SPE COMPOSITES

DECEMBER 2016

Composites Connection™

Official Newsletter of the SPE Composites Division

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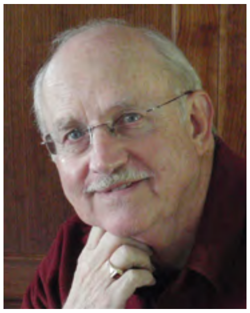

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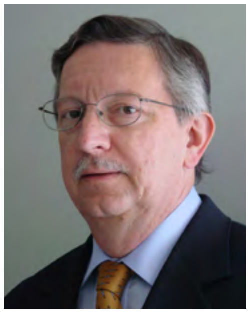
Board of Directors continued...



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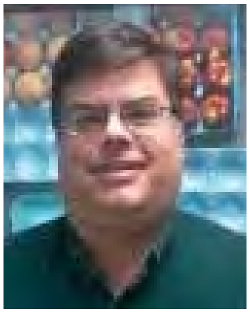

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This Issue:

Councilor Report

By: Creig Bowland

The August Council meeting included approval of several Bylaw & Policy modifications that will transform the Society's governance model at the inception of the 2017 Council term. Under the new model, the Executive Committee will be replaced by an Executive Board comprised of functionally qualified and accountable individuals. This board will provide direction and oversight for most Society governance matters, thereby enabling Council to focus on initiatives consistent with key Society objectives, including improving member value, expanding educational programs, etc.

Dues Increase

Unlike other societies, SPE has not increased its member dues in nearly a decade. Not surprisingly our membership 'price' is at the low end of the market. Our member dues remain our largest source of income and provide much needed support for new programs. Accordingly, it was decided to increase the yearly dues to $155 for new and renewing members. Those memberships which expire in the next few months will still have the opportunity to renew at the current rates before the new rate comes into effect on 1/1/2017. We ask your help to inform your members about this pending change.

Membership Numbers and Reports

Whilst our paying membership has been 'relatively stable' between 13,500 and 15,000 over the years, we have seen a steady decline to 13,150 (from about 15,000) between 2011 and the summer of last year. This rate of decrease is generally the same across all Sections and Divisions. In the upcoming weeks, new, comprehensive membership reports will be rolled out using a dashboard format. These dashboards will provide a much improved perspective of your group membership including: member contact information, membership trends, a list of recent additions, and a list of members that chose not

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Councilor Report continued...

to renew their membership. We expect this new information will be especially helpful to membership chairs.

On a positive note, overall membership (which includes e-Members) has grown to over 21,000 members. This growth expands the audience for SPE's marketing efforts. As you might expect, we recently began implementing new programs designed to convert e-Members to regular membership.

Key Benefits Are Not Well Known to Our Members

During our meetings we provided more info regarding the ongoing development of our 'Plastics Insight' technical news brief. Surprisingly we found that many Councilors were not aware of the benefits and features of this newsletter (and in some cases even its existence). This news brief is fully customizable to your interest fields and needs.

Even 'The Chain', our community platform for plastics professionals, which has existed now for over a year, and which has very versatile functionalities, seems to be 'untested ground' for many. Recent enhancements include improved graphics, sampling of current discussion topics, and the introduction of Industry Exchange our newest community supporting general industry awareness. As a reminder, The Chain includes private communities for use by your boards and committees. Our MarComm Manager Sue Wojnicki is available to help you 'spread this news' to your members and leaders. Contact Sue at swojnicki@4spe.org.

The Future of ANTEC and Membership

The whole of Council actively participated in two important workshops. One group focused on improving the ANTEC model while the other focused on growing Membership. There were many valuable ideas gathered from the effort. Look for continued discussions of these two important subjects on The Chain as we seek to put these ideas to work. We will keep you apprised of this effort in future communications.

This Issue:

Call for Papers

COMPOSITES DIVISION

Invites
Original Papers in the following categories
for presentation at the
SPE Annual Technical Conference
ANTEC® 2017
May 8-10
Anaheim, California, USA

Thermoplastic Composites
Thermosetting Composites
Novel Manufacturing Methods
Non-Destructive Inspection / Evaluation
Nanocomposites
Joining of Composites
Long / Short Fiber Composites
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And more ...

For more information contact:
Jim Griffing
Box 3707, MC 0ER-202
Seattle, WA 98124-2207
(425) 238-2180
james.s.griffing@boeing.com

Or, visit: www.antec.ws and click on "Speaker Resources"

Papers are due no later than January 13, 2017

COMPOSITES

This Issue:

Board Meeting Minutes Sept 6, 2016

By: Antoine Rios

Tuesday, September 6, 2016
Diamond Center - Novi, MI

Attendees:
Executive Committee

Michael Connolly, Chair
Ray Boeman, Vice Chair
Tim Johnson, Treasurer (phone)
Creig Bowland, Councilor
Andy Rich, Past Chair

Directors

Steve Bassetti (phone)
Dale Brosius
Dan Buckley
John Busel
Rich Caruso (phone)
Fred Deans (phone)
Jack Gillespie (phone)
Klaus Gleich
Jim Griffing (phone)
Dale Grove (phone)
Enamul Haque
Frank Henning
Nippani Rao
Ian Swentek
Uday Vaidya

Guests

Rani Richardson
Shankar Srinivasan (phone)

