Wednesday, September 7

— IN ONYX ROOM —

SESSION 1: Bonding, Joining & Finishing - Part 1 of 3: *Adhesion & Finishing*

Andy Stecher, Plasmatreat North America

Enhancing the Bonding of Dissimilar Materials with Atmospheric Plasma

Recent automotive industry trends include a focus on weight and cost reduction. The development of new composite materials have increased the likelihood that dissimilar materials will need to be joined, sealed, or bonded together. Such combinations can present significant challenges to achieving proper adhesion and can result in failures leading to substantial costs. This presentation examines the use of atmospheric plasma for surface conditioning in order to enhance the bond between adhesives and sealants to composites and other materials. Atmospheric plasma improves adhesion by removing organic contaminants that reduce electrostatic and mechanical forces, and by increasing the functionality of composite surface chemistry. Empirical data and examples of high-value, high-volume automotive applications that have been enabled by the use of atmospheric plasma surface conditioning will also be discussed.

Raymond Sanedrin, Krüss USA

Why Test Inks Cannot Tell the Full Truth About Surface Free Energy

Adhesive bonding has been the tool of choice for connecting metals, plastics, or other materials of interest. Extensive pre-treatments such as cleaning, surface roughening, or plasma activation are typically applied to these materials prior to the gluing process in order to improve the wettability of glue to the surfaces of a material. To monitor the efficiency of the pretreatment, the surface free energy (SFE) of the substrate is typically measured. In many cases, dyne inks are used to determine the total SFE following the assumption that a surface having an SFE value above a certain threshold is already sufficiently pre-treated for subsequent adhesive bonding. It is well known, however, that SFE is more than one single value and its distribution into polar and disperse constituents is essential if wetting and long-term adhesion are to be characterized. In contrast to dyne inks, contact-angle measurements determine the polar and disperse contributions to the SFE. In a thorough experimental study, SFE values of various materials were determined using different types of dyne inks and contact-angle measurements. Results were compared to illustrate advantages and drawbacks of each technique. This presentation also will explain why for some materials the test inks and contact-angle measurements yield different results.

Shan Gao, Western University

Powder Coating of Underhood Plastic Components

The application of powder-coating technology during processing of plastic substrates has many advantages. However, the conventional electrostatic coating process used with metals is not easily applied to plastics, which are inherently non-conductive. In this presentation, the powder coating technique is applied to processing long-fiber thermoplastics. This research describes a process for coating the long-fiber thermoplastics by preheating the work piece to the temperature between 120º-160ºC, then coating with a corona spray gun. Three common powder coatings (polyester, epoxy, and hybrid) have been tested and show promising results. In addition, infrared curing has been used to aid the curing process of low-cure epoxy. Experimental results showed that by preheating the plastic substrate, the powder deposit has been greatly improved, resulting in better finishes. The surface conditions are further evaluated for gloss, depth of image (DOI), and haze.

SESSION 5: Bonding, Joining & Finishing - Part 2 of 3: *Welding & Bondline Issues*

Michael Barker, Ashland Inc.

Lightweighting with Composites: Adhesive Properties and Initial Bond Line Read Through Measurements

Regulations mandating improved automotive fuel efficiency and reduced carbon emissions have accelerated the need for lighter weight vehicles. The resultant use of thinner gauge composites for exterior body panels to achieve weight reduction has put renewed focus on the need to understand the causes and mitigation of adhesive bond-line read through (BLRT). This presentation will review and question the fundamental causes of BLRT in view of both laboratory data and finite-elemental analysis from a design, adhesive, and process perspective. Several key constitutive properties such as adhesive elongation, modulus vs. temperature, coefficient of thermal expansion, and percent reaction will be examined through formula manipulation for their respective contributions to surface deformation.

Akio Ohtani, Kyoto Institute of Technology

Effect of Energy Director on Welding State of Ultrasonic Welding for c-FRTP

In this study, ultrasonic welding was adopted for woven fabric-reinforced thermoplastic composites, and the effect of welding conditions for ultrasonic welding on joint properties was examined. In addition, the effect of insertion of resin materials with different forms (e.g. film, and mono-filament woven mesh shape) inserted between specimens on welding properties was investigated and also will be discussed.

Sarah Stair, Baylor University
2013-2014 SPE ACCE Scholarship Winner
Investigation & Identification of the Bondline between a Carbon Fiber Reinforced Laminated Composite and a Metal Structure via Ultrasonic Techniques

Incorporating carbon fiber-reinforced laminated composites into traditionally metal components and assemblies often leads to bondlines between two dissimilar materials. To ensure the quality of the bondline, a nondestructive evaluation method is needed. The present study focuses on ultrasonic inspection methods for evaluating the bondline between a woven carbon fiber-reinforced laminated composite and an aluminum plate.

— IN OPAL/GARNET ROOM —

SESSION 2: Opportunities & Challenges with Carbon Composites - Part 1 of 2: *B-Class & Recycled Fibers*

Hiroyuki Hamada, Kyoto Institute of Technology
Utilization of B Class Carbon Fiber in Composite Materials

Carbon fiber (CF) reinforced polymer composites were fabricated by the direct fiber feeding injection molding (DFFIM) process. Three polymer matrices were used, including polyamide 6/6 (PA 6/6), polypropylene (PP), and polycarbonate (PC). Two types of commercial treated CF (standard CF (CF-A) and a non-standard CF (CF-K)) were applied in this research. Additionally, the CF-K was desized to remove its surface treatment. The effect of fiber types and the desizing on tensile properties and morphology of the composites was investigated. The desizing of fiber promoted fiber dispersion, reduced fiber agglomeration, and improved adhesion between fiber and the matrix.

Frazer Barnes, ELG Carbon Fibre
The Role of Recycled Carbon Fibres in Cost Effective Lightweight Structures

Recent years have seen the development of commercial operations for the recovery of high-grade carbon fibers from manufacturing and end-of-life wastes. Two challenges faced by this developing industry are the conversion of recovered fibers into usable product forms and the acceptance of these products by the market. This presentation describes the development and testing of recycled carbon fiber products that have the potential to enable cost effective, lightweight structures in transportation. The products were reinforced thermoplastics designed for injection molding and nonwoven textiles designed for composites manufacturing. The technical performance of these materials is compared with current materials, and the economic and environmental benefits are highlighted. Finally, the challenges that have still must be addressed before the materials become widely accepted in the market are discussed.

SESSION 6: Virtual Prototyping & Testing - Part 1 of 4: *Woven Composites & Draping*

Paul Van Huffel, Altair Engineering
Composite Draping to Enhance Structural Analysis

With composite analysis and optimization on the rise, the accuracy of assumptions are becoming more and more important to product development. In the case of woven fiber composites with organized fiber orientations, the need for accuracy in the orientation definition in finite element models early on in development is critical. There are 2 ways this can be established. Either the forming process for the fiber composite can be explicitly simulated and the results used to condition a model for product performance simulation, or a drape estimating program can be employed to implicitly calculate and set the fiber orientations. This presentation will cover both methods and compare the net predictions for a B-pillar model with impact and normal modes simulations.

William Rodgers, General Motors Co.
Draping Simulation of Woven Fabrics

Woven fabric composites are extensively used to mold complex geometrical shapes due to their high conformability compared to other fabrics. During preforming, orientation of the yarns may change significantly compared to the initial positions. This paper presents a systematic investigation of the angle changes during the preform operation for carbon fiber-reinforced twill- and satin-weave fabrics.

Chris Boise, Baylor University
2015-2016 SPE ACCE Scholarship Winner
Construction and Implementation of a Material Independent Finite Element for use in Orthotoropic Stiffness Tensor Prediction of a Woven Fiber Composite Lamina

As woven fabric composites become more popular in the aerospace and automotive industries, it becomes important to understand how various fiber reinforced laminated composites react to structural loadings. This presentation discusses a method to obtain the effective stiffness tensor of a woven fiber composite lamina through finite element analysis (FEA) of a representative volume element (RVE) through the use of a novel approach that allows individual finite elements to contain multiple materials. Typical meshing within the RVE is complicated by the undulation of the fiber tows within the RVE, and this presentation introduces a unique formulation of a finite element that allows meshing to be performed independent of the woven geometry within the RVE. The results presented in this work demonstrate the method for a woven fabric geometry similar to that found in many glass and carbon fiber laminates. Preliminary results for the stiffness tensor components show very-good agreement with results obtained doing the full geometry dependent analysis using a commercial software package. In all cases, the proposed method is either better than or equal to alternative material independent elements.

SESSION 10: Virtual Prototyping & Testing - Part 2 of 4:

Benedikt Fengler, Karlsruhe Institute of Technology

Application of a Multi Objective Optimization Approach for Continuous Fiber Tapes in Hybrid Composite Structures

Optimization tools generally require problem-specific strategies to find the best solution. As part of the product development process, a commonly used optimization objective is to achieve the maximum stiffness for a component with a given material and design space. For lightweight applications, the combination of multiple material types offers additional optimization potentials. In this work, a combination of discontinuous and continuous fiber-reinforced polymers is used, where position, geometry, and orientation of the reinforcing continuous fiber tape needs to be optimized. Standard optimization tools hardly consider manufacturing constraints and, thus, often find product solutions that are impractical to manufacture. Furthermore, usually either only 1 objective function at a time can be set as the optimization target, or weighting function are used that influence the optimization results. In the presented work, an optimization method is introduced that considers manufacturing constraints like distances to boundaries and available patch widths during the optimization process. Beside these constraints, a geometric draping simulation is implemented to calculate the deformed tape geometry and position, for each iteration step. An evolutionary algorithm allows consideration of both arbitrary manufacturing constraints and multiple objectives during an optimization run. The resulting Pareto front provides a basis for the decision of the final tape design. Therefore, the proposed approach combines an evolutionary algorithm with a structural simulation in the finite-element software. The proposed optimization strategy is demonstrated by an example hybrid composite structure.

