SPE COMPOSITES

SEPTEMBER / OCTOBER 2019

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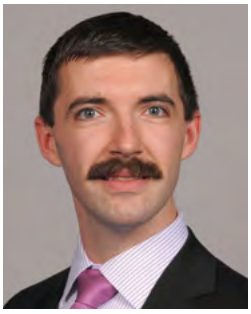
Board of Directors



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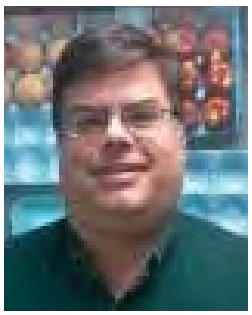

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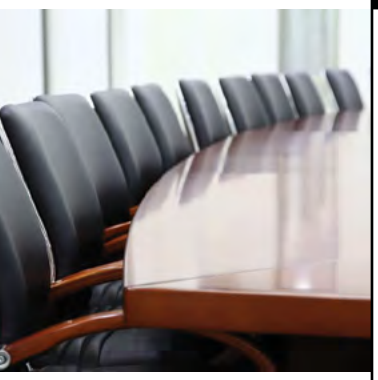

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See page 29 for more details

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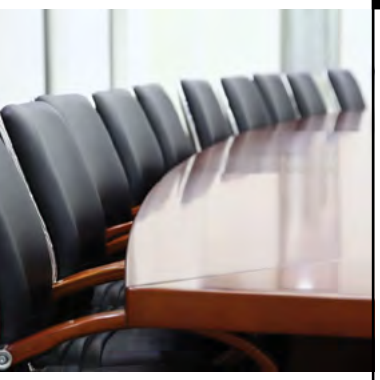
Board of Directors continued...



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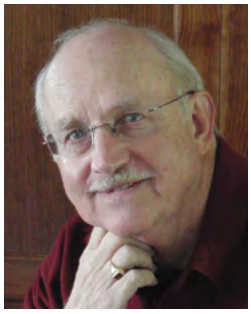

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SPE Composites
Director (Retired)
Emeritus Director

Oleksandr G. Kravchenko, Ph.D.
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Board Meeting Minutes Mar 18, 2019

By: John P. Busel

Monday, March 18, 2019
12:00 - 2:00 PM Eastern US
Courtyard Detroit Downtown, Detroit, MI

1. Welcome

- Ray Boeman called the meeting to order at 12:05 pm.
- The group made self-introductions.

2. Administrative

- Ray Boeman reviewed the last meeting minutes of December 19, 2018. One correction was made to change the header from "agenda" to "minutes". It was moved and seconded to approve the last meeting minutes as corrected. Motion passed.
- Ray Boeman reviewed the action items from the last meeting. The updated policy manual has not been distributed to the Board. Dale Brosius noted that SPE HQ has requested the policy manual conform to SPE format requirements. Ray Boeman will review the requirements to make sure the division policy manual conforms to the SPE format requirements before distribution. It was also pointed out that the Division needs to use the new SPE logo for all communications.

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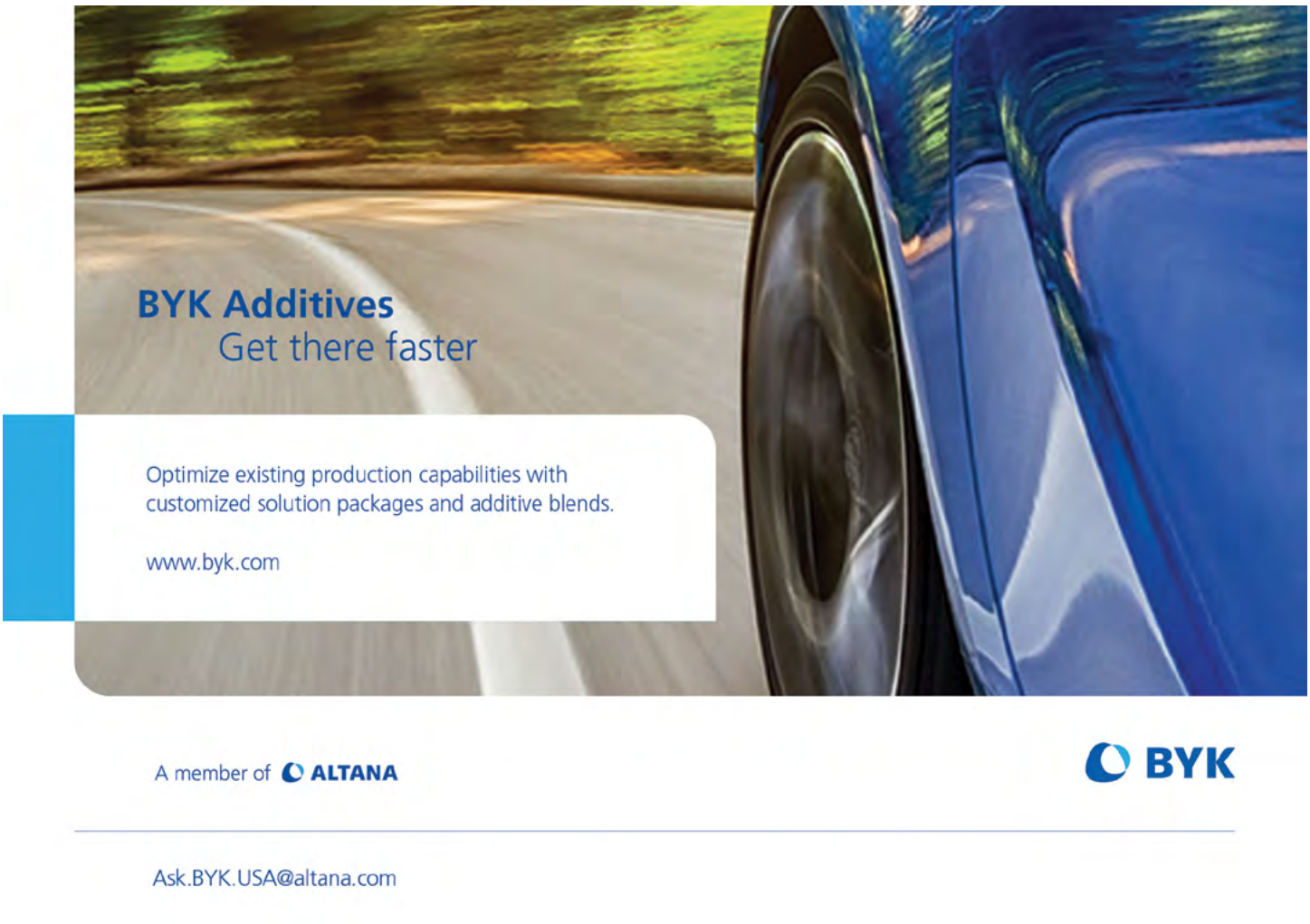

Board Meeting Minutes continued...

3. Election Update – Board of Directors

- John Busel reviewed the results of the recent election for new Board of Directors. There were eight candidates for directors for eight postions. The ballot was executed on February 7th and closed on February 15th per SPE HQ direction. All candidates for directors were approved. Several ballot comments were received by members who volunteered to help in serving on the Board.
- Prior to the ballot and upon a review of the division membership, it was pointed out that there were a number of members whose SPE membership had lapsed and were not a part of the election balloting. The group agreed that lapsed members need to be contacted to ensure they rejoin SPE.

ACTION: Ray Boeman to reach out to those volunteers from the Composites Division ballot that requested to be considered for service on the Board.

