiber-Plastic Composite Applications

John J. Winski, General Sales Manager, K-Tron America, Pitman, N.J., USA; *Terry Allen*, Managing Partner, Allen/Davis Technology, Batavia, Ill., USA

Precise flow rate of various bulk materials such as pellets, powders, and other similar materials may represent a uniquely difficult feeding challenge. Free-flowing, highly floodable when aerated, and apt to bridge or arch in a hopper when compacted, these materials will often require a feed system which addresses three special attributes. First, appropriate material handling capabilities are required to physically condition the material and control its movement through the feeder to discharge. Second, a high-performance weighing system is needed to accurately and reliably detect the relatively small changes in weight required for short-term feed rate accuracy, notwithstanding the typical vibration-prone process conditions. And third, a high-performance control system is mandatory if precision performance is to be established and maintained throughout the feeder's loss-in-weight cycle, including the potentially perilous refill phase. This presentation highlights each of these areas, presents their solutions, and discusses relevant application considerations.

WoodTruder™ - System for Extrusion of Woodfiber and Polymer Composites on Counterrotating Parallel Twin-Screw Extruders

Dave Murdock, Business Area Manager, Building Products, Davis-Standard Corp., Pawcatuck, Conn., USA

This presentation gives insight on techniques and equipment that are critical to the efficiency of processing woodfiber and polymers on various extrusion systems. Detail is given to single-screw extruders, counterrotating twin-screw extruders, co-rotating twin-screw extruders, and the WoodTruder for woodfiber-polymer composite extrusion. Each type of woodfiber-polymer composite extrusion system is fully explained to specify the equipment needs and processing requirements. The advantages and disadvantages of each system are documented as compared to the other extrusion methods.

One-Step Composite Decking Manufacture

Steven M. Jackson, Manager, Process Engineering, Coperion Corp., Ramsey, N.J., USA

Composite decking has moved into the mainstream of commercialization. Manufacturers must have a method that can process at high rates for a given capital investment. It must also be able to process a variety of materials so as to take advantage of formulation changes that increase quality and/or reduce costs. A one-step process will be discussed that converts undried cellulosic fibers and polyolefin pellets into finished decking. Technical as well as commercial issues will be addressed. The focus of this presentation will be the need for an integrated manufacturing system to provide the maximum economic return on investment.

Direct Extrusion of Wood-flour/Plastic Composites on Conical Counterrotating Twin-Screw Extruders

Chris Weinrich, Product Manager, Milacron Inc., Batavia, Ohio, USA

Plastics have been quite successful in gaining market share in building and construction applications from wood and metal because they have shown advantages in terms of properties, appearance, and value. However, in the last few years, the game seems to be changing. Plastic and wood are being combined to produce composite products superior over those made from only one ingredient. The term wood-flour/plastic composite is a general term for many, many different blends and formulations. Wood flour has been successfully blended with PVC, HDPE, PP, PS, and ABS. Furthermore, many natural fiber materials other than wood flour or woodfibers have been blended with these plastics. Because the types of wood-flour/plastic composites blends and formulations vary so dramatically, many types of processes have been tested and are being used today to produce wood-flour/plastic composite products. In the different processing methods, all three major types of extruders – single screws, co-rotating twin screws, and counterrotating twin screws – are utilized. The methods used today to blend wood-flour/plastic composites can be categorized into three general processes: melt blending, pelletizing, and direct extrusion. This presentation will review the three methods utilized to process wood-flour/plastic composites and the three major types of extruders used in these processes. It will then cover in greater detail the functions of an extruder and the challenges of accomplishing these functions when processing wood-flour/plastic composites. Finally, the presentation will explain how the conical, counterrotating twin-screw extruder is ideally suited to handle these challenges.

Extrusion Tooling for Woodfiber-Plastic Composite Products

Wayne Song, Technical Director, Futuresoft Technologies Inc., Mississauga, Ont., Canada

Woodfiber-plastic composite processing has emerged as one of the fastest growth industries. On the other hand, there are failures and a lot of trial-and-error. A successful woodfiber-plastic composite production requires proper formulation of woodfiber-plastic composition for the end products, processing equipment, which is dominated by the twin-screw extruder, proper tooling or die design, and product design. In this presentation, we will share our 10-year experience in woodfiber-plastic extrusion technology started from the University of Toronto by giving a brief technical review of woodfiber-plastic technology and addressing the importance of proper extrusion tooling. It is believed that the extrusion tooling contributes significantly to the productivity of the processing and mechanical properties of the end products. The state-of-the-art of extrusion tooling will be reviewed and key issues in extrusion die design and differences between PVC and woodfiber-plastic profiles will be discussed. Case studies of die design and cooling design for a thick I-beam product will be discussed in detail. Computer simulations of the composite flowing through the die will be conducted. It is concluded that with the understanding of end products, woodfiber-plastic composite behavior, extrusion processing, and utilizing computer-aided engineering tools, proper extrusion tooling can be achieved.

Advances in Cooling Technologies for Woodfiber-Plastic Composites

Robert H. Bessemer, Product Manager, Extrusion, The Conair Group, Inc., Pittsburgh, Penn., USA

Woodfiber-plastic composites and their associated applications have emerged as clear winners with huge strides in product acceptance in the construction market. This increased popularity is a direct result of enhancements in processing allowing lower costs of production and thus selling price. The economics of composite extrusion require goals of 2,000 pounds per hour or more to compete directly with the wood market. To attain these rates, it has been necessary to enhance many individual aspects of the extrusion process. Materials and their associated formulations, drying and loading equipment, extruders, dies, calibrators, vacuum and/or spray cooling tanks, pullers, and even saws have all seen advancements. In this presentation, Mr. Bessemer will review enhancements in cooling technology, which have allowed higher processing rates to meet today's more demanding requirements. The object has been to both size and cool the extruded woodfiber-plastic composite at increasing rates with minimum scrap, and in some cases less space. Most processors began with immersion cooling to attempt to remove BTU's from the material. The process was improved by creating water turbulence in the tank to break up the barrier of hotter water, which surrounds the product as the product emits heat. These tanks became increasingly long to offer more residence time, especially with solid or heavy wall composites. It is not uncommon for a line to use 40 to 120 feet of cooling tanks with immersion cooling. Evaporative cooling, which has offered tremendous improvements to the pipe industry, quickly became adapted to the processing of composites, offering faster cooling rates. This presentation will discuss how evaporative cooling works and how it dramatically increases cooling rates. We shall discuss how hydraulic spray nozzles work and why water droplet size is so important in optimizing heat removal without causing unwanted surface defects. We shall also discuss the importance of full and even coverage of the composite extrusion to be cooled to maintain consistent heat transfer and thus stable dimensions. The importance of proper water pump sizing for the required pounds per hour, both in gallons per minute and pressure, will also be discussed. Heat exchanger sizing and proper filtration to optimize the process is another topic of discussion. Chiller requirements in both gallons per minute and temperature to optimize the cooling process will also be reviewed. Due to all the advances that are taking place in the processing of woodfiber-plastic composites, including cooling rates, extrusion rates will continue to increase. Along with these increases, many composites will become even more economical to process, which will further increase usage.

