AUTOMOTIVE PLASTICS NEWS

A PUBLICATION OF THE AUTOMOTIVE DIVISION OF THE SOCIETY OF PLASTICS ENGINEERS

OCT 2019
VOL 49, ISSUE 1

19TH-ANNUAL

AUTOMOTIVE COMPOSITES CONFERENCE & EXHIBITION

Presented by SPE Automotive Division and SPE Composites Division

MARK YOUR CALENDARS
ACCE 2020 – SEPT. 9-11

COMPOSITES
FORMING THE FUTURE OF TRANSPORTATION WORLDWIDE

SEPT 4-6, 2019

AUTOMOTIVE COMPOSITES CONFERENCE AND EXPO (ACCE) IS A SUCCESS

The 19th annual Automotive Composites Conference & Exhibition (ACCE), organized by SPE's Automotive and Composites Divisions, was a success according to sponsors and exhibitors. "The entire event was excellent in terms of content, organization, and value," said Erik LaBelle – Automotive Technical Business Development Specialist at 3M. "My recommendation to our team will be to ensure 3M's continued participation in the event in the future, perhaps in bigger or broader ways as possible," continued LaBelle. "Congratulations on another successful ACCE – Hexion had a great show and we look forward to next year," said Cedric Ball – Automotive Business Development Manager, Hexion, Inc.

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SUBURBAN COLLECTION SHOWPLACE

The Diamond Banquet & Conference Center at the Suburban Collection Showplace
46100 Grand River Ave., Novi, MI 48374 USA

DIAMOND CENTER

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SPE AUTOMOTIVE

MEETING SCHEDULE & SPECIAL EVENTS CALENDAR

SPE Auto. Div. Board Meeting
American Chemistry Council - Auto. Ctr. 5:30 - 7:30 p.m.
Troy, MI USA October 21, 2019

49th-Annual SPE Automotive Innovation Awards Gala
Burton Manor 5:00-11:00 p.m.
Livonia, MI USA November 6, 2019

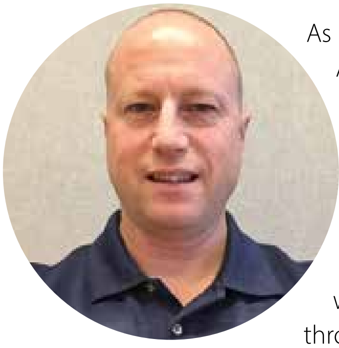
SPE Auto. Div. Board Meeting
American Chemistry Council - Auto. Ctr. 5:30 - 7:30 p.m.
Troy, MI USA December 9, 2019

Automotive Division Board of Directors meetings are open to all SPE members. All events are listed on our website at http://speautomotive.com

Email Dave Helmer at auto-div-chair@speautomotive.com for more information.

CHAIR'S WELCOME

DAVE HELMER, SPE AUTOMOTIVE DIVISION CHAIR



As the leaves are changing, SPE Automotive is in the middle of our busy season.

This time of year, we transition roles within SPE Automotive Division. Drew Geda, Jeff Mayville, and Keith Siopes will be new board members through 2022 replacing outgoing members Cynthia Flanigan and Ed Luibrand, Luibrand, while Rodrigo Orozco will be the new Intersociety Chair replacing Dhanendra Nagawanshi. A big thank you to all volunteering for future service and time already spent to make SPE Automotive Division strong.

Our just completed events for 2019 include the annual golf outing, Automotive Composites Conference and Exhibition, and the TPO Conference Support. The golf outing held on September 3rd at Fieldstone Golf Club in Auburn Hills was a success. The Automotive Composites Conference held September 4th through 6th at the Diamond Banquet and Conference Center in Novi continues to grow in sponsorship, papers, and exhibitors. The TPO conference held on October 6th through 9th at Troy Marriott is always a great success. Thank you to all SPE members for working hard to make these great networking and learning events.

Additionally this fall, SPE has the Innovation Awards Gala which will be held on November 6th at Burton Manor in Livonia. We are in process of reviewing all the entries and going through the judging process. The Industry Awards Gala is always a celebration of plastic innovation related to improving all our automobiles. For more details on attending the event, please go on our website **http://speautomotive.com/** and go to the events link – we hope to see you there.

At any time, if you have ideas on how to make our division better or would like to volunteer, do not hesitate to contact me at **auto-div-chair@speautomotive.com.**

Thank you,

Dave Helmer

19TH-ANNUAL

SPE AUTOMOTIVE COMPOSITES CONFERENCE & EXHIBITION

Presented by SPE Automotive Division and SPE Composites Division

COMPOSITES
FORMING THE FUTURE OF
TRANSPORTATION WORLDWIDE

SEPT 4-6, 2019

BY TERI CHOUINARD, SPE AUTOMOTIVE DIV. COMMUNICATIONS CHAIR

AUTOMOTIVE COMPOSITES CONFERENCE AND EXPO (ACCE) IS A SUCCESS

Continued from Page 1

ACCE's mandate is to educate the global transportation composites supply chain on the latest developments in polymeric materials, process, machinery and applications. Known as "The World's Leading Automotive Composites Forum," the conference is continuously improving and advancing the industry.

Once again, excellent leadership was provided from ACCE Co-Chairs, Dr. Alper Kiziltas, Lead Research Scientist, Ford Motor Company and SPE Automotive Div. Education Committee Chair Matthew E. Carroll, Materials Engineering, General Motors Company and recent SPE Automotive Div. Chair. Having two OEMs chair the event, for two years in a row, is a huge testament to the interest OEMs have in composites for automotive applications.

90 PRESENTATIONS ON THE LATEST AUTOMOTIVE COMPOSITES TECHNOLOGIES

This year's technical program included 90 presentations on the latest advancements in thermoplastic and thermoset composites; enabling technologies; reinforcement technologies; additive manufacturing and 3D printing; carbon composites, virtual prototyping, testing, and modeling; bonding, joining and finishing; sustainable composites; and business trends and technology solutions. Technical Program Chairs Dr. Leonardo Simon, Professor, Chemical Engineering at Waterloo University and Dr. David Jack, Associate Professor, Mechanical Engineering at Baylor University vetted the paper submissions and enhanced many of the presentations with their expertise greatly improving the quality of the program.

This year's keynote presentations, panel discussions and the technical sessions were the best ones ever.

ALPER KIZILTAS

MATT CARROLL

DR. DAVID JACK

DR. LEONARDO SIMON

INTRODUCING 2020 ACCE CO-CHAIR DR. XIAOSONG HUANG

Xiaosong Huang was academically trained in polymers and composite materials. He received his Ph.D. from Cornell University in 2007. After working as a polymer scientist in upstate New York for one year, Xiaosong joined General Motors Research & Development as a researcher in Polymer Composite Systems group in 2008. He has extensive experience in polymer composites for automotive applications and advanced lithium ion battery materials. He is currently the Lab Group Manager of Polymer Composite Systems in GM Global Research & Development.

ACCE 2019 KEYNOTE SPEAKERS

The first keynote of the conference, **"Driving Automotive Materials Forward,"** was delivered by **Dr. Cynthia Flanigan, *Chief Engineer, Vehicle Research & Technology, Ford Motor Company.*** Her presentation outlined how the growth of the automotive industry, current policy frameworks and R & D efforts encourage the use of cost-effective, lightweight, sustainable and advanced materials for automotive applications and how plastic composites technologies fit that criteria. Pioneering developments of sustainable and advanced materials by Ford scientists including nanocomposites, aerogels, natural fiber reinforced composites, polymeric and soft materials made from renewable feed stocks, 3-D printed plastic parts, bio-inspired and patterned functional materials as well as plastic parts made from recycled carbon dioxide were featured.

See SPE Automotive Division News, June 2019 edition for more on Cynthia Flanigan.

The second keynote of the conference, **"Chemistry-Driven Composite Innovation – The Future Is Now,"** was presented by **Gulay Serhatkulu, *Senior Vice President, Performance Materials North America, BASF Corp.*** Her keynote demonstrated how the increased desire for stronger, lighter, more sustainable material solutions can only be achieved with new chemistries together with creative product designs. She outlined the challenges facing composites solutions in the automotive industry and what needs to happen to increase the adoption. Examples from BASF illustrating how they are using chemistry to drive composites innovation now and into the future, by implementing a different way of working that brings the company offering new chemistries and the part designer closer than ever before, were presented.

ABOUT GULAY SERHATKULU

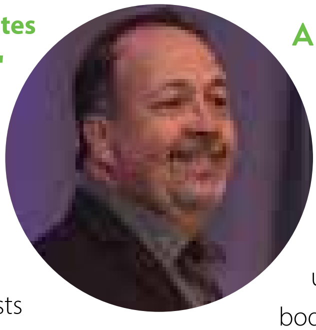
Gulay Serhatkulu is Senior Vice President responsible for the Performance Materials business of BASF Corporation in North America. This business encompasses the entire materials know-how of BASF regarding innovative, customized plastics under one roof and is globally active in four major industry sectors – transportation, construction, industrial applications and consumer goods.

"Chemistry-driven innovations drive BASF technology advancements in automotive applications making BASF the #1 chemical supplier to the automotive industry," said Serhatkulu. "Increasing desire for stronger, lighter, more sustainable material solutions can only be achieved with new chemistries together with creative product designs. This leads to a different way of working, bringing the company offering new chemistries and the part designer closer than ever before."

ACCE 2019 KEYNOTE SPEAKERS

The third and final keynote, **"Composites on the New Chevrolet Corvette,"** was delivered by **Ed Moss, *Engineering Group Manager, Corvette Body Structures, General Motors Company.*** His presentation featured the use of composites on the all-new 2020 Chevrolet Corvette Stingray. The body structure boasts many innovative elements making it the stiffest Corvette ever, utilizing lightweight composites to integrate functional elements into its form. Highlights included:

- The 2020 Stingray maintains Corvette's signature aluminum frame, innovative SMC and carbon fiber underbody components and the SPE award-winning lightweight exterior SMC body panels.
- Corvette continues to lead the automotive industry in the use of lightweight composites, and the 2020 Stingray introduces the automotive industry's first curved, multi-hollow, pultruded carbon fiber bumper beam.
- The Corvette offers class-leading storage for a mid-engine vehicle. It features front and rear storage units that are constructed of an industry-first "float SMC", which boasts a specific gravity less than 1.0.
- The jewel to the car's setting, the all-new LT2 V-8 engine, is visible through a large window mounted to the low-density SMC rear hatch.



ABOUT EDWARD D. MOSS

Ed Moss was named Engineering Group Manager (EGM) for Corvette Body Structure at GM in 2009. Moss is responsible for the engineering execution of the aluminum frame, the SMC and carbon fiber underbody components, and the exterior SMC body panels.

Moss joined General Motors in 1990, and has held numerous engineering positions on Corvette, including Total Vehicle Analysis Engineer, Body Vehicle System Engineer and Integration EGM for Body Structure.

He has been at the forefront of many GM firsts on the Corvette Body Structure, including: the patented Fifth Generation Body Structure; four body structure patents on the Seventh Generation Corvette; and eight body structure patents pending on the Eighth Generation Corvette. His work on the 1997 Fifth Generation Corvette and the 2014 Seventh Generation Corvette resulted in Ed receiving GM's Boss Kettering Award in 1997 and 2014: this is the highest technical honor bestowed by the company.

Moss received his Bachelor of Science in Engineering from the Michigan Technological University in 1983. He received a Master of Science in Engineering from Wayne State University in 1989.

He lives in Walled Lake, Mich. with his wife, Donna and their four children Eric, Drew, Jacob and Megan.

ACCE 2019 PANEL DISCUSSIONS

PANEL DISCUSSION 1

The first panel discussion, **"Polymer Composites in Automotive Applications, State of the Art and Approval Work Flow"** was led by ACCE Co-Chair Dr. Alper Kiziltas, Lead Research Scientist, Ford Motor Company and included panelists Drew Geda, Senior Materials Engineer, Hyundai-Kia America Technical Center, Inc.; Umesh Gandhi, Executive Scientist, Toyota Research Institute North America TMNA R & D; Bradley Rogers, Materials Engineer, Composites Material Specialist, General Motors Company and Dennis Chung, Honda Research & Development Americas, Inc.

The panel of OEMs outlined how automotive trends (light-weighting/metal replacement, increasing under-hood temperatures, predictive analysis & engineering, electrification, advanced driver assistance systems, and global regulatory requirements) may affect material requirements, test methods and the approval process.

PANEL DISCUSSION 2

The second panel discussion, **"What We Can Learn from Other Industries"** included Jay Olson, Manager, Materials Engineering, John Deere; Amar K. Mohanty, Director, Bioproducts Discovery & Development Centre (BDDC), Premier's Research Chair in Biomaterials & Transportation, Research Leadership Chair Professor, University of Guelph; Maurizio Longhi, Materials Technology Principal Engineer, Whirlpool Corporation; and Soydan Ozcan, Senior Scientist – Oak Ridge National Laboratory.

The multifaceted panelists discussed how they are using composites in their products and potential ways to work together to share technologies.

PLASTIVAN®

Once again, on Wednesday, Sept. 6th, the first day of the conference, the ACCE hosted the PlastiVan® program including 100 students and 2 teachers from Clarkston High School. The PlastiVan program provides sound science and educational programs – including fun experiments with plastics – which spark scientific curiosity in students while increasing their knowledge of the contribution plastics make to modern life and encouraging them to seek careers in engineering.