4. Composites Program - ANTEC 2019

- Shankar Srinivasan provided an update on ANTEC. See report. He thanked Rich Caruso for soliciting the keynote speakers. The composites program consists of 22 presentations including 2 keynotes and 20 technical sessions. The sessions were distributed across 2 days of ANTEC. The group commented that Monday's keynote was excellent. He thanked the support of the moderators for the sessions.

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Board Meeting Minutes continued...

- Shankar Srinivasan reported that personal emails are very successful when soliciting papers. A comprehensive distribution list is used to reach out to those in industry and academia. He asked the Board members for help to update the distribution list.
- The issue was raised that there was not enough promotion of the session keynote speakers and presentations as compared to the conference keynote sessions. No solution was provided other than marketing the sessions with the distribution list.
- The issue was raised that unlike what was done at ANTEC 2018, the industrial sessions was not supported for 2019. The question remains as to what will happen in 2020. The group discussed the issue and suggested to have tutorials on a variety of subjects but that would be dependent on time at the conference. There was a suggestion of simulating the "planet" sessions from JEC as a potential option to be done at ANTEC.

ACTION: SPE Board members are to provide edits and additional names to the distribution list that will be used to solicit presentations for future ANTEC sessions to Shankar Srinivasan.

5. Treasurers Report

- Tim Johnson reviewed the treasurer's report distributed to the Board which provided a graphical analysis on the revenue and expenses. He noted that this year, by design, the Division will be running a negative budget.
- Tim Johnson noted that income from ACCE was lower compared to previous years. Expenses related to ACCE were higher in 2018 than previous years. Tim Johnson noted that projecting the correct revenue for the Division budget will be a challenge for future years.
- Tim Johnson distributed the current financial report to the Board. The report included details of income and expenses. The group discuss support of different activities. It was suggested to establish $5K sponsorship for the NGAB. The group supported this initiative. Dale Brosius moved to provide $5K from the ComDIV budget for NGAB support. The motion was seconded. The motion passed unanimously. The group discussed whether this impacts both the current year and next year's budget. The group decided to have this discussion at the next meeting.
- Tim Johnson reported that no funds were used for a composites division reception at ANTEC as done in previous years. It was also noted that no allowance has been made in the budget for those who are TPC representatives to attend ANTEC. It was stated that this can be a burden on the individuals who are the TPC contacts. The group discussed the options for reimbursement. The costs associated would be included in the budget this year and future years of ANTEC. It was suggested a cap be applied to this line item budget. Tim Johnson moved to add in the budget up to $3K for expenses incurred by the TPC representatives to attend ANTEC. The motion was seconded. The motion passed unanimously.
- Tim Johnson raised the issue of the education grants provided by the division. He does not recommend raising the amount for next year. He suggested that someone help the Education Committee chair Uday Vaidya to track the use and results of the grant funds provided to the schools. Hicham Ghossein volunteered to help on this project. The group discussed making the application better that provides better connection and visibility with the respective school to make sure how the monies are used properly.

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Board Meeting Minutes continued...

- Tim Johnson stated that the Finance Committee needs to work on a better investment plan for the Division that balances both risk and income. He offered examples as to how the process could be done. The group agreed that a number of actions need to take place before the start of the fiscal year. It was suggested to conduct a special Board meeting to review and prepare a budget for approval after a review by the Executive Committee.
- Tim Johnson suggested the Board think about adding a new item for the budget for a new award-named scholarship. He proposed that this would be called the Dan Buckley Award. The group discussed acknowledging long term Board members who have dedicated time and effort over many years that would not necessarily be a monetary award. It was suggested the Award Committee come back to the board with a proposal.

ACTION: The Finance Committee is to develop a plan for the investment strategy to be proposed to the Board.

ACTION: The Finance Committee is to develop next year's budget. All Board Committee Chairs are asked to contact the Treasurer with changes to existing or identify new budget expenses.

ACTION: The Awards Committee is to evaluate options for a new scholarship award and prepare a proposal for review by the Board by the next meeting.

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Board Meeting Minutes continued...

6. Report from Next Generation Advisory Board

- Dale Brosius invited representatives from the NGAB to attend the Board meeting and provide and update on their activities.
- Lyndzie Nebel reported to the Board about the function of the NGAB. NGAB provides advice and support to student chapters and engage and help young professionals in the industry. The engagement involve a variety of activities.
- The Board suggested NGAB become more involved at ACCE in Novi, MI because of the heavy involvement of students and young professionals at this event.
- NGAB is financed through SPE headquarters and through donations. The NGAB are looking into ways to be more financially sustainable.
- The Board asked a variety of questions on how to best engage this group.

7. Membership Report

- No membership report was presented.

ACTION: The Membership Committee needs to provide a report at the next meeting. 8. Communications Report

- Andy Rich reviewed the distributed report to the Board. He noted that SPE HQ has used the Composites Division website as a model for other divisions to follow. He reported that he can update the website content at any time. He asked all Board members review the website and provide comments and changes.
- Andy Rich asked the Board members to get more involved with Twitter by posting and re-Tweeting information.

ACTION: All Board members are asked to review the Composites Division website and provide feedback to Andy Rich with any changes.

9. Committee Updates

- Awards: Dale Grove reviewed the report distributed to the Board. Dr. Jan Anders Mansson, representing the Composites Division successfully became a SPE Fellow. Dr. Pilla from Clemson University won the Educator of the Year award. Despite ample advertising, not a single student applied for the Composite Division Travel Award. There was a concern that no students applied for the award. He reported that he needs help with chairing the Awards Committee. Ray Boeman asked for volunteers. A Board member will be assigned to take over the responsibilities of this committee following the meeting.

ACTION: Shankar Srinivasan to share a distribution list that could be used to communicate the availability of division awards.

- Education: Jack Gillespie had nothing to add to the distributed report prepared by Uday Vaidya.
- Newsletter: Pritam Das reported that he needs reports from all the committees to be used in the newsletter. He reported that sponsorship of the newsletter has declined and has ask the sales person for additional help. It was suggested to add the Automotive Division membership on distribution for the Composites Division newsletter.

ACTION: All Division Committee Chairs are to provide a short summary report of their committee for publication in the newsletter. Reports are to be sent to Pritam Das.

10. New Business

- Ian Swentek reported the Audit Committee met on February 14, 2019 to discuss the specifics of performing an audit and plan going forward. The committee proposed to review our financial transactions and bank statements for the past three years, but an-

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This Issue:

Board Meeting Minutes continued...

nually thereafter. They proposed to produce a written report for our annual general meeting later this year which would subsequently be publicly available via the Board minutes. The main output would be a confirmatory statement of the status of our finances and audit outcome, and would optionally include any recommendations for the finance committee to review.

- Ian Swentek reported that a new chair elect will need to be selected at the next meeting. He reported that Fred Deans has volunteered to be a candidate. He asked if others are interested in the position to contact him before the next meeting.
- Ian Swentek reported that the submission for the Pinnacle Award for the Composites Division was not done and the deadline was missed. He committed to making this a priority for the next opportunity to submit. It was noted that submissions can be made year round.
- Fred Deans suggested the Composites Division consider a second activity to produce income for the division that would be something non-automotive. He offered to lead an initiative to explore options and present a proposal to the Board. John Busel and Hicham Ghossein volunteered to help.

ACTION: Fred Deans to provide a scope of this activity for distribution to the Board for comment.

11. Wrap Up

- The next meeting will be a conference call to be scheduled either in May or June and will be dependent on when the budget will be ready for discussion and approval.

12. Adjourn

- There was no further business to discuss. Ray Boeman adjourned the meeting at 2:00 pm.