Staff

Kathy Schacht – SPE

Meeting started at 5:00 pm
Chair: Michael Connolly

- Michael Connolly announced the participants for the meeting. He stated that John Busel will be taking minutes for the meeting.
- Michael Connolly reviewed the agenda and requested that the awards report be moved towards the beginning of the agenda. Dale Brosius requested that Rani Richardson join the meeting discussion for ACCE topics.
- Michael Connolly presented the key thrusts for 2016/17 and how that relates to the work plan and contributes to the content of Composites Division Policy Manual. Michael Connolly asked the directors who are assigned to specific areas review the content and add the needed information.
- Michael Connolly distributed the draft policy manual to the Board members for review and comment and what is involved in the SOP. He had no expectations to discuss this subject in detail today's meeting but wants to complete the review of the Policy Manual by the November BOD meeting.
- Klaus Gleich requested to select a different time to accommodate those in Europe. The group agreed to conduct meetings at Noon Eastern in the future.
- The group agreed to make sure that committee reports be distributed to the BOD in advance of the meetings.
- Dale Brosius emphasized that all Board members need to review the content of the policy manual.

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This Issue:

Board Meeting Minutes continued...

Secretary: Michael Connolly for Antoine Rios

- Dale Brosius read the election report as submitted by Antoine Rios. 33 members voted. All candidates were elected or re-elected: Nippani Rao, Pritam Das, Rich Caruso, Steven Bassetti, Uday Vaidya, Enamul Haque, Daniel Buckley, Frederick Deans, Jim Griffing.
- Michael Connolly stated that the minutes were balloted via email. No further comment.
- John Busel reported he updated the contact sheet for the Board meeting.

Chair-Elect: Ray Boeman

- Michael Connolly recommended to Ray Boeman to attend the officers workshop. Kathy Schacht indicated that this workshop is not being done, but there are other outlets to prepare officers for the expected performance.
- Ray Boeman said the Pinnacle Award process is due Feb. 12, 2017. He noted that Rich Caruso heavily contributed to the last process and thanked him for his help. The group suggested to start the process of filling out the award as early as possible.
- Kathy Schacht reported that next year's process will be exactly the same as last year, however the process is being reviewed and will be revamped in future years.

ACTION: *Kathy Schacht will help Ray Boeman with training materials for new officers.*

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Board Meeting Minutes continued...

Awards: Ian Swentek

- Ian Swentek reported on the progress with the division awards. He suggested that Jack Gillespie is a candidate for Fellow. The group agreed that the process was difficult to complete based on recent candidate submissions.
- Ian Swentek requested that we clarify the awards policy to address multiple award winners. The committee made some decisions during the last session to deal with this issue. Ian Swentek moved to amend our awards policy such that a single person applying to multiple awards under SPE-CD could only win a single award. In cases where an individual was selected as a top applicant for multiple awards, the most prestigious would be awarded. Andy Rich seconded. The group discussed the merits of the motion and how to best clarify the process to give better direction to the awards committee. The group wondered whether all awards fall into this problem. The committee would assign the most prestigious award to a single candidate. It was also pointed out that if there are no qualified candidates, should an award be given? There is no specific guidance. Michael Connolly recommended to table this motion to make sure that all the variables are considered. Creig Bowland recommended that there should be consideration that the awards committee be left with the discretion to do what is needed and proper for the applicants being consid-

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Board Meeting Minutes continued...

ered. The awards committee was seeking input from the Board to clear up this situation. Ian Swentek withdrew the motion. Michael Connolly stated that future issues will be left at the discretion of the awards committee.

- Ian Swentek moved to increase the amount of the award for the Harold Giles Scholarship to $2500 to $3500 for both the undergrad and graduate levels. The motion was seconded. The group discussed the history and current amount of the award. Ian Swentek stated that this is to keep the award current to the economy. The group discussed that travel might be given with the award, but that was done on a case by case basis. The group was thinking to increase the award to $3500. The group felt this might encourage more entries. It was noted that the total outlay would be $7000. Motion passed. Ian Swentek moved to increase the contribution to cover the new expenses associated with the recent motion. It was suggested to increase the amount over $7000. Currently, the contribution is $6000. With this new amount, it was suggested to increase the amount to $8000. One nay. Motion passed.
- Michael Connolly suggested that $5000 should be considered to be contributed to the Jackie Rehkopf Scholarship account. The group was supportive of this scholarship and discussed the current situation of this particular scholarship. The group felt the message needs to be sent to the Automotive Division the intent of the Composites Division relative to this scholarship. Ian Swentek moved to contribute $6000 to the Jackie Rehkopf fund. Dale Brosius seconded. Michael Connolly explained the process of how the award was funded and how it is maintained each year which explained the reason of the motion. The group noted that this amount maintains the Composites Division share. Motion passed. Dale Brosius asked for a summary of all the awards that are being supported by the Division.