WEDNESDAY AFTERNOON, MAY 16

SESSION 3A: FIBER-POLYMER INTERACTIONS AND INTERPHASES

Interfacial Adhesion Studies of Lignocellulose-Fiber/Polymer Composites Using the Raman Microbond Test

William T.Y. Tze, Graduate Research Assistant, *Stephen M. Shaler*, Professor, and *Douglas J. Gardner*, Associate Professor, Advanced Engineered Wood Composites Center, *Carl P. Tripp*, Associate Professor, Laboratory of Surface Science & Technology, and *Shane C. O'Neill*, Laboratory Engineering Specialist, Advanced Engineered Wood Composites Center, Univ. of Maine, Orono, Maine, USA

The objective of this research was to study the adhesion between lignocellulose fibers and thermoplastic polymers using a Raman microspectroscopy technique that has been proven successful for carbon fiber-thermosetting polymer systems. Lignocellulose fibers were coated with silane coupling agents having alkyl and phenyl functionalities. Single fibers were subjected to tensile loads at different strain levels under the Raman spectroscope. From the resulting Raman spectra, the peak that changed in its wavenumber was identified as the strain-dependent Raman peak. The wavenumber of that peak was plotted against strain to produce a correlation curve. Single-fiber model composites were then prepared by applying microdroplets of polystyrene and polyethylene onto the fibers. A polymer droplet was sheared off from the fiber while simultaneously, Raman spectra were taken at 10-micrometer intervals along the fibers inside and outside of the droplet. The Raman-band shifts at different points of the fiber-polymer interface were converted to fiber axial strains using the correlation curve established earlier. Thus, a point-to-point variation of strain could be mapped at the interface; these strain values were subsequently translated, using the balance of forces equilibrium, into shear stresses to yield a distribution of interfacial shear stress. The maximum shear stress reflected the stress transfer ability of the interface. Results show that the Raman probe technique is a powerful tool to evaluate the interfacial properties of lignocellulose-fiber/polymer composites, thereby allowing a better understanding of the interface for bonding improvement.

Surface Energy and Acid-Base Characterization of Components Used for Woodfiber-Polymer Composites

Magnus E.P. Wålinder, Post-Doctoral Research Associate, and *Douglas J. Gardner*, Associate Professor, Advanced Engineered Wood Composites Center, Univ. of Maine, Orono, Maine, USA

This presentation focuses on surface energy characterization of wood particles and a polyamide material. Such information may be useful to improve the adhesion properties between these constituents in extruded woodfiber-polyamide composites. Inverse gas chromatography (IGC) at infinite dilution and contact angle analyses were used to characterize the surface energy and the acid-base properties of the two components. Apparent contact angles were estimated by a column wicking method. In the IGC and wicking experiments, a series of both non-polar and polar Lewis acid-base probe gases and probe liquids, respectively, were used. Results indicate that higher surface energy values are obtained by the IGC method as compared with the wicking method. One explanation for this could be that IGC analysis at infinite dilution strictly evaluates the high-energy sites for molecular interaction, whereas an advancing contact angle, as obtained by the wicking method, represents the lower-energy sites. One complication with the IGC analysis on wood is the occurrence of “negative” enthalpies for the adsorption of the acid-base probes. The probable cause for this is attributed to preferential sorption due to strong acid-base interactions.

Coupling Agent/Lubricant Interactions in Commercial Woodfiber-Plastic Composite Formulations

Michael P. Wolcott, Research Director/Louisiana-Pacific Professor, and *Mohammed J.A. Chowdhury*, Post-Doctoral Fellow, Wood Materials & Engineering Lab., Washington State Univ., Pullman, Wash., USA; *Richard B. Heath*, Senior Technology Manager, Honeywell, Morristown, N.J., USA; *Timothy G. Rials*, Research Physical Scientist, USDA Forest Service, Southern Research Sta., Pineville, La., USA

Maleated polyolefin copolymers have been widely studied for their ability to enhance the interaction between wood and polyolefin matrix polymers. In most studies, the copolymer is applied to the wood prior to extrusion. However, in commercial operations a simple mixture of material components may be used where the copolymer might only comprise a small percentage of the total formulation. To emulate commercial practice, copolymers are blended with other components at relatively low levels (< 3%). The crystallization rates of the woodfiber-plastic interface are thermally characterized using DMA and DSC. The existence of transcrystalline morphologies in the interface region is determined using polarized light microscopy. Mechanical and physical properties of formulations incorporating copolymers are determined from characterization of extruded sections. As previously reported, maleated copolymers significantly improve the mechanical performance of extruded woodfiber-plastic composites. The composite moisture absorption and wet-strength are also enhanced, presumably by reducing interfacial gaps and defects. Some commercial lubricants interfere with the action of the commercial coupling agents, although the extent of disruption is highly dependent on lubricant type.

Engineered Natural Fiber Reinforced Polypropylene Composites: Synergism of Environmentally Benign Processing and Water-Based Coupling Agent

Amar K. Mohanty, Research Associate, *L.T. Drzal*, and *M. Misra*, Composite Materials & Structures Center, Michigan State Univ., East Lansing, Mich., USA; *Tom Mase*, *R. Jurek*, and *C. Dunn*, Advanced Materials Engineering Expt. Sta., Midland, Mich., USA

Natural fibers, which traditionally were used to fill thermosets, are becoming one of the fastest growing additives for thermoplastics. The advantages of natural fibers over man-made fibers such as glass and carbon are: low cost, low density, high specific strength and stiffness properties, carbon dioxide sequesterization, and biodegradability. Of all the thermoplastic matrices available, polypropylene (PP) shows the most potential benefits when combined with natural fibers in making composites of industrial value. Most work on natural fiber-PP composites is based on melt mixing of short natural fibers and PP granules with subsequent compression/injection molding. Such two stage processing techniques expose the biofibers to high shear and thus damage the fiber. The best use of biofibers will occur when processing methods reduce or minimize fiber damage. Environmentally benign powder impregnation processing (wet and dry) is being studied as an enabling technology for the production of high-performance natural fiber - polypropylene composites. In wet processing, a process similar to the paper making process is adopted for making the composites. Natural/Bio-fiber reinforcements e.g. bast fibers like kenaf, flax, hemp; leaf fiber like sisal, henequen; and cellulose fibers from recycled cardboard are combined with micron size polypropylene powder as the matrix system, either in a water slurry process or a dry powder impregnation process - Biocomposite Stampable Sheet (BCSS) processing. A notable shortcoming in natural fiber - PP composite system is the poor bonding between the biofiber and the plastic. This is due to the dissimilar nature i.e. biofiber is hydrophilic while PP is hydrophobic. The development of useful composite materials requires that fiber-matrix adhesion be optimized to ensure good mechanical properties. Since a significant feature of natural fiber composites is their potential low cost, the surface treatments that rely on liquid immersion methods is our primary goal. The novelty of sizing of natural fibers is based on the treatment of both the silane and a polypropylene compatible coupling agent in water-based systems unlike organic solvent medium. The suitably surface treated bast and leaf fibers are blended in right proportion to design our "engineered natural fibers" to manipulate the flexural and impact performance of the resulting composites with an objective of producing natural fiber composites from chopped "engineered natural fibers" and powder thermoplastic polymer to fabricate future generations of composites for automotive, building and consumer goods applications.