Respectfully Submitted,
John P. Busel, Secretary

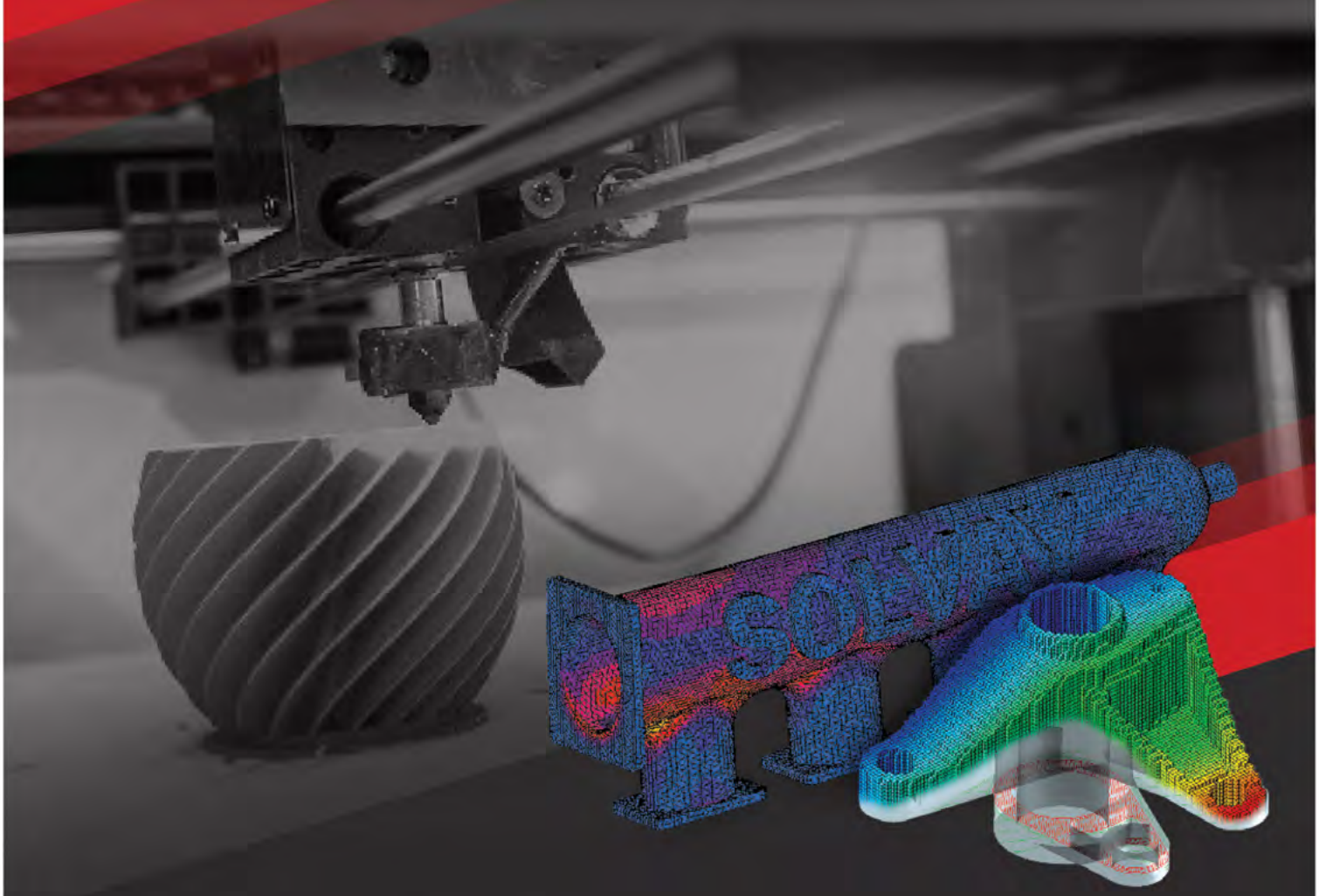
Attendees

OFFICERS:
Ray Boeman, Chair
Ian Swentek, Chair-Elect
Tim Johnson, Treasurer
John P. Busel, Secretary
Dale Brosius, Councilor

DIRECTORS:
Creig Bowland
Rich Caruso
Pritam Das (phone)
Fred Deans
Hicham Ghossein
John Gillespie (phone)
Jim Griffing (phone)
Dale Grove (phone)
Enamul Haque
Alex Kravchenko (phone)
Nipanni Rao (phone)
Andy Rich
Antoine Rios
Shankar Srinivasan
Mingfu Zhang (phone)

GUESTS:
David Jack
Erin Keaney
Lyndzie Nebel

This Issue:



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Newsletter Chair Message

By: Pritam Das

The SPE Composites Division's goal is to promote the benefits of composite materials and the advantages that high-performance, energy-efficient composite structures and components bring to society at large and to industries like Automotive / Motor Sports / Ground Transportation, Agriculture / Off-Highway, Aviation / Aerospace / Defense, Electrical / Electronics / Converged Devices, Infrastructure / Building & Construction, Industrial / Materials Handling, Marine Sporting Goods / Recreation, Wind Energy / Solar Photovoltaic and More.

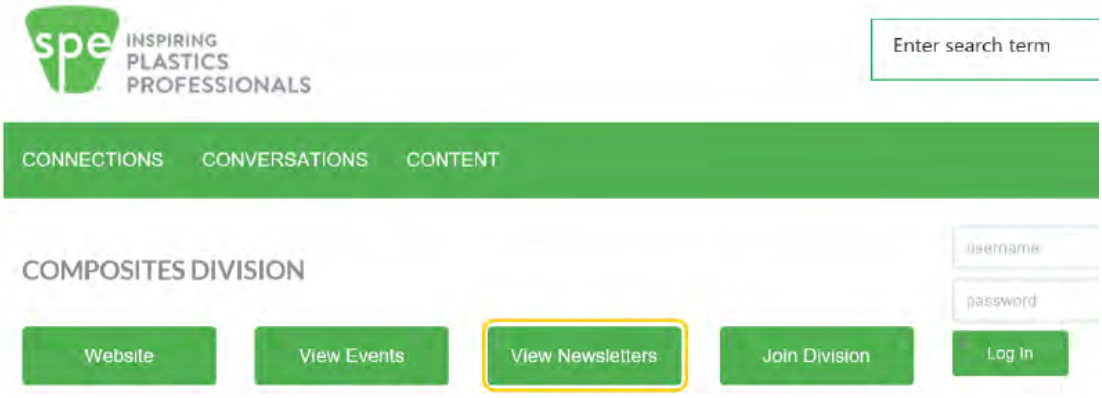
The SPE Composites Newsletter is a tool to continue to stimulate flow of information in the field of Composites for the SPE Composites Division and the Composites Industry as a whole.

Digital versions of the SPE Composites newsletter are available at the SPE Composites Division website (www.4spe.org/composites). Snapshot is below. Newsletters are released three times a year. New newsletter releases are updated in social media groups such as LinkedIn as well.

We are always looking for short articles to be featured in the newsletter. If there are any other new ideas, please do not hesitate to contact us. We are always excited to hear back from our members as well as sponsors.

Thanks to all of our energetic members, supporting sponsors, and hardworking board members.

Best,
Pritam Das,
SPE Composites Division,
Newsletter Chair



This Issue:

Scholarship Information

The organizing committee for the SPE Automotive Composites Conference & Exhibition (ACCE) announced the winners of the annual SPE ACCE scholarships and the Dr. Jackie Rehkopf. SPE ACCE and Rehkopf scholarship winners will be honored at the SPE ACCE, Sept. 4 -6, 2019 at the Suburban Collection Showplace in Novi, Michigan; both scholarships are administered as part of the SPE Foundation.