EVE VITALE

Eve Vitale, Chief Executive, welcomed the students in the Diamond Ballroom upon their arrival. Three PlastiVan classes were conducted. In between sessions, the students visited the Student Poster Displays and interacted with the college students to learn about their research and careers in the industry. They also visited the exhibits and learned about the companies, products and services in the composites industry.

STUDENT POSTER COMPETITION

Every year at ACCE, students from the U.S.A. and international universities present their innovative research related to plastic composites materials and manufacturing technologies relevant to automotive applications. This annual event is a great opportunity for the students to interact with members of the automotive composites industry and learn about what it is like to work as a scientist or engineer in the field. OEMs and their suppliers benefit as well as they are able to meet the next generation of automotive composites engineers and scientists and potentially to hire them.

The ACCE 2019 Student Poster Competition, sponsored by DuPont & Ford Motor Company, was the largest one ever. ACCE hosted 75 Students (49 Graduate, 23 Undergraduate and 3 High School) from 29 schools in the U.S.A., Canada, Germany and Turkey to present their state-of-the-art work at the event. Students were provided with hotel rooms and stipends to help with travel expenses. In addition, scholarships ($100 – $750 each) were provided to the students whose posters were judged (by industry experts from industry and academia and conference sponsors and attendees) to be most outstanding in their category.

Here are the winners of this year's competition:

PHD CATEGORY DESIGN, MANUFACTURING, SIMULATION, JOINING:

1ST PLACE

Void Evolution During Vacuum Bag-only Processing of Composite Prepregs

Wei Wu, PhD, *University of Southern California*

2ND PLACE

Automotive Lightweighting of Class A Panels via Supercritical Foam Injection Molding of Thermoplastic Olefins

Sai Aditya Pradeep, PhD, *Clemson University*

3RD PLACE

Characterizing Hybrid Composites Designed to Increase Light-Weighting in Automotive Composites

Nate Blackman, PhD, *Baylor University*

PhD CATEGORY NANO/BIO/ADDITIVE MANUFACTURING:

1ST PLACE

Petroleum Pitch-based Carbon Fibers with Modified Transverse Microstructure and Enhanced Properties: Fiber Focus

Sagar Kanhere, PhD, *Clemson University*

2ND PLACE

Measurement and Prediction of Pressure Drop of Nozzle Flow in Fused Filament Fabrication Additive Manufacturing

Jingdong Chen, PhD, *Baylor University*

3RD PLACE

Preparation of Multi-Particle Polyamide Copolymer Nanocomposite Utilizing a Hybrid Solvent/Melt Compounding Methodology

Erik Stitt, PhD, *Michigan State University*

PhD CATEGORY: NDE/TESTING

1ST PLACE

Measuring Fiber Length in the Core Layer in Injection Molded Polypropylene Plaques

Abrahan Bechara, PhD, *University of Wisconsin – Madison*

2ND PLACE

Thermoplastic Composites, Testing/Characterization, Modeling and Simulation

Kayode Emmanuel Oluwabunmi, PhD, *University of North Texas*

3RD PLACE

An Investigation on Effect of Adhesive Distribution on the Strength of Single Lap Bonded Joints

Akash Pisharody, PhD, *Baylor University*

MS CATEGORY

1ST PLACE

Food Industry Waste-derived Biocarbon and Biobased Engineering Thermoplastic for Sustainable Composite Applications

Maisyn Picard, *University of Guelph*

2ND PLACE

Bonding of Composite Structures with Additive Manufactured Adhesives

Paul Oehlman, *University of Wisconsin – Madison*

3RD PLACE

Manufacturing Process Effects on Crashworthiness Analysis Through a Numerical Simulation Pathway

Madhura Limaye, *Clemson University*

STUDENT POSTER COMPETITION

UNDERGRADUATE CATEGORY

1ST PLACE

Next Generation Hybrid Composites Using Multifunctional Graphene Nanoplatelets
Noemie Denis, Florida *International University*

2ND PLACE

Sustainable Biocomposites from Poly (3-Hydroxybutyrate) (PHB) and Agave Fibre: Reactive Extrusion and Performance Evaluation
Megan Smith, *University of Guelph*

3RD PLACE

Voids and Other Microscopic Features in 3D printed Carbon Fiber Reinforced PA 12 Composites
Elsie Kowalski, *University of Michigan/Ford*

HONORABLE MENTION

3D Printed Sustainable Biocomposites from a Biobased Engineering Plastic and Biocarbon
Elizabeth Deiderich, *University of Guelph*

HONORABLE MENTION

Generating Automotive Grade Polymer and Composites Materials for Additive Manufacturing
Alicia Samson, *University of Michigan*

HIGH SCHOOL CATEGORY

WINNER

Developing Sustainable Hybrid Thermoplastic Composites Based on engineered Polysaccharides and PA6
Maxwell Topping, *South Lyon East High School*

WINNER

Effects of Recycled PEI in PU Foams
Sheela Gubachy, *Redford Union High School*

WINNER

The Future of Automotive is 1 Atom Thick: Graphene in NVH Foam
Tara Ellwood-Mielewski, *Rudolph Steiner High School*

THANK YOU!!

Special Thanks to Dr. Uday Vaidya, ACCE Student Poster Competition Chair for many years and to Douglas Smith for helping Uday in organizing the judging for this year's event.

DR. UDAY VAIDYA
UNIVERSITY OF TENNESSEE-KNOXVILLE

DOUGLAS SMITH
BAYLOR UNIVERSITY

ACCE PART COMPETITION

This year's ACCE Part Competition included 12 nominations. A panel of 13 automotive composites industry experts, from industry and academia, studied the nominations in advance of the event and reviewed the parts onsite and voted for the most innovative applications in each of 4 categories. Two winners are awarded in both the Materials and Process Categories (Most innovative Production Part and Most Innovative Prototype Part).

Nominations are judged on the impact and trendsetting nature of the application, including materials of construction, processing method, assembly methods, and other enabling technologies that made the application possible. Nominations emphasize the benefits of design, weight and cost reduction, functional integration, and improved performance.

A fifth prize, the People's Choice award, is selected by vote of conference attendees. Here are the winners:

MATERIALS CATEGORY
MOST INNOVATIVE PRODUCTION PART

Industry First Implementation of Biocarbon for Headlamp Housing

Submitted by: Ford Motor Company

Suppliers: Competitive Green Technologies, Varroc Lighting Systems

PROCESS CATEGORY
MOST INNOVATIVE PRODUCTION PART

Chevy Corvette Rear Impact Beam

Submitted by: General Motors Company

Suppliers: SGL Carbon, VectorPly and Scott Bader

MATERIALS CATEGORY
MOST INNOVATIVE PROTOTYPE PART

Organo Sheet Insert for Brake Pedal Assembly

Submitted by: Hyundai-Kia

Suppliers: Donghee, Kolon Plastics

PROCESS CATEGORY
MOST INNOVATIVE PROTOTYPE PART

In-Mold Assembly of Rotational Kinematic Linkage

Submitted by: Magna

Suppliers: Magna is currently working with industry leading suppliers of glass-filled resins

PEOPLE'S CHOICE

Industry First Exterior Application Using Natural Fiber Composites – Underbody Shield

Submitted by: Ford Motor Company

Suppliers: BASF, Cadillac Products Automotive Company

ACCE PART COMPETITION

OTHER NOMINATIONS:

MATERIALS CATEGORY PROTOTYPE PARTS

Lightweight Hydrogen Tank Support Frame
Submitted by: Hyundai
Suppliers: Donghee, LG Hausys

Carbon Fiber Composite Floor Reinforcement Structure (HP-RTM Reinforcement)
Submitted by: General Motors Company
Suppliers: Continental Structural Plastics, Coats, Hexion

Thermoplastic Composite Solid Interior Part of the Armrest
Submitted by: Kruger Biomaterials
Supplier: Plastiques Moore

PROCESS CATEGORY PROTOTYPE PARTS

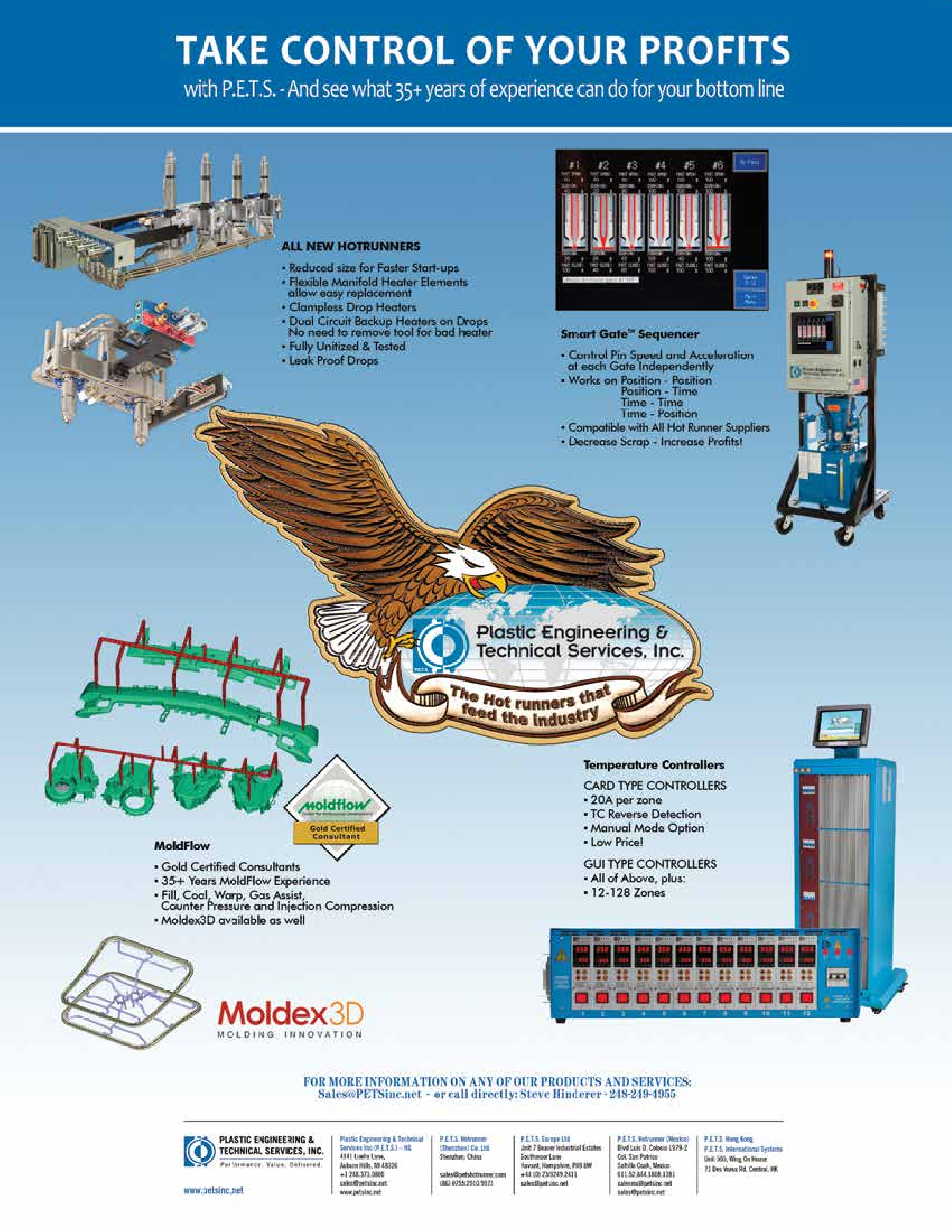
A Full Composite SMC Liftgate for the Volkswagen Atlas
Submitted by: Volkswagen
Supplier: Molding at IACMI SURF

HP–RTM Process – Door Inner
Submitted by: TPI Composites
Suppliers: University Of Delaware. Hexion, Chomarat. A&P, Krauss-Maffei

MATERIALS CATEGORY PRODUCTION PARTS

Composite Space Frame, Structural Reinforcement for Automotive Liftgates/Tailgates
Submitted by: Magna
Suppliers: BASF, Modelárna LIAZ spol. Cannon, AURA, VUTS

Carbon Canister - Recycled Carpets are Utilized to Make Car Part Resulting in Cost Saving and Reduced Greenhouse Gas Emissions
Submitted by: Ford Motor Company
Suppliers: Wellman, Delphi



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TREASURER'S REPORT

BONNIE BENNYHOFF, SPE
AUTOMOTIVE DIVISION TREASURER

AS OF OCTOBER 4, 2019, THE DIVISION'S ACCOUNT BALANCES WERE:

Checking:	$479,346.83
Savings:	$ 27,481.96
Total:	$506,828.79

spe ANTEC® 2020
San Antonio, TX • March 30-April 2, 2020

DR. NORM KAKARALA & TOM PICKETT

CALL FOR PAPERS

The 2020 SPE Annual Technical Conference (ANTEC) will be held at the Marriott Rivercenter in San Antonio, Texas USA from March 30 – April 2, 2020. ANTEC is the largest and most respected technical conference in the plastics industry.