Lignin-Polypropylene Composites

Raymond A. Young, Professor, and *Guillermo Toriz*, Graduate Student, Dept. of Forest Ecology & Management and Center for Plasma-Aided Manufacturing, and *Ferencz Denes*, Assistant Professor, Dept. of Biological Systems Engineering, Univ. of Wisconsin, Madison, Wis., USA

Lignin polypropylene (lignin/PP) composites were prepared with lignin contents at 10 to 60 percent by weight. Blending of the lignin resulted in reduced strength properties since lignin acts as an unreactive filler in the thermoplastic matrix. When lignin was added in combination with conventional modified fillers, improvements were noted in the composites. Improved strength was also noted when maleic anhydride grafted polypropylene (MAPP) was utilized as a coupling agent in the lignin/PP composites. Surface modification of both lignin and PP in several plasma environments was performed to enhance the composite properties. This was made possible through construction of a unique radio-frequency, rotating plasma reactor with ferro-fluidic sealings. This allowed for the first time large volume plasma treatment of powdery, particulate materials such as lignin. It has been shown that efficient surface modification can be achieved by plasma treatment, which avoids the long reaction times and large volumes of reactants for modification by conventional wet chemistry. Silicon chloride plasma treatment resulted in incorporation of 10 to 15 percent silicon and improved strength properties of the composites. However the best results were obtained by plasma state copolymerization of acryloyl chloride using pulsing plasma conditions, with properties equivalent to those obtained using MAPP for coupling of the composites. SEM demonstrated the improvement in blend morphology when using coupling agents and plasma treated components. DMTA showed that adding lignin increased the composite storage due to the higher stiffness of lignin. Higher lignin content composites made with coupling agents and pulsed plasma treatments (acryloyl chloride) showed better compatibility between the components of the composite. Plasma modification of lignin and PP is a promising approach for enhancing interactions for improved composite properties.

SESSION 3B: PROCESSING II

Processing Highly Filled Pre-Compounded Pellets on Single-Screw Extruders for Woodfiber-Plastic Composite Applications

Edward L. Steward, Director of Process Technology, American Kuhne, Inc., Norwich, Conn., USA

In the realm of profile extrusion utilizing wood-filled plastic materials, there are a few machinery approaches that have proven successful. Although these machinery setups will be discussed and briefly compared, the single-screw machine being fed pre-pelletized material will be the main focus of the presentation. The best choice for a given installation typically comes down to economics. Both the capital costs and the operational costs are important when selecting the extrusion means. Some of the major processing and equipment comparisons will be discussed. Since no one machinery approach has monopolized this application to date, perhaps different extrusion houses will still decide on different means to get successful profiles from high wood (or other filler) percentages.

Farrel Compact Processor: A Package Solution for Wood and Organic Fiber Composite Profile Manufacturing

Mike R. Kearney, Manager, Process Laboratory, *L.N. Valsamis*, and *Mike F. Hotchkiss*, Farrel Corp., Ansonia, Conn., USA

The Farrel Compact Processor (CP) has long been utilized for thermoplastic polymer compounding. The strength of the CP has been incorporating high levels of non-polymer fillers into a variety of plastic and elastomeric materials. The generous surface area to volume ratio of the CP's continuous mixer lends itself to atmospheric removal of vapors and steam. The CP package includes a single-screw extruder underneath the continuous mixer that is configured for profile extrusion. The continuous mixer uses efficient surface renewal to expose the molten compound at low pressures to a large atmospheric vent in the top of the mixing chamber. Specific operating conditions and mixer rotor geometries have been developed to optimize the moisture removal capability without sacrificing compound quality. The extruder is configured for high-quality profile extrusion of the composite materials. This presentation describes the CP concept for wood composite compounding, moisture removal, and profile extrusion in a unitized mechanical system.

Characterization of Material Properties of Woodfiber-Plastic Composites Exposed to Secondary Manufacturing Processes

Urs Buehlmann, Assistant Professor, *James B. Taylor*, Senior Research Associate, and *Richard L. Lemaster*, Director, Wood Machining & Tooling Research Program, Dept. of Wood & Paper Science, North Carolina State Univ., Raleigh, N.C., USA

Woodfiber-plastic composites are being chosen more frequently as materials and are being used for a wider range of applications. Most research so far has focused on primary production processes needed to produce materials with specific characteristics. This presentation will present results obtained from ongoing research at North Carolina State University about the characterization of woodfiber-plastic composites used in secondary manufacturing applications. Focus will be given to commercially available woodfiber-plastic composites' mechanical properties and machinability.

The Effect of Chemical Foaming Agents on the Processing and Properties of Polypropylene/Woodfiber Composites

Alan Franc, Development Manager, Clariant Additive Masterbatches, Winchester, Va., USA

Chemical foaming agents are materials that have a significant effect on both the processing of polymeric materials and physical properties and appearance of the finished article. Some typical advantages that chemical foaming agents can provide to an extrusion process include reduced melt temperature, increased throughput, and reduced shear and motor torque. Some of the advantages that chemical foaming agents can provide for the extruded article include reduced weight, lower per unit cost due to material savings, increased stiffness to weight ratio, and better dimensional stability and reduced shrinkage. There are several different types of chemical foaming agents, which differ mostly in the type of gas that is generated and the type of reaction that generates that gas. The reaction that produces the gas can either absorb energy (endothermic) or release energy (exothermic). The most common gases generated by chemical foaming agents are carbon dioxide by endothermic foaming agents, and nitrogen by exothermic foaming agents. This presentation will explore the effects of chemical foaming agents on the processing and properties of wood-fiber-filled polypropylene composite lumber. Endothermic, exothermic, and endothermic/exothermic blend chemical foaming agents will be evaluated to determine the advantages and disadvantages of each in the process and resulting properties of the extruded profiles.

Pelletized Woodfiber Composites: An Alternative to Direct Extrusion

Chris Anderson, Sales Manager, North Wood Plastics, Inc., Baraboo, Wis., USA

Woodfiber composites are a fast growing segment in the plastics industry. These new compounds can be processed using extrusion, injection, and even blow-molding equipment. Industry decision makers looking to become players in these new and exciting markets must weigh the merits of purchasing pre-compounded pellets of the composites formulated to meet their needs or investing in complete direct extrusion lines. Direct extrusion, combining woodfiber and resin to make a finished product in a continuous process, is quite unique to the plastics industry. G.O.R. Spa in conjunction with ICMA pioneered the idea in Italy by extruding woodfiber and polypropylene into a continuous sheet. The process was developed in 1973 and brought to the United States in 1983. The sheets are used by the automotive industry as thermal-formed interior panels. In the early 1990s, TREX, Strandex, AERT, Timbertech, and others began developing markets for sales of direct compounded and extruded decking and molding for the building materials industry. As successful as these companies have been, this production technique amounts to a fraction of the plastics extrusion industry. Pre-compounded woodfiber composites became commercially available as a pelletized feed stock in 1996. Research funded by a State of Wisconsin Department of Natural Resources grant plus contributions by industrial members of a joint consumption with the USDA Forest Products Laboratory in Madison, Wisconsin, was adapted on a large scale for mass production. Woodfiber composites are readily available today in base resins of polypropylene, high-, medium-, and low-density polyethylene, polystyrene, ABB, and SAN. Custom-engineered formulations allow processors a variety of product design and economic flexibility. This presentation will discuss the merits of using pre-compounded wood or other natural fibers as raw material for use in conventional thermal-plastic processing systems. Economic models and in depth cost analyses will be used to help maximize returns on investments in order to evaluate purchasing direct extrusion equipment, enhance and support systems as opposed to using the same money to improve existing equipment, and enhance product design and increased market exposure for finished goods. In short, the presentation will help the reader decide whether to expand into a new technology or focus on the company's existing core business.