ACTION: *The Awards Committee is to summarize the current list of awards, criteria, and monetary obligation and distribute this information to the Board.*

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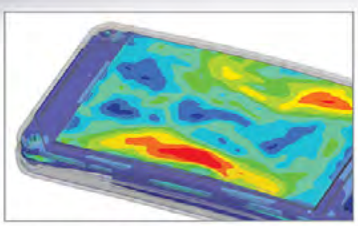
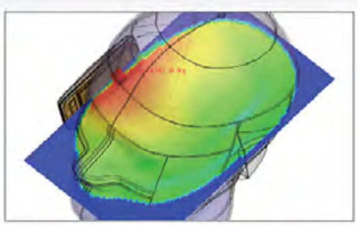
This Issue:

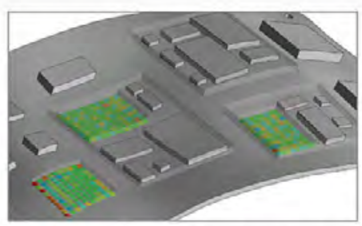
Been there, dropped that...



Impact Simulation: RADIOSS



Electromagnetic Analysis: FEKO



Structural Analysis: OptiStruct

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Board Meeting Minutes continued...

Communications: A. Rich

- Andy Rich reported that the burden of Communications appears to fall on a single person versus an entire committee. He asked input from the group as to what improvements could be made. Michael Connolly recommended that Andy Rich take the lead to make the appropriate changes to the website. Andy Rich noted that the news is very old and needs to be removed and the current newsletter is available. It was recommended to look at the analytics for the website to determine what pages need to be changed or updated. Michael Connolly requested from Andy Rich to propose recommendations for changes to the website.

ACTION: ***Andy Rich is to compile a list of changes he recommends for the website for review by the Board.***

Membership: Ray Boeman

- Ray Boeman reported that his has reviewed the data from the membership for the division. He observed that CD head count drops in April and correlates to all divisions within SPE. It was noted that this shows a correction to the data and it appears that the membership numbers were inflated due to people involved in multiple divisions which affected the rebates to some divisions. There are 701 members in the Composites Division as of the end of August.
- Ray Boeman reported he received reports from attendance at past events. He is still reviewing the data but he intends to look at potential candidates for the division. Michael Connolly pointed out that the Policy Manual provides direction for

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Board Meeting Minutes continued...

lapsed members. Ray Boeman feels that both Membership and Communications need to work together to address this issue. Tim Johnson and Dan Buckley volunteered to help on the Membership Committee. Michael Connolly added that we want to understand our members better and a succession plan is needed for the Membership Committee.

Councilor Report: C. Bowland

- Creig Bowland reported that SPE has voted to change its governance. The governing body of 9 individuals, elected by the Council and membership as a whole, for a 3-year term, will be evaluated for the type of position and duties they will undertake on the governing body. He noted that all of this is presented on the SPE website. Council will be more of an advisory group with veto rights to presented issues. He noted that this streamlines the process of making decisions.
- Creig Bowland reported that a task force was created to review the ANTEC process and conference. He noted that the most successful conference are ones that are focused and targeted. One of the possibilities is to vary the topics. The exhibit hall was declining so there is a focus to do more to bring emphasis to this area of the conference. Another item being evaluated is that technical papers would be not required and

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Board Meeting Minutes continued...

Powerpoint presentations only could be submitted to encourage more and better participation on timely topic areas.

- Michael Connolly noted that a successor for the Councilor will need to be identified before ANTEC 2017.

Treasury Report: Tim Johnson

- Tim Johnson reported that the treasury is in really good shape with the most current report in the newsletter.
- Tim Johnson stated that the $75K moved into an investment account after the last BOD meeting is showing returns. He expects that the ACCE will add to the monies in the account.
- Dale Brosius reported that $16K was saved on the Composites Division contribution to the planning and execution of ACCE. There are expected to be good revenues from this year's conference based on early registration.
- Tim Johnson noted that predicating the expenses and revenues is rather difficult since the Automotive Division takes on a large portion of running the ACCE. It was stated that the monies associated with the conference always runs in the black throughout the planning process due to significant "Early Bird" sponsorships.

ACCE: Michael / Creig / Dale

- Michael Connolly noted that Peggy Malnati does marketing communications for ACCE. She volunteers to coordinate the technical program for the ACCE. Michael Connolly noted that the amount of time that Peggy Malnati puts into the conference might change come next .
- The group also felt that she might leave all of these duties to explore other options. The group discussed how to fill the potential gaps if Peggy Malnati leaves these positions.
- Michael Connolly reported that the executive committee agreed to give Peggy Malnati bonus compensation based on a percentage of the profits. The group agreed that this compensation is worth the work that Peggy Malnati puts into this conference.

ACTION: *Executive Committee to discuss the issue with the Automotive Division leadership and potentially Peggy Malnati to investigate and resolve the issue.*

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Board Meeting Minutes continued...

Education: U. Vaidya

- Uday Vaidya distributed a proposal from Winona State University for support of equipment to teach a curriculum on composites engineering utilizing 3-D printing. The group discussed the merits of the proposal and the equipment requested. The group felt the system should be capable of doing composites and not just plastics. It was noted that the equipment to support composites would be more expensive. The group presented both sides of the issue.
- Uday Vaidya reported there are 43 posters including undergraduate, graduate, and high school for ACCE. Some travel was provided for several submissions.
- Michael Connolly requested that there be better marketing for this initiative to provide visibility to the work coming from the posters. Kathy Schacht offered some help from SPE to assist in the process.
- Fred Deans introduced an education opportunity at Oakland University in MI. Michael Connolly asked for more information to be discussed in detail at the next meeting.