Why presenting at ANTEC® 2020 in the Automotive Sessions is important to you:

- Opportunity to present to interested peers.
- Educate attendees on the most recent advances in the automotive plastics industry
- Raise awareness of your research
- Grow your knowledge
- Network and meet others in your field
- Contribute to your resume and professional development

The Automotive Division Sessions of ANTEC are well attended each year by leaders in the Automotive Industry. Dr. Norm Kakarala and Tom Pickett are Technical Co- Chairs of the ANTEC Automotive Division Session. We are seeking paper submissions in the following high demand automotive applications:

- Lightweight Materials and Part Designs for Automotive Applications
- Plastics & Composites Materials for Electric and Autonomous Vehicles
- Biobased & Recycled Materials for Sustainability
- Fillers & Additives for Property Improvements
- Measurements & Control of Chemical Emissions in Automotive Interiors
- Elastomers for Static & Dynamic Gasket Sealing Applications
- Material Developments for Automotive Applications
- Analysis & Modeling for Performance Prediction

THE DEADLINE IS OCTOBER 25, 2019

Log on to the SPE website address and follow the directions to register and submit your paper. The SPE website is: www.4spe.org/antec

BEST PAPERS

Sponsored by

INSPIRING PLASTICS PROFESSIONALS

SPE® ANNOUNCES 2019 AUTOMOTIVE COMPOSITES CONFERENCE & EXHIBITION (ACCE) BEST PAPER AWARD WINNERS

The 2019 SPE ACCE Best Paper Award winners received the highest average ratings by conference peer reviewers out of a field of close to 100 contenders. All three winners were honored for excellence in technical writing, with a commemorative plaque, during the SPE ACCE opening ceremonies on Wednesday morning, September 4th.

Sara Andrea Simon, a PhD candidate at the Polymer Engineering Center (PEC), University of Wisconsin-Madison (Madison, Wisconsin, USA), won first place in this year's competition; **Dr. Xiaoming Chen,** a Technical Expert at Ford Motor Company (Dearborn, Michigan, U.S.A.), won second place; and **Dinesha Ganesarajan**, a graduate student working on his Master of Science degree in the Chemical Engineering department at the University of Waterloo (Waterloo, Ontario, Canada), placed third in the competition.

Sara Andrea Simon won first place for her paper titled ***Direct Fiber Model Validation: Orientation Evolution in Simple Shear Flow.*** The paper was presented on **September 4th** from **1:00 to 1:30 PM** in the **Advances in Thermoplastic Composites** session at the conference. About this topic, the author says, "The ability to simulate the processing of fiber reinforced composites has become indispensable for the automotive industry. Particle level simulation, in specific, is a promising tool that can be employed in the improvement of commercial software. In this work, reliable fiber orientation evolution data was obtained to aid in the validation and development of our particle modeling approach for reinforcing fillers."

Simon is a PhD candidate at the Polymer Engineering Center (PEC), University of Wisconsin-Madison. She currently works in collaboration with Volkswagen on a new physical foaming injection molding technique to advance lightweight automotive constructions. Simon holds a Master of Science degree in Mechanical Engineering as well as a Master of Science degree in Natural Sciences. Her research interests focus on characterization and simulation of discontinuous fiber composites. In the past three years at the PEC, Simon investigated fiber breakage, fiber-matrix separation and fiber orientation during mold filling.

Simon's paper is our featured technical article in this edition of SPE Automotive Plastics News, starting on page 31.

INSPIRE

Dr. Xiaoming Chen won second place in the competition for her paper titled ***Fatigue and Strength CAE and Test Results.*** She presented her paper on **September 6th** from **10:30 to 11:00 AM** in the **Opportunities and Challenges with Carbon Composites** session at the conference. About her topic, Chen explains "The carbon fiber composite subframe design was CAE driven. The performance of the prototype subframe was verified by component and vehicle tests. The CAE predictions for the tests had various degrees of correlation with the physical test results."

Chen is a Technical Expert at Ford Motor Company. She holds a PhD in Mechanical Engineering from Northwestern Polytechnical University in China and is an Alexander von Humboldt fellowship recipient. Chen started her career as a crash safety engineer at Ford Truck Operations and later joined the Lightweight Architecture Team of Research and Advanced Engineering. She was the lead engineer for the crash safety development of an aluminum intensive passenger car, the Ford GT magnesium cross car beam, and an advanced high strength steel body side design using hydro forming technologies. Her current projects are related to lightweight chassis systems and components using advanced high strength steel, aluminum, magnesium and composites materials.

Third place winner, **Dinesha Ganesarajan's** paper is titled ***Latest Breakthroughs with Hybrid Reinforced Composites in Lightweight Applications.*** Dr. Leonardo Simon, University of Waterloo and ACCE Technical Program Co-Chair, presented his paper on **September 5th** from **10:30 to 11:00 AM** in the **Sustainable Composites** session at the conference. About his research, Ganesarajan comments, "My work explores the utilization of hybrid composites in the automotive industry for body interior and under the hood applications. The use of naturally-sourced filler material with the combination of glass fiber yields superior performance properties with a lightweighting initiative. This is a necessary intermediate step to achieve the ambitious goal of a circular economy just like the introduction of hybrid vehicles before the emergence of electrification."

Ganesarajan is a graduate student pursuing a Master of Science degree at the University of Waterloo's Chemical Engineering department. His thesis topic explores the use of naturally sourced filler materials being combined with glass fiber to produce hybrid composites for body interior and under-the-hood applications in the automotive industry. He completed his undergraduate program at the University of Waterloo majoring in Chemical Engineering with an energy systems specialization.

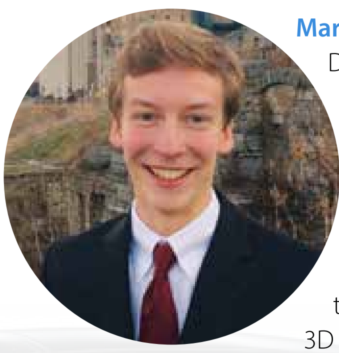
Ganesarajan has four years of industry experience having worked at companies like Tesla Motors, Ford Motor Company, Ballard Power Systems, and Northern Cables. His expertise is in materials science and his passion is in sustainability and achieving a "circular economy".

SCHOLARSHIP

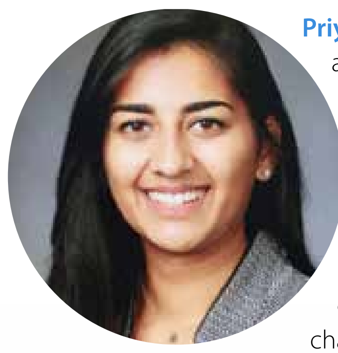
SPE® ANNOUNCES WINNERS OF THE ACCE & DR. JACKIE REHKOPF SCHOLARSHIPS FOR THE 2019-2020 ACADEMIC YEAR

The three winners of the SPE ACCE scholarships ($2,000 USD each) are **Martin Eichers,** a student at North Dakota State University, **Priya Venkatraman,** a PhD candidate at Macromolecular Science and Engineering, Virginia Tech, and **Bradley Sutliff,** also a PhD candidate at Macromolecular Science and Engineering, Virginia Tech.

The Dr. Jackie Rehkopf Scholarship is sponsored by the SPE Automotive Division, the SPE Composites Division and generous donations from friends and family. The two winners of the Rehkopf scholarship ($5,000 USD split between the two) is **Mariana Desireé Reale Batista,** a PhD candidate in Materials Science and Engineering at Michigan State University, in the Composite Materials and Structures Center, and **Akshata Kulkarni,** a PhD candidate in Polymer Engineering, University of Akron. Both scholarships are administered as part of the SPE Foundation®.



Martin Eichers is a senior at North Dakota State University (NDSU) majoring in Mechanical Engineering with minors in Chemistry and Coatings and Polymeric Materials. Martin is the project lead for the Formula SAE Electric team and president of the 3D Printing Club at NDSU. As a research assistant in the Mechanical Engineering Department, Martin works to develop low-cost biocomposite PLA 3D printing filament by designing various material formulations and manipulating manufacturing conditions to produce the strongest filament. After extruding a new filament, he determines its properties through mechanical testing. He became interested in polymeric materials after learning more about 3D printing. His career goals include to providing 3D printing and materials expertise to assist in the development of new technologies for the aerospace, automotive, and biomedical industries.



Priya Venkatraman is currently a PhD candidate pursuing a degree in Macromolecular Science and Engineering (MACR), in the Macromolecules Innovation Institute (MII) at Virginia Tech. Her research is comprised of the design, processing, and characterization of nanocellulose composites with applications in producing environmentally sustainable, lightweight material alternatives for use in various industries including automotive and aerospace. Through her active involvement in the nanocellulose community, Priya was elected chair of the Technical Association of Pulp and Paper Industry (TAPPI) Nano Student Committee in 2018, where she previously served as the Student Engagement Subcommittee Chair. Her involvement with SPE has been an integral part of her graduate career as well, facilitating her knowledge of the polymer engineering community. Priya is currently organizing and serving as co-chair of the National Graduate Research Polymer Conference, which is set to be hosted at Virginia Tech in 2020. She intends to pursue a career in research and development to improve industrial-scale polymer engineering processes and develop materials with unique, enhanced properties, while being more mindful of the environmental impact. Priya will be defending her dissertation in the upcoming academic year (2019-2020).

AWARDS

Bradley Sutliff is a third-year PhD student at Virginia Tech, studying Macromolecular Science and Engineering. Under the advisement of Dr. Michael J. Bortner, Brad studies the rheology of cellulose nanomaterials similar conditions to current industrial processes. Prior to this he earned a Master's degree in biomedical engineering at Syracuse University. At SU, he manipulated bacteria to produce polyhydroxyalkanoates, a category of biopolymers that show promise for medical devices and environmental degradation. As a staunch supporter of developing bioplastics for both medical and general usage, he understands such materials will not succeed if they cannot meet current industry needs. This has focused Brad's career on not only studying bio-based materials, but also interacting with the plastics professionals of the world to identify their requirements and questions. To this end, SPE has been a tremendous help, allowing Brad to meet many professionals at his first ANTEC® in 2019. He is currently in his second year as the president of the SPE student chapter at Virginia Tech, and has recently joined SPE's Next Generation Advisory Board. This year, Brad will be focusing on growing VT's student chapter, and on planning the National Graduate Research Polymer Conference (NGRPC) for July 2020 at Virginia Tech.

Mariana Desireé Reale Batista is currently completing her PhD studies in Materials Science and Engineering at Michigan State University, in the Composite Materials and Structures Center under Professor Lawrence Drzal's supervision. Her research is focused on developing lighter, safer, more sustainable and cost-effective materials for components used in automotive and aerospace industries. She is investigating polymer composites, specifically the modification of the fiber-matrix interphase with nanoparticles, to simultaneously strengthen and toughen the composites and impart multifunctionality to them. She has been optimizing the adhesion of carbon fiber reinforced composites through the incorporation of Cellulose Nanocrystals and optimizing the mechanical properties of bamboo fiber reinforced composites by incorporating Graphene Oxide at the composite interphase. She interned at the Ford Motor Company (Research and Innovation Center), where she developed lightweight hybrid cellulose-inorganic reinforcement composites for automotive applications. More recently she interned at NASA (AMES Research Center) developing flexible UV sensors. Batista graduated summa cum laude with a B.S. degree in Mechatronics Engineering and received an M.B.A. degree in Administration and Business Management, both from Universidade Salvador - UNIFACS, Brazil. While at MSU she has been involved in many organizations as a volunteer, providing assistance in outreach activities dedicated for young students.

Akshata Kulkarni started her career in polymers in 2012 when she opted for a Bachelor's degree in Polymer Engineering at the Institute of Chemical Technology in Mumbai. During her undergraduate years, she gained hands-on experience in the field through industrial and academic internships, and was chosen as the Summer Research Fellow of the Indian Academy of Sciences in May 2014. At the University of Akron, Akshata is currently pursuing her PhD under the guidance of Dr. Sadhan C. Jana. As a part of her doctoral dissertation, she has worked on developing energy efficient vulcanizing systems for low energy loss tire tread compounds. The work involved using benzocyclobutene based crosslinking agents for obtaining improved properties of the final tread compound, as well as a lower crosslinking time. This project was executed under the aegis of CenTiRe and was a collaborative effort between Dr. Sadhan Jana and Dr. Coleen Pugh from the College of Polymer Science at the University of Akron. Currently, she is working on utilizing highly porous aerogel materials for separating oil-water mixtures. Along with her academic accolades and research experience, she has also served as the President of the Akron SPE Student Chapter during the 2017-2018 academic year. Recently, she also received the Ohio Rubber Group Graduate Student Award as well as the Paul Glasgow Student Scholarship from the ACS Rubber Division. Akshata intends to work in the polymer industry after her graduation.

COUNCILOR'S REPORT

SPE COUNCIL MEETING MINUTES, BALTIMORE, MD SEPTEMBER 20, 2019, BY DR. SURESH SHAH

This was remote WebEx meeting.

The agenda was approved as published.

President Landes briefed Council on what we are trying to accomplish at today's meeting, **specifically proposed changes to our election cycle and governance model.** Landes went on to memorialize Jerry Fischer, Donald John Jambro, Franklin Palmer, Peter Simmons Sr., Robert Swain and Mark Vliem.

NEW ELECTION TIMELINE PRESENTATION – B. GRADY

Past President Grady reviewed his presentation regarding a **proposed change to the election cycle.** Grady outlined the contrasts between the current timeline and the proposed model, leading to benefits for the candidates and the Society…primarily increased engagement with the future leaders of the Society.