The ACCE Scholarships ($2,000 USD each) are sponsored by the SPE Automotive and SPE Composites Divisions and are awarded to students pursuing advanced studies in a composites-related field. The three winners of the SPE ACCE scholarships are Priya Venkatraman, a Ph.D. candidate at Virginia Tech Bradley Sutliff, a Ph.D. candidate also at Virginia Tech, and Martin Eichers, a senior at North Dakota State University

The Dr. Jackie Rehkopf Scholarships are sponsored by the SPE Automotive Division, the SPE Composites Division and the generous donations of friends and family. Two winners selected this year for the Rehkopf Scholarship ($2,500 USD each) are Mariana Desireé Reale Batista, a Ph.D. candidate at Michigan State University and Akshata Kulkarni, a Ph.D. candidate at the University of Akron

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This Issue:

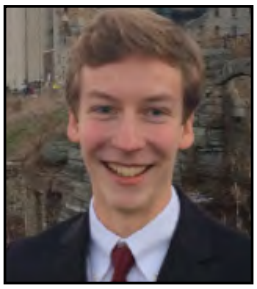
Scholarship Information continued...

Priya Venkatraman 2019 ACCE Scholar

Priya Venkatraman is currently a Ph.D. 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. 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.

Bradley Sutliff 2019 ACCE Scholar

Bradley Sutliff is a third-year Ph.D. student at Virginia Tech studying Macromolecular Science and Engineering, under the advisement of Dr. Michael J. Bortner. Brad studies the rheology of cellulose nanomaterials under similar conditions to current industrial processes. 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.



Martin Eichers 2019 ACCE Scholar

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.

This Issue:

Scholarship Information continued...

Mariana Desireé Reale Batista 2019 Jackie Rehkopf Scholar

Mariana Desireé Reale Batista is currently completing her Ph.D. 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. While at MSU she has been involved in many organizations as a volunteer, aiding in outreach activities dedicated for young students.

Akshata Kulkarni 2019 Jackie Rehkopf Scholar

At the University of Akron, Akshata is currently pursuing her Ph.D. under the guidance of Dr. Sadhan C. Jana. As a part of her doctoral dissertation, she 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 also served as the President of the Akron SPE Student Chapter during the 2017-2018 academic year. Recently, she received the Ohio Rubber Group Graduate Student Award as well as the Paul Glasgow Student Scholarship from the ACS Rubber Division.

This Issue:

Award Winning Paper

Flow Pattern Prediction & Validation For Discontinuous Prepreg Using Anisotropic Viscous Flow Simulation

Anthony J. Favaloro, Drew E. Sommer, R. Byron Pipes
Composites Manufacturing and Simulation Center, Purdue University, West Lafayette, IN

Abstract

Carbon fiber prepreg cut and slit into rectangular platelets offer an intermediate material solution between continuous carbon fiber composites and short fiber molding composites. Prepreg platelet molding compounds (PPMCs), sometimes called carbon fiber SMC, can be used to mold moderately complex geometries while providing moderate mechanical performance. However, to understand the mechanical behavior of the final geometry, the orientation state of the reinforcing platelets must be known. Herein, we present an anisotropic viscous flow simulation coupled with orientation evolution for PPMCs. This simulation technique is applied to the molding of a double dome geometry with two different initial charge orientations. The simulation is validated through blind prediction of flow patterns that compare well to short shot experiment for both charge orientations. The resulting orientation states are analyzed and compared.

Introduction

In order to accurately describe the mechanical performance of fiber reinforced composites, the fiber orientation state must be known [1]. While high performance composites applications directly prescribe the fiber orientation state, high rate processes such as compression molding or injection molding contain flow induced orientation states [2]. Recently, a class of materials referred to as prepreg platelet molding compounds (PPMCs) has been introduced to serve as an intermediate material solution between continuous fiber composites and short fiber molding composites. PPMCs are formed by cutting and slitting pre-impregnated composite tape to a prescribed length and width while inheriting the thickness of the parent tape. The resulting platelets are then gathered into a mat. A photograph of an unconsolidated mat can be seen in Figure 1. Thus, the high fiber volume fraction obtained in the prepreg process is maintained in the molding material. Concurrently, an additional scale of interest is introduced (i.e. the platelet scale). The VORAFUSE™ M6400 material system by Dow is investigated in this work. The matrix material of the M6400 system is a fast curing thermoset enabling high rate manufacturing.

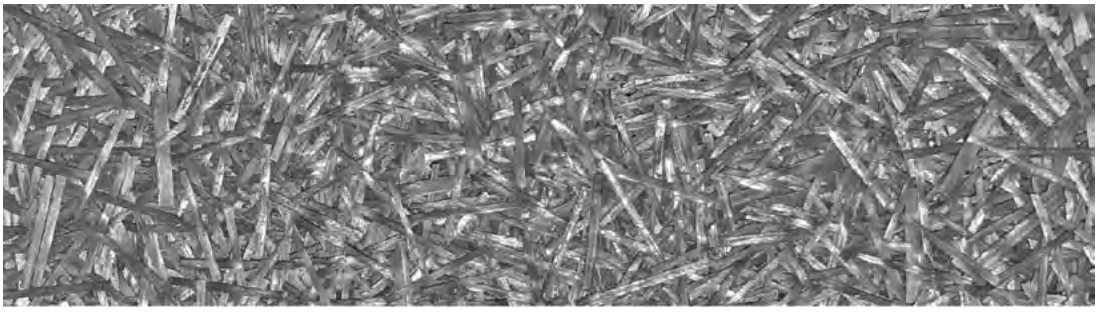


Figure 1: Photograph of Unconsolidated PPMC Mat

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Herein, the double dome geometry and two initial charge orientations are investigated as shown in Figure 2. The physical manufacturing process involves:

- preparing the charge of material by cutting the PPMC mat to the appropriate dimensions and stacking a number of layers of mat to the desired weight
- preheating the tool, manual placement of the material into the charge cavity including by-hand forming of the material onto the tool contours
- closing the tool to a moderate clamping force to initiate efficient heat transfer for a short time allowing the viscosity of the thermosetting matrix to drop to the processing window
- applying large clamping force to flow the material to fill the cavity and holding the force until the material has cured.

In this way, the full manufacturing process represents a complex thermal, chemical, and rheological problem. Thus, the scope of this investigation is limited to modeling only the flowing stage of the process assuming the material has uniformly reached the processing window (i.e. the viscosity drop of the matrix material) and that the time scale of the molding is shorter than the time scale of the curing process. Under these assumptions, the process simulation is approached as isothermal with a Newtonian matrix viscosity but with anisotropic reinforcing effects of the fiber accounted for through a fully coupled anisotropic viscosity and fiber orientation analysis constitutive model. The simulation is applied to the double dome geometry with an initial transverse charge and an initial axial charge. The simulated flow patterns are compared to experimental short shots as an initial validation and the orientation state between simulation parts is compared. The simulations were performed prior to the experiments as a blind prediction.