ACTION: Uday Vaidya will approach Winona State University to consider different equipment which incorporates composites.

Technical Conference Reports:

- Cyclitech 2016 with JEC (Dec 6-7, 2016, Newport Beach, CA) – Creig Bowland
- Creig Bowland reported that the conference program is set with 25 presentations. There are 6 sponsors for the event. He expects the conference will at least break even. Creig Bowland stated that there are many people involved with coordinating the marketing and promotion of the event.
- Tim Johnson clarified that this conference will alternate from Europe and USA. He asked if the site selection has been set for year 3 and 4. Creig Bowland was not aware if any decisions were made.
- Creig Bowland suggested that the conference topic might be broadened to sporting goods. This is a joint effort between SPE and JEC.

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Board Meeting Minutes continued...

- Thermosets 2017 (March 21-22, 2017, Phoenix, AZ) – Dale Brosius
- Dale Brosius brought up the opportunity of partnering with the division in support of their conference to explore other market segments. The group discussed options for support of working with this division. Dale Brosius offered to take the lead to come up with a proposal for engagement with this initiative. Fred Deans offered to assist on this project.
- ANTEC 2017 (May 8-11, 2017, Anaheim, CA) – Jim Griffing
- Jim Griffing asked the Board analyze the presentations this week for potential candidates for presentations next year at ANTEC. Rich Caruso and Shankar Srinivasan from Iowa State agreed to serve as Co-TPC's for ANTEC 2018. They will participate with Jim G. in a conference call for TPC's with SPE HQ in mid-Sept. and will generally "shadow" Jim G. for ANTEC 2017 in order to learn the process.

ACTION: All Board members are to review the ACCE technical program for candidate presentations at ANTEC 2017 for consideration.

Inter/Intra-Society: John Busel

- John Busel reported that there will be 3 presentations presented at CAMX that will be promoted as a SPE session. The session will take place on Wednesday, September 28th. There are two educational presentations and one technical paper. The presentations are as follows:
- Fundamentals and Emerging Technologies of Fiber Sizing and Interfacial Adhesion, 2:30 PM - 3:15 PM, Speakers: Steve Bassetti & Roxana McMican, Michelman.
- Fatigue of Carbon/Epoxy Laminates: Beyond Experimental Testing Thanks to Multiscale Modeling [Tech Paper], 3:30 PM - 3:55 PM, Speaker: Pierre-Yves Lavertu, eXstream engineering.
- Design and Processing Considerations for Optimal Performance of Short-Fiber Composite Parts, 4:00 PM - 4:45 PM, Speaker: Erik Foltz, The Madison Group
- Frank Henning reported that there will be a conference in Europe on automotive composites based on a technical journal on the topic. The conference is International Conference on Automotive Composites, September 21-23, 2016, Lisbon, Portugal. Fran Henning is a part of the editorial committee but suggested this could be a potential partnering opportunity.
- Frank Henning is giving a presentation titled: "Development of Thermoset Composite Structures for Automotive Lightweighting"

Newsletter: P. Das

- Michael Connolly reported that the newsletter was completed and distributed both electronically as normal and in a limited print run for ACCE. This was excellent work and metrics need to be applied to see who all is reading the publication.

Meeting adjourned at 7:15pm

Respectfully submitted,
John P. Busel

This Issue:

Award Winning Paper

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

Christoph Kuhn, William Kucinski, Olaf Taeger

Volkswagen AG, Group Research, Wolfsburg, Germany

Tim A. Osswald

Polymer Engineering Center, University of Wisconsin, Madison, WI

Abstract

During the processing of long fiber-reinforced thermoplastics (LFT), various long fiber specific effects occur, which can have significant influence on the component properties. A major effect that results when processing LFT is Fiber Matrix Separation (FMS), which leads to a non-uniform fiber density distribution throughout the part. The development and impact of this effect is not thoroughly examined. Experimental investigations in compression molding with long fiber reinforced thermoplastics have shown an unequal distribution of fiber content with increasing fiber length. With effects already visible in free flow regions, FMS especially leads to significant changes in fiber content in complex geometries. Particularly in specific rib sections, fiber content decreases greatly, leading to a significant change in component behavior. Furthermore, extensive fiber bundling and clogging is observed at the rib entrance. With the results of the experiments, the governing mechanisms of FMS were analyzed and a new approach for the simulative prediction of FMS is pursued.

Introduction

Global car manufacturers aim to reduce the weight of vehicles, since more appliances, functions and safety features are integrated due to consumer demand and government regulations. With the increase of electrified power trains, in fully electric cars or hybrids, the weight of batteries significantly increases the total weight of a car. The aim for future cars is to reduce weight in order to achieve stricter carbon emission regulations [1-3] while still maintaining great performance. Fiber reinforced polymers (FRP) offer high mechanical properties to weight ratios and low cost processes for large scale production. By intelligent combination with other lightweight materials, FRP make future lightweight design possible.

Virtual process simulation tools for processing of discontinuous FRP minimize unnecessary process steps during component design and evaluation. Commercially available simulation tools are used to model numerous effects during processing. In the field of fiber reinforced polymers, the resulting fiber

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parameters (orientation, length, content) inside the composite are of great value, especially for the use in structural and safety-related components. By using the predicted fiber parameters in the process simulation, the component behavior can be precisely simulated for multiple scenarios, such as crash and fatigue. Current simulation tools have multiple models available for the prediction of fiber orientation [4] and fiber length degradation [5]. With increasing fiber length, a non-uniform fiber density distribution appears throughout the component. Current simulation tools do not adequately represent this phenomenon.