Michael Doyle, Dassault Systèmes

Progress on Light-Weight Automotive Materials

This presentation will discuss a product focused on materials science, both the virtual and the real. Technologies from the product's science portfolio such as *ab-initio* quantum mechanics models, atomistic, polymer, and mesoscopic models can be applied to critical intersections of materials nature, design, and manufacturing. Linking materials performance across length and time scales is a critical element of such an endeavor and is well underway from the microscopic regime to the macroscopic finite element domain. Inclusion of chemical and materials nature across all levels of the composites and plastics product lifecycle is a game-changing capability

— IN EMERALD/AMETHYST ROOM —

SESSION 3: Advances in Thermoplastic Composites - Part 1 of 5: *High-Volume Applications*

Ji Hwan Choi, Hanwha Advanced Material Co.

Development of Automobile Front Bumper Beam using CFRP and GMT

There has been a recent rise in applications of carbon fiber-reinforced plastic (CFRP) applications in the automotive industry to improve fuel efficiency. A hybrid bumper beam system consisting of CFRP and glass-mat thermoplastic-(GMT)-based materials has been manufactured for Hyundai Motors. If this process is introduced to the front bumper beam, the weight of front beams can be significantly reduced. In this presentation, a front beam concept combining CFRP and GMT will be described. This beam results in significant weight savings (11.3%). To satisfy high performance, this hybrid system has been evaluated through LS-DYNA-based CAE simulation as well as actual tests of 40% offset barrier and NCAP Cart Impact at 25 km/h and 35 km/h with a rigid barrier.

Tomasz Czarnecki, EconCore N.V.

Continuous Production of Thermoplastic Honeycomb Sandwich Components for Automotive Interiors: Low Weight – Low Cost Technology

To address the challenge of providing lightweight material solutions at acceptable costs, unique technology has been developed that allows for continuous production of lightweight thermoplastic honeycomb cores. This technology allow for integrated lamination of a variety of skin layers to core, resulting in strong, lightweight sandwich panels. The technology is especially useful for cost sensitive, high volume applications using high speed processes.

Queein Månson, EELCEE Ltd.

High-Volume Manufacturing of Composite Door Module by a Novel 3D-Preform Technology

The technology discussed in this paper enables complex 3D shaping of preforms, which considerably reduces cost and time for high-rate processing of thermoplastic-based composites. Both the manufacturing approach and the design freedom offered by this preform technology and its full 3D design and molding capabilities will be demonstrated for a car door module currently under development with major supply-chain partners.

SESSION 7: Advances in Thermoplastic Composites - Part 2 of 5: *Emissions, FR, & Tailored Fiber Placement*

Tanmay Pathak, A. Schulman

Low Emission Polypropylene Composites for Automotive Interiors

Low-emission products are highly sought after in the automotive industry for interior applications that measure odor and fog, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). This presentation will focus on new glass- and mineral-filled composites that have been developed to meet the regulatory requirements for VOCs and SVOCs in GMW and VW specs. This was accomplished through a careful selection of base polypropylenes, additives, and compounding technology and will be presented in this work.

Ruomiao "Grace" Wang, Hanwha Azdel

Self-Extinguishing Light Weight Reinforced Thermoplastic Composite

A recent development to make a polyolefin-based light weight reinforced thermoplastic (LWRT) composite self-extinguishing will be discussed. By adding expandable graphite as a flame-retardant additive, the LWRT composite shows self-extinguishing performance when tested by the SAE J369 method. The new self-extinguishing LWRT composite maintains its mechanical performance and molding characteristcs at the same level as a standard LWRT.

Hironori Nishida, Doshisha University

Development of Automatic Placement Machine for CFRTP Tapes Using Machine Stitching

An advanced automated tape placement (A-ATP) method was developed by using a modified, inexpensive industrial embroidery machine. The method can reduce the initial cost compared to other expensive ATP machines. In order to confirm the effect of the A-ATP, a 3-point bending test was conducted for unidirectional (UD) laminates using CF/PA6 tapes. The flexural properties of the stitched UD laminates were almost the same as those of UD laminates fabricated using the conventional CF/PA6 sheets under the same fiber volume fraction.

SESSION 11: Advances in Thermoplastic Composites - Part 3 of 5: *Lightweighting with LFT & D-LFT*

Christoph Kuhn, Volkswagen AG

2016 Best Paper Award Winner

Lightweight Design with Long Fiber Reinforced Polymers – Technological Challenges due to the Effect of Fiber Matrix Separation

During the processing of long fiber-reinforced thermoplastics (LFT), various long fiber-specific effects occur that can have significant influence on final component properties. A major effect that results when processing LFT is fiber matrix separation (FMS), which leads to a non-uniform fiber density distribution throughout the part. The development and impact of this effect is not thoroughly examined. Experimental investigations with compression molded LFT materials have shown an unequal distribution of fiber content with increasing fiber length. With effects already visible in free flow regions, FMS especially leads to significant changes in fiber content in complex geometries like ribs, where fiber content decreases greatly, leading to a significant change in component behavior. Furthermore, extensive fiber bundling and clogging is observed at the rib entrance. This presentation will describe recent work in this area.

Russell Goering, Addcomp North America Inc.

Progress on Light-Weight Automotive Materials

Glass-microbubble-filled thermoplastic composites show promise in automotive lightweighting due to uniformity of distribution, low processing sensitivity, and potentially good retention of physical properties. New advances in formulating and processing glass bubbles into polyolefin- and nylon-based composites are reported.

Ying Fan, Western University

2016 Best Paper Award Winner

Effects of Processing Parameters on the Thermal and Mechanical Properties of D-LFT Glass Fiber/Polyamide 6 Composites

In this work, the influences of the process parameters (i.e. melt temperature, extruder fill level, glass fiber (GF) temperature and screw speed of the mixing extruder) on the thermal and mechanical properties of dry, as-molded materials were investigated. The material system of focus is 30 wt% GF reinforced polyamide 6 (PA 6) manufactured via the direct (inline compounded) long fiber thermoplastic extruder compression molding (LFT-D-ECM) process. Characterization by tensile, flexure, and impact tests on samples cut in both the flow and cross-flow directions was carried out. Glass transition temperature, which plays an important role in the properties and failure mechanism of PA 6 composites, was examined using dynamic mechanical analysis (DMA) and the degree of crystallinity was measured by differential scanning calorimetry (DSC). Fill level and melt temperature were observed to play the greatest role in determining the properties of the composite. The effects of processing parameters on glass transition temperature, melting temperature, and the relative degree of crystallinity values of composites are presented.

— IN PEARL ROOM —

SESSION 4: Additive Manufacturing & 3D Printing - Part 1 of 2:

Robert Gorham, National Center for Defense Manufacturing and Machining (NCDMM), America Makes

Smart Collaboration: America Makes - Adventures in Public Private Partnerships

America Makes, driven by the National Center for Defense Manufacturing and Machining (NCDMM), is the national additive manufacturing institute with over 170 member organizations that include industry, academia, government, and makers across the country that, together, are innovating, accelerating, and advancing 3D printing. To answer this charge, the institute is developing a National Additive Manufacturing Roadmap and Investment Strategy that link economic opportunities and potential products/services with the development of proper technologies to support future needs not only of membership but also industry at large. In this presentation, roadmap version 2.0 will be presented with technical areas of focus for design, process, materials, value chain, and additive manufacturing genome being discussed.

Rajasundar Chandran,
École Polytechnique Fédérale de Lausanne (EPFL)

Non-Isothermal Fusion Bonded Soft/Hard Interfaces for Thermoplastic-Based Materials

Although fused deposition modeling (FDM) is of great interest for the cost-effective manufacture of polymer parts with complex, customized geometries, it currently provides insufficient mechanical integrity to produce high-performance functional structures, and is restricted to too limited a range of materials. The present work is aimed at investigating the suitability of new combinations of hard and soft thermoplastics for FDM. To this end, nonisothermal fusion bonding of polypropylene (iPP) and a thermoplastic elastomer (TPE) with a continuous plasticized iPP matrix was investigated by overinjecting the TPE onto a solid iPP insert. The influence of temperature and pressure was evaluated by tensile testing of butt joint specimens, and optical and electron microscopy. Results are discussed in terms of the interfacial morphology and the dominant bonding mechanisms in each case.

SESSION 8: Additive Manufacturing & 3D Printing - Part 2 of 2:

Douglas Smith, Baylor University

Continuous Fiber Angle Topology Optimization for Polymer Composite Fused Deposition Modeling

Mechanical properties of parts produced with the fused filament fabrication (FFF) process are known to be dependent on the printed bead direction, especially when short carbon fiber reinforcement is added to the filament. Given that many FFF filament suppliers now offer carbon fiber-filled products, a unique opportunity emerges in the design of polymer composite FFF parts since bead and fiber direction can potentially be prescribed to give the best structural performance. As FFF moves from a technology for rapid prototyping and the hobbyist to a viable additive manufacturing method, it is important to also have a design tool that takes advantage of the opportunities that present themselves when polymer composites are employed. This presentation discusses a topology optimization method for continuous fiber angle optimization approach (CFAO), which computes optimal material distribution (as in the well known SIMP method) in addition to a preferred fiber angle direction by minimizing compliance of statically loaded structures. Future work includes extension of the method to 3-D structures for further application.