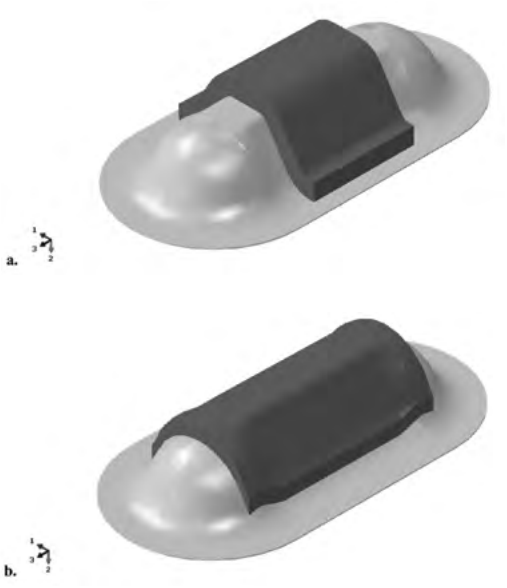

Figure 2: Double Dome Geometry and Two Initial Charge Patterns: a. Transverse Charge, b. Axial Charge

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Theory and Implementation

In this work, the approach taken is of modeling the flow behavior of the PPMC charge using an anisotropic viscous constitutive relationship coupled with fiber orientation analysis. The constitutive model is implemented as a VUMAT in Abaqus/Explicit and the smoothed particle hydrodynamics method (SPH) method is used such that microstructural variable (i.e. fiber orientation) is tracked in a Lagrangian framework capable of extreme deformations [3,4]. In addition to the constitutive model, simulation model creation and initialization methods are developed to mirror the physical process of placing and forming the material in the tool by hand.

Fully Coupled Constitutive Model

Orientation analysis is a well-studied problem when concerning injection molding material systems. In the state of the art, Jeffery's equation [5] is expressed in a tensorial form as introduced by Advani and Tucker [6]. Next, a diffusion term, isotropic [7] or anisotropic [8–10], is added such that after large total strain an appropriate, non-collimated steady orientation structure is approached with anisotropy in diffusion introduced primary to prevent out-of-plane orientation to develop in thin structures. These simulations are typically performed neglecting anisotropy of the effective viscous fluid. For planar, glass mat thermoplastics (GMT) with large aspect ratio fibers, Ericsson et al. [11] demonstrated that the flow front of squeeze flow charges could be captured using affine motion for the fiber orientation model (i.e. Jeffery's equation with a shape factor of unity) and a coupled anisotropic constitutive model. The authors have previously reproduced the experimental results of Ericsson et al. using a finite element based approach in Abaqus/Standard [12]. Without sufficient experimental evidence to suggest the need for more complex fiber orientation models, the simplest possible model is adopted of affine motion. The local orientation structure of a platelet is described by three unit vectors as shown in Figure 3: the fiber direction, p, the transverse direction, q, and the normal direction, r. Limiting considerations to the fiber direction, affine motion gives the fiber orientation, p, after the material point has undergone a certain deformation gradient, F, from an initial orientation, p^0, as in Equation (1).

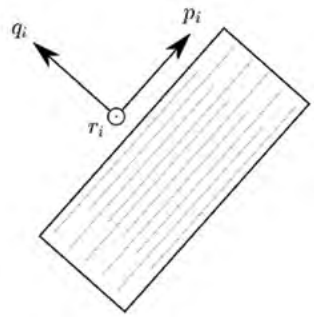

Figure 3: Platelet Coordinate System

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$$p = \frac{F \cdot p^0}{\|F \cdot p^0\|} \quad (1)$$

The fiber orientation is then coupled to the viscous behavior through an orientation averaged transversely isotropic viscosity tensor [3,12], Equation (2), where A and $\mathbb{A}$ are the common second and fourth order orientation tensors [6], η_{23} is the isotropic shearing viscosity representing an increase over the matrix viscosity due to the presence of fibers, and $R_\eta = \eta_{11}/\eta_{22}$ is the anisotropy ratio representing the ratio of the resistance to extensional deformation along fiber axes versus transverse to fiber axes [13,14]. As the SPH method, an explicit method, is used to enable extreme deformation analyses the total stress tensor is expressed as in Equation (3) where K is a penalizing bulk modulus to enforce near incompressibility but allow for a non-zero stable time increment. In this work, $R_\eta = 116$ while the exact value of η_{23} is unimportant for flow pattern and orientation state predictions as it will simply scale the required force.

$$\langle \eta \rangle_{ijkl} = 4\eta_{23}(R_\eta - 1)\left[\mathbb{A}_{ijkl} - \frac{1}{3}\left(A_{ij}\delta_{kl} + A_{kl}\delta_{ij} - \frac{1}{3}\delta_{ij}\delta_{kl}\right)\right] + 2\eta_{23}\left[\frac{1}{2}\left(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}\right) - \frac{1}{3}\left(\delta_{ij}\delta_{kl}\right)\right] \quad (2)$$

$$\sigma_{ij} = \langle \eta \rangle_{ijkl}\dot{\epsilon}_{kl} + K(\det F - 1)\delta_{ij} \quad (3)$$

In typical analyses, sheet molding compounds (SMC) are treated as isotropic materials. However, Dumont and coworkers have developed an anisotropic material model [15] for SMCs dependent upon the local normal direction of the tool. In carefully designed flow cases in which large orientation state changes are not encountered, this modeling simplification could be quite useful. The viscosity tensor of Equation (2) can be adapted to such a form by substituting the form of the second and fourth order orientation tensors for a planar, uniform orientation state as shown in Equations (4) and (5) where $M_{ij} = n_i n_j$ is a second order tensor representing the local normal direction, n_i.

$$A_{ij}^{2DUniform} = \frac{1}{2}\left(\delta_{ij} - M_{ij}\right) \quad (4)$$

$$\mathbb{A}_{ijkl}^{2DUniform} = \frac{1}{8}\left[\left(\delta_{ij} - M_{ij}\right)\left(\delta_{kl} - M_{kl}\right) + \left(\delta_{ik} - M_{ik}\right)\left(\delta_{jl} - M_{jl}\right) + \left(\delta_{il} - M_{il}\right)\left(\delta_{jk} - M_{jk}\right)\right] \quad (5)$$

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As an additional model consideration, the flow solution is computed with pure slip boundary conditions. This choice is motivated two-fold. First, due to the typical manufacturing approach of placing cool or room temperature material charges into preheated tooling, under these conditions the development of an apparently slip boundary conditions has been observed in SMC [16,17]. Additionally, Tucker observed in an orders of magnitude analysis that in the presence of large anisotropy and flat orientation states, apparent plug flow (slip) develops in narrow gaps [18]. Thus, as heat transfer and curing effects are not considered, a pure slip boundary condition is adopted.

Simulation Model Creation

The process of manually placing material charges into the tooling cavity is a source of difficulty for developing an accurate simulation as compared to highly controlled processes such as injection molding. For the transverse charge, the length of the charge was totally contained in a portion of the double dome geometry having only two dimensional complexity. For this case the creation of the initial charge domain was performed by simple geometric means, see Figure 4. However, the length of the axial charge extends into a portion of the double dome geometry that contains three dimension features.

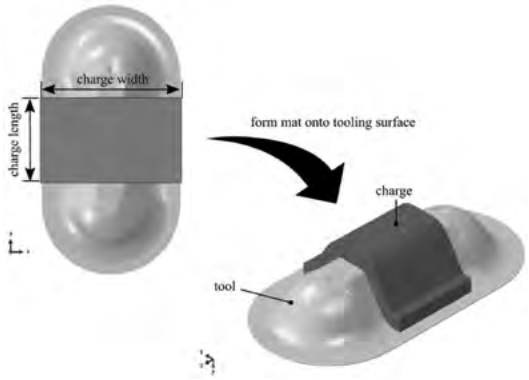

Figure 4: Diagram of Model Creating via Forming Type Operation of Charge

To form the initial domain for the axial charge, a simple elastic forming simulation was performed considering a quasi-isotropic material definition. The charge domain was then padded from the forming simulation results. The transverse charge domain contained 221,076 PC3D elements, while the transverse charge contained 287,335 PC3D elements.

Following creation of the charge domains the orientation state must be initialized. As a simple method, the charge domains were segmented into five regions as shown in Figure 5 and each element was assigned an initial orientation vector generated from a planar uniform orientation distribution about the regional surface normal.