The effect of FMS has been mentioned in earlier publications [7-8], but it is not thoroughly examined to date. Fiber content experiments with BMC by Schmachtenberg et al. [7] show an increase in fiber content over a flow path in relation to the processing parameters. Experiments with Londoño et al. [8] show a significant change in fiber content in a breaker box. Londoño gives a first introduction to complex forces working at the rib geometry and the principle of the complex interaction between fibers and matrix. He describes the two governing forces during mold filling of rib geometries. According to Londoño, the fibers are squeezed into the rib according to Darcy's Law (Eq.1), which describes the flow of a fluid through a porous medium in relation to the fluid velocity (V), the porosity (κ), viscosity (η) and the pressure gradient (dp/dx). Bakharev and Tucker [9] predict the permeability of a glass fiber bed (Eq.2).

(1) $$V = \frac{\kappa}{\eta}\left(-\frac{dp}{dx}\right)$$

(2) $$\kappa = 0.00025\,\phi^{2.4} D^2$$

The hydrodynamic force on the fiber at the rib entrance can then be calculated as the pressure on the effective fiber area, as described in Londoño et a. (3), where $\dot{h}$ is the closing speed of the press, L_{rib} the width of the rib and L the length of the fiber bundle.

(3) $$F_{hyd} = \frac{\dot{h}\,\eta\,L_{rib}\,L}{K}\,dx$$

According to Londoño et al. [8], the force counteracting the fibers getting squeezed into the rib geometry is represented by the force (F) needed to bend fibers into the rib (Eq. 4), where (C_f) is a constant, (E) the Young's modulus, (EI) the moment of inertia, (δ) the deflection of the fiber and (L_r) the free length of deflection.

(4) $$F_F = C_f \frac{EI\delta}{L_r^3}$$

Londoño introduces a Fiber-Matrix Separation constant θ, which describes the ratio of fiber deflection force to hydrodynamic forces (Eq. 5). FMS occurs for values of $\theta \ll 1$, when the fiber bending forces are higher than the hydrodynamic forces and the matrix is squeezed out of the fiber bed.

(5) $$\Theta = \frac{F_{hyd}}{F_F}$$

A suggested continuum model describes the interaction of the fibers and the polymer matrix as a two phase flow (Figure 1). Hereby, the fibers and the polymer matrix are divided into two separate domains, which are displayed as an elastic fiber domain (grey, velocity vector v) and a viscous polymer matrix domain (red, velocity vector u). These two domains interact as described in the Fiber Matrix Separation constant. The ratio of elastic fiber forces to viscous hydrodynamic forces θ describes the differences in flow of the two phases. A simplified description of

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This Issue:

Award Winning Paper continued...

Figure 1: A continuum model of a two phase flow of matrix (red) and fiber phase (grey)

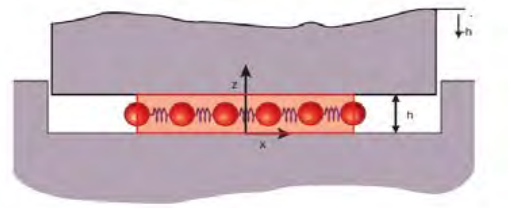

Figure 2: Interaction of the elastic fiber and viscous matrix domain in a continuum model for Fiber Matrix Separation

the counteracting forces is shown in Figure 2. During Fiber Matrix Separation, the elastic fiber forces excel the hydrodynamic forces, leading to a reduced fiber content in the flow front and an agglomeration along the flow path.

In this paper, the effect of Fiber Matrix Separation is examined in compression molding experiments with long glass fiber reinforced thermoplastic materials. The selected mold geometry features a series of different ribs with alternating design. The effect of differing material properties and rib designs on Fiber Matrix Separation is analyzed. In this context, the fiber properties are measured using traditional processes like pyrolysis as well as state of the art CT imaging. The gathered data is then analyzed and compared to the process simulation results.

Material

Compression molding experiments were performed with glass mat thermoplastic sheets (GMT) supplied by Quadrant, Lenzburg, Swit-

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zerland. GMT is manufactured by impregnating a needled glass mat with thermoplastic resin in a belt press. The advantage of GMT is the high achievable fiber length in the final part. In comparison to other LFTs, the GMT is not extruded prior to the compression molding, hence fiber damage and attrition is reduced. In order to analyze the influence of fiber properties during processing, GMT materials with varying fiber contents and fiber lengths are used. An overview of the used materials is given in Table I.

	Standard GMT	I F-GMT
Matrix Material	PP	PP
Fiber Length [mm]	50	80
Fiber Content [wt.-%]	30 / 40	30 / 40

Table I: Material parameters of the selected GMT

Compression Molding Tests

The compression molding experiments were conducted using a Diefenbacher hydraulic press located at the Institut für Leichtbau und Kunststofftechnik in Dresden. A generic star shaped component geometry with multiple rib designs and a free flow region was chosen, as depicted in Figure 3.