Ron Rogers, e-Xstream engineering

Holistic Multiscale Simulation Approach for Additive Layer Manufacturing of Plastics

Additive layer manufacturing (ALM) of plastics has been rapidly developing over the last few years, notably with unreinforced- and reinforced-plastics applications. To ensure competitiveness of the additive manufacturing process, some requirements must be met, such as repeatability of process and part performance, and addressing the needs of high performance industrial applications. Inherent complexity of additive manufacturing calls for a need for simulation tools to unveil the full potential offered by this manufacturing technology, allowing engineers to be able to predict the effect of any parameters on process and part performance. A holistic simulation approach is presented covering process, material, and structural engineering for both SLS and FFF applications. Finally, a procedure will be demonstrated to allow prediction of as-manufactured plastic part performance via strongly coupled process-structure simulation approaches that ultimately open the door to optimization of part performance prior to physical prototyping.

Blake Heller, Baylor University

Computing Mechanical Properties from Orientation Tensors for Fiber Filled Polymers in Axisymmetric Flow and Planar Deposition Flow

Fused filament fabrication (FFF) is quickly becoming an industrially viable additive manufacturing (AM) method that produces economical and intricate 3D parts. The addition of discrete carbon fibers to the polymer feedstock has been shown to improve mechanical properties and the quality of the printed part. The improvement in mechanical properties is directly dependent on the fiber orientation state in the deposited polymer. To calculate the decoupled fiber orientation state, the flow field must be evaluated for the extrusion process. The mechanical properties of the extruded fiber-filled composite are shown to be substantially affected by the abrupt changes in the flow field due to extrudate swell and melt deposition.

SESSION 12: Advances in Reinforcement Technologies - Part 1 of 1:

Hiroyuki Hamada, Kyoto Institute of Technology

Development on Fabrication and the Mechanical Property of Hybrid-SMC

Sheet molding compound (SMC) is used for structural composites. Generally, the mechanical properties of SMC reinforced with glass fiber (GF) are relatively low, so SMC with carbon fiber (CF) has been developed. This research focused on developing a new hybrid SMC consisting of continuous woven fabrics sandwiched by chopped fiber strands. This new SMC is called Hybrid-SMC. Composites from GF-SMC, CF-SMC and hybrid-SMC were compression molded and then their flexural properties were measured. This presentation describes the results of the study.

Gleb Meirson,
Fraunhofer Project Centre for Composites Research

Basalt Fiber and its Application to Structural Composite Design

The current market for composite materials is growing at an incredible rate given the ability of these materials to enable efficient, lightweight design. For structural applications, the current material selection focuses on glass and carbon fibers, which operate at extreme ends of the performance and cost scales. Basalt fiber is an intermediate offering in terms of both performance and cost, with the potential to excel in flexure and energy absorption applications for both thermoplastic and thermoset applications. When applied to the high-pressure resin transfer molding process, the basalt fiber is shown to have properties exceeding those of a similar glass-based composite. The basalt-reinforced composite has a specific strength that is ~50% higher and a specific stiffness that is ~25% higher than the glass-reinforced composite. A new engineered fiber is presented as an alternative to currently available selections for high-volume applications.

Asami Nakai, Gifu University

Fabrication of Thermoplastic Composites with Partially-Impregnated Commingled Yarn as New Intermediate Materials

Continuous fiber reinforced thermoplastic composites (CFRTP) have been attractive material systems due to their recyclability and secondary processing in recent years. However, impregnation of thermoplastic resin into fiber bundles is difficult because of the continuous fiber and the high viscosity of the matrix resin. In order to solve this problem, commingled yarn, which was the intermediate material for CFRTP has been developed. Commingled yarn was the superior intermediate material in terms of impregnation and textile workability, but the misalignment of carbon fibers sometimes occurred because of resin shrinkage during molding. To solve this problem as well as improve impregnation and mechanical properties, partially-impregnated commingled yarn (PCY) was developed. PCY is a new intermediate material in which polymer fiber from commingled yarn is melted and used to impregnate a portion of the matrix.

– IN DIAMOND BALLROOM –

KEYNOTE 1

Craig Blue, Institute for Advanced Composites Manufacturing Innovation (IACMI)

IACMI – The Composites Institute: Progress, Roadmap and Opportunities

The need to reduce CO_2 emissions and improve fuel economy is providing an impetus for developments in lighter weight materials and alternative powertrains. In order to realize commercial application in mass produced vehicles for advanced composites, costs and cycle times both need to be reduced. Further, end-to-end simulation tools need to be integrated, validated, and made widely available to speed development time and improve confidence in the ability to predict as-built performance. The Institute for Advanced Composites Manufacturing Innovation (IACMI) is integrating materials, manufacturing, and simulation development concurrently in order to aggressively meet the needs of the automotive industry for hybrid and composite-intensive vehicle structures. This presentation will review the progress made after the first year of operation, including key activities currently underway, and the roadmap for future work. Key technology needs will be presented as well as opportunities for the entire supply chain to be integral to the success of the institute and the composites industry.

KEYNOTE 2

Rick Neff, Cincinnati Inc.

BAAM - Big Area Additive Manufacturing - Using Reinforced Plastics to Drive Innovation in Big 3D Printing

One of the latest and certainly one of the biggest innovations in additive manufacturing technology is the development of big area additive manufacturing (BAAM). Oak Ridge National Laboratory (ORNL) and Cincinnati Inc. have collaborated to prototype a very-large 3D printer. This additive manufacturing machine is big enough to print furniture, a car, and even a house in a very reasonable amount of time. The timeline of the development will be explored from the CRADA process through to a number of ground-breaking projects, and industry and government partners introduced technology challenges that earned a lot of publicity in the manufacturing world. Additive manufacturing is no longer just for prototyping and is truly migrating to production of some products.

Thursday, September 8

– IN ONYX ROOM –

SESSION 13: Advances in Thermoset Composites - Part 1 of 3: *Epoxy Systems*

Gleb Meirson, Fraunhofer Project Centre for Composites Research

Recyclable High Pressure Resin Transfer (HP-RTM) Molding Epoxy Systems and their Composite Properties

Implementation of composites in automotive manufacturing is driven by cost reduction. High-pressure resin transfer molding (HP-RTM) allows part manufacturing cycle time to be as low as a few minutes, helping to lower costs. However, the thermoset materials used in HP-RTM are not recyclable, which is damaging to the environment and increases production costs. A new series of epoxy curing agents have been developed that enables the manufacture of recyclable thermoset products. In the present work, manufacturing of epoxy/carbon fiber preform panels is described. Following a subsequent processing, the epoxy used in production was recycled and the carbon fiber reused. Mechanical testing was done and the results will be discussed.

Peter Dijkink, Alzchem AG

New Liquid Latent Epoxy Hardeners for Automotive RTM Applications

Much development work in recent years has focused on the resin-transfer molding (RTM) process for producing carbon fiber-reinforced composite parts. One of the challenges in this market is to ensure a reliable and robust process that consistently produces high quality part-to-part. The drawback in amine-cured systems is their very-short processing windows. Already during flow they start to react, with resin viscosity increasing and impregnation becoming difficult or even coming to a stop. The advantage of a latent-curing system is that it gives a relatively long, stable and low viscosity, allowing homogeneous resin flow and excellent fiber impregnation during injection. Only after complete mold filling does the resin start to react. Additionally, a dedicated accelerator has been developed to tailor flow and cure time further. Such a latent cure systems allows for injection of large surface areas, complicated shapes, and high fiber content structural parts.

Sigrid ter Heide, Hexion Inc.

Epoxy Matrix Technologies for Mass Production of Composite Leaf Springs

Traditional leaf springs in vehicles are made of steel. As lightweight material solutions become more attractive in view of compliance with fuel consumption and exhaust emission reduction legislation, composite leaf springs offer significant weight savings and lower energy consumption during manufacture and use vs. steel. In addition to offering greater design freedom, the composite leaf springs eliminated the need for coatings or paint because final parts are inherently corrosion free. The high build rate of high-pressure resin transfer molded (HP-RTM) epoxy composite leaf springs is discussed. Challenges in preforming and molding are addressed. Finally, life-cycle analysis (LCA) demonstrates lower carbon footprint and energy consumption during the part's use life.

SESSION 17: Advances in Thermoset Composites - Part 2 of 3: *Sheet-Molding Compound*

Husam Rasoul, Ashland Inc.

Low VOC / Low Odor SMC for Interior Applications

Significant changes in consumer attitudes toward vehicle interior odor is one reason hampering the used of sheet molding compound (SMC) inside the vehicle. In recent years, odor has generally been associated with volatile organic compounds (VOCs) and poor air quality, and the industry as a whole is interested in lowering VOCs and odor for interior applications. Articles made with unsaturated polyester- and vinyl ester-resin-based SMCs where styrene is used as the reactive solvent are potential sources for VOCs. This presentation will introduce new low VOC/low odor standard density, low density, and structural SMC systems. Also discussed will be methods of testing VOCs and comparison of results to current systems.

Michael Sumner, Ashland Inc.