TUESDAY EVENING, MAY 15

BOOTH 1

Crystallization Morphology of the Semicrystalline Polymer on the Linear Fiber Surface of Woodfibers: In the Different Aspects of Crystallization Behavior

Sang Yeob Lee, Research Assistant/Ph.D. Candidate, and *Thomas M. Gorman*, Professor/Head, Dept. of Forest Products, Univ. of Idaho, Moscow, Idaho, USA; *Michael P. Wolcott*, Research Director/ Louisiana-Pacific Professor, Wood Materials & Engineering Lab., Washington State Univ., Pullman, Wash., USA

The purpose of this study was to evaluate crystallization behaviors of polypropylene (PP) on the linear surface of woodfibers associated with the degree of oxidation. Oxygen and carbon (O/C) ratio on the identical fiber surface was a potential measuring stick for PP crystallization behaviors to induce the nuclei on the surface of kraft pulp fibers and thermomechanical pulp fibers. For the analyzing O/C ratio, a scanning electron microscope-energy dispersive x-ray analysis (SEM-EDXA) system was applied for the surface analysis of raw materials. The different O/C ratios among the eight different fiber surfaces affected the crystallization process without addition of a coupling agent. Most TMP fibers had high O/C ratios and the oxidized surface accelerated crystallization process of 100 percent PP. The thickness of the transcrystalline layer (TCL) and the radius of spherulites were decreased with the increased O/C ratios during the crystal formation process. DMA results showed that the differences among storage modulus (E') as a function of temperature during the solidification process were slightly shifted with the degree of oxidation on the fiber surface. DMA results also show the co-relationship between the growth rate of TCL and increased modulus. At the TCL formation, TMP fibers formed the TCL in a relatively early stage while kraft fibers did not.

BOOTH 2

Effect of Moisture Exposure on Fungal Decay in High-Density Polyethylene Filled with 50 Percent Wood Flour

Vina Yang, Microbiologist, *Craig M. Clemons*, Research General Engineer, and *Barbara Illman*, USDA Forest Products Laboratory, Madison, Wis., USA

Woodfiber-plastic composites are a relatively new class of materials. They are finding applications in various industries. Some wood plastic composites are used as non-structural building components replacing treated wood in exterior environments. This research focused on the effect of moisture exposure on fungal decay of high-density polyethylene filled with 50 percent wood flour. Decay tests were conducted on samples exposed to 35, 70, and 90 percent relative humidity and 80ºF. Two brown rot (*Gloeophyllum trabeum* Mad-617 and *Poria placenta* Mad-698) and two white rot (*Trametes versicolor* Mad-697 and *Phanerochaete chrysosporium* ME-461) decay fungi were used for this study. Changes in weight due to fungal attack and moisture sorption were determined. Scanning electron microscopy (SEM) was employed to examine the composites for fungal penetration. The effect of moisture exposure on fungal degradation and SEM evaluation of the wood-flour/polyethylene composites are reported.

BOOTH 3

Effect of Wood Decay Fungi on High-Density Polyethylene Filled with 50 Percent Wood Flour

Vina Yang, Microbiologist, *Craig M. Clemons*, Research General Engineer, and *Barbara Illman*, USDA Forest Products Laboratory, Madison, Wis., USA

The use of woodfiber-plastic composites has been growing increasingly in the market for construction materials in exterior environments. These products are promoted as more environmentally friendly and as an alternative to pressure-treated wood. However, the susceptibility of fungal decay has not been substantially tested. In this study, we focused on the effect of wood decay fungi on high-density polyethylene filled with 50 percent wood flour. Eleven brown rot and six white rot fungi were selected for evaluation by standard soil block method ASTM D1413-76. Changes in weight due to fungal attack and moisture sorption were determined. Scanning electron microscopy (SEM) was employed to examine the woodfiber-plastic sample for fungal penetration. Our results showed no detectable weight loss during the test period by 17 fungal species. SEM on cross sections of the samples showed that most fungal attacks were on the sample surface and had not penetrated into the center of the sample.

BOOTH 4

Extrusion Foaming of LDPE/Wood-flour Composites Using Chemical Foaming Agents

Qingxiu Li, Ph.D. Student, and *Laurent M. Matuana*, Assistant Professor, School of Forestry & Wood Products, Michigan Tech Univ., Houghton, Mich., USA

Although woodfiber-plastic composites have been commercialized, their potential for use in many industrial applications has been limited because of their brittleness, lower impact resistance, and higher density compared to neat plastics. The potential range of uses for these materials in innovative applications would be expanded if these shortcomings could be improved. Recently, the concept of creating microcellular foamed structures in the composites as a means to improve these shortcomings has successfully been demonstrated. Microcells have been developed in the composites through a batch microcellular foaming process by using carbon dioxide as a foaming agent. Because of the generated microvoids, the impact strength, brittleness, and density of the composites were dramatically improved. These enhancements were achieved without significantly compromising other mechanical properties. Despite these promising results, the batch foaming process used to generate cellular foamed structures in the composites cannot now be implemented in the industrial production of foams because it is not cost-effective. A procedure for continuous manufacture of foamed woodfiber-plastic composites is required for the expanding commercialization of these products and is the focus of this study. The concept of creating cellular structures in the LPDE/ wood-flour composites through a continuous extrusion process will be presented. Each step of extrusion processing with chemical foaming agents (CFAs) will be addressed including the compounding of the composites with CFAs, the characterization of thermal decomposition behavior of CFAs, the bubble growth, and the cell morphology characterization of foamed samples. The experimental results indicate that the density reduction and cell morphology of extrusion-foamed LPDE/wood-flour composites are a strong function of the polymer melting index and the CFA type. With a proper choice of polymer melting index and CFA type (endothermic vs. exothermic), foamed composites with lower density, fine cell size, and higher cell-population density can be achieved through a continuous extrusion process.

BOOTH 5

Green Materials for Automotive Interior Panels

Kristiina Oksman, Project Manager, Natural Fibre Composites, and *Runar Långström*, Swedish Inst. of Composites (SICOMP AB), Piteå, Sweden

The growing environmental awareness and new rules and regulations are forcing the automotive industry to seek more ecologically friendly materials for automotive applications. The demand for lightweight applications is also an important factor leading to the development of green materials. The focus on this project is to study different automotive applications: panels and headliners. The product should be of 100 percent renewable materials including the panel and the surface materials (textile, comfort layers, and adhesives). The majority of the interior materials used today are based on fossil raw materials. Different renewable polymers have been tested as matrix materials: polylacticacid (PLA), cellulose acetate butyrate (CAB), cellulose acetate propionate (CAP), and starch- and lignin-based polymers. The reinforcing fibers for the applications are flax and wood-based fibers. The possibility to manufacture composite materials with known processing methods is also important, and the results, until now, have shown that processing of PLA is similar to other more commonly used thermoplastics such as polypropylene. The processing temperatures and the viscosity are suitable to be compounded with natural fibers. The preliminary results show that the mechanical properties of PLA and flax fiber composites are promising. The composite stiffness and strength are superior compared to PP-flax fiber composites, which are used today in many automotive panels. The study of interfacial adhesion, which is a well-known problem between natural fibers and synthetic polymers, also shows that adhesion needs to be improved to optimize the mechanical properties of the composites.