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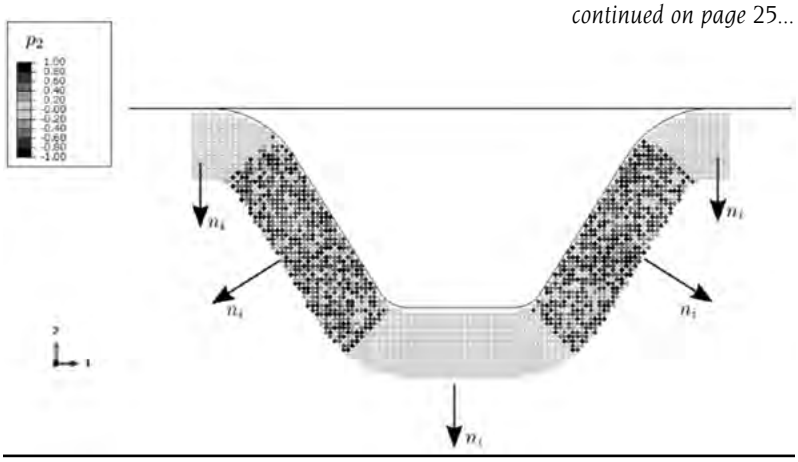

Figure 5: Regional Orientation Initialization Scheme

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Experimental and Numerical Results

Experimental short shots were performed by shimming the double dome tool to six positions: 5 mm, 4 mm, 3 mm, 2 mm, 1 mm, and no shim. The full material charge was used in each case so that the conditions did not vary between trials other than the stopping position. In Figure 6, we show the results of the short shot experiment and flow simulation results at corresponding states.

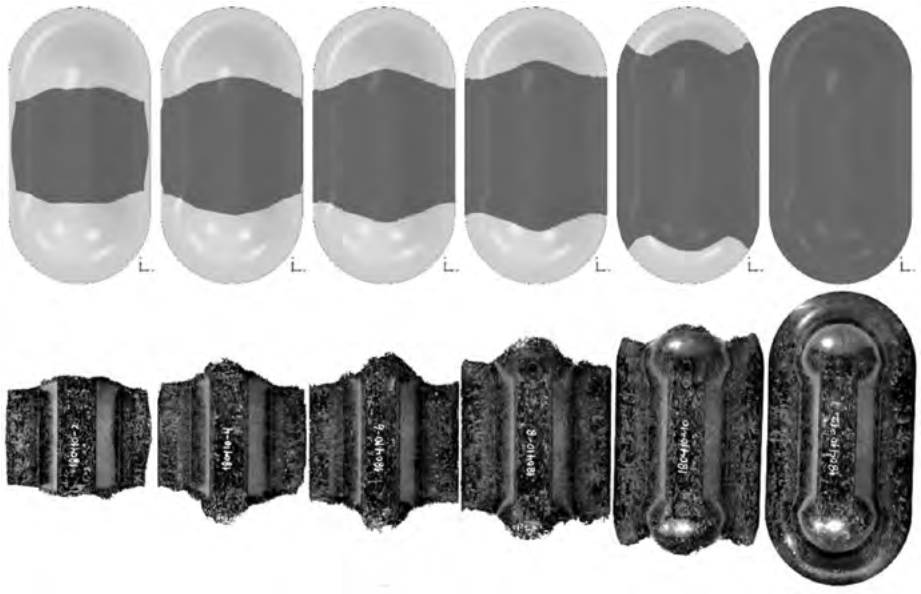

Figure 6: Top View of Experimental Short Shots (bottom) and Simulated Flow Pattern (top) for Transverse Charge

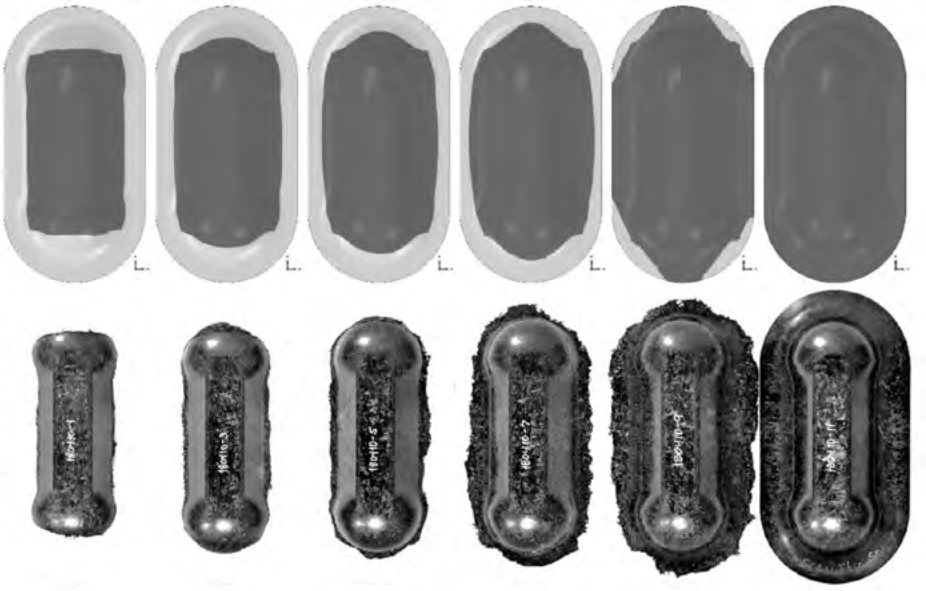

Figure 7: Top View of Experimental Short Shots (bottom) and Simulated Flow Pattern (top) for Axial Charge

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Clearly, there is strong agreement between the predicted flow patterns and the short shots for the transverse charge. In this orientation, the charge initially flows similarly in all direction. However, the side boundary is encountered quite early in the total filling process; thus, the remainder of the flow proceeds as nearly one-dimensional flow, extending in the axial direction. Interestingly, the material near the side boundary flows faster than the rest of the charge and a knit line forms at the axial boundaries. The knit line can be seen clearly in the orientation structure shown in Figure 8 at both axial ends of the double dome, there are two regions of low A_{33} separated by a line of large A_{33} indicating that fibers are not crossing that line. Similarly, Figure 7 shows the flow pattern of the axial charge. The axial charge is sized and orientated so that the entire double dome fills relatively uniformly, in this case, the behavior is quite uninteresting. However, it must be noted that the initial charge of the simulation can be seen to be slightly too wide compared to the experiment. This source of this discrepancy arises from the charge domain creation technique. The formed surface was padded using the outward normal. While the formed surface had the correct width, the padding increased the average width of the charge. Again, this discrepancy was not correct as this work represents a blind prediction. The degree of alignment along the axial direction of the double dome can be seen in Figure 8.

To investigate the orientation state in the resulting simulations further, path plots were created which loosely correspond to the regions from which tensile bars could be excised from the double dome geometry. From a top view, a thin rectangular inspection region centered along the axial direction of the double dome and 150 mm long is swept along the x_1 direction. The average orientation tensor is then computed over the entire inspection region. The resulting orientation tensor components are plotted versus relative distance along the sweeping path. Figure 9 shows the orientation state variation for the transverse charge with the orientation tensor expressed in global coordinates.