Development of Ultra Low Density Class A SMC with Reduced Water Absorption

There is a very high interest in "lightweighting" in the automotive industry due to pending regulations to increase fuel economy. Recently, developmental efforts have focused on 1.1 SG and lower sheet molding compound (SMC) systems with a good balance of both surface quality and mechanical properties. Unfortunately, lower density systems appear to have a greater propensity for water absorption. Surviving the e-coat process is a requirement for low density systems in high volume automotive applications. Due to the high temperatures associated with the e-coat process, minimizing water absorption is critical to eliminate blister formation. Product development efforts will be presented that have led to 1.1 and 1.0 density tough Class A SMC with lower water absorption.

Paul Rettinger, Chromaflo Technologies Corp.
Lora Mason, Ashland Inc.
Mayur Shah, Continental Structural Plastics

UV Stable, Weather Resistant Sheet Molding Compound: An Alternative Approach to Building Strong, Durable Transportation Components

Parts molded from a UV-stable, weather-resistant sheet molding compound utilizing a black internally pigmented color system are being used in demanding automotive applications, including the 2017 *Honda Ridgeline* pickup box (including durable bed floor, in-bed trunk, and tailgate liner). This SMC technology not only brings strength and durability, but the molded composite eliminates the need to paint. This feature allows for a more environmentally friendly process, and since the color is integral throughout the composite part, scratches and chips to the bed will have negligible impact on consumer perception. This presentation will review the development of the technology, outline the properties of the composite, and demonstrate why this technology was chosen for the demanding application.

Atieh Motaghi, Western University

Microstructure Characterization in Direct Sheet Molding Compound

The direct sheet molding compound (D-SMC) process is one of the newer techniques for manufacturing fiber-reinforced composite materials. In the D-SMC process, bundles of fibers are cut to approximately 25 mm lengths and distributed randomly across the width of a paste consisting mainly of polyester resin filled with calcium carbonate and other additives. The sandwich of paste and fiber is passed through a roller section for degassing, tow impregnation, and consistent dispersion, as well as glass fiber wetout. The impregnated material then moves through a rapid-maturation zone where, in a temperature-controlled environment, chemical thickening of the D-SMC material takes place within a few minutes. In this work, charges of D-SMC consisting of 20% volume fraction fiber in a polyester matrix were produced and compression molded, then samples were cut and evaluated to characterize the material. Results of the work will be presented here.

SESSION 21: Advances in Thermoset Composites - Part 3 of 3: *Urethane & Epoxy Systems*

Corentin Pasco, Warwick Manufacturing Group

Characterisation of the Prepreg Compression Moulding Process

Composites materials have shown great potential in replacing traditional materials for automotive applications due to their high specific strength and stiffness. However, developments in the manufacturing process are necessary in order to scale up the use of composite materials into high-volume applications. One possible solution is prepreg compression molding due to its short cycle time and potential for a high level of automation. Because is necessary to prove that these processes are reliable and repeatable, the current research focuses on the characterization of the prepreg compression molding process through the use of in-line monitoring methods, allowing process control to be demonstrated as well as increasing understanding of the compression molding process.

Daniel Park, Fraunhofer Project Centre for Composites Research

Development of Polyurethane Sheet Molding Compound

The rapid increase in viscosity associated with highly reactive polyurethane (PU) resins have prevented their use in sheet molding compound. Recent advancements in catalyst chemistry in conjunction with direct sheet molding compound (D-SMC) technology has allowed for the continuous compounding and molding of polyurethane-based SMC. The PU system in this study maintains a low viscosity during compounding for effective fiber impregnation. The tunable viscosity of PU-SMC facilitates the uniform transport of fibers during the flow phase of molding, with a snap-cure at molding temperature. A molding window of up to several hours is attainable. A filled, glass fiber-reinforced PU system has been investigated with fire retardant additives to comply with regulations for rail applications. Very good molding, de-molding, and surface appearance were observed in demonstration parts. Initial testing showed PU formulations with a 23% increase in tensile strength, 25% increase in tensile strain at break, and an increase in energy absorbed in impact over conventional polyester SMC formulations of similar fiber content and filler loading. The most recent study of PU SMC that has been formulated for structural applications with improved properties will also be discussed in this presentation.

— IN OPAL/GARNET ROOM —

SESSION 14: Virtual Prototyping & Testing - Part 3 of 4: *Multi-Scale Modeling*

Andy MacKrell, MultiMechanics

Multiscale Analysis of a Chopped Fiber Injection Molded Part using Abaqus and MultiMech

One of the challenges with the computer-aided engineering of composite materials is the limited ability to efficiently identify, isolate, and model the interrelated mechanisms contributing to material non-linearity and failure. The goal of this study was to determine if local damage initiation and propagation could be sufficiently modeled via finite-element analysis so as to predict the dominant damage mechanisms and the force-time responses of a composite part. This analysis requires 3 interrelated steps, a) the generation and analysis of a composite microstructure model, b) the generation of a global scale coupon c) the multiscale analysis of these previously created models. Good correlation with experiment and acceptable run-times were achieved for this analysis.

Tod Dalrymple, Dassault Systèmes

Multi-Scale Simulations for Material Modeling

Most materials have some complexity of structure at the nano or micro scale that influences their behavior at the continuum level. To ensure continuum models are built to capture this complexity, it is necessary to bridge the gap between molecular scale models and the continuum. This approach is likely to be particularly helpful for simulations of composite materials and materials involved in additive manufacturing processes. Classical and mesoscale simulations based on molecular structure can be used to predict key properties, including cohesion and wetting, mechanical behavior, diffusion, adhesion at surfaces, and phase separation. Such simulations can be leveraged in finite element (FE) simulations through homogenization of the predicted material structure and through use of the simulated material properties for FE input. In this presentation, we will work through and extend one particular multi-scale workflow starting with the construction and characterization of a thermoplastic co-polymer at the atomistic level and ending with a macroscopic part level simulation.

Don Robbins, Autodesk, Inc.

Enhancement of Multiscale Modeling Methodology for Short Fiber Filled Injection Molded Parts Subjected to Bending Loads

To facilitate progressive failure structural simulation of short fiber-filled injection molded parts, the multiscale modeling methodology and software have been seamlessly combined to link the results of injection molding simulation with subsequent nonlinear multiscale structural response simulation. Recently, this multiscale modeling methodology has been enhanced to encompass short fiber-filled injection molded parts that are subjected to out-of-plane bending loads, which required two different enhancements that are the focus of this presentation.

SESSION 18: Virtual Prototyping & Testing - Part 4 of 4: *Simulation of Chopped Fiber-Reinforced Composites*

Donald Baird, Virginia Polytechnic Institute and State University

Simulation of the Role of Fiber Length on the Orientation Distribution During Injection Molding

Long-fiber (lengths > 1mm) thermoplastic composites (LFTs) possess significant advantages over shorter fiber (< 1mm) composites in terms of their mechanical properties while retaining their ability to be injection molded. Mechanical properties of LFTs are highly dependent on the microstructural variables imparted by the injection molding process, including fiber orientation and fiber length distribution. As the fiber length increases, the mechanical properties of the composites containing discontinuous fibers can approach those of continuous fiber materials. However, there is a lack of knowledge about the effects of fiber length and fiber length distribution (FLD) on fiber orientation kinetics. This lack of information provides an opportunity to understand the length effect inherent in long fiber systems. The Bead-Rod fiber orientation model takes into account the flexibility of semi-flexible fibers that show small bending angles. In this model, a flexibility parameter representing the resistive bending potential is fiber-length dependent.

Dustin Souza, e-Xstream engineering

Local Anisotropic Stiffness & Damping Behaviors of SFRP for Automotive FEA Applications

Reinforced plastic materials show a very interesting characteristic that helps to improve the acoustic comfort of car passengers. Their damping behavior is much better than metals and this specific performance became a very important criteria to evaluate the global quality of vehicles. Predicting the acoustic level inside a passenger cell and also outside of the car is a very difficult challenge as it depends on many parameters. The first step is therefore to be able to efficiently capture the noise generated by a single component. This already is not a simple task when the part is made of reinforced plastics. Predicting the acoustic response of a component requires accurate simulation of its vibrational behavior, meaning its stiffness and damping. When the part is made of reinforced plastics, the design engineer has to deal with a material fully dependent on the local fiber organization. In such a part, the microstructure usually shows a high degree of heterogeneity and anisotropy in terms of stiffness and vibrational response. Only a material model based on the matrix and fiber properties and taking into account the fiber orientation distribution throughout the part can accurately predict the stiffness response, and eventually the vibrational response of said component. This also requires a material model able to capture its damping behavior — itself anisotropic and dependent on the local definition of the microstructure. This presentation addresses current research and developments regarding the prediction of reinforced plastic material behavior applied for frequency domain analyses. Demonstrations will show how simulation can be improved for automotive safety design simulations in particular, helping to reduce design delay, cost, and mass of structures.