BYLAWS AND POLICIES UPDATE – M. MACLEAN-BLEVINS

Mark reviewed the recommended changes to the bylaws that were posted on The Chain for 30 days. Mark started with the bylaws related to the proposed changes to the election cycle. (**see The Chain**). As found on The Chain, there are proposed changes to:

1) 3.13 Council Year
2) 7.3.7 Nominations at Large
3) 7.4.3 Election Date
4) 7.4.4 Order of Election
5) 7.5.2 Assumption of Duties
6) 8.1.2.2 Section or Division Counselor
7) 8.2 Section of Division Counselor Term of Office
8) 8.2.4 Vacancy Replacement
9) 8.3 Reporting of Election Results
10) 14.7.5.3.1 Nominations (new bylaw entry)
11) 14.7.5.3.2 Election
12) 14.7.5.3.3 Responsibility

Mark motions to comprehensively accept the recommended changes to the bylaws and the motion was seconded by Past President Grady. Discussion on reasons to allow candidates to run from the floor as well as questions regarding the updated roles of the Nominating Committee. The motion is approved.

GOVERNANCE TASK FORCE PHASE 2 PRESENTATION – B. MULHOLLAND

VP Mulholland reviewed his presentation regarding a proposed change to SPE governance. He started by outlining the current governance and how it has evolved as a result of the first phase of governance changes in March 2017. Bruce went on to list some observations he has made, either personally or from communication with other Councilors, regarding our current situation. **Bruce cited research suggesting the appropriate Board size for nonprofits is 14-18 members.** Prior to presenting the proposed model, he highlighted the goals of a new governance model which centers on generating greater member value. Bruce concluded by commenting that the **presentation will be put on the Chain and it is imperative that we continue discussions to do what is best for the relevance of the Society.**

SERVICES ROLLOUT UPDATE – P. FARREY

CSE Farrey gave an update on the HQ Services model. He reviewed the members of the team and the contributions that each has given based on their experiences in their respective Sections and Divisions. A variety of options were evaluated before settling on bundled, standard packages for event services, a la carte pricing for additional services and the inclusion of many standards HQ services, free of charge. In the end, those select chapters that have been historically low will pay more and those that have historically been high will pay less. **This model eliminates the historical 12% tax that Chapters have previously been subject.**

This effort is not intended to be a profit center for SPE but rather a sustainable service for our Chapters. In most cases, the services offered will cost less than what is obtainable from 3rd parties and the learning curve is eliminated. This model is for events scheduled after 1/1/2020.

DIVISIONS NAME CHANGE REQUEST – J. LYONS

Sustainability Division name was changed to the Recycling Division as per request from their board members.

OLD BUSINESS/NEW BUSINESS – B. LANDES

President Landes entertained old and new business, both receiving none.

ADJOURN: NEXT MEETING – B. LANDES

President Landes asked for a motion to adjourn which was seconded and approved. **November 14 & 15, 2019. New SPE HQ in Danbury, CT.**


TOP WORK PLACES 2016
TOP WORK PLACES 2018
Detroit Free Press
TOP WORK PLACES 2017

25TH ANNUAL 2019 SPE AUTOMOTIVE DIVISION GOLF OUTING

FIELDSTONE GOLF AND COUNTRY CLUB, AUBURN HILLS, MI

SPECIAL THANKS TO OUR SPONSORS, PARTICIPANTS & *RON PRICE* FOR HIS SPE SUPPORT OVER THE YEARS

Friends and members of the SPE Automotive Div. enjoyed great weather and golf while supporting SPE Student Chapters. Thanks to our loyal sponsors, who have supported the event for many years, great fun and comradery was enjoyed by all. This year's outing was dedicated in memory of Ron Price – a long time SPE member and part of a group of plastics professionals who contributed to the founding and growth of SPE in the Detroit area.

Joe Mihelich, from JSP, delivered a tribute to Ron. He acknowledged Ron for his great mentorship to him and many others in the automotive plastics community and advised how grateful Ron's family was for the Golf Outing being dedicated to his memory. On behalf of the SPE Automotive Div., Fred Deans, Golf Chairman for Life, expressed how much he appreciated Ron's dedication to the SPE and the great photos he took as our volunteer photographer at the Golf Outing and many other SPE events.

The day started with a continental breakfast at 8:30 am and practice on the driving range. There was a 10 am shotgun start with lunch and beverages at the turn sponsored by BASF. A delicious dinner was sponsored by Plastics Engineering & Technical Services (PETS), who have supported the event with dinner sponsorship and more for many years. After dinner, trophies were awarded to the winning teams. Attendees received golf related items, donated by sponsors and attendees, for participating in the event.

Fieldstone Golf and Country Club, Auburn Hills, Michigan, has consistently hailed as one of the top 3 public golf courses in Southeast Michigan for the past decade. Fieldstone includes an exceptional variety of hole designs by the renowned architect, Arthur Hills, that mesh the diverse landscape and wetlands with gently rolling fairways through majestic hardwoods. **Mark your calendars - next year's event will be held there on Tuesday, Sept. 8th, 2020.**

1st Place Team: ID Additives

2nd Place Team: Trinseo

3rd Place Team: Plastics Engineering & Technical Services (PETS) Team 3

Closest to the Pin Contest Hole Winner: Adam Pailson Adam won a Gift Card to Ruth's Chris Steak House, Sponsored by ID Additives.

Joe Mihelich, from JSP, Praises Ron Price for his Mentorship and Leadership.

THANKS TO OUR 2019 SPONSORS

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PERFORMANCE MATERIALS

PRET WELLMAN
ADVANCED MATERIALS

LIFETIME ACHIEVEMENT AWARD

SPE® ANNOUNCES "LIFETIME ACHIEVEMENT AWARD WINNER" – MICHAEL J. WHITENS WILL BE HONORED AT SPE AUTOMOTIVE INNOVATION AWARDS GALA NOV. 6, 2019

Michael J. Whitens, retired former Global Director for Ford's Vehicle and Enterprise Sciences at Ford's Research and Innovation Center, has been named the ***2019 Lifetime Achievement Award*** winner by the Automotive Division of the ***Society of Plastics Engineers (SPE®).*** In his most recent role at Ford (2014 – 2018) he led the development of technology strategy and implementation in support of emerging areas including plastics/polymers, advanced plastics processing technologies, composites and material formulations with responsibility for over 500 researchers at three Ford Motor Company global facilities.

He has demonstrated expertise working on several advanced plastics processes including micro-cellular foaming, long-fiber thermoplastic (D-LFT) composites, natural fiber composites, carbon fiber composites, nano additive based composites, metal-plastics hybrid molding, co-injection molding, twin screw extrusion compounding, polyurethane foams and more. His work includes the development of several innovations for numerous automotive plastics applications, ranging from interiors and exteriors to under the hood and safety – including instrument panels, door panels, door modules, molded-in-color, seating, NVH foams, fuel systems components and more.

An automotive industry veteran with over 30 years of experience, Whitens has spent the majority of his career at Ford Motor Company in various body engineering disciplines. He also spent three years as the Mustang PVT (Platform Vehicle Team) manager, bringing the second-generation Bullitt and Mach 1 to life.

He is a recognized leader in the development of innovative technologies in the automotive field, with 35 patents in many areas of component innovation, new material development, safety, body interior, exterior and vehicle execution. He will be honored for his lifetime of industry expertise and innovation, contributing to the advancement of the automotive plastics industry, at the ***49th Annual Automotive Innovation Awards Gala*** on November 6, 2019 at Burton Manor (www.burtonmanor.net) in Livonia, Mich.

"I am very grateful to be recognized with this esteemed SPE Automotive Division award for Lifetime Achievement, and especially grateful to the talented teams of people I have had the honor to work with who have made this possible," said Whitens. "This award would not be possible without the challenging work experience that I enjoyed, the innovative support from my associates at Ford and their supplier base, participation in SPE and other professional trade associations and education," added Whitens.

"Mike is known industry wide as one of the best problem solvers and innovators in the field of plastics and composites," said Dr. Alper Kiziltas, industry expert, Ford Motor Company. "He has a rare combination of expertise that is hard to find in the industry, including an understanding of the total system – an interaction between polymeric materials and chemistry, plastic processes, plastics part design, CAE, characterization and tooling," continued Kiziltas.

"Mike has a unique combination of global cross-functional leadership and refined people skills, giving him the ability to handle any business challenge," said Dr. Cynthia Flanigan, chief engineer, vehicle research & technology, Ford Motor Company. "He's a great leader who is very well-liked and respected in the industry, and most deserving of this award," added Flanigan.

MICHAEL J. WHITENS WORK EXPERIENCE:

Global Director – Vehicle & Enterprise Sciences, Ford Motor Company (2014 – until Retired)

Lead development of technology strategy and implementation in support of emerging areas. Responsible for more than 500 researchers at three global facilities.

Global Director – Body Interior Engineering, Ford Motor Company (2011 – 2014)

Responsible for quality, cost, weight, function and delivery of a more than $15 billion commodity base managing a $100 million budget. This included an all global cockpit, hard and soft trim, seats, restraints, climate and interior lighting for all Ford vehicles globally, leading a team of over 2,000 people in nine engineering centers around the globe.

LIFETIME ACHIEVEMENT AWARD

MICHAEL J. WHITENS

Global Chief Engineer – Body Interior Engineering, Ford Motor Company (2006 – 2011)

Responsible for quality, cost, weight, function and delivery of more than $6 billion commodity base, including all global cockpit, hard and soft trim, interior lighting and restraints for all Ford vehicles globally. Led more than 600 people in nine engineering centers around the globe.

Chief Engineer – Body Engineering Exterior & Interior Small Car Cluster (Mustang, Windstar, Focus, Escape, Villager, Lincoln LS), Ford Motor Company (2001 – 2005)

Responsible for quality, cost, weight, function and delivery of all body interior and exterior commodities, including all small car vehicle body structures, closures, exterior ornamentation/lighting, global cockpit, hard and soft trim and seats and restraints.

Mustang PVT Manager, Ford Motor Company (1999 – 2001)

Responsible for quality, cost, weight, function and delivery of all Mustang vehicles.

Lincoln LS / Jaguar S-type Global Body Structure Platform Supervisor, Bumper/Exterior Ornamentation Mirror Supervisor, Front End & Underbody CAD Supervisor, Ford Motor Company (1987 – 1999)

Developed common underbody structure to support first Ford global vehicle platform.

Doors & Mechanical Component Engineer, General Motors (1985 – 1987)

Developed door and deck lid mechatronics for C-H platform vehicles.

SIGNIFICANT ACCOMPLISHMENTS AND AWARDS INCLUDE:

- Numerous Society of Plastic Engineers (SPE) – Automotive Innovation Awards
- Numerous PACE Awards in Collaboration with Suppliers
- Automotive News Award in Collaboration with Ernst & Young
- Design for 6-Sigma National Award Recipient, Ford Motor Company
- Awards for People Development, Ford Motor Company
- Numerous Quality Awards, Ford Motor Company
- Distinguished Alumni Recognition, Michigan Technological University, Electrical and Computer Engineering Academy (ECE Academy)

CONTRIBUTION TO PROFESSIONAL SOCIETIES, LEADERSHIP ROLES AND ACADEMIA CONTRIBUTIONS INCLUDE:

- Served on Board of Directors of SPE Automotive Division
- A member of the Blue Ribbon Judging Committee for SPE Automotive Division Innovation Awards Competition and Gala
- Chaired, organized and contributed to several SPE technical sessions at industry conferences, including SPE TPO (Thermoplastic Engineered Polyolefins) SPE AUTO EPCON (Automotive Engineering Plastics), SPE ACCE (Automotive Composites) and SAE (Society of Automotive Engineers) conferences and events.
- SPE member since 2000
- Michigan Technological University External Advisory Board
- Our Lady of Victory Volunteer Coach

CONTRIBUTION TO INNOVATIONS AND INTELLECTUAL PROPERTIES/TECHNICAL SPEAKERS IN AUTOMOTIVE PLASTICS INCLUDE:

- **35 IP (Intellectual Properties) – US and worldwide PATENTS** related to plastics materials processes and automotive applications
- **His patents** range from plastics process innovations, material formulations, to product innovations (interiors, safety, seating, exterior and under-the-hood) and tooling
- **Invited Keynote Speaker** at prestigious conferences and exhibitions, both nationally and internationally, such as SPE ACCE, SPE TPO, SPE Antec, SAE, and more. Invited reviewer as a subject matter expert. Invited committee member for SPE Innovation Awards Competition.
- **Several citations** in prestigious magazines, such as Plastics Engineering, Plastics Technology, Modern Plastics, Ward's AutoWorld, Injection Molding, Automotive Engineering, Automotive Interiors International, Plastics World, Plastics Design Forum, Design News and other Automotive & Transportation Interiors publications.

LIFETIME ACHIEVEMENT

MICHAEL J. WHITENS

AUTOMOTIVE
INNOVATION AWARDS
COMPETITION & GALA
HONORING THE BEST IN AUTOMOTIVE PLASTICS

SPE's Automotive Innovation Awards Program is the oldest and largest competition of its kind in the world. Dozens of teams made up of OEMs, tier suppliers, and polymer producers submit nominations describing their part, system, or complete vehicle and why it merits the claim as the *Year's Most Innovative Use of Plastics.* This annual event typically draws over 800 OEM engineers, automotive and plastics industry executives, and media. As is customary, funds raised from this event are used to support SPE educational efforts and technical seminars, which help educate and secure the role of plastics in the advancement of the automobile.

The mission of SPE is to promote scientific and engineering knowledge relating to plastics worldwide and to educate industry, academia, and the public about these advances. SPE's Automotive Division is active in educating, promoting, recognizing, and communicating technical accomplishments in all phases of plastics and plastic-based composite developments in the global transportation industry. Topic areas include applications, materials, processing, equipment, tooling, design, and development.