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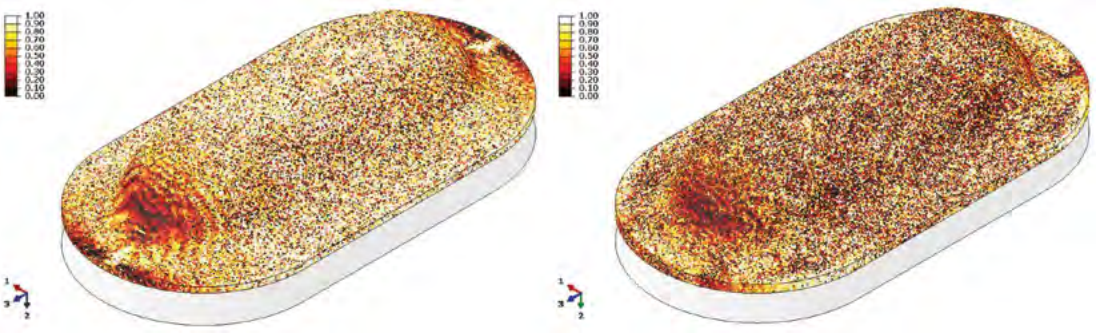

Figure 8: Iso-View of Axial Degree of Alignment (A_{33}) for the Transverse Charge (left) and Axial Charge (right)

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$$\bar{A} = \begin{bmatrix} \bar{A}_{aa} & \bar{A}_{at} & \bar{A}_{an} \\ \bar{A}_{at} & \bar{A}_{tt} & \bar{A}_{tn} \\ \bar{A}_{an} & \bar{A}_{tn} & \bar{A}_{nn} \end{bmatrix} = R \cdot A \cdot R^T, \qquad R = \begin{bmatrix} 0 & 0 & 1 \\ n_2 & -n_1 & 0 \\ n_1 & n_2 & 0 \end{bmatrix} \qquad (6)$$

While this representation is direct, it is not particularly useful for interpretation as the orientation state in the slanted walls appears more complex than in reality. Therefore, in Figure 10 and Figure 11, the orientation tensor components of local orientation tensors are shown for the transverse charge model and axial charge model respectively, where the local orientation tensor, $\bar{A}$, is determined using Equation (6) where n_i is the local surface normal.

From Figure 10, we see that due to the one-dimension extension type flow encountered by the transverse charge the orientation state has been pulled towards axial alignment reaching an average degree of alignment of approximately $A_{aa} = 0.7$. However, as the axial charge experienced two-dimensional extension throughout, the orientation state maintained approximately planar random. In both cases, the orientation state remained locally planar.

Conclusions

A simulation method for the flow and orientation analysis of prepreg platelet molding compounds, specifically a carbon fiber filled thermosetting materials used similarly to traditional SMC, has been presented. The method was limited by considering only essentially pristine molding conditions: isothermal conditions with uniform matrix viscosity through the domain and a molding time scale much less than the thermoset curing timescale. Nevertheless, the presented coupled fiber orientation and anisotropic viscosity approach implemented in Abaqus/Explicit using a VUMAT and taking advantage of the SPH solution method showed predictive results for flow patterns of two different charge configurations. The full simulation procedure involves charge domain creation, orientation initialization, and, finally, flow simulation.

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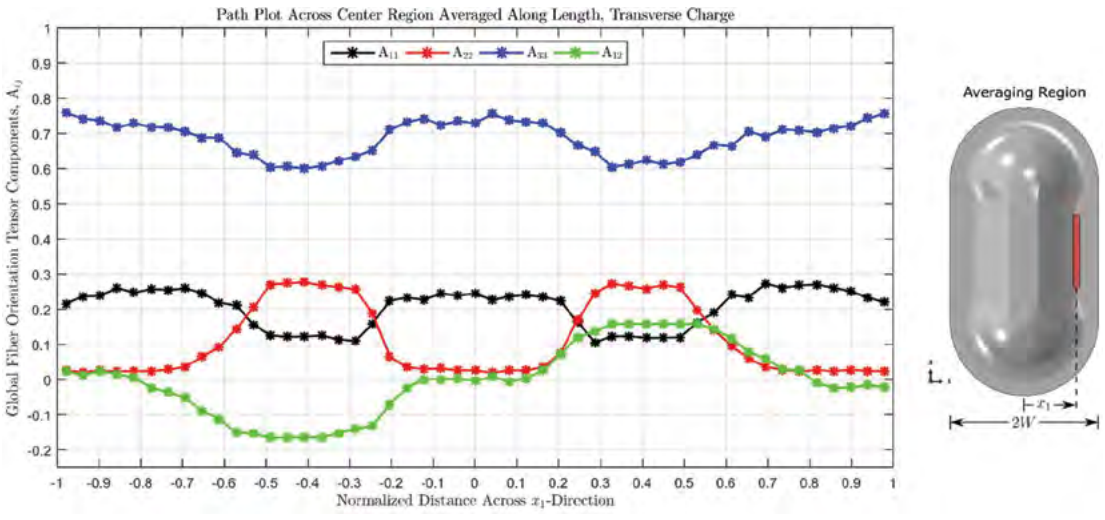

Figure 9: Orientation State across Width of Double Dome for Transverse Charge in Global Coordinates

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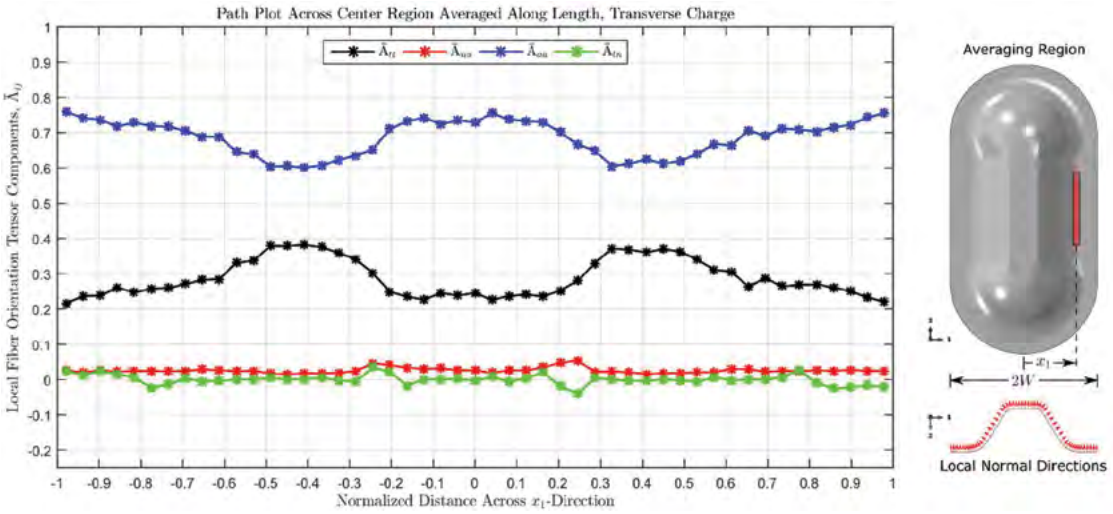

Figure 10: Orientation State across Width of Double Dome for Transverse Charge in Local Coordinates