BOOTH 6

Woodfiber Composites in Sweden

Kristiina Oksman, Project Manager, Natural Fibre Composites, and *Runar Långström*, Swedish Inst. of Composites (SICOMP AB), Piteå, Sweden

The use of woodfiber-based thermoplastic composites has increased enormously in the United States and Japan during the last 5 years. Though Europe has fallen behind in this development, interest is currently increasing. In Sweden, where the development of woodfiber composites started 40 years ago by PRIMO SVERIGE AB, the industry has experienced a rebirth, and several small- and medium-size industries have started to manufacture and/or use woodfiber thermoplastic composites in their products. A consortium including 12 companies has formed with representatives from the whole processing line of woodfiber thermoplastic composites, including SICOMP AB. The participating companies come from the traditional wood industry, recycling/plastics companies, compounders, and manufacturers. This consortium has started a collaboration project called New Woodfiber Composite Products, which is financially supported by The Swedish Agency for Innovation Systems (VINNOVA). The project's goal is to develop new products from woodfiber composite materials and to increase the publicity of woodfiber thermoplastic composites in Sweden and other Scandinavian countries. Other goals are to provide the participating companies with basic knowledge of the processing of woodfiber composites and to give them better knowledge of material properties and how to improve them. SICOMP's role involves project leadership and technical support for the companies. The project is running until 2002.

BOOTH 7

Leather Fiber Provides Added Strength and Lubrication in Plastic Composites

Bruce Krantz, Vice President/General Manager, Hynite Corp., Oak Creek, Wis., USA

Since 1919, Hynite Corporation has been converting scrap leather into an organic fertilizer. For many reasons this product has been losing favor in agriculture. Seeking alternative markets, Hynite recently initiated research through Rensselaer Polytechnic Institute (Troy, N.Y.) to determine the potential of using leather fiber as a structural filler in thermoset phenolic resins. The leather fiber comes from "wet blue" leather scrap generated by local tanneries. It does not contain the dyes, solvents, or other agents found in "finished" leather. This research compares leather fiber to wood flour, cotton, and glass fillers with regard to impact strength, cost, modulus, and other parameters. Leather-filled resins demonstrated significantly greater impact strength than wood-filled resins as well as lower cost. Leather fiber may also provide some fire rating benefits. Although both cooked (hydrolyzed) and uncooked (raw) leather fibers were available, only the cooked fiber was evaluated at this time in this resin. Both cooked and uncooked leather fiber contains 5 to 10 percent moisture and 2-1/2 percent sulfur. The screen size is -30 mesh and the pH = 4 (i.e., acidic). This unique fiber also contains 1-1/2 to 3 percent natural fat and oil, as found in animal hide, which provides process lubrication. The bulk density of uncooked leather fiber (21 lb./ft.^{3}) is half that of cooked leather (42 lb./ft.^{3}). Various laboratory tests are also being conducted to determine the potential use of leather fiber in polyesters, epoxies, and marine coatings.

BOOTH 8

Material Quality of Jute/Polypropylene Composites

David Plackett, Professor, Danish Polymer Center, Technical Univ. of Denmark, Lyngby, Denmark; *Tom L. Andersen*, Researcher, Materials Research Dept., Risø National Lab., Roskilde, Denmark

Jute fibers are of considerable interest for use as reinforcement in polymer composites. This is because jute has excellent specific properties and is available at relatively low cost. It is possible at present to purchase commercial jute fiber mats in Europe for industrial applications or for research purposes. Mats are used in compression molding processes whereas loose fibers are typically used in processes such as extrusion. The use of jute fiber mats in combination with polymer films potentially offers a rapid and simple means of manufacturing composites through film stacking, heating, and press consolidation. This poster describes research in which the quality of jute fiber reinforced polypropylene (PP) composites is being studied as a function of various process parameters. Stacks of jute fiber mats sandwiched between layers of PP film are pre-compressed, hot-pressed under vacuum, and then cooled under pressure. The quality of the resulting jute-reinforced PP can be examined using light microscopy and/or scanning electron microscopy and by measuring fiber content, porosity, and tensile properties. Microscopy has shown that fiber wetting is related to process heating time, and it is possible to obtain total fiber wet-out of 2-mm-thick laminates at heating times under 10 minutes. New composite products and processes can be conveniently and quickly evaluated and optimized by using rapid press consolidation.

BOOTH 9

Manufacture and Properties of Unidirectional Hemp/PP Composites

Tom L. Andersen, Researcher, Materials Research Dept., Risø National Lab., Roskilde, Denmark; *David Plackett*, Professor, Danish Polymer Center, Technical Univ. of Denmark, Lyngby, Denmark; *Bo Madsen*, Ph.D. Student, and *Hans Lilholt*, Senior Researcher, Materials Research Dept., Risø National Lab., Roskilde, Denmark

Plant fiber-reinforced polymer composites have found applications as interior components for automobiles, and there is considerable potential for these materials in other industrial sectors. The focus in northern Europe is on the use of long fibers from plants such as hemp and flax that are particularly suited to the region's climatic conditions. This poster describes recent research in Denmark in which filament-wound hemp yarn was used in combination with polypropylene (PP) film to produce samples of unidirectional fiber-reinforced PP by a film-stacking process. The objective was to better understand the properties of such composites. Material quality of the unidirectional composites was characterized in terms of fiber content and porosity as well as tensile strength and stiffness. Composite tensile strength and stiffness values in excess of 200 MPa and 20 GPa, respectively, were recorded in the longitudinal direction. In contrast, corresponding values in the transverse direction were less than 10 MPa and 2 GPa, respectively. Therefore, although unidirectional hemp yarn provided a 10-fold increase in the tensile properties of PP in the direction of filament winding, tensile properties in the transverse direction were reduced to values below those of the pure PP matrix. The research demonstrated the feasibility of obtaining composites with very good tensile properties in one direction when using hemp yarn. Investigations on improvements to composite properties through fiber surface modification are being pursued.

BOOTH 10

Natural Fiber Surface Modification Using Plasma Treatment

Debes Bhattacharyya, Professor/Head, Dept. of Mechanical Engineering, *Krishnan Jayaraman*, Senior Lecturer, and *Xiao Yuan*, Post-Graduate Student, Centre for Composites Research, School of Engineering, Univ. of Auckland, Auckland, New Zealand

Natural fibers, such as sisal, woodfibers, etc., are abundantly available renewable materials. Recently, environmental awareness of renewable materials and social interest in recycling have provided the impetus for reinforcing thermoplastic polymers with natural cellulosic fibers. The full potential of such composite materials has not been realized due to the often-found poor interfacial bonding between the fibers and the thermoplastic polymers. While chemical treatment of fiber surfaces has been somewhat successful in improving interfacial bonding, there are environmental concerns related to the disposal of chemicals after treatment. Physical treatment of fiber surfaces, such as plasma treatment, is clean and dry and without environmental problems. This presentation will describe the radio-frequency generated plasma treatment of natural fibers and its effects on the interfacial bonding with polypropylene. Argon gas is used to either etch the fiber surface or plant reactive groups on the surface. SEM analyses of the fiber surfaces have shown differences in surface structure between the untreated and treated fibers. The Taguchi method of experimental design with three factors and multiple levels has been used to optimize the treatment parameters in relation to fiber strength and reduce the number of actual experiments. Results show that the principal parameters affecting the results are the treatment time, the input power level, and the working chamber pressure. The variation in uncontrolled factors has little effect on the treatment.