For more information about the ***SPE Automotive Innovation Awards Competition and Gala*** see **www.speautomotive.com**. For more information on the ***Society of Plastics Engineers***, see **www.4spe.org**.

First given in 2001, the SPE Automotive ***Lifetime Achievement Award*** recognizes the technical achievements of individuals whose work – in research, design, and/or engineering – has led to significant integration of polymeric materials on passenger vehicles. Past winners include:

- **J.T. Battenberg III,** then chairman and chief-executive officer of Delphi Corp. (2001)
- **Bernard Robertson,** then executive vice-president of DaimlerChrysler (2002)
- **Robert Schaad,** chairman of Husky Injection Molding Systems, Ltd. (2003)
- **Tom Moore, r**etired vice-president, Liberty and Technical Affairs at then DaimlerChrysler (2004)
- **Mr. Shigeki Suzuki,** general manager - Materials Division, Toyota Motor Co.(2005)
- **Barbara Sanders,** then director-Advanced Development & Engineering Processes, Delphi Corp. (2006)
- **Josh Madden,** retired executive at General Motors Corp. (GM) & Volkswagen of America (2007)
- **Frank Macher,** former CEO of Collins & Aikman Corp., Federal Mogul Corp., and ITT Automotive (2008)
- **Irv Poston, r**etired head of the Plastics (Composites) Development-Technical Center, GM (2009)
- **Allan Murray,** Ph.D., retired technology director at Ford Motor Co. (2010)
- **David B. Reed** P.E., retired staff engineer, Product Engineering, GM (2011)
- **Gary Lownsdale,** P.E., then chief technology officer, Plasan Carbon Composites (2012)
- **Roy Sjöberg,** P.E., retired staff engineer - Body, Chevrolet-Pontiac-Canada Div.,GM and retired executive engineer-Viper Project, Chrysler Corp. (2013)
- **Dr. Norm Kakarala,** retired senior technical fellow, Inteva Products LLC (2014)
- **Fredrick Deans,** P.E., chief marketing officer, Allied Composite Technologies LLC (2015)
- **Dr. Lawrence T. Drzal,** university distinguished professor of Chemical Engineering and Director-Composite Materials and Structures Center at Michigan State University College of Engineering (2016)
- **Dr. Suresh Shah,** retired senior technical fellow at Delphi Corporation, formerly General Motors – ACG (Automotive Components Group) (2017)
- **Dr. Rose A. Ryntz,** retired vice president, Global Advanced Development and Material Engineering at International Automotive Components Group (IAC). (2018)

INTERSOCIETY REPORT

DR. RODRIGO OROZCO, SPE AUTO. DIV. INTERSOCIETY CHAIR

SUSTAINABILITY: KEY CHALLENGE FOR PLASTICS IN AUTOMOTIVE

Overwhelmingly the recent trend in automotive plastics has been a focus on sustainability and automotive electrification. Dr. Cynthia Flanigan, keynote speaker at SPE ACCE, presented the five key challenges for plastics in automotive: i) Sustainability, ii) Emerging materials for electric vehicles, iii) Additive manufacturing, iv) Advanced processing & design, and v) Artificial intelligence. In particular, sustainability covers multiple aspects for plastic materials in automotive, including: interior air quality that may be affected by VOCs and odor, fabric alternatives including recycled or bio-based resins, material differentiation based on natural fillers, utilization of ocean plastic, and overall air quality improvement.

At the American Chemical Society CTO Summit in Washington, CTOs from 25 leading chemical companies discussed discussed climate change mitigation and opportunities for the chemical industry's contribution. The summit generated several ideas to support the United Nations Sustainable Development Goals (SDGs) and innovation will have to play a key role.

The United Nations climate summit in New York focused on global emissions, which are reaching record levels and showing no sign of peaking. Leaders from the member nations presented their plans to achieve the goals of the Paris agreement, stop the increase in emissions by 2020 and dramatically reduce emissions to reach net-zero emissions by mid-century. These plans include fuel economy and greenhouse gas emission standards for light-duty and internal combustion engine powered vehicles, which covers about 80% of new light-duty vehicles sold globally, according to ICCT Policy update.

The 54th annual CAR Management Briefing Seminars debated the mobility revolution that is transforming the global automotive industry. Carla Bailo, President and CEO of CAR, said: "We have never been in a more disruptive period in our business". Electric vehicles (EV) and autonomous driving capabilities are creating transformative implications for automakers, suppliers, policymakers, and consumers. The speed to adopt EVs and increasing level of autonomous capabilities in the US and other key markets around the world remains uncertain, despite estimates forecasted by various entities. Additionally, government policymaking around electric and autonomous vehicles has large consequences for every stakeholder.

The Original Equipment Suppliers Association (OESA) published their 2019 third quarter newsletter edition. Brian Daugherty (CTO MEMA) reported the advanced vehicle technology in electrification, advanced safety systems, and automation. Automotive OEMs globally have announced investments that exceed $300 billion on electrification technologies to improve fuel economy and meet regulatory standards. These standard requirements may drive a rapid growth globally of hybrid vehicles, mainly at the low-cost end based on start-stop technology and 12V to 48V hybrid systems. Battery electric vehicle volumes will likely continue to grow at a steady rate due to government policy. Autonomous vehicles remain in the development phase and multiple Advanced Driver Assistance Systems (ADAS) and Automatic Emergency Braking (AEB) are becoming standard equipment on new light-duty vehicles and heavy trucks.

The 2019 Frankfurt motor show, organized once every two years and one of the biggest auto shows on the planet, presented multiple concept vehicles and technologies following a common trend: electrification. An impressive number of the electric vehicles exhibited are either production-ready or nearly ready and cover a wide range from supercars to modest compact car for city driving. In addition, the show featured forward-looking machines with the future of electrified luxury and autonomous off-roading.

Lastly, the "Circular Economy" will be the main theme at the upcoming 2019 K show. Multiple suppliers have announced their new technologies with focus on sustainability, in particular, recycling, more environmentally friendly or bio-based feedstock and plastic waste reduction.

Sustainability and electrification in automotive have large implications for plastic materials. Multiple investments have already been announced for the development of technologies to meet automotive emissions and fuel economy, which drives material and process innovations for the evolving "mobility industry".

spe AUTOMOTIVE

HALL OF FAME

FIRST PLASTIC-METAL HYBRID FRONT END STRUCTURE NAMED 2019 SPE® AUTOMOTIVE INNOVATION AWARDS "HALL OF FAME" WINNER

The first Plastic-Metal Hybrid (PMH) front end structure, used on the 1999 C170 Ford Focus GOR from Ford Motor Company, has been named the 2019 Hall of Fame winner by the Automotive Division of the Society of Plastics Engineers (SPE®). This will be celebrated by honoring the technology and the companies and people originally involved in developing this application during SPE's 49th annual Automotive Innovation Awards Competition & Gala on November 6, 2019. The plastic-metal front end structure, made with Durethan® BKV30H2.0 (30% glass filled PA6/heat stabilized) resin from LANXESS (formerly Bayer from 1999-2004) with a steel insert enabled a 40% weight reduction, 30% cost reduction, high function integration with reduced process steps, higher accuracy and quality, and higher load capacity compare to a 100% steel structure. To be considered for a Hall of Fame Award, an automotive plastic or composite component must have been in continuous service in some form for at least 15 years and broadly adopted in the automotive industry. This application certainly qualifies as there have been more than 70 applications and 70 million manufactured parts to date worldwide.

The companies involved in developing the first PMH front end application include: OEM - Ford Motor Co.; System Supplier – Visteon; Molder/Processor – Visteon; Toolmaker – Misslbeck; and Material Supplier – LANXESS (formerly Bayer). Boris Koch is the inventor and designer of the PMH innovation with Bayer/LANXESS and Dr. Hubert Goldbach is the inventor and designer for the PMH innovation with Bayer.

The LANXESS PMH technology combined the great design freedom, good flexibility and low density of glass filled PA 6 with the high strength, stiffness and low thermal expansion of metal. This thermoplastic and metal integration enabled a part with higher load capacity compared to sheet metal profiles, higher torsional stiffness compared to open sheet metal profiles, higher precision in production and use, and higher integration of functional elements.

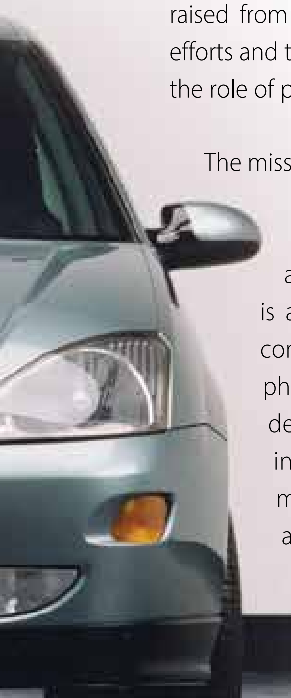
Key design features include an injection molded rib structure, in the thin wall metal sheet profile, with form closure grips, lay-on surfaces, overmolded edges and supporting ribs on the outside of the profile (providing a mechanical adhesion) resulting in improved part strength and support.

Other key design features, enabling a mechanical connection of the thermoplastic and metal structures, include: conical piercing in the sheet metal creating ports for the thermoplastic ribs to be secured; fixing area at sheet metal flange for the thermoplastic ribs to snap in place; and the thermoplastic rib structure providing additional strength and support inside the metal profile.

HALL OF FAME

The LANXESS PMH front end structure technology permitted the integration of features (piercings in the metal for connecting 21 different parts to the structure) in a single operation greatly improving production efficiency, cost effectiveness, and part performance.

On Wednesday, November 6, 2019, representatives from Ford Motor Company, Visteon, Misslbeck and LANXESS will accept the award on behalf of the original team that worked to develop the first Plastic-Metal Hybrid (PMH) Front End Structure on the 1999 C170 Ford Focus GOR at the 49th annual SPE Automotive Innovation Awards Program, at the Burton Manor in Livonia, Michigan. www.burtonmanor.net This is the oldest and largest competition of its kind in the world. Dozens of teams made up of OEMs, tier suppliers, and polymer producers submit nominations describing their part, system, or complete vehicle and why it merits the claim as the Year's Most Innovative Use of Plastics. This annual event typically draws over 800 OEM engineers, automotive and plastics industry executives, and media. As is customary, funds raised from this event are used to support SPE educational efforts and technical seminars, which help educate and secure the role of plastics in the advancement of the automobile.



The mission of SPE is to promote scientific and engineering knowledge relating to plastics worldwide and to educate industry, academia, and the public about these advances. SPE's Automotive Division is active in educating, promoting, recognizing, and communicating technical accomplishments in all phases of plastics and plastic-based composite developments in the global transportation industry. Topic areas include applications, materials, processing, equipment, tooling, design, and development.

The 2019 SPE Automotive Division Hall of Fame committee was chaired by **Nippani Rao,** Chrysler LLC, retired and co-chaired by **Dave Reed,** General Motors Corp., retired and **Fred Deans,** Allied Composite Technologies, LLC; . Committee members include:

- **Matt Carroll,** General Motors Company;
- **John Fialka,** INEOS Styrolution America, Inc.;
- **Jeffrey Helms,** Celanese;
- **Norm Kakarala,** Inteva Products, LLC, retired;
- **Mark Lapain,** Magna International Inc.;
- **Allan Murray,** Allied Composite Technologies, LLC;
- **Kevin Pageau,** International Marketing Alliance;
- **Tom Pickett,** General Motors Company;
- **Irv Poston,** General Motors Corp., retired;
- **Tom Russell,** Allied Composite Technologies LLC;
- **Dr. Rose Ryntz,** Ryntz & Associates, LLC;
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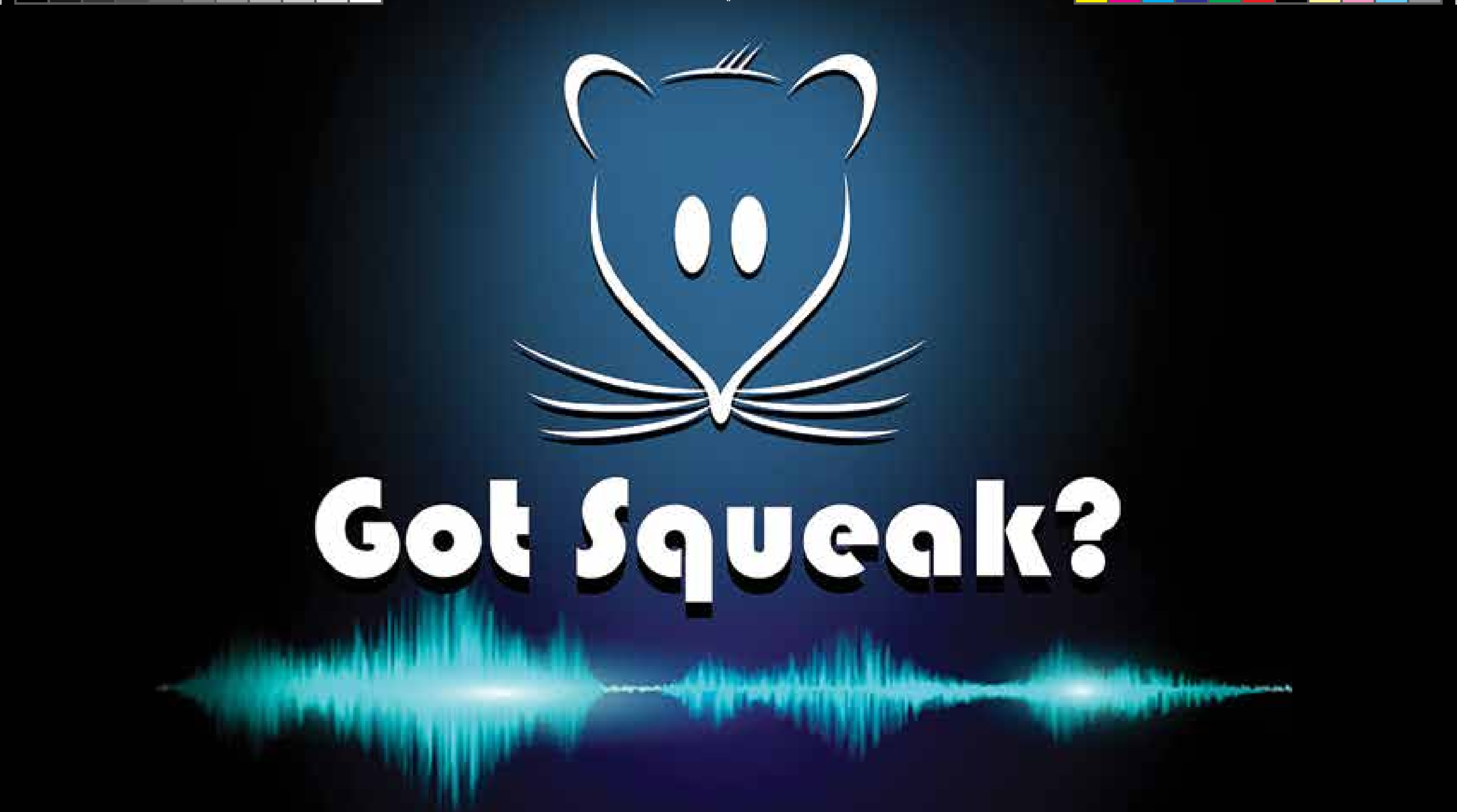
Got Squeak?