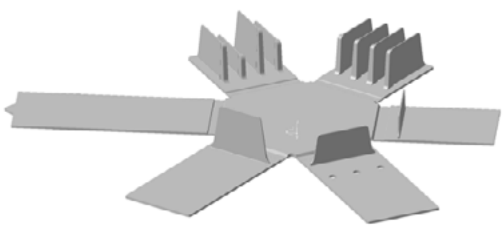

Figure 3: Star-shaped tool geometry with straight ribs, cross ribs and a free flow region

The GMT material was cut and preheated in an infrared heating field before processing. Then, the heated material was manually transferred into the center of the mold and compression molded, evenly filling the star shaped geometry. During the processing, the GMT material is forced into the mold geometry under pressure, filling the cavity (Figure 4) [10].

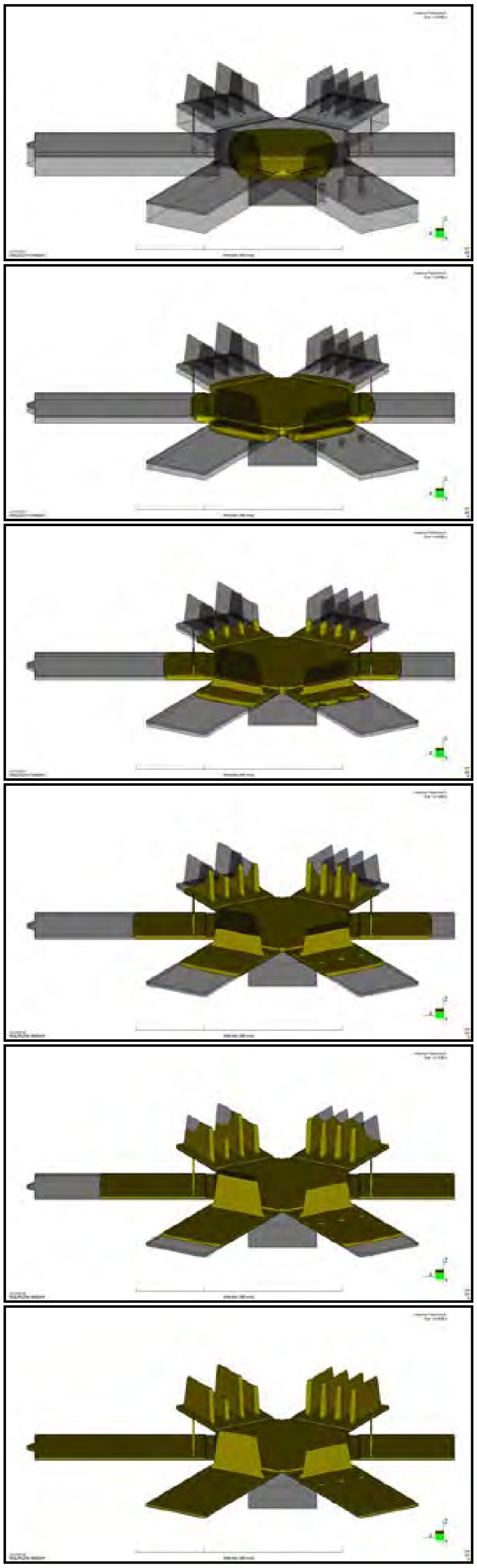

Figure 4: Mold filling simulation in compression molding at different time steps

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Fiber Weight Content Analysis

The components from the compression molding experiments were cut into sample sizes. The fiber weight content of the gathered samples was then analyzed according to DIN EN ISO 1172 [11]. With this process, the fiber reinforced component is pyrolyzed in an electric oven. During the pyrolization process, the sample region is exposed to a temperature higher than the decomposition temperature of the polymer matrix and lower than that of the reinforcement fibers. This results in solely fibers remaining after sufficient exposure. The fiber weight content Φ_{wt} of the sample region is specified by comparing the remaining fiber weight mf to the compound weight mc before the pyrolysis, consisting of both fiber mf and polymer matrix weight m_m.

(4) $$\Phi_{wt.} = \frac{m_f}{m_c} = \frac{m_f}{m_f + m_m}$$

Free Flow Region

Sections 1 - 8 were chosen in relation to the distance from the part center to analyze the change of FWC over the flow path as displayed in Figure 5. The fiber content results for the free flow region are displayed in Figure 6 and Figure 7.

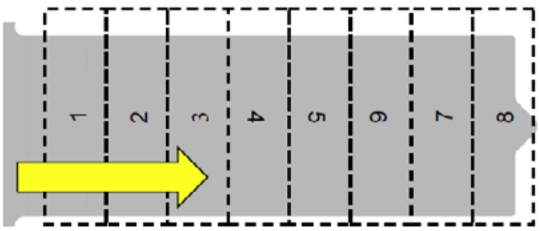

Figure 5: Sections in the free flow region used for fiber content analysis

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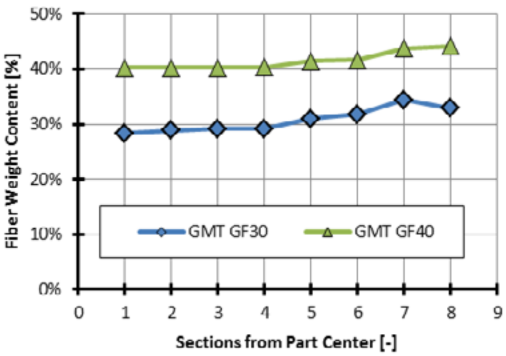