BOOTH 11

Effect of Moisture-Drying Cycling on the Decay Properties of Aspen Fiber High-Density Polypropylene Composites

Rebecca E. Ibach, Research Chemist, *Roger M. Rowell*, Project Leader, and *Sandra E. Lange* and *Rebecca L. Schumann*, Physical Science Technicians, USDA Forest Products Laboratory, Madison, Wis., USA

Aspen fiber-polypropylene composites were prepared with various levels of fiber (0, 30, 40, 50, and 60%), polypropylene (100, 98, 70, 68, 60, 58, 50, 48, 40, and 38%), and the compatibilizer maleated polypropylene, MAPP (0 and 2%). Specimens were either subjected to 10 cycles of 1-week room temperature water soaking-ovendrying, or 2-hour boiling water-ovendrying and thickness swelling, and weight loss was calculated. Specimens were then exposed to the brown rot fungus *G. trabeum* or the white rot fungus *C. versicolor* for 12 weeks to determine the effect of repeated water cycling on decay. Results indicate that as the amount of aspen fiber increases, there is an increase in weight and thickness swelling, as well as an increase in fungal attack after the water cycling tests. Presence of the compatibilizer seems to have an effect on the moisture weight gain, thickness swelling, and attack by fungi.

BOOTH 12

Damage in Woodfiber-Plastic Composites: A Look Up Close and Personal

Suzanne Peyer, Research Associate, and *Michael P. Wolcott*, Research Director/Louisiana-Pacific Professor, Wood Materials & Engineering Lab., Washington State Univ., Pullman, Wash., USA

Wood-filled plastic composites experience significant loss of bending strength and stiffness after exposure to water. Micrographs, from scanning electron microscopy, at the surfaces of the composites revealed damage to the matrix in the form of broad gaps at the interface of the wood particles and surrounding plastic following exposure to water. Gaps between the wood and plastic and cracks present in the wood or plastic prior to exposure to water were much magnified after exposure. Separation between the wood and plastic and induced cracks in the wood and plastic not only reduce the integrity of the composites, but also provide a pathway for further water penetration. Micrographs at the core of the composites did not show the same extent of damage as at the surface. However, given that the outer-most fibers experience the highest strains, it is not surprising that loss of bending strength and stiffness were still substantial.

BOOTH 13

Crystallization Behavior of Maleic Anhydride-Isotactic Polypropylene Blends in Woodfiber-Plastic Composites

David P. Harper, Graduate Research Assistant, and *Michael P. Wolcott*, Research Director/Louisiana-Pacific Professor, Wood Materials & Engineering Lab., Washington State Univ., Pullman, Wash., USA

Maleic anhydride polypropylene (MAPP) has been investigated extensively for its use as a coupling agent in woodfiber-plastic composites. However, the ability of MAPP to impact the crystal morphology and kinetics of crystallization in isotactic polypropylene (iPP)-MAPP blends has gained little attention. In this study three commercially available MAPPs were blended with a commercially available iPP. Crystallization growth kinetics were calculated by means of a polarized microscopy. The results of the growth kinetics study showed no impact on crystal growth rate with the presence of wood for any of the polymer blends and homopolymer. However, the heterogenuous nucleation ability was impacted by some two of the commercial MAPPs. The impact on the nucleation ability also has a direct impact on the thickness of the transcrystalline interphase.

BOOTH 14

Creep and Load-Duration Behavior of Extruded Woodfiber-Plastic Composites

Christopher W. Brandt, Graduate Research Assistant, and *Kenneth Fridley*, Professor, Dept. of Civil & Environmental Engineering, Washington State Univ., Pullman, Wash., USA

One of the important characteristics affecting wood, plastic, and woodfiber-plastic composite products is the time-dependent behavior known as creep. Creep is the increase in deformation over time while subjected to a sustained load. It has a considerable effect on woodfiber-plastic composite products and must be accounted for in design. The load-duration, or creep-rupture, behavior of wood and wood composite products has been studied extensively by numerous researchers, and simplified design to account for creep effects are in place. However, the load-duration behavior of composite products made out of the combination of wood and plastic is not well understood or documented. Currently, woodfiber-plastic composite products are available on the commercial market, yet no standardized design procedure to account for creep or duration-of-load effects exist. An initial approach proposed by code and standards organizations was to create a set of performance criterion that, once met, would allow current design procedures and creep factors for solid sawn lumber to be applied to woodfiber-plastic composites. This approach makes a blanket assumption that all woodfiber-plastic products exhibit load-duration behavior similar to that of wood and wood-based products. Given the lack of understanding of the load duration behavior of woodfiber-plastic composites, a research effort was initiated to investigate the load-duration behavior of various woodfiber-plastic composite products and to compare the observed behavior to that of solid sawn lumber. The results of this experimental study will provide information leading to a better understanding of the load-duration behavior of woodfiber-plastic composite products and will aid in the development of design procedures to account for creep and load-duration effects in woodfiber-plastic composites.

WEDNESDAY EVENING, MAY 16

BOOTH 1

Performance of Woodfiber - Bioderived Plastic Composite Materials

Armando G. McDonald, Group Leader, Material Discovery, *Brendan J. Lee*, *Ross Anderson*, and *Stephanie Weal*, *Forest Research*, Rotorua, New Zealand

Incorporation of natural fibers into commodity plastic is now standard technology to improve the mechanical properties of plastics while reducing cost. However, the use of petrochemical derived plastics is widespread for these types of materials and unfortunately is not a sustainable resource. Alternatively, the use of bioderived thermoplastic materials as a sustainable resource to commodity plastics is a promising option to form fully bioderived composites. This study was focused on evaluating the properties of woodfiber-plastic composites using bioderived plastics (cellulose acetate and polyhydroxybutyrate/valerate), which were compounded in a co-rotating twin-screw extruder. The compounded material was either a calendered sheet or pelletized strand. ASTM test specimens (tensile dog-bones, bending, impact, and water absorption discs) were injection molded or cut from the sheet for evaluation of mechanical properties. Fiber content of up to 40 percent was satisfactorily obtained by blending in the extruder. Blending of woodfibers into plastic was shown to increase the density of the injection molded samples over that of the pure plastic. The tensile strength was shown to decrease with the addition of fiber, while the tensile modulus was shown to increase with the addition of fiber. The flexural modulus was positively influenced by the addition of fiber.

BOOTH 2

The Influence of Esterification Treatments on the Mechanical Behavior of Fique Fiber-Polypropylene Composites

Iñaki Mondragon, Professor of Chemical Engineering, Dpto. Ingenieria Química y M. Amb., Universidad País Vasco/Euskal Herriko Unibertsitatea, San Sebastián - Donostia, Spain; *Piedad Gañan*, Assistant Professor, Grupo de Nuevos Materiales, Universidad Pontificia Bolivariana, Medellin, Columbia

Esterification treatments have been performed for enhancing the compatibility on fique fiber-polypropylene matrix composites. These treatments have been carried out with MAPP, propionic acid (PA), and maleic anhydride (MA). The changes introduced by these treatments on the mechanical and thermal behavior of fique fibers have been investigated. The efficacy of these treatments has been measured by contact angle measurements. The wettability study has been completed with determination of surface free energies. On the other hand, thermal resistance and mechanical properties of the composites have also been studied. Thermogravimetry was employed to obtain thermal behavior of fibers and composites. For mechanical behavior of the untreated and treated fibers, 30 fibers were studied. Mechanical properties of composites were measured according to ASTM D-760. Contact angles were measured by dynamical angle method, using the Wilhelmy plate technique. Fique fiber thermal analysis presents two regions of weight losses: 60º to 105ºC and 220º to 660ºC. The first region corresponds to the moisture absorption. The second region is associated with degradation of fiber components as hemicellulose, cellulose, and lignin. The changes introduced on thermal behavior of the fique fiber by the presence of the treatments are associated with variations on initial and maximum decomposition temperatures of these regions. In the first region, a reduction on the moisture absorption of the treated fibers is observed. Treated composites present a higher thermal stability than that for untreated ones. Tensile strengths of the esterified fibers are lower than that for untreated fibers. These results indicate that the esterification process affects the fiber structure, which is responsible for the fiber mechanical properties. According to results obtained through the wettability study, all esterification treatments reduce the polar contribution of the fiber. An increase on mechanical behavior can be observed by the effect of esterification, above all for the MAPP treatment, whereas for MA and PA, lower differences with respect to composites with untreated fibers exist.