TECHNICAL REPORT

DIRECT FIBER MODEL VALIDATION: ORIENTATION EVOLUTION IN SIMPLE SHEAR FLOW

Sara Andrea Simon, Abrahán Bechara Senior, Tim A. Osswald,
Polymer Engineering Center, University of Wisconsin-Madison

ABSTRACT

Direct particle models are a promising tool for predicting microstructural properties of fiber reinforced composites. In order to validate our modeling approach for fiber orientation prediction, compression molded reinforced Polypropylene samples were subjected to a simple shear flow in a Sliding Plate Rheometer. Micro computed tomography was used to measure the orientation tensor for deformations up to 60 shear strain units. The fully characterized microstructure at zero shear strain was used to reproduce the initial conditions in the particle simulation. Fibers were placed in a periodic boundary cell and a flow field matching the experiment was applied. Samples created with the proposed compression molding technique showed repeatable and controlled initial orientation. The model showed good agreement with the steady state orientation; however, it showed a faster orientation evolution at the start of the shearing process.

ABOUT SARA SIMON

Sara Simon is a PhD candidate at the Polymer Engineering Center (PEC), University of Wisconsin-Madison. She currently works in collaboration with Volkswagen on a new physical foaming injection molding technique to advance light weight automotive constructions. Sara holds a Master in Science in Mechanical Engineering as well as a Master in Science in Natural Sciences. Her research interests focus on characterization and simulation of discontinuous fiber composites. In the past three years at the PEC Sara investigated fiber breakage, fiber-matrix separation and fiber orientation during mold filling.

INTRODUCTION

Computational tools to simulate the processing of fiber reinforced composites have become indispensable for the automotive industry. The ability to accurately predict the microstructure of molded components is a key factor not only for design calculations but also for addressing issues such as shrinkage and warpage before mold fabrication. Almost all commercially implemented models (Folgar-Tucker, Anisotropy Rotary Diffusion (ARD) Reduced Strain Closure (RSC)) use experimentally determined fitting parameters. However, these experiments are costly, lengthy and limited in the amount of information they can provide.

Particle level simulations have been used in the past to aid in the understanding of these type of systems [1, 2]. In these simulations, each fiber is modeled individually as a chain of rigid elements. Fibers are placed in a predetermined flow field and hydrodynamic forces, as well as fiber-fiber interactions, are computed to predict fiber motion [3, 4].

Obtaining parameters numerically has advantages over obtaining them experimentally. In a numerical setup, all parameters can be accurately controlled, detailed information is always available and the simulations are relatively inexpensive to perform. An additional advantage of these models is the high accuracy that is reached by modeling the actual motion of individual fibers [5].

The objective of this paper is to provide reliable fiber orientation evolution data in a well-defined simple shear flow to aid in the validation and development of a multi-particle model for reinforcing fibers. Simple shear was chosen since it is one of the fundamental flow conditions present in most polymer processes. Selecting it allows us to directly correlate the rate of deformation with the filler's behavior. Compression molded glass fiber-reinforced polypropylene samples were sheared in a Sliding Plate Rheometer following Cieslinski et al. [6]. As has been shown by the same author, compression molding is not a suitable sample preparation method since it has no control over the planar orientation of the fibers. In this work, we will therefore present a compression molding technique which ensures a controlled and repeatable initial fiber orientation for shear experiments. Results from both simulation and experiment are compared.

EXPERIMENTAL

SAMPLE PREPARATION

The material used in this work was a commercially available glass fiber-reinforced polypropylene with 20 %wt. fiber content (SABIC®, STAMAX 20YM240). The material properties are listed in Table 1.

Table 1: SABIC® STAMAX 20YM240 material properties.

Material Property	Value
Nominal Fiber Density [%vol]	8.2
Nominal Fiber Length [mm]	15
Fiber Diameter [µm]	19±1
Density of Fibers [g/cm³]	2.55
Density of Composite [g/cm³]	1.04
Density of Polypropylene [g/cm³]	0.91

Samples for the sliding plate rheometer (SPR) were prepared by compression molding extruded strands. Compression molding was chosen as the sample preparation method to obtain a simple, repeatable and controlled initial fiber orientation (FO). Starting with identic initial FO is important to accurately validate the proposed direct fiber model. Previous work [6, 7] has shown that samples created with injection molding also provide a repeatable initial FO, however, injection molded specimen show a more complex core shell structure [8], which is it difficult to reproduce computationally.

The material was received as 15 mm long pellets created through a pultrusion process where the length of the fibers is identical to the pellet length. This means that fibers are not dispersed within the matrix. In order to disperse the fibers, the material was first processed in an Extrudex Kunststoffmaschinen single screw extruder with a smooth barrel (EDN 45X30D). The 45 mm 30 L/D extruder was equipped with a gradually tapering screw and a 3 mm die. The processing settings were based on the processing guidelines provided by SABIC®. The seven temperature zones of the extruder were set to 210, 210, 220, 220, 230, 230 and 230 °C, respectively. The composite was extruded at 5 rpm. The extrudates were pulled by a Conair precision puller to ensure homogenous strands.

Due to the low extrusion speed, most of the initial fiber length (FL) was maintained after processing, giving a number average fiber length (LN) of 6.7 mm and a weight average fiber length (LW) of 11.4 mm. The maximum detected FL showed the initial pellet length of 15 mm. The FL measurements follow the method developed at the Polymer Engineering Center and will be described in the following chapter.

Computational time for the mechanistic model simulation is geometrically proportional to the maximum detected FL. In order to reduce computation, the strands were pelletized to 3.2 mm. Initial trials showed that alignment of pellets in the mold did not yield a repeatable initial FO as, during compression, pellets could move easily and rotate. Therefore, pellets were re-extruded and strands were cut to the mold dimensions. Analysis of the strands showed a LN of 0.83 mm and LW of 1.53 mm and a maximum detected FL of 4 mm. The mold geometry used in this study was a rectangular prism (14 mm x 14 mm x 2.1 mm).

The top and the bottom of the mold were coated with aluminum foil to facilitate sample extraction. The bottom half of the mold was placed on a heating plate to cause partial melting of the aligned strands (Figure 1a, 1b). The resulting plate was flipped and re-molten; this second step was needed to remove air bubbles caught between strands.

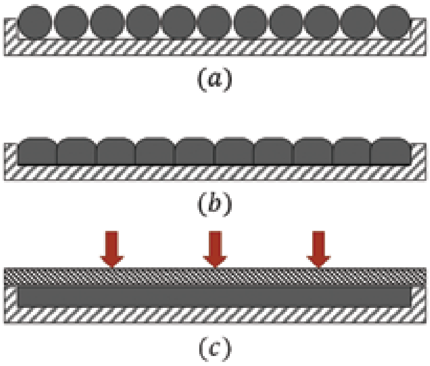

Figure 1: Sample preparation steps. (a) alignment of strands, (b) partial melting of strands, (c) compression molding.

The plates were then compression molded with a Carver compression molding machine (Model 3889.1NE1000) (Figure 1c). The two platens were heated to 210 °C and a load of 1000 lbs was applied for 2 minutes. After compression, the plates were sandwiched between two cold steel plates to prevent warpage. The fiber properties (FO, FL and fiber density distribution) of the final plates were analyzed and the results are summarized in Table 2. Multiple samples were taken within a compression molded plate to ensure homogeneity.

Table 2: Average fiber properties of compression molded plates, with a_{11} (extrusion direction), a22 and a33 as the orientation tensors.

Material Property	Value
a_{11} [-]	0.86
a_{22} [-]	0.11
a_{33} [-]	0.03
Fiber concentration [%vol]	7.93
L_N [mm]	0.83
L_W [mm]	1.53

SLIDING PLATE EXPERIMENT

FO evolution as a function of shear strain was determined by shearing compression molded samples in a SPR under a controlled simple shear flow. The SPR was based on the design of Giacomin et al. [9]. This rheometer was chosen over a rotational rheometer to overcome curvature effects observed in previous work [6]. The SPR rheometer used in this study is shown in Figure 2.

Figure 2: Sliding Plate Rheometer assembly.

The SPR has an effective surface of 100 x 300 mm2, a maximum stroke of 120 mm and a gap size of 2 mm. The maximum displacement and the fixed gap size limit the deformation that can be imposed on the sample to a maximum shear strain of 60. The SPR rests inside a forced convection oven and the sliding plate is moved by an Interlaken 3300 test frame.

The experimental procedure is based on Cieslinski et al. [6]. The rheometer was heated to 260 °C for 2 hours prior to sample loading. Upon loading, the test specimen was rotated 90° with respect to the extrusion direction, effectively swapping the a11 with the a22 tensor. This was done to have the experiment start with a low alignment in the shearing direction so a larger change in orientation could be observed. The samples were secured between the rheometer plates and allowed to melt evenly before tightening the screws to a final gap of 2 mm (Figure 3a). Since the initial thickness of the compression molded plates was 2.1 mm, the sample was slightly compressed when tightening the plates to guarantee full contact. After an additional 10 minutes of heating the sample was sheared at a rate of 1 s-1 (Figure 3b). Forced convection was used to accelerate the cooling of the sample in the rheometer to preserve its shape and FO. Once room temperature was reached, the sample was extracted and cut for analysis (Figure 3c). Six repetitions per testing condition were used to ensure accuracy and repeatability of results.

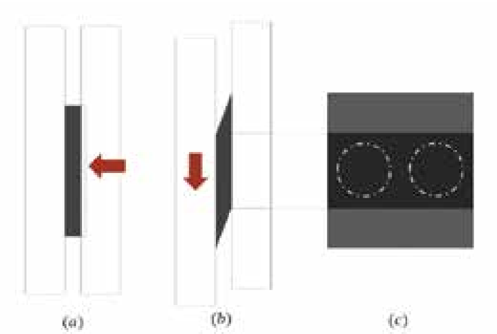

Figure 3: Sliding Plate Rheometer procedure, (a) Compression of molten sample during loading, (b) shearing of sample, (c) sample extraction for fiber orientation analysis; dark region represents area of pure shear.

MEASUREMENT OF FIBER MICROSTRUCTURE

A fully characterized microstructure is required to accurately reproduce the initial conditions in the mechanistic model simulation. The in-plane microstructure analysis involved determining the fiber concentration as well as the fiber length. Analysis of the thickness-wise microstructure included determining the fiber volume fraction and the fiber orientation. A detailed description of the employed analysis techniques is given in the following paragraphs.

Fiber Orientation Characterization

FO was measured by using the micro computed tomography (µCT) technology approach (Figure 4). For the measurement an X-ray source illuminated the specimen which was fixed on a rotating platform. The X-rays passed through the sample and were attenuated by the material. Depending on the configuration of the constituents of the sample, the energy of the X-rays was absorbed differently. A detector recorded the attenuated X-rays as radiographs at each predetermined angle. A full 3D representation of the sample was generated by all radiographs [8, 10]. The µCT data set was then further processed by using the VG StudioMAX (Volume Graphics) software. This software has an implemented tool for FO analysis and quantifies the FO using the structure tensor approach [11].