Sebastian Goris, University of Wisconsin-Madison

2014-2015 SPE ACCE Scholarship Winner
2016-2017 Rehkopf Scholarship &
2016 Best Paper Award Winner

Progress on the Characterization of the Process-Induced Fiber Microstructure of Long Fiber-Reinforced Materials

Over all stages in processing long fiber-reinforced thermoplastic (LFT) materials, the configuration of the reinforcing fibers changes, which ultimately affects the mechanical performance of the finished part. In order to gain a fundamental understanding of the effects of processing on the microstructural properties of the finished part, accurate and reliable measurement concepts are necessary. This presentation discusses progress on new measurement approaches to determine the full 3D fiber architecture. The analyses include local cauterization of fiber orientation, fiber length, and fiber density distributions by applying sophisticated measurement techniques, such as micro-computed tomography (µCT) as well as an automated process to determine the fiber length distribution. A comprehensive study of the process-induced microstructure of injection molded samples was carried out for a glass fiber-reinforced polypropylene at a weight fraction of 40% and the heterogeneity of the fiber architecture was analyzed. Results show that the assumption of a uniform fiber length and fiber density distribution throughout injection molded parts is not valid. The potential impact of the heterogeneity of process-induced microstructure can be critical and the simplified assumptions of uniform fiber length and fiber density distribution might not be appropriate for accurate material modeling approaches, especially when considering LFT materials.

SESSION 22: Opportunities & Challenges with Carbon Composites - Part 2 of 2: *Applications & Technology Advances*

Marco Bernsdorf, Solvay

Automotive Serial Application Process & Resin Development for BMW M4 GTS hood program

Within the serial automotive business, cycle time and costs are the main drivers when selecting a manufacturing process. Thus it remains very difficult to insert carbon fiber-reinforced plastic (CFRP) parts in serial cars. This presentation reports on a fast and fully automated winding process to create a flat blank suitable for press forming. It was essential to develop a new rapid cure B-stage resin system to address the contradicting demands of material handling during production and final part requirements. This was the key to meet the customer's "less than 5-min takt-time" target. Additionally, an insight into anticipated results regarding takt-time reduction will be provided.

Yutaka Yagi, Teijin Advanced Composites America Inc.

Changing the Future of Carbon Fiber Reinforced Thermoplastic Composites

This presentation will describe a newly developed carbon fiber-reinforced thermoplastic (CFRTP) that can be compression molded to provide highly planar and isotropic fiber orientations with longer fiber length in molded parts. These parts show greater balance between excellent moldability and high mechanical properties. The material's superior isotropic nature provides many advantages, such as more accurate CAE predictability, dimension control in large parts, and excellent energy absorption in compression mode — properties that are well suited for use in automotive part design.

— IN EMERALD/AMETHYST ROOM —

SESSION 15: Advances in Thermoplastic Composites - Part 4 of 5: *Hybrid Composites*

Warden Schijve, SABIC

New Thermoplastic Composite Solutions Present Viable Options for Automotive Lightweighting

For automotive lightweighting needs, new innovative composite material forms and design solutions can deliver the required weight savings at acceptable cost. This will be illustrated on examples of so called "hang-on" components, such as an instrument panel cross-car beam and a side door. These composite solutions are shown to be competitive compared to alternative lightweight solutions.

Recep Yaldiz, SABIC

Innovative Predictive Solutions for Hybrid Thermoplastic Composite Technology

Increasingly tighter requirements on CO_2 emissions urge the automotive industry to seek radical weight savings. This has led to investigation of many new metal and plastic material systems, including continuous fiber reinforced thermoplastic composites. Multi-material hybrid solutions, combining continuous fiber composites with short fiber composites via overmolding technology, have been shown to be attractive. The overmolding technology enables design freedom for functional integration in combination with high performance lightweight composites. Despite the fact that continuous fiber reinforced thermoplastic composites principally meet the performance requirements from industry, confidence still seems to be lacking for widespread adoption today. Insufficient maturity of the manufacturing process and predictive methods for these relatively new materials are two of the main reasons. Therefore, a unique test component was developed, enabling the demonstration of a complete manufacturing process chain as well as predictive capabilities, providing confidence for any generic future component in a car.

Bert Rietman, SABIC

Manufacturing Solutions for Hybrid Overmolded Thermoplastic UD Composites

Hybrid overmolding of unidirectional (UD) thermoplastic composites is considered to be one of the most promising technologies for enabling further weight reductions in cars. Although UD composites feature excellent properties, defect-free handling, and fixation still pose a challenge. This presentation discusses new solutions that are well-suited for automated production to overcome the handling and fixation issues.

SESSION 19: Advances in Thermoplastic Composites - Part 5 of 5: *Process Developments*

Mark Cieslinski, BASF Corp.

Material Properties of Injection Molded Glass and Carbon Fiber Reinforced Thermoplastic Composites – A Review

A review of glass and carbon fiber- reinforced injection molding materials is presented in order to provide a general reference for proper material selection in a desired end-use application. Quantifiable trends in the composites' mechanical properties highlight the differences between glass and carbon fibers as a function of concentration and fiber geometry.

John Dorgan, Colorado School of Mines

Reactive Processing - Cure Time vs. Heat Transfer

Some composites manufacturing techniques are difficult to perform using thermoplastics. For example, infusion techniques including RTM and VARTM typically rely on low molecular weight precursors, which flow easily but then cure to form a cross-linked matrix. In principle, thermoplastic precursors can also be used and a number of ring-opening systems have been successfully demonstrated (e.g. polyamide 6, polybutyleneterephthalate, etc). However, many inexpensive polymers are derived from monomers containing vinyl groups. In these cases, the curing reaction is highly exothermic so that the cure time must purposely be lengthened to avoid excessive heating. In this work, a mathematical model is developed that incorporates reaction kinetics and heat transfer. The model is validated against the Elium thermoplastic system commercially available from Arkema. Once validated, the model enables calculation of the appropriate amount of initiator to be used for a given wall thickness. In addition, the model provide the ability to explore "what if" scenarios that can be used to develop various processing strategies. Cases are presented that show how reaction rate and heat transfer can be manipulated in order to minimize cycle times.

Hiroyuki Hamadat, Kyoto Institute of Technology

Thermoplastic Prepreg Insert Injection Molding Composites: Mechanical & Adhesive Properties

Thermoplastic composites are widely applied within the automotive industry. They are lightweight, have high specific strength, and can be processed by injection molding. Insert-injection molding is a process that can be applied to a reinforcing or decorative material to produce complex injection molded parts. With insert-injection molding, molten polymer is injected around the inserted material placed in the mold cavity, allowing components to be joined without mechanical fasteners or adhesives. In this study, two types of thermoplastic prepregs (glass fiber/polypropylene (GF/PP) prepreg and carbon fiber/polyamide 6 (CF/PA 6) prepreg) were inserted. GF/PP resin is injected over GF/PP prepreg while GF/PA 6 resin is injected over CF/PA 6 prepreg. The role of adhesion between inserted part and injected resin on the mechanical properties was measured by tensile and bending tests and will be described.

Hiroyuki Hamada, Kyoto Institute of Technology

Study of Production Stability in DFFIM

The direct fiber feeding injection molding (DFFIM) process is an alternative method for producing long fiber-reinforced polymer composites. The reinforcing fiber is fed in and compounded with molten polymer at the vented barrel of an injection molding machine. In this research, two types of glass fiber (GF) were injected with recycled polyethylene terephthalate (RPET) matrix by DFFIM. The effect of GF types and matrix feeding speed on fiber content and mechanical properties of RPET/GF composites were investigated. Additionally, the effect of short- and long-term processing was studied. Fiber contents were varied according to types of GF and number of GF roving as well as controlling matrix feeding speed. Tensile modulus and tensile strength of the RPET/GF composites increased with increasing GF contents. It can be noted that the fiber content and tensile properties of the RPET/GF composites with DFFIM process were consistent with long term processing.

SESSION 23: Enabling Technologies - Part 1 of 3: *Process Comparisons & Automatic Inspection*

Javier Acosta, Fagor Arrasate

Manufacturing Cost Comparison of RTM, HP-RTM & CRTM for an Automotive Roof

Manufacturing costs for conventional resin-transfer molding (RTM), high-pressure RTM (HP-RTM), and compression RTM (CRTM) have been analyzed for an automotive roof case. Process simulation results have been used to refine the cycle time, equipment specifications, and layout of each technology. Filling time for RTM is 5-times longer than for HP-RTM and 12-times longer than for CRTM. The shorter injection times for CRTM mean that higher molding temperatures can be used, reducing total cycle time per part, and greatly reducing the need for additional presses and tools at high production volumes. Since equipment and tooling costs dominate the total cost of the roof part, comparable parts molded in HP-RTM and RTM are much more costly than those molded in CRTM.

Martino Lamacchia, Cannon USA

CFRP Mass Production in Automotive: A Comprehensive Review of the Main Approaches Available from a Machinery Perspective

The growing demand for the reduction of CO_2 emissions is pushing the OEMs to decrease vehicle mass. Composites are one of the most promising solutions, permitting a combination of high mechanical performances with low weight. Traditional process technologies like vacuum-assisted resin-transfer molding (VARTM) or autoclave, however, are not productive enough to be used for typical automotive production volumes. Average cycle times to obtain carbon fiber-reinforced plastic (CFRP) parts, in fact, can easily go beyond two hours, which seriously limits adoption of these types of materials wherever higher volumes are required. Thanks to the R&D efforts of both chemical companies and machinery suppliers, a whole new way of making CFRP parts has been developed. This presentation reviews the main CFRP mass production technologies available from an equipment perspective and focuses on how to combine preforming, injection, and pressing technology to achieve production lines for high-pressure resin-transfer molding (HP-RTM), wet pressing, and compression molding of both thermoset and thermoplastic composites.

Scott Blake, Assembly Guidance Systems, Inc.