BOOTH 3

Woodfiber-Polypropylene Composites: Effects of Fiber Treatments on the Mechanical Behavior

Rodrigo Llano-Ponte, Assistant Professor of Chemical Engineering, *G. Cantero* and *Aitor Arbelaiz*, Ph.D. Students, and *Iñaki Mondragon*, Professor of Chemical Engineering, Dpto. Ingenieria Química y M. Amb., Universidad País Vasco/Euskal Herriko Unibertsitatea, San Sebastián - Donostia, Spain

This work focuses on the effects of fiber treatments on the mechanical properties of composites made with wood flour (*Pinus insignis*) and polypropylene (WF/PP). Addition of a maleic anhydride polypropylene (MAPP) copolymer and mercerization and their combined action, as well as two different compounding methods, have been investigated. The most effective chemical modifications involve coupling agents capable of reacting with the fibers and the polymer. For the untreated WF/PP composites, the stiffness increases with higher fiber content, whereas the flexural strength decreases. MAPP addition slightly enhances both properties for all fiber contents, with a 2.5 to 5 wt% MAPP providing the best results. On the contrary, mercerization can lead to fiber weakening, thus producing poorer mechanical properties. Otherwise, for outdoor applications of these materials, the influence of weathering action on the mechanical behavior becomes necessary. The investigation includes the analysis of variations on the mechanical properties of these WF/PP composites after exposure to variable cyclic temperature and moisture conditions. Results indicate that these properties are affected upon exposure, but the water uptake over time depends upon the used fiber treatments.

BOOTH 4

Study on the Properties of Various Woodfiber-Plastic Formulations

Wayne Song, Technical Director, Futuresoft Technologies Inc., Mississauga, Ont., Canada

A series of woodfiber-plastic formulations based on various polymers and woodfibers was studied. The objective is to formulate a series of composite materials to substitute some plastic or wood products in a wide range of industries and everyday commodities. First of all, for good extrusion, the pretreatment of woodfibers, including drying, is very important. The surface modification of the fibers was proved to have significant influence on the properties of the woodfiber-plastic composites. More than 50 surface modification methods were studied and it was found that some methods are rather effective to improve the impact strength, tensile strength, and bending modulus of such materials. Various formulations with different kinds and contents of resins, woodfibers, and additives were studied as well, including PE, PP, PVC, recycled plastics, sawdust, rice hull, bonding agents, lubricants, stabilizers, etc. Based on the results of more than 200 formulations studied, it was found that different materials with different properties can be obtained with changed formulations, which can be applied in various traditional plastic processing methods such as extrusion, injection, molding, calendering, and so on. The most distinctive properties of these composites are that they can double the properties of the component plastic resin and the woodfiber. These properties include mechanical properties, resistance to the environment, water, and sunlight, and dimensional stability.

BOOTH 5

Application of Agricultural Residues in Composites

José Cláudio Carashci and *Alcides Lopes Leão*, Dept. of Natural Resources, College of Agricultural Sciences - UNESP, Botucatu, Brazil

The interest in the use of natural fibers has grown during the last decades due to their low costs and the search for renewable sources. Composites with polypropylene (PP), sugar cane bagasse, and other agricultural residues were prepared by an extrusion and injection molding technique. Mechanical properties of the composites were evaluated. The effect of the fiber content and MAPP on the mechanical properties of natural fibers/PP composites was studied. The results showed that the fiber content and coupling agent do influence tensile properties. Results showed that sugar cane bagasse and other agricultural residues can be used as excellent reinforcing materials for low-cost composites, and they are able to match economical and ecological interests.

BOOTH 6

Juniper/Polymer Processing for the Sign Industry

Jim Muehl, Forest Products Technologist, *Andrzej Krzysik*, Scientist, *John A. Youngquist*, Retired, and *Ted Laufenberg*, General Engineer, USDA Forest Products Laboratory, Madison, Wis., USA

Forest Service maintenance personnel have had problems with informational and route signs on southwestern national forests (i.e., freeze/thaw delamination of reflective aluminum sheeting and plywood damage by porcupines). We were contacted by a private sign manufacturer in Mountainair, New Mexico, interested in developing an alternative to the traditional plywood panel substrate for his signs. He was interested in woodfiber-plastic composites as a replacement for plywood. A juniper/plastic sign had the potential to reduce installation and lifetime costs, to be more durable in service, and to be resistant to animal damage compared with those made from aluminum or plywood. We worked with him to develop the process and produce small prototype signs from juniper and plastic. These were installed on the Kaibab and Cibola National Forests for field evaluation to examine the effects of weathering, resistance to gunfire, and damage from animals and insects. As a demonstration project, we have worked with the sign manufacturer to identify equipment for commercial production of signs from juniper woodfiber-plastic composites. A processing plant has been built and equipment installed to start the production of sign panels and posts. He expects that this process will create a number of new jobs: up to 12 in the processing area and 8 to 10 in harvesting and restoration.

BOOTH 7

Effect of Fiber Type and Fiber Modification on Moisture Behavior and Mechanical Properties of Woodfiber-Polypropylene Composites

Riitta Mahlberg, Research Scientist, *Arto Laine*, Senior Research Scientist, *Leena Suomi-Lindberg*, Research Scientist, *Antti Kivistö*, Chief Research Scientist, and *Pirjo Ahola*, Senior Research Scientist, VTT Building & Transport and VTT Chemical Technology, Espoo, Finland

The use of by-products of the wood industry as reinforcing fillers in woodfiber-plastic composites was evaluated. The by-products such as cutter particles, wood-wool, wood flour, sawdust, or flakes were mixed with polypropylene (PP) (compounding ratio: 30% wood material, 70% PP) followed by injection molding to tensile test bars. Maleic anhydride grafted polypropylene (MAPP) was used as a coupling agent. Mechanical properties such as tensile strength, E-modulus, tensile toughness, and impact strength of the specimens were determined. The mechanical properties and appearance of the composites were influenced by the origin, shape, and size distribution of the wood material. Dimensional stabilization of the reinforcing fillers might be feasible, especially in composites with a high woodfiber content. Test specimens made of chemically or thermally modified fibers and polypropylene were immersed into water for 10 days and tested for dimensional stability and wet tensile strength. The chemical modifications of the fiber material included treatments with acetic anhydride or with a mixture of maleic acid and glycerol (MG). Modification of the fibers resulted in reduced water absorption and swelling of the test specimens. The effect of the acetylation and thermal treatment of the fibers on the moisture behavior of the specimens was more pronounced than that of the MG treatment.