Figure 6: Fiber content over free flow area

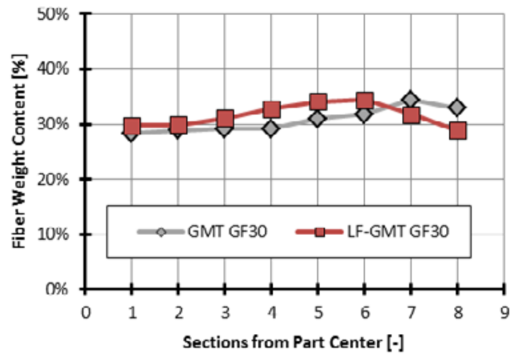

Figure 7: Fiber content over free flow area, comparison of Standard GMT (grey) and LF-GMT (red)

The results for Standard GMT are shown in Figure 6. It is apparent that the fiber content in the two standard materials with GF30 and GF40 is increasing towards the end of the flow path. Both samples show an increase in fiber content after section 4 of approx. 5 wt.-%, while the fiber content in sections 1-4 is mostly constant. Towards the end, a slight tendency towards lower fiber content is visible with the GF30 samples.

The change of fiber content over the free flow path with long fiber GMT (or LF-GMT) is displayed in Figure 7. With the use of longer fibers, the fiber content increases earlier and more drastically. While the standard GMT samples start increasing in section 4, the LF-GMT samples of GF30 and GF40 increase in sections 3 and 2, respectively. While standard GMT samples demonstrate only a slight

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decrease in fiber content towards the end of the free flow region, LF-GMT samples show a sharp decrease in fiber content in sections 7 and 8.

The resulting fiber content profiles of the free flow region comply with the findings of Schmachtenberg's [7] experiments with compression molded bulk molding compound (BMC). The increasing flow velocity of the material in combination with a decreasing flow cross section leads an increase of fiber forces and fiber interaction. This induces a relative motion between the fibers and the polymer matrix. Fibers accumulate with increasing flow length, leading to sections with higher fiber content along the flow path and lower fiber content at the end of the flow path. With longer fibers, this effect appears earlier and more drastically due to increasing fiber interaction. The changes in fiber content over the flow path and the observed fiber content profile is therefore caused by Fiber Matrix Separation.

Straight ribs

The change of fiber content inside the straight ribs was analyzed in different sections as described in Figure 8. Sections were separated into base, section A (rib entrance), midsection B and top section C. Due to sample size restrictions, the 3 cm rib is divided only into sections A and C.

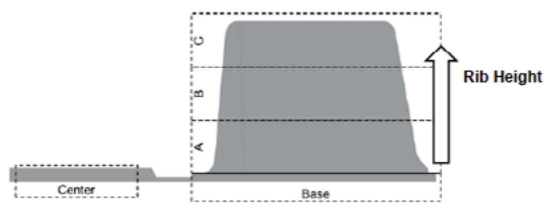

Figure 8: Overview of component selection for pyrolysis

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Figure 9 - Figure 11 show the fiber weight content in the different rib sections A, B, C with rib heights of 3, 4 and 6 cm using both the Standard GMT and the LF-GMT with a fiber content of GF30.

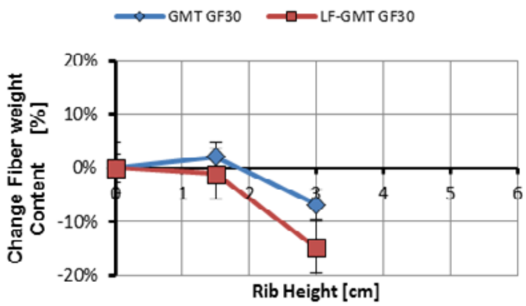

Figure 9: Change of fiber content in a straight rib (3cm)

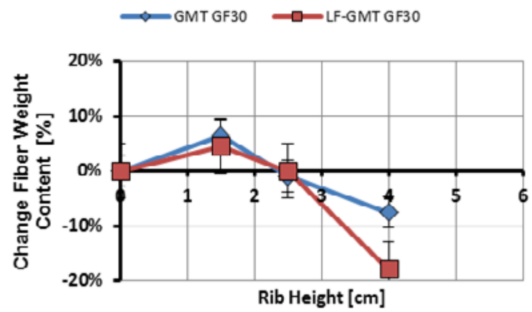

Figure 10: Change of fiber content in a straight rib (4cm)

In all figures, the fiber content in the top region C is significantly lower than the fiber content in the initial material. Due to the excessive fiber interaction and the narrow cross section at the rib entrance, the fibers are inhibited to access the upper rib regions B and C. The samples with longer fibers show a generally lower fiber content in section C. In all top regions, the fiber content decreases greatly from Standard GMT to LF-GMT. With increasing fiber length, the fiber interaction and fiber retraction force increases significantly, inhibiting the matrix's ability to pull fibers into the rib.