Automatic Inspection of Composite Parts

Meeting high-rate production requirements for composite parts for automotive applications requires in-process, automatic inspection to ensure that parts are being produced correctly. Automatic inspection processes for aerospace parts are used to monitor composites production for material location, shear, fiber orientation, wrinkles, bridging, and secondary bridging. Examples of these systems and results are presented. Implementation issues such as inspection data generation, physical installation, inspection results data, and process control are also presented.

— IN PEARL ROOM —

SESSION 16: Nanocomposites - Part 1 of 3: *Key Trends & Hybrid Systems*

Jo Anne Shatkin, Vireo Advisors, LLC

Addressing Safety, Health and Environmental Aspects of Nanocomposites Across the Product Life Cycle

Nanoscale materials are being introduced into composites to take advantage of a number of potentially beneficial properties, such enhanced barrier properties, strength, sensing, lightweighting, labeling, and improved environmental performance. However, as novel materials, there is a high bar to acceptability, often requiring safety demonstrations more challenging than for conventional and long-accepted composite materials. The dynamic regulatory landscape for nanomaterials introduces a diversity of requirements depending on markets, including consideration of consumer safety and end-of-life management. End users and retailers also introduce safety and sustainability requirements. Challenges are varied and include the current uncertainties about the risks from exposure to nanoscale materials as well as simple measurement issues. Further complexities relate to the lack of established methods for demonstrating nanomaterial safety in composites and unstudied nanomaterial transformations that could occur under environmental conditions associated with post-manufacturing stages of the product life cycle. This presentation will explore some of the driving toxicology and exposure concerns from a risk and product safety perspective, and offer ideas about how to advance the demonstration of safety and gain market access for this exciting class of new technologies. Examples such as cellulose nanomaterials and carbon nanotubes will be discussed as case studies.

Douglas Gardner, University of Maine

Mechanical Properties of Hybrid Talc-Cellulose Nanofibril-Filled Polypropylene Composites

There is considerable interest in vehicle lightweighting in the automotive industry through the application of new material technologies, and polymer matrix composites are of primary importance in meeting those goals. In addition, the application of renewable materials like wood and plant fibers is of interest in meeting sustainability goals and to replace petroleum-derived feedstocks. This presentation discusses results of a study examining novel hybrid polypropylene (PP) composites using a combination of cellulose nanofibrils and talc for potential use in automotive applications. The results showed that cellulose nanofibrils can replace a portion of the talc which produces PP composites with improved mechanical properties and lower density.

SESSION 20: Nanocomposites - Part 2 of 3: *Thermal & Mechanical Issues*

Leonardo Simon, University of Waterloo

Improvement of Thermal and Mechanical Properties of Polyimide using Metal Oxide Nanoparticles

Polyimide-based nanocomposites have attracted great attention owing to their exceptional properties like outstanding thermal stability, excellent mechanical properties, high glass-transition temperature, good chemical, radiation and fire resistance etc. Therefore these polymers are widely used in aerospace, automotive, and microelectronic industries as films, adhesives, sealants, coatings, insulators etc. Properties of polyimides are mainly dependent on inter-chain interactions, hence can be affected dramatically by introducing small fractions of inorganic fillers within the polyimide matrix. This presentation reports on work about the effect of Al_2O_3 and ZnO nanoparticles on thermal and mechanical properties of polyimides.

Daniele Bonacchi, Imerys

Effects of Graphite Selection on Thermally Conductive Compounds for LED Lamp Heat Sinks

Thermally conductive compounds are viewed as potential replacements for metallic heat sinks in automotive and non-automotive LED lamp applications. Graphite is certainly the main candidate for thermally conductive applications that tolerate electrical conductivity due to their high efficiency and reduced costs. This presentation discusses how the introduction of graphite substantially increases the thermal conductivity, especially along the plastic flow (in-plane) direction. Several commercially available graphite grades were tested in polyolefin model polymers and showed that crystallinity, average particle size, and aspect ratio are the 3 main factors that promote thermal conductivity. Also tested was a special high-aspect-ratio graphite that delivers high thermal conductivity at low loadings, providing an advantage in terms of weight reduction.

Jacob Anderson, PPG Industries

Thermal and Mechanical Performance of Polyamide-6 Reinforced with Glass Fibers and Nanoparticles

Polyamide-based glass-fiber composites have been used successfully in automotive underhood applications to reduce vehicle weight through metal replacement and parts consolidation. Some components, however, are difficult targets due to their associated operating temperature and stiffness and/or strength requirements. As such, the focus of this work was to identify the effect of a nano-talc additive and increasing levels of glass fiber reinforcements on the thermal and mechanical performance of the resulting polyamide 6 composite. Researchers found that heat deflection temperature (HDT) of the composite could as effectively be increased with just 3 wt-% nano-talc as with 20% fiber glass, although with some reduction in strength.

Nicholas Kamar, Michigan State University

Graphene Nanoplatelet (GnP)/Triblock Copolymer Epoxy Nanocomposites and GnP Modified CFRPs

This work explored the fracture behavior, toughening mechanisms, and mechanical, thermomechanical, and fracture properties of graphene nanoplatelet (GnP) and poly(styrene)-block-poly(butadiene)-block poly(methylmethacrylate) (SBM) modified epoxy. At only 1 wt% in the sizing, GnPs increased CFRP mode-I fracture toughness (GIc, J/m^2) by 100% with no corresponding reduction in T_g and a 14% reduction in longitudinal flexural strength. SEM of mode-I double cantilever beam fracture surfaces showed that GnPs in the matrix near the fibers activated crack bifurcation and deflection toughening mechanisms to increase fracture energy.

SESSION 24: Nanocomposites - Part 3 of 3: *Graphene, Carbon Nanotubes, & Nanocellulose*

Alper Kiziltas, Ford Motor Co.

2012-2013 SPE ACCE Scholarship Winner

Graphene-Reinforced Bio-Based Polyamide Composites

This presentation will report on a sustainable approach to the development of lightweight and high strength and modulus materials for underhood applications. Composites based on bio-based polyamide 6/10 and graphite nanoplatelets were prepared. Mechanical, thermal (crystallization and thermal degradation), and rheological properties of the composites were determined and correlated with phase morphology.

Gurminder Minhas, Performance BioFilaments Inc.

Nano Fibrillated Cellulose for Reinforcing Composites

Cellulose filaments are produced using a proprietary process that utilizes a mechanical treatment on renewable, sustainably produced wood pulps to generate fibrillated cellulose. Due to their high aspect ratio and low density, cellulose filaments have shown improved performance of a wide variety of composites suitable for use in automotive applications. The presentation will highlight the use of cellulose filaments in reinforcing composite materials while providing lightweighting opportunities. Recent work on compounding cellulose filaments with polypropylene, polyamide, and polyurethane composites will also be discussed.

Hao Zou, SINOPEC

Research on MWNTs and iPP Composites and their Mechanical Properties

In this work, multiwall-carbon-nanotubes (MWNTs), β nucleating agent, and polypropylene (PP) were mixed together to prepare composites. These materials were subsequently molded at specific processing conditions and the dispersion and mechanical properties of the materials were studied.

— IN DIAMOND BALLROOM —

KEYNOTE 3

Rich Fields, Lockheed Martin Missiles and Fire Control

Accelerated Introduction of New Material Systems

The need for accelerated product development continues to drive design schedules, while the introduction of new materials in new product designs continues to lag behind. The speed at which new material systems are brought into product design can be accelerated by early communication of a consensus understanding of the needs and expectations of the various stakeholders, and by developing tailored plans for new material maturation. This presentation will reintroduce an existing, but often poorly understood, framework for the central portion of a rational material development process, supplemented with additional steps before and after, which can accelerate new material introduction while continuing to mitigate risk.

PANEL DISCUSSION:

Critical Issues in Automotive Composites: Technology, Policy and Supply Chain

Moderator:
Dale Brosius, Institute for Advanced Composites Manufacturing Innovation (IACMI)

Panelists:
Craig Blue, IACMI
Rich Fields, Lockheed Martin
Ove Schuett, Dassault Systèmes
James Staargaard, Plasan Carbon Composites
Rick Neff, Cincinnati Inc.

Friday, September 9

— IN ONYX ROOM —

SESSION 25: USCAR/USAMP Carbon Fiber Composite Front Bumper Crush Can Project - Part 1 of 2

Omar Faruque, Ford Motor Co.

Validation of Material Models for Crash Testing of Carbon Fiber Composites

This presentation provides an overview and highlights of a multi-year U.S. Council for Automotive Research (USCAR)-led collaborative project, conducted under the U.S. Automotive Materials Partnership (USAMP) of General Motors Co., Ford Motor Co. and Fiat Chrysler Automobiles. The objective of this four-year, U.S. Department of Energy-sponsored project on Validation of Material Models (VMM) project is to validate new physics-based crash models and evaluate commercial codes used for simulating primary load-carrying automotive structures made of production-feasible carbon fiber-reinforced composites for crash energy management. The successful validation of these crash models will allow the use of lightweight carbon-fiber composites in automotive structures for significant mass savings.

Praveen Pasupuleti, ESI Group

Design of a Composite Bumper and Assessment of Current Composite Crash Simulation Capabilities

Significant challenges impede the implementation of production-feasible crashworthy composite designs into automotive applications, including throughput, part quality, and the relative immaturity of performance-prediction capabilities. The objective of the USAMP VMM design task was to deliver an accurate crash prediction of the front bumper and crush can (FBCC) system that met the performance objectives based on baseline crash testing of a steel surrogate design. This presentation provides an overview of the design and analysis considerations of a compression molded thermoset composite front bumper beam and crush can system, applying 2D carbon fiber-woven fabrics for the primary structures. Industry best practices in virtual engineering and optimization of a manufacturable geometry of the composite bumper beam also will be discussed.