BOOTH 8

Thermal Degradation of Resol/Vegetable Fibers Composites

María M. Reboredo, Professor/Researcher, *Mirta I. Aranguren*, Associate Professor, and *Claudia N. Zarate*, Master Student, Facultad de Ingeniería / INTEMA, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina

Phenolic resins are fire resistant materials with low smoke emission and low toxicity, hence they exhibit very favorable flame retardant characteristics under fire conditions. Its rigid three-dimensional structure resists thermal stress and facilitates the formation of a high-carbon foam structure (char) that radiates heat and functions as an excellent heat insulator. When vegetable fibers are added in a phenolic matrix, its thermal behavior is modified. In this work, a phenolic resin (resol), different vegetable fibers (cotton, sisal, and sugar cane bagasse), and their composites (with different fiber volume fractions, V_f) have been analyzed by thermogravimetry analysis (TGA). Pure resol was heated up to 1,000ºC and showed three stages: 1) up to 250ºC, where water and unreacted monomers were released; 2) between 425º and 550ºC, with random chain scission and emission of several gaseous components; and 3) about 775ºC, with an increase of density due to material shrinkage. Fibers analysis was performed up to 500ºC. Cotton fibers showed the lowest residual weight percent, compared with sisal and sugar cane bagasse. This could be attributed to the chemical composition: cotton is mainly cellulose and the others also contain lignin, hemicelluloses, and derivatives. Composites behaved according to the results obtained for the components alone. The lowest residual weight percent was found for cotton composites. Since the resol capability of leaving a char during pyrolysis is larger than that of the fibers, it was found that as V_f increases, the residual weight percent of the composite decreases. Based on this observation, TGA could provide a qualitative measure of the percentage of fiber in a resol composite material.

BOOTH 9

Effect of Maleated Polyolephin Copolymer and Lubricant in Wood-Polyolephin Composites

Mohammed J. A. Chowdhury, Post-Doctoral Fellow, and *Michael P. Wolcott*, Research Director/Louisiana-Pacific Professor, Wood Materials & Engineering Lab., Washington State Univ., Pullman, Wash., USA; *Timothy G. Rials*, Project Leader, Southern Research Sta., USDA Forest Service, Pineville, La., USA

Composites are extruded with blends of maple wood flour, maleated polyolephin copolymer, lubricant, and high-density polyethylene. Maleated copolymers are added to aid filler dispersion and interfacial compatibility between filler and matrix. Lubricants are included to aid processing. Selected mechanical and physical properties of the extruded composites are determined. In the presence of some maleated copolymers, the composites showed superior mechanical properties and better dimensional stability. The extent of improvement in mechanical and physical properties depends on the type of copolymers. Lubricants are found to decrease the action of the maleated copolymers. The crystallization behavior of polyolephin/maleated copolymer/lubricant blends in the presence of wood are thermally characterized using dynamic mechanical analysis and differential scanning calorimetry.

BOOTH 10

The Influence of Maleation on Wood Surface Wettability and Interfacial Bonding Strength in Wood-PVC Laminates

John Z. Lu, Graduate Research Assistant, and *Qinglin Wu*, Associate Professor, School of Forestry, Wildlife & Fisheries, Louisiana State Univ. Agricultural Center, Baton Rouge, La., USA

Surface wettability of maleated wood veneer samples and its influence on interfacial bonding strength of wood-PVC laminates were investigated in this study. Two maleated polypropylenes (MAPPs), Epolene E-43 and Epolene G-3015, were used to treat yellow poplar veneer samples. The retention rate of coupling agent, static contact angle on treated samples, and shear strength of resultant wood-PVC laminates manufactured under hot pressing were measured. It was shown that the retention of the coupling agent increased with the increase of coupling agent concentration in the treating solution. The relationship between the retention and concentration was linear for G-3015 and curvilinear for E-43. Maleation treatment greatly improved the compatibility and interfacial adhesion. The veneer samples treated with these two MAPPs presented different wetting behaviors. For the wood samples treated with G-3015, measured static contact angles varied from 110 to 120 degrees. The retention rate of G-3015 did not have a significant influence on the contact angle. For the samples treated with E-43, the contact angles varied from 60 to 90 degrees and decreased as the retention rate of E-43 increased. Compared with controls made of untreated wood and PVC, shear strength of the maleated wood-PVC laminates increased over 20 percent on average. Accordingly, the retention rate of MAPP, contact angle, and shear strength were related to graft rate, acid number of MAPP, polarity of treated veneer samples, and extractives in wood. There was no direct correlation between measured contact angle and shear strength. Thus, larger contact angle values do not necessarily ensure a strong interfacial bonding of resultant composites.

BOOTH 11

Static and Dynamic Properties of Cellulose Whiskers

R. Borsali and *M. Miriam De Souza Lima* (also Maringa Univ., Maringa, Parana, Brazil), Laboratoire de Chimie des Polymères Organiques, LCPO - ENSCPB, Bordeaux Univ. I, Talence, France

This poster presentation will describe the structure and the dynamics of microcrystal cellulose whisker suspensions. These rod-shaped particles are obtained from tunicate (a marine animal). New results on fractionated systems (L = 0.9 µm and d = 10 µm; where L and d are the length and diameter, respectively) using scattering techniques will be presented. In these studies, we have particularly highlighted the effects of electrostatic interactions (polyelectrolyte effects) on the structure (long range order) and the dynamics (diffusion coefficient, *D*) of these colloidal particles.

BOOTH 12

The Effect of Interfacial Interactions on the Mechanical, Viscoelastic, and Flow Characteristics of Cellulose Fiber Reinforced Polymer Composites

Abi Santhosh Aprem, Senior Research Fellow, and *Sabu Thomas*, Professor, School of Chemical Sciences, Mahatma Gandhi Univ., Kottayam, Kerala, India

In recent years, cellulose fibers have been increasingly used for the manufacture of cost-effective composite materials from thermoplastics, thermosets, and rubbers. Cellulose fibers, which originate from renewable resources, are interesting alternatives to mineral fillers. Their low cost, low density, high specific stiffness, biodegradability, and recyclability constitute the major incentives for their use. The properties of composites depend on those of the individual components and on their interfacial compatibility. The stress transfer at the interface between two different phases is determined by the degree of adhesion. A strong adhesion at the interface is needed for an effective transfer of stress and load distribution throughout the matrix. Therefore, the modification of the interface is a key area of research at present, to obtain the optimum properties of the composites. The interaction of cellulose fiber with a series of polymer matrices has been considered. Polymer matrices such as LDPE, PP, PS, polyester, phenolic resins, epoxy, and natural and various synthetic rubbers have been selected. The fiber surfaces have been modified by a series of chemical treatments such as sodium hydroxide, acetylation, benzoylation, coupling agents, permanganate, monomer grafting, and isocyanates. The treated surfaces have been characterized by spectroscopy, solvatochromism, zeta potential measurements, and microscopy techniques. The role of fiber/matrix interaction on the mechanical, viscoelastic, and rheological properties have been analyzed in detail.

BOOTH 13

Composites Materials on Basis Products Esterification of Wood

M.V. Efanov and *L.A. Pershina*, Professors, Altai State Univ., Barnaul, Russia

Acetylated wood, lignin, and cellulose were used in varying proportions as a binder for the manufacture of composite panels made with an aspen sawdust furnish. Panels were made using 10 to 30 percent binder and pressed at 5 MPa pressure at press temperatures ranging from 120º to 180ºC. The proportion and type of acetylated binder had a considerable influence on the properties of the panels, as did press temperature, but in general the panels exhibited good physical and mechanical properties.

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NOTES

FOREST PRODUCTS SOCIETY

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