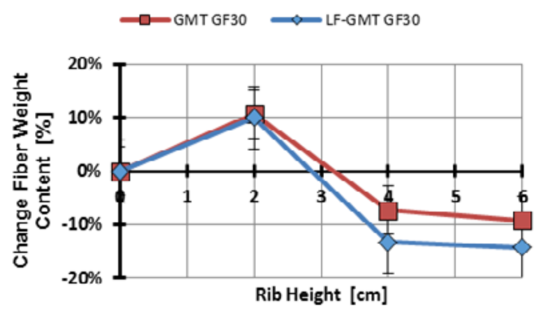

Figure 11: Change of fiber content in a straight rib (6cm)

Prior to the final decrease in section C, a significant increase of fiber content is visible in the rib entrance section A. This fiber content profile leads to a noticeable fiber content gradient from section A to section C. The fiber content peak in section A increases with the rib height. This is due to fiber jamming at the rib entrance, where fibers accumulate and restrain movement into the higher rib sections, creating a "fiber dam." With increasing rib height, more fibers accumulate within the fiber dam. Due to increasing fiber content at the rib entrance, the hydrodynamic forces increase drastically (Eq.2) and the matrix is able to push the fiber dam further into the rib.

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Figure 12 and Figure 13 show the relative change of fiber content in a straight rib based on the initial fiber content of GF30 and GF40.

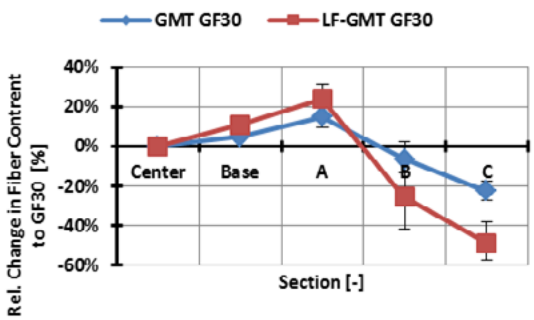

Figure 12: Change of fiber content in straight rib (5cm) with both GMT *and* LF-GMT GF30 *samples*

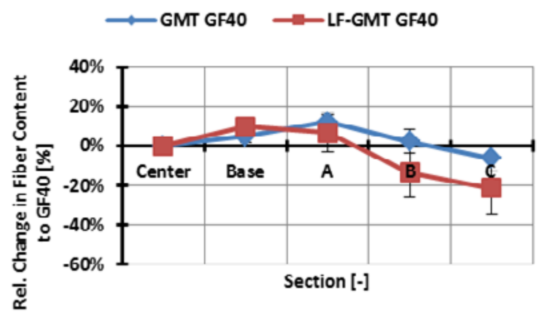

Figure 13: Change of fiber content in straight rib (5cm) with both GMT *and* LF-GMT GF40 *samples*

The same behavior as in Figure 9 - Figure 11 – an initial increase and a following decrease in fiber content - is observed. Again, the LF-GMT shows lower fiber contents in the top region C of the rib. Comparing the GF30 and GF40 samples, it appears that the fiber content gradient is generally lower with the GF40 samples. With higher fiber content, the hydrodynamic forces increase significantly and fibers are pushed into the rib. This validates Londono-Hurtado's mechanism.

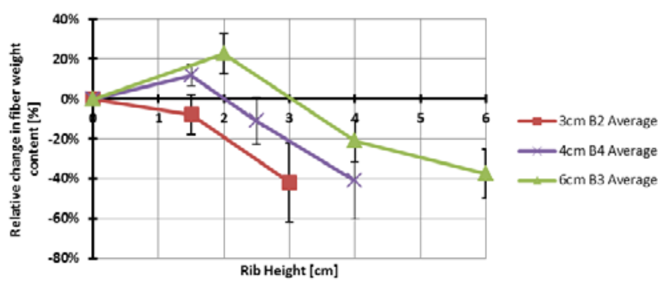

Figure 14: Change of fiber content in straight ribs with different heights

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Figure 14 describes the average change of fiber content in the different rib heights relative to the initial fiber content of the material.

Ribs with heights of 3, 4 or 6 cm show the same fiber content in the top regions. However, significant changes in fiber content can be observed in the lower rib region as rib height increases. This shows that the achievable fiber content in the top section is not based on the rib height, but rather on the flow properties at the rib entrance. The fiber content peaks in the rib entrance section show an increase of fiber jamming and congestion at the rib entrance with longer flow duration. Therefore the parameter of interest of fiber content in the rib is the geometry of the rib entrance.

Cross Ribs

Figure 15 shows the change of the FWC of the three different cross ribs with increasing rib height.

As observed in the straight ribs, the cross ribs show a decrease in fiber content in the higher rib region C with comparable fiber content values. In contrast to straight ribs however, cross ribs show no excessive increase in fiber content in the lower rib section A. Fiber accumulation and the observed fiber dam is not as excessive in the cross rib as in the straight rib. This may be caused by less fiber interaction during the rib filling due to the pre-orientation of the fibers before entering the cross ribs. With less reorientation of the fibers during rib filling, fiber interaction decreases significantly, leading to less fiber bundling and congestion at the rib entrance.

CT Analysis

For the accurate display of fiber properties inside the sample, state-of-the-art non-destructive CT scanning is used in combination with a software analysis tool. For CT image generation, the fiber reinforced sample is placed into a micro-CT machine, where a series of X-ray pictures of the sample are taken from different angles. The inner structure is displayed as different greyscale values, which correspond to the transmissibility of x-rays through the material. A 3D model of the sample is then generated in the analysis software. By defining a greyscale threshold value, the matrix and the