Derek Board, Ford Motor Co.

Physical Crash Testing of Composite Bumper Beams

The USAMP's VMM project required physical crash testing of carbon fiber-reinforced composites. These destructive tests were comprised of preliminary baseline steel front bumper/crush-can (FBCC) assemblies under 6 crash modes (full frontal NCAP, IIHS offset, 30 degree angular, frontal pole, and low-speed quarter and midpoint) in order to provide design targets for the carbon composite FBCC. The newly proposed CORA ISO standard was used to quantify the time-histories of each steel system and correlate crash modes to CAE predictions using LS-DYNA, RADIOSS, Abaqus, and PAM-CRASH. Next, carbon composite FBCCs were designed, manufactured, and tested following the same procedure. The presentation will cover work-in-progress to analyze carbon composite beam crash data and provide preliminary results.

Anthony Coppola, General Motors Co.

Thermoset Composite Materials & Processing for a Composite Bumper Beam System

This presentation will focus on the commercially available thermoset materials and processing procedures used to manufacture the front bumper and crush can (FBCC) system. The materials and processing selection and validation is based on a design-build-test strategy, which relies heavily on prediction at all stages of the process. The FBCC system uses compression molded carbon fiber/epoxy prepreg for primary structural zones and carbon fiber/vinyl ester sheet molding compound for geometrically complex architectures. Manufacturing details including layup, preforming, and molding procedures are described with a focus on issues that arose and solutions that were implemented.

SESSION 29: USCAR/USAMP Carbon Fiber Composite Front Bumper Crush Can Project - Part 2 of 2

Art Cawley, Dow Automotive

Joining and Assembly System for Thermoset & Thermoplastic Composite Materials

The USAMP VMM Project's front bumper beam and crush-can system (FBCC) were designed for ease of assembly using commercially available adhesive materials with a patent-pending joining approach, and readied for crash testing under 6 high-speed and low-speed loading conditions. A joining and assembly approach was first validated for simple part shapes, and then scaled up to arrive at a production-feasible joining process for the FBCC. This presentation describes the use of mechanical analysis and test methods to qualify the joints, and the learning applied to the development of equipment and fixtures designed to handle unique adhesive preparation and cure requirements. Close collaboration between automotive OEMs, academia, and supplier team members helped establish the optimum bonding methodology for the thermoset and thermoplastic composite materials.

Praveen Pasupuleti, ESI Group

Composite Fabric Manufacturing Studies by Simulation and Experiment

This presentation discusses the application of draping and manufacturing simulation tools to anticipate potential defects and try out different process setups with initial design for manufacturability of a composite front bumper beam and crush can system. The specific focus will be simulation studies on these 2 continuous-fiber, 2-D fabric-reinforced composite parts with simulation and experimental trials, and the layup of multiple plies of fabric composite prepreg for fabrication of the bumper beam and crush cans. Two different approaches are discussed for the simulation of a large and complex geometric part, and different simulation trials run on relatively smaller but more complicated parts. The manufacturing simulation method is based on finite element analysis of composite materials in draping, and to calculate the bending and in-plane shearing effects with de-coupled stiffness values.

Jeff McHenry, Shape Corp.

Development of Carbon Fiber Reinforced Thermoplastic Composites

Thermoplastic composites reinforced with continuous carbon fibers face significant barriers to overcome before they are widely used in large and complex automotive structural components, such as a front bumper crush can system. These include cost, mass production methods, and predictive techniques. This presentation will outline the primary development of carbon fiber-weave reinforced polyamide for production of crush cans under the collaborative effort between automotive OEMs and suppliers on the USAMP VMM Composites project.

Cameron Dasch, Highwood Technology LLC

Non-Destructive Testing throughout the Development of a Carbon Fiber Composite Automotive Crash Structure

This presentation is a case study of how non-destructive evaluation (NDE) can accelerate the carbon fiber-reinforced composite component development process, and how to modify a composite design to facilitate NDE. NDE techniques were used to verify the quality of the materials, joining, and assembly throughout the development of the USAMP carbon composite front bumper and crush can (FBCC) system. These methods were used at each stage, from flat plaques to simple geometric shapes to the final 3-dimensional FBCC structure, and included studies of both as-built and crash-tested components in order to study and correlate failure modes. The methods selected were chosen for sensitivity, speed, and ability to deal with complex 3-D structures, such as ultrasonic pulse/echo (both conventional and phased-array), low-energy X-ray radiography, computed tomography (CT), and optical surface scans.

— IN OPAL/GARNET ROOM —

SESSION 26: Sustainable Composites - Part 1 of 2: *Biopolymers & Bio-Precursors*

Fatimat Bakare-Batula, University of Böras

2014-2015 SPE ACCE Scholarship Winner

Synthesis & Characterization of a Biobased Thermoset Resin from Lactic Acide & Allyl Alcohol

New bio-based thermoset resins have been synthesized using lactic acid oligomers to produce 2 different resin structures. The first resin is comprised of an allyl alcohol-terminated lactic acid oligomer, which was end-functionalized with methacrylic anhydride (MLA) resin. The second resin is comprised of a mixture of allyl alcohol-lactic acid oligomer and pentaerythritol. The mixture was then end-functionalized with methacrylic anhydride (PMLA resin). The resins were then characterized and results showed that the PMLA resin has better mechanical, thermal, and rheological properties than the MLA resin, and both had properties that were comparable with a commercial unsaturated polyester resin. The bio-based content of 90% and glass transition temperature at 113°C for the PMLA resin makes it a good candidate for composite applications where petroleum-based unsaturated polyester resins are normally used.

Christopher Ellen, BioAmber Inc.

Bio-Based Succinate Polyester Polyols in Thermoplastic Urethanes

For decades, various bio-based monomers have been used to increase the renewable carbon content of polyester polyols (PEP) for polyurethanes. Bio-based succinic acid (SA) is now readily available from bio-technology, which uses sugar (derived from corn or other plant sources) as a feedstock in a yeast fermentation and extraction process. Bio-based SA and SA-PEPs provide formulation flexibility for polyurethanes and can enable thermoplastic urethanes with differentiated properties and renewable carbon content, thus enabling sustainability and performance.

Ayse Ademuwagun, Varroc Lighting Systems

Biobased Headlamp Housing for Automotive Lighting

Miscanthus or switchgrass fibers are bio-sourced renewable materials that can be used as fillers in various polymer matrices. Carbonization and oxidative acid treatments make these bio-materials more compatible with a polypropylene (PP) matrix. These bio-carbons could replace talc to reduce part weight by 8-20%, while reducing the carbon footprint and improving sustainability for the automotive industry. In this study, the performance of headlamp housing parts made with bio-PP were compared and tested against talc PP.

SESSION 30: Sustainable Composites - Part 2 of 2: *Carbon Capture & Natural Fiber Reinforcements*

Mica DeBolt, Ford Motor Co.

Ford Blue Sky Project - The Future of Recycling CO_2 into Polyurethane Foams

Carbon dioxide is one of the greenhouse gases present in Earth's atmosphere that is contributing to global warming. The carbon from carbon dioxide can be used to synthesize different molecules such as polyols, which, in turn, can be used to formulate materials like polyurethane foams. Flexible polyurethane foam samples were prepared using concentrations of up to 50% of 2 polyols derived from waste carbon dioxide to determine whether the final foam products met automotive standards for use in seating applications. Due to limitations in viscosity, processing, and wet compression set properties, inclusion of 30% of these polyols into flexible polyurethane foam showed potential for use in automotive applications. To further enhance the strength and thermal stability properties of the carbon dioxide-based flexible polyurethane foams, fillers derived from recycled or sustainable sources were used. Micronized rubber, rice husk ash, and cellulose filaments were incorporated into the foam structure at various concentrations.

William Jordan, Baylor University

Banana Fiber Reinforced LDPE Composites for Use in Injection Molded Parts: Properties and Processing

This study looks at two different chemical treatments designed to promote the interfacial bonding between banana fibers and an LDPE matrix: peroxide treatment and permanganate treatment. The effects of the treatments on the tensile properties of individual banana pseudo-stem fibers were explored, with peroxide treatment enhancing the tensile properties and permanganate treatment having an inconclusive effect. Untreated banana pseudo-stem fibers provided a measurable increase in composite properties, especially in tensile stiffness. Permanganate treated fibers provided little to no advantage in composite properties compared to their untreated counterparts, even with post-fracture analysis showing enhanced interfacial bonding.

Henning Karbstein, BASF Corp.
Marc Hayes, International Automotive Components
Natural Fiber-Reinforced Sunroof Frame

An environmentally sustainable and lightweight, natural fiber-reinforced sunroof frame has launched on a 2017 sedan-type vehicle. The proprietary innovation is made of 70% renewable raw material content and provides up to 50% weight saving vs. conventional metal-reinforced steel sunroof frames. A water-based, low emission acrylic binder technology was used to enable this thermo-stable nonwoven composite with hemp and kenaf fibers.