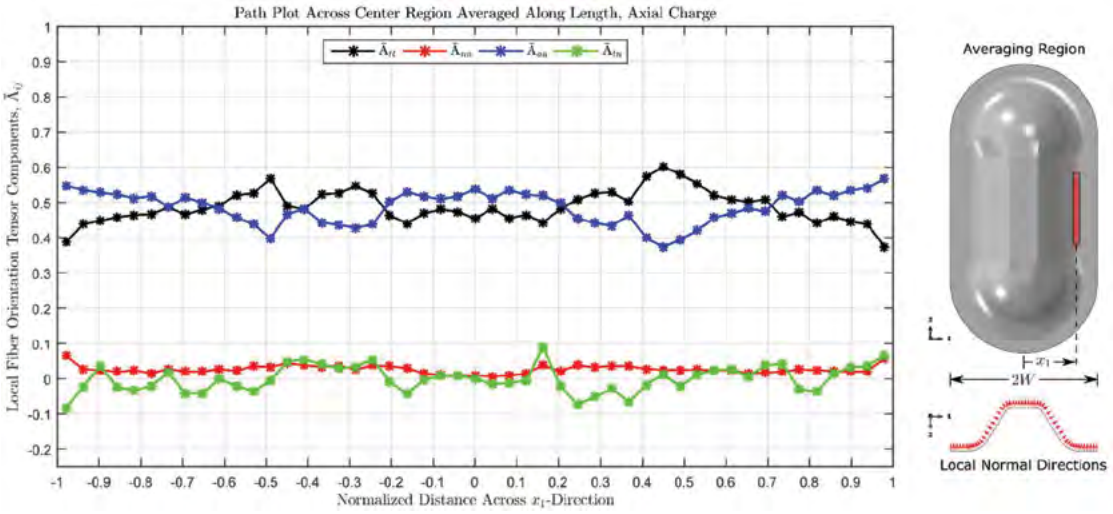

Figure 11: Orientation State across Width of Double Dome for Axial Charge in Local Coordinates

The investigation shows the large effect initial charge placement and charge orientation have on the flow pattern and resulting orientation state in the final part. Future work involves development of automated charge domain creation and orientation initialization using local surface normals rather than regional. These advancements are necessary so that the presented approach can be applied for more general and complex tool geometries and initial charge placements.

Acknowledgements

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This Issue:

ACMA Press Release

SPE Composites BOD is excited to share the following news released by ACMA regarding John Busel.

FOR IMMEDIATE RELEASE
(Updated:8/12/2019)

Media Contact: Barry Black ll
Senior Manager, Marketing
American Composites Manufacturers Association
703-682-1664 • bblack@acmanet.org

ACMA Announces 2019 Membership Award Winners

August 8, 2019, (Arlington, VA) – The American Composites Manufacturers Association (ACMA) is proud to announce its 2019 Membership Award winners. Each year, ACMA recognizes outstanding members for their dedication and hard work in the development and growth of critical markets, advocacy on behalf of the composites industry, and their efforts to help others in the industry prosper. "Our 2019 award winners truly represent the best and the brightest that the composites industry has to offer," said Tom Dobbins, President of ACMA. "With a pool of individuals as talented as these serving as ambassadors for composites, there is no limit to what we can achieve."

Award winners were named in several categories, including:

Lifetime Achievement Award

The ACMA Lifetime Achievement Award recognizes a business owner who has been in the composites industry for at least 20 years and, through their involvement, has made a significant and lasting contribution to the industry. The 2019 Lifetime Achievement recipient is:

- Steve Dehmlow – Chief Executive Officer, Composites One

Hall of Fame Award

The ACMA Hall of Fame Award recognizes a member who has attained distinction among his or her peers through their efforts, involvement and accomplishments in the composites industry and its associations. The 2019 Hall of Fame recipients are:

- Richard Holland – Vice President - Business Development, Composites One
- John P. Busel – Vice President - Composites Growth Initiative, American Composites Manufacturers Association, Fellow - American Concrete Institute

Outstanding Volunteer Award

ACMA's Outstanding Volunteer Award is given to a member who has contributed significant volunteer time and effort to achieve positive results on behalf of the industry through service to ACMA. The 2019 Outstanding Volunteer Award recipient is:

- Rick Pauer – Applications Specialist, Polynt Composites USA

In honor of ACMA's 40th anniversary in 2019, the Pioneer Award has been created to recognize individuals who have either developed, enhanced or created processes and/or materials that have advanced the composites industry. Pioneer Award winners will be announced prior to CAMX.

ACMA Membership Award winners will be celebrated for the inspiration they provide at the Membership Awards Ceremony and Reception, sponsored by Gordon Plastics, Nippon Electric Glass, PRC Composites, and The RJ Marshall Company on September 23, 2019 in Anaheim, CA, during the industry's largest trade show and conference in the US, CAMX – The Composites and Advanced Materials Expo (thecamx.org). The Membership Awards Ceremony and Reception is held each year at CAMX to allow ACMA Membership to come together to honor winners and reflect on the past year's achievements. Press are invited to attend.

ACMA Press Release continued...

About ACMA

The American Composites Manufacturers Association (ACMA) is the world's largest composites industry trade group. We are manufacturers, material and equipment suppliers, distributors, academia and end users, dedicated to growing the composites market. We serve our members and the industry by promoting the competitive advantage and versatility of composite materials. ACMA offers composites industry educational resources through our CAMX show, conferences and Certified Composites Technician (CCT®) program. We develop standards and specifications that drive preference for the use of composites in place of traditional materials. We lead advocacy efforts via legislative and regulatory channels to achieve a more viable composites industry. Together, we are shaping the future of composites. Learn more at www.acmanet.org.

Biodata of John Busel

John Busel is Vice President, Composites Growth Initiative of the American Composites Manufacturers Association. Mr. Busel has led composites industry programs in market development of new opportunities and existing markets in the composites industry, very active in codes and standards development, and promotes composites through education and awareness to industry, consumer and trade press. Mr. Busel has 30 years of experience in market development, composites design, tool engineering, manufacturing, and research and development of thermoset and thermoplastic composite materials. Mr. Busel held positions in market development, engineering, manufacturing, and R&D for the following companies: Market Development Alliance (MDA), SPI Composites Institute, Brunswick Composites, Martin Marietta Aerospace, and Boeing-Wichita. He is a Fellow of

American Concrete Institute, and member of American Society of Civil Engineers, SAMPE, SPE, and ASTM. He was the past chairman of ACI Committee 440 – FRP Reinforcement. He is active in standards development through ACI, ASCE, IEEE, and ASTM and has been recognized by ACI for Distinguished Service. Mr. Busel has a BS Civil Engineering degree from Bradley University.

This Issue:

TOPCON 2020

TOP NETWORKING OPPORTUNITIES

Announcing the SPE Thermoset TOPCON 2020 event in Madison, Wisconsin at the beautiful Monona Terrace Community and Convention Center. Join the leaders in the industry and learn about opportunities for thermoset innovative technologies in multiple markets.

– Automotive – Agricultural – Aeorspace – Heavy Truck – Wind Energy – Marine – Medical – Electro/Electronics – Outdoor Sporting Goods & More!

Enjoy networking during breakfast, lunch and a first class cocktail reception all included with your registration.

TOP INDUSTRY INNOVATIONS

Sponsor and/or exhibit at the event and feature the latest thermoset products and services. Networking breakfasts, lunches and the cocktail receptions will be in the exhibit area enhancing sales opportunities and corporate exposure.

With pristine views of Lake Monona from the Community Terrace exhibit area, you and your customers will have a relaxing and enjoyable experience!

Present your innovative thermoset products, services and technologies from the stage of the very comfortable lecture hall equipped with everything you need for a great presentation.

TOP CONFERENCE LOCATION

Inspired by Wisconsin native Frank Lloyd Wright's design, at the peak of his creative powers in 1938, the Monona Terrace Community and Convention Center is one of the country's premier conference and convention facilities.

On the shores of Lake Monona, it is an architecturally striking structure that connects the state capital, the cityscape, and the community.

Join us for golf at University Ridge Golf Course and a cruise of the Madison shoreline via private yacht with deluxe appetizers and beverages with your industry peers on **Monday, May 11,** the day before the conference!

spe

THERMOSET TOPCON

Madison, Wisconsin • May 12-13, 2020

Presented by SPE Thermoset Division

For more info and to register go to:
https://spethermosets.org/topcon

Contact teri@intuitgroup.com
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for info on Sponsorship and Exhibit Opportunities