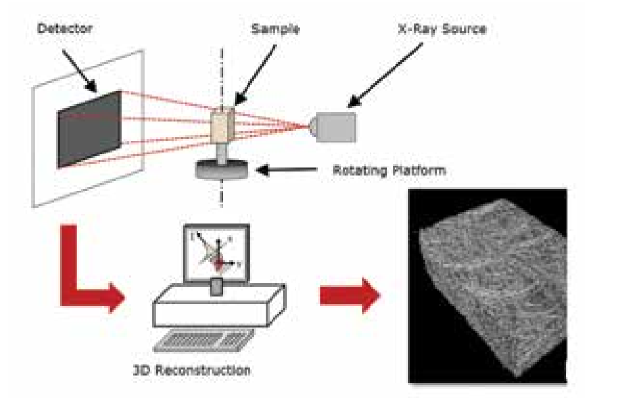

Figure 4: Schematic of the micro computed tomography system used in this study. Image was adapted from [8].

Samples were scanned with a Metrotom 800 µCT system (Carl Zeiss AG). The used scan parameters are summarized in Table 3.

Table 3: Micro computed tomography settings.

Parameter	Value
Voltage [V]	80
Current [A]	100
Integration Time [ms]	1000
Gain [-]	8
Voxel Size [µm]	3.5
Number of projections [-]	2200

Fiber Length Characterization

The FL was determined by using the FL measurement concept developed at the Polymer Engineering Center, UW-Madison. This technique consists of a time-efficient dispersion system and a fully automated image-processing algorithm to measure a large amount of fibers.

As even small samples might contain several million fibers this measurement technique applies a downsampling step based on the method proposed by Kunc et al. [12]. Coupons were cut out, transferred into specially designed perforated brass sample holders and a weight was put on top. The container and the added weight act as a constraint to help to maintain the original sample size and prevent the fiber network from expanding during pyrolysis. The polymer matrix was burned off for a period of 2 hours at 500 °C. To obtain a sub-sample of the ashed fibers a hypodermic needle was centrically inserted through a needle guide into the fiber network and a column of resin was injected. The resin was cured with a LED Flashlight. A second burn-off for a period of 1.5 hours at 500 °C was performed to remove the resin [12, 13].

As a next step the fibers were dispersed through an air dispersion chamber using bursts of compressed air at 1.5 bar. Due to the turbulences in the enclosed system a disentanglement and a uniform dispersion of the fibers on glass plates can be achieved. The fibers were then scanned at 2400 dpi. The scanned image was processed and enhanced in Photoshop. A binary image was created by using a thresholding technique.

The Marching Ball image processing algorithm was employed in this work as it automatically detects single fibers and quantifies the fiber length distribution (FLD). The algorithm can identify bent as well as intersecting fibers, which is particularly important for long fiber reinforced composites. At least 30,000 fibers were analyzed for each sample.

It is known that down-sampling methods result in skewing the FLD. Thus, the Kunc correction function was used for all FL values to provide an unbiased FLD (Equation 1).

$$N(L) = \Phi(L)\left(1 + \frac{4L}{\pi d}\right)^{-1}$$

Equation 1: Corrected number of fibers of a certain length N(L), where Φ(L) is the number of fibers of length L and d the diameter of the glue column, respectively [12].

The output of the analysis is a data set consisting of the individual lengths of all fibers. This raw data set needs to be statistically processed in order to obtain comparable results, such as the FLD, L_N and L_W. The FLD and the average values can be calculated according to equation 2-4.

$$W(L_i) = P(l \leq L_i) = \sum_{i=0}^{L_i} \frac{N_i}{n}$$

Equation 2: Cumulative FLD W, which gives the probability that fibers of length l are shorter than a certain value L_i. W is calculated by summating the relative frequency of each length interval (quotient of the number of fibers of a certain length N_i divided by the total number of fibers n) [10].

$$L_N = \frac{\sum_i N_i l_i}{\sum_i N_i}$$

Equation 3: Number average FL, L_N. The lengths l_i span the range of the data. N_i is the number of fibers with lengths between l_i-Δl/2 and l_i+Δl/2 (Δl is the experimental bin width and a set of length values l_i such that l_i+1=l_i+Δl) [10, 14, 15, 16].

$$L_W = \frac{\sum N_i l_i^2}{\sum N_i l_i}$$

Equation 4: Weight average FL, L_W. The lengths li span the range of the data. N_i is the number of fibers with lengths between l_i-Δl/2 and l_i+Δl/2 (Δl is the experimental bin width and a set of length values l_i such that l_i+1=l_i+Δl) [10, 14, 15, 16].

Fiber Concentration Characterization

The local fiber density was obtained by determining the fiber weight fraction through pyrolysis at a temperature of 500 °C for 2 hours. The specimen was weighed before and after pyrolysis and the fiber volume fraction was determined according to Equation 5:

$$V_f = \frac{v_f}{v_c} \times 100$$

Equation 5: Fiber volume fraction V_f in %vol, with vf as the volume of the fiber in g/cm³ and v_c as the volume of the composite material in g/cm³, respectively.

This method is a quick and effective way to determine the average fiber volume fraction, but it does not give any information on the fiber concentration (FC) in each layer of the sample. Pyrolysis can also be used to study the FC in the thickness direction. However, this approach requires the collection of material of several sample layers through the thickness. For each data point the sample would need to be prepared by grinding. As has been reported in literature, this approach is not only cumbersome and time consuming, but also leads to errors in analysis [8].

We will therefore use the µCT approach to determine the fiber density through sample thickness. The layer wise FC was quantified with VG StudioMAX (Volume Graphics) software. In this approach the µCT data set is converted into a stack of 2D cross-sectional images aligned normal to the thickness direction. These grayscale images are transformed into binary images by thresholding, which separates the image into black (matrix) and white (fibers) pixels. Subsequently, the fiber volume fraction through the thickness is calculated [8].

MODELING AND SIMULATION

SINGLE PARTICLE MODEL

Single Particle Model

The computational model, subject of this study, is based on the work done by Schmid et al. [17]. Each fiber is represented by a chain of rigid segments connected with spherical joints. Particle inertia is neglected in anticipation of the low Reynolds numbers characteristic of viscous suspensions. Extensional and torsional deformations are neglected as well. There is no Brownian motion and no buoyant effects.

As shown in Figure 5a, a segment is hydrodynamically represented as a chain of beads. The force (F^i) and torque (T^i) exerted by the fluid on an individual segment are computed through the hydrodynamic force (F^k) and torque (T^k) acting on spheres located along the segment's axis (r_k).

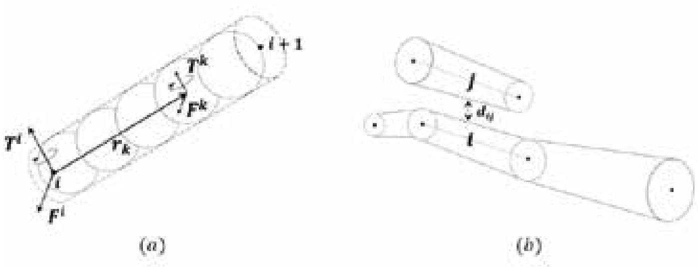

Figure 5: (a) Hydrodynamic representation of segments, (b) Fiber interaction is depicted. The contact force is different than zero when d_{ij} < D [3].

The contact force between fibers is treated with a discrete penalty method. Penalty methods work by detecting proximity between colliding objects and applying a repulsive "penalty" fo rce when the distance (d_{ij}) to the collision target is small, increasing the strength of repulsion force as distance decreases (Figure 5b).

After defining the rules of motion for a single fiber, a simulation can be set up by placing a representative number of fibers in a unit cell and imposing a flow field (Figure 6). Periodic conditions are defined in the boundaries perpendicular to the flow direction in order to guarantee a constant fiber volume fraction. Fibers exiting through these boundaries are cloned as reent ering fibers. "Ghost" cells are placed adjacent to the periodic boundaries to maintain continuity in the force calculation (Figure 6).

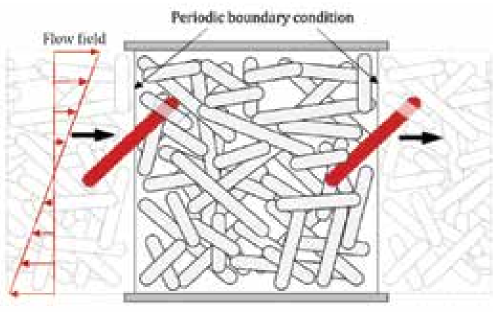

Figure 6: Unit cell with periodic boundary conditions. Image adapted from [3].

REPRODUCING INITIAL CONDITIONS

As noted by Cieslinski et al. [6] accurate and repeatable initial conditions are needed for obtaining reliable rheological data. For this purpose, the microstructure of the experimental samples was carefully characterized and used to generate a matching cluster of fibers for the simulation. In the pre-processing stage of the simulation, global values of orientation (a_{ij}), fiber density (%vol) and average fiber length (L_N, L_W) can be assigned to a cluster of fibers. Since the experimental samples do not show homogeneous microstructure through the thickness, a discrete approach must be taken in order to reproduce these characteristics.

Discretization of Fiber Density and Fiber Orientation

µCT analysis generates a continuous set of fiber volume fraction and orientation tensors across the thickness of the sample; this thickness was discretized into 10 segments (Δt=0.2 mm) and the continuous values were averaged per each segment as shown in Figure 7 and Figure 8.

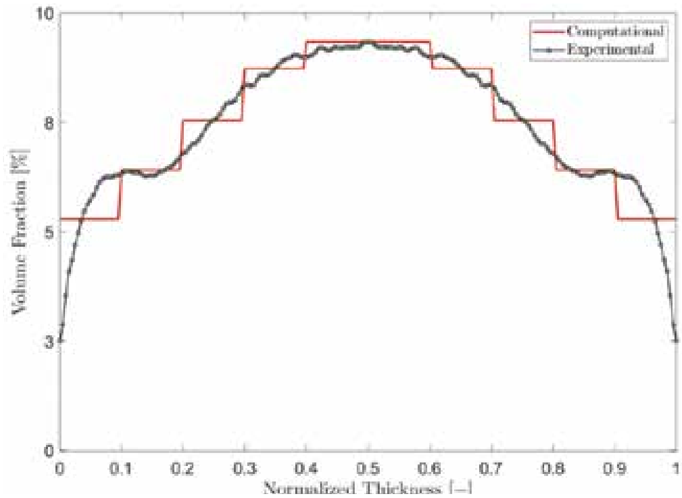

Figure 7: Discretization of fiber concentration through thickness.

It is worth noticing that the maximum number of segments that can be used is limited by the a_{33} component of orientation. As the thickness of the individual clusters reduces, achieving a desired value of orientation in that direction becomes unattainable.

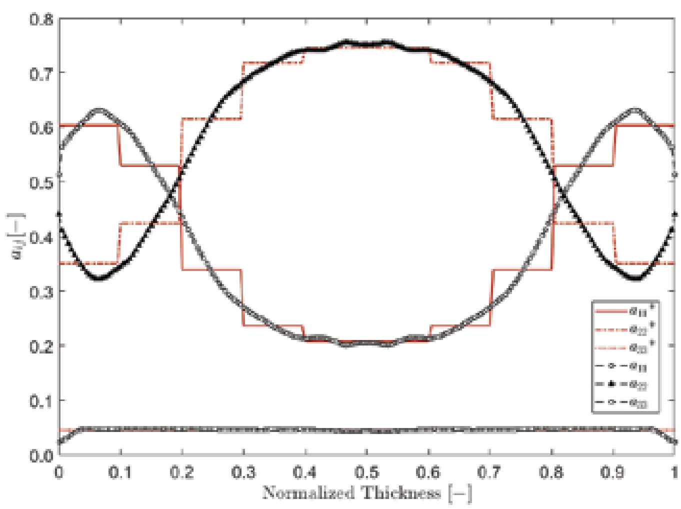

Figure 8: Discretization of fiber orientation through thickness.

Average Fiber Length Reproduction

The experimental FL is given in the form of number and weight averages (L_N 0.83 mm, L_W 1.53 mm). The cell's volume and the global fiber volume fraction are used to calculate the cumulative length of the fibers. This cumulative length is then broken down into individual length bins until the length distribution averages match the experimental values (Figure 9a).

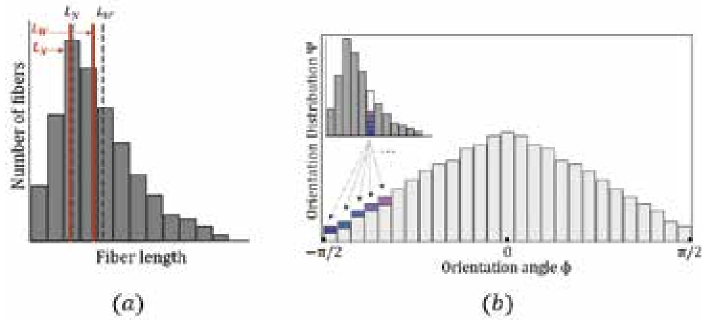

Figure 9: (a) Length distribution function and experimental averages (red). (b) Length assignment to orientation distribution.

When placing the fibers inside the unit cell, fibers of same length are distributed equally among the individual angle bins, thus guaranteeing equal length representation for every orientation (Figure 9b). Longer fibers start populating the cell first, then progressively shorter fibers fill in the remaining volume until the desired volume fraction is achieved.

Finally, all individual clusters are stacked in the same sequence as the discretized data to create the complete microstructure as shown in Figure 10.