— IN EMERALD/AMETHYST ROOM —

SESSION 27: Enabling Technologies - Part 2 of 3: *Compression & Injection Molding*

Neil Reynolds, Warwick Manufacturing Group
The Development of an Augmented Stamp-Forming Process for High-Volume Production of Thermoplastic Composite Automotive Structures

While stamp-formed aligned continuous fiber reinforced engineering thermoplastics (CFRTPs) offer the automotive engineer an attractive blend of performance, cost, and recyclability, the geometric complexity, and hence the opportunity for parts integration is inherently limited due to the nature of laminate materials. Conversely, short- and long-fiber reinforced thermoplastic flow-forming compounds have proven to be very capable in delivering highly integrated components, but only up to a semi-structural performance level. The addition of sub net-shape CFRTP inserts into these flow-formed components has yielded increased performance and weight saving potential, but ultimately limitations on the maximum structural performance remain, restricting thermoplastic composite (TPC) insert molding to automotive semi-structures. In this presentation, a 1-shot augmented stamp-forming (ASF) manufacturing process for TPCs is presented. The ASF process employs a combination of a stamp-formed CFRTP high-performance laminate outer with a flow-formed high geometric complexity inner structure. The opportunities, challenges and disadvantages of using the ASF process are discussed and component manufacturing case studies are described, demonstrating the research carried out from initial process proof-of-concept towards full process definition.

Matthias Graf, Dieffenbacher GmbH Maschinen- und Anlagenbau
Tailored Fiberplacement LFT-D - Flexible and Economical Process for the Mass Production of Hybrid Lightweight Composites

This presentation will introduce the features and performance of a new tailored fiber placement system that allows for layup of unidirectional (UD) tapes with any fiber orientation, near net shape into a tailored blank, and it can do so rapidly and reliably. The machine is capable of laying up 4 different types of tape within the process. The new generation system is designed to suit the needs of the automotive industry in terms of product dimensions, throughput capacity, and material efficiency. The system can be integrated into different line configurations, such as with a tailored direct long-fiber thermoplastic (D-LFT or LFT-D) line that allows for back molding of the tailored blanks with LFT compound so as to produce semi-structural and structural parts. By functionalizing the UD tape structure with LFT, thin ribs can be formed and inserts can be molded in. Both materials can be combined flexibly in order to use UD tapes for local reinforcement, thereby minimizing material cost. With this technique, component production with a very-short cycle time of < 1 min is possible.

Stephen Greydanus, Hexion Inc.
Liquid Compression Molding (LCM) Technology for Mass Production of Continuous Fiber Composite Epoxy Matrix Components

Material and process technologies enabling mass production of continuous fiber composites for lightweight automotive applications have matured greatly in recent years. Many production programs have been introduced successfully to the market. Liquid compression molding (LCM) has developed as a complimentary process technology to high-pressure resin transfer molding (HP-RTM), both of which have become essential technologies for rapid molding of epoxy-based carbon and glass fiber-reinforced composites. The LCM process allows manufacturers to take full advantage of today's fast-cure epoxy systems and dispensing/compression press molding technologies. Sub-90 second "button-to-button" times are being achieved today, supporting annual part productions volumes of 50,000-100,000 units. Whereas in the HP-RTM process, resin is injected into a closed mold cavity containing the fiber stack, in LCM resin is applied by automated pouring on top of (or beside) the fiber stack before the mold is closed. As the tool closes, resin is pressed into the fiber stack and the part is rapidly cured.

Alexander Roch, Fraunhofer Institute for Chemical Technology
2-Component Air Guide Panel Manufactured by Co-Molding & Foaming using Core-Back Technology

Using the example of an air guide panel for the next generation of *BMW 7 Series* cars, the lightweight potential of foam injection molding in combination with core-back technology is highlighted. The part is a co-molded, hard-soft combination consisting of 2 different materials: a hard polypropylene and a soft thermoplastic elastomer. This presentation introduces the manufacturing process and focuses on the material savings that can be achieved by the core-back expansion technology, which in this case was 20%.

SESSION 31: Enabling Technologies - Part 3 of 3: *Tooling, Cores, Profiles, & HP-RTM Variants*

Steve Verschaeve, RocTool

An Innovation in Composites Process: Light Induction Tooling

This presentation will introduce a new molding technology called light induction tooling (LIT). This process is presented as a complete manufacturing solution for both thermoplastic and thermoset composite materials. A wide range of transformed material will be presented, in association with their process parameters using LIT as compared with the conventional compression molding process. The light tooling structure integrating induction technology allows for a reduction of cycle times, better control of temperature, and low energy cost. Also included will be a real-world application showing the progression of a production project from a standard compression process to an LIT process.

Ottorino Ori, Persico SpA

New Moldable & Washable Cores for Hollow Composite Parts

Different techniques may be used to form fiber-reinforced parts around a sandwiched core, which often is made from foamed polyurethane or special structural foams. In spite of the wide range of applications of core elements, the process for removing such a part from the final molded component still presents some limitations and involves difficult and costly procedures. Recent research has focused on development of a new class of polymers in combination with tooling for composites and advanced rotomolding. This led to the development of moldable cores that can be washed away with hot water in an efficient industrial process. The cores may be molded via injection or rotomolding depending on geometry and production volumes required.

Klaus Jansen, Thomas GmbH + Co. Technik + Innovation KG

Mass Production of Curved Profiles for Car Bodies - Process and Machines

Profiles of various shapes and cross-sections are a central element of today's chassis, drivetrains, and car bodies, especially for vehicles based on a space-frame concept. From a profile manufacturer's point of view, suitable classification criteria for the profiles needed are the kind of curvature, the kind of cross-section and the design of the connection area. All these features might need different manufacturing processes like rolling, extruding, forging, bending etc. Until recently pultrusion was the only real mass production process for fiber reinforced profiles and it could only be used to manufacture straight profiles, which greatly limited its use for the automotive industry. With the newly developedradius pultrusion process, in which a moving and elastic mold is used to create profiles, this barrier has been overcome. The mass production of profiles with constant curves of practically any radius is already state of the art. The manufacture of profiles with variable radii has been demonstrated and even the production of variable cross-sections is a potential with this technology. Theory, practical examples, and also some examples for the equipment are described in this presentation.

Philipp Rosenberg,
Fraunhofer Institute for Chemical Technology

New Process Variants of the HP-RTM Process

With focus on future requirements for manufacturing highly complex shapes with integrated functions, a new variant on the high-pressure resin transfer molding (HP-RTM) process has been developed to enable the process for quick and precisely controlled injection and curing. Relevant process parameters have been investigated to generate the basic know-how for the pressure controlled RTM process (PC-RTM), which uses an integrated cavity pressure control during injection and compression steps and has the potential to decrease cycle time further to enable HP-RTM to service mid- and high-volume production in the near future.

— IN DIAMOND BALLROOM —

KEYNOTE 4

Ove Schuett, Dassault Systèmes

An Innovative Approach to Light Weighting and Managing Vehicle Development Complexity

Crash detection systems, numerous passenger comfort options, sophisticated car-to-car electronic communications, advanced hybrid / electric propulsion systems, advanced materials targeted at reducing in-cabin volatile compounds, and overall mass reduction, are just a few of the many complicated systems consumers and governments demand in today's vehicles. And all must be integrated into sleek designs and validated to a diverse set of multiple global standards. Add in the variety of customer wants, the variation of their price point, and the expanding use of new materials, and we begin shed light on the ever-increasing complexity of global vehicle development. Automotive OEMS and their suppliers have in the past attempted to manage this complexity by hiring additional highly skilled workers. Unfortunately the added structural cost, massive training efforts, last minute costly reworks to eliminate human error and improve quality before starting vehicle production, and the documentation to confirm validation and compliancy have proven to be extremely difficult to control solely through the use of human capital for most in the automotive industry. Research has shown that we will generate more data this year than we have in all the time up until 2003, and this copious amount of information is enough to challenge even the most highly skilled workforce. Since we know that computers are infinitely more accurate than the human brain, does it not make good business sense to increase the leverage of the best technology instead of relying on a less accurate method? Highly developed computer-aided technology has given OEMs and suppliers the ability to virtually innovate, validate, and drive quality into the increasing complex electronic and mechatronic devices found in consumer-desired vehicles today. A very few exceptional enterprises have already recognized this and are utilizing technology to enable their shift to 1) a single environment to architect, define, simulate, and validate vehicle performance, mechatronic systems, manufacturing processes, and regulations; 2) the capability to define, execute, and monitor virtual and physical tests; 3) manage the entire advanced materials lifecycle, including their assignment to vehicle components; and 4) in-context simulation with CAD/CAE with complete integration enabling fast iterative learning cycles.

KEYNOTE 5

James Staargaard, Plasan Carbon Composites

Development of a Carbon Fiber Reinforced Roof Frame Using the High Pressure Resin Transfer Molding Process

Composites technology for the automotive market continues to advance rapidly. Increasing knowledge of composite design, simulation tools, new materials, and process equipment are all contributing to making composites better performing and more affordable for mass-produced vehicles. In particular, the high-pressure resin transfer molding (HP-RTM) process is enabling manufacturers to produce complex composite parts at shorter and shorter cycle times. This presentation will describe the development of a carbon fiber-reinforced composite roof frame slated for future production. Several composite processes were considered for the roof frame. The case illustrates that when the (product) design, material, and process are considered together, a very efficient part can be produced. Meeting all requirements, the resulting part weighs 60% less than the original in magnesium. The part will be the first HP-RTM part made in North America for a series production vehicle. Of equal significance, the development process for the part involved a unique collaboration of several companies. Each company contributed its particular expertise to the project including resin, reinforcement, analysis, process simulation, tool construction, preforms, and molding. The collaboration enhanced the speed and technical success of the overall development.