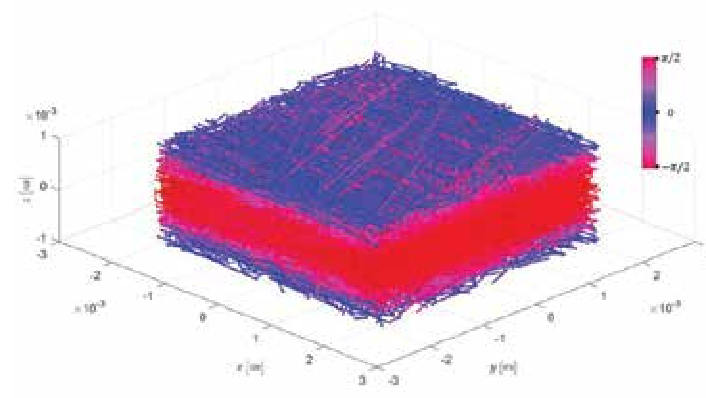

Figure 10: Computational cluster, with x as the shearing direction.

SIMULATION

To match the experimental conditions, a simple shear flow field was imposed on the unit cell with a rate of deformation of 1 s^{-1}. The viscosity was calculated using the experimental temperature, rate of deformation and properties of the neat polypropylene. The dimensions of the cell are dictated by the sliding plate gap in Z direction of 2 mm and the maximum FL of 4 mm. In order to allow free rotation, the dimension in X and Y were set to 1.1 x the maximum FL. The simulation time was set to 60 seconds to reach the total deformation of 60. Cell walls parallel to planes XZ and YZ have a periodic boundary condition. A tight array of static fibers was placed on the upper and lower boundaries to emulate the SPR walls. The simulation outputs the nodal coordinates of each fiber at every time step. With this information both global and thickness wise orientation tensors can be calculated.

After the sliding plate was tightened to the final gap thickness of 2 mm the orientation tensors changed from the values reported in Table 2. The actual values corresponding to the initial conditions are listed in Table 4.

Table 4: Experimental and computational orientation tensors used to reproduce initial conditions. Material Property Experimental Computational

Material Property	Experimental	Computational
a_{11} [-]	0.36	0.36
a_{22} [-]	0.59	0.62
a_{33} [-]	0.05	0.02

RESULTS AND DISCUSSION

Global diagonal components of the orientation tensor as a function of shear strain are shown in Figure 11. The a_{11} component starts at 0.36 and transitions to a steady state value of around 0.7 for both the experiment and the simulation. The steady state is reached at a total strain of 50, again, for both cases. Since this material falls in the category of long fiber composites, values of a33 component are expected to be low since long fibers will orient mostly on the XY plane. Experimental values at zero strain show a low standard deviation which demonstrates a repeatable initial FO, validating the sample preparation method. From the start, the simulation shows faster orientation evolution than the experiment. This phenomenon has also been reported in literature [18] for other diffusion models. Jeffrey's Hydrodynamic model is based on Jeffrey's equation for the motion of a single fiber which was later modified with an isotropic rotary diffusion term to account for fiber-fiber interactions. It has been proven that this model always predicts faster orientation kinetics in a transient state when compared to related experiments. This issue was addressed by combining the Hydrodynamic model with the ARD model. However, results still showed the initial quicker rate of orientation [18]. To treat this fast response problem of orientation, Wang et al. [19] developed a new evolution equation of the second orientation tensor and named his model the RSC model. This model still shows a slightly quicker initial rise of flow-direction orientation (a_{11}) but achieves nearly the same steady orientation states as obtained with experiments [18]. A recent study by Mezi et al. [20] addresses a current issue with direct particle approaches, namely, the missing coupling between particle and fluid i.e. the models only consider hydrodynamic forces acting on the particles but not the effect of particles on the surrounding fluid. When the effect of particle motion on the flow field is accounted for, the effective shear rate decreases in value leading to a slower orientation evolution. However, implementing this coupling is extremely costly computationally, therefore it was not implemented in this work.

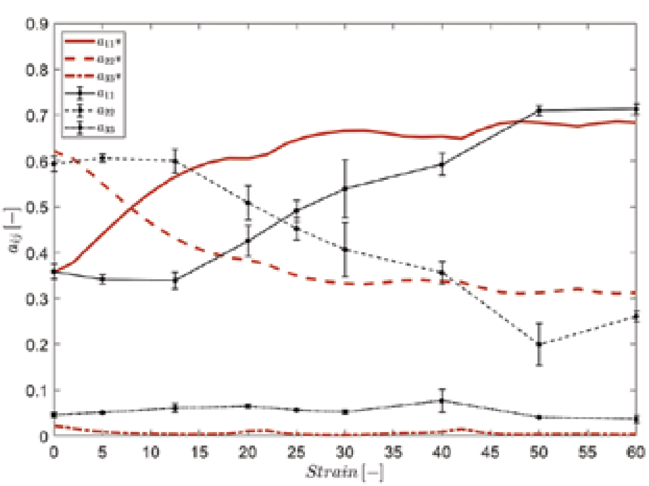

Figure 11: Experimental (black) and predicted (red) fiber orientation evolution.

The experimental core-shell structure is largely unchanged at 12.5 strain units when compared to the initial orientation (Figure 12). At the same applied strain, the simulation already shows a large transition to a rather homogenous structure. This once again shows that the direct particle model exhibits a faster orientation evolution. Once 60 strain units are reached, the core-shell profile disappears and a good match between experiment and simulation can be observed. It is assumed that shearing beyond 60 strain units would lead to fiber orientations which would be constant throughout the thickness demonstrating a steady state FO [6].

The simulation results for a_{11} through thickness were smoothed and plotted for different strains in Figure 13. Under a constant shear the heterogeneous orientation profile transitions into a homogeneous steady state. The most significant change in orientation occurs in the core of the sample. The rate of change slows down as orientation approaches steady state. This aligns with results published in literature [6] as well as previous work with injection molded plaques [7].

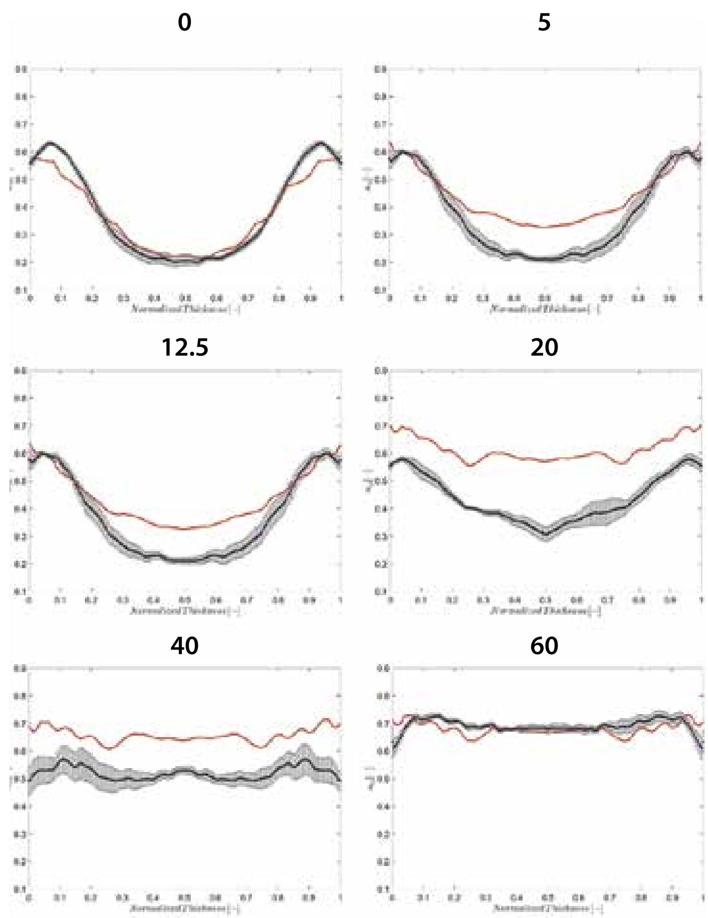

Figure 12: Experimental (black) and predicted (red) a_{11} values through sample thickness at varying shear strains.

µ-CT data (Figure 14) also shows fiber alignment in the flow direction and underlines the trend seen in Figure 13. The green/blue regions demonstrate fibers which are aligned with the flow direction, characterized by large values of a_{11} and low values of a_{22}, whereas red regions represent a crossflow orientation state, with low values of a_{11} and high values of a_{22}. Yellow indicates fibers which are oriented in the thickness direction (a_{33}). This color is almost absent in Figure 14 which indicates a nearly planar orientation state [18]. The clearly define core-shell structure becomes homogeneous after shearing.

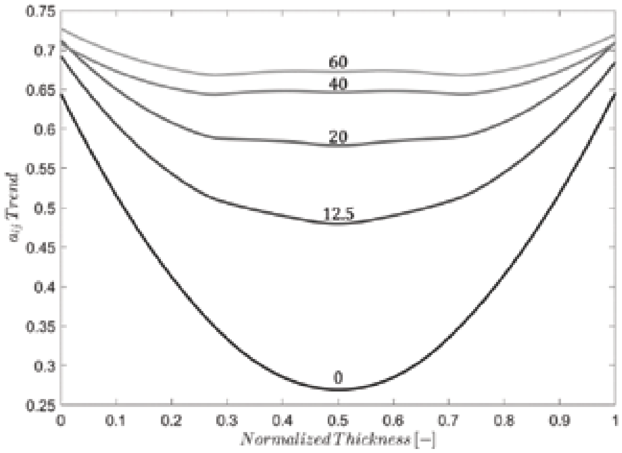

Figure 13: Smoothed computational a11 evolution.

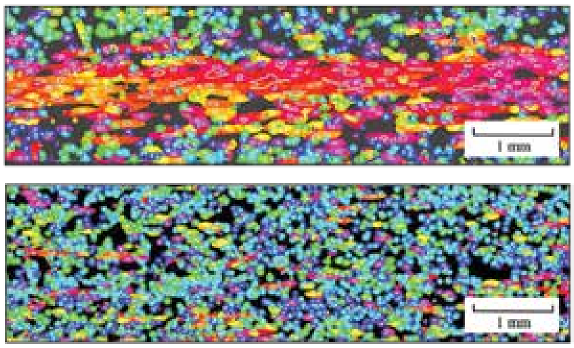

Figure 14: µCT FO through thickness from VG StudioMax analysis, top: 0 shear strain, bottom: 60 shear strain.

CONCLUSIONS AND OUTLOOK

A particle-level simulation for reinforcing fibers was successfully used to determine the FO evolution. Results showed good agreement with the steady state orientation tensor. In its current state the model can be employed for two main tasks: firstly, the periodic boundary cell can be used as a numerical rheometer, where correlations between process parameters and fiber properties are established. This is especially useful for determining fitting parameters for commercially implemented continuum models [1]. Secondly, the model can be coupled with mold filling simulations in order to study fiber motion and fiber-mold interaction in small scale geometries; for example, fiber matrix separation during rib filling [2] or FO in the flow front [21].

A reliable method for preparation of samples for suspension rheology was developed. Repeatable and controlled initial orientation can be achieved through the presented compression molding technique.

Next steps of this project include:

1. Reproducing further experiments conducted by Cieslinski et al. [6] with different FC to evaluate the impact of coupling in the direct fiber model.
2. Repeating the study with an extensional flow to gain insight on this fundamental type of flow.
3. Predicting the FO evolution with currently employed diffusion models which are based on the orientation tensor scale to evaluate how the mechanistic model performs.

This future work will be used to evaluate the model and aid in its development. Additionally, a better understanding of the underlying physics of the motion of fibers and their interaction in concentrated regimes can be gained.

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+1.248.825.7135

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+1.248.635.2482

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+1.586.218.9405

Dr. Allan Murray, Director Emeritus
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+1.248.814.8072

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+1.248.444.1753

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+1.248.655.8483

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Ravago Americas
+1.248.797.7433

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+1.313.322.0595

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+1.517.304.2979

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+1-248.289.2508

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+1.248.904.7925

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BASF Corporation
+1.734.309.1738

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Intuit Group, LLC
+1.248.701.8003

Kimberly Hoodin, ACCE Administration
+1.513.582.2442

Fred Deans, Golf Outing
Allied Composite Technologies LLC
+1.248.760.7717

Chuck Jarrett, Design in Plastics
The Materials Group
+1.248.310.3283

2020-2022 DIRECTORS

TO MAY 2020

Marc Bahm +1.734.309.1738
BASF Corporation

Fred Deans +1.248.760.7717
Allied Composite Technologies LLC

Umesh Gandhi +1.734.995.7174
Toyota Technical Center

Brian Haggart +1.248.228.5959
Styrolution

Chuck Jarrett +1.248.310.3283
The Materials Group

Dr. Gary Kogowski +1.248.797.7433
Ravago Americas

Tim Rush +1.313.495-4523
Ford Motor Company

TO MAY 2021

Neil Fuenmayor +1.517.898.7117
LyondellBasell

Brian Grosser +1.248.941.9368
Lotte Advanced Materials

Paula Kruger +1.248.979.6128
DSM

Tom Pickett +1.248.431.9724
General Motors Company

Sassan Tarahomi +1.248.259.5624
Alterra Holdings

Steve Van Loozen +1-248.289.2508
Celanese Engineered Materials

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Drew Geda +1-734.337.2561
Hyundai America Technical Center, Inc.

Mark Lapain +1.248.567.5455
Magna International

Jeremy Lee +1.248.409.3584
Faurecia

Dr. Norm Kakarala +1.248.655.8483
Inteva Products, LLC (retired)

Jeff Mayville +1.313.805.9500
Ford Motor Company

Dhanendra Nagwanshi +1.248.760.3860
SABIC

Keith Siopes +1.248.497.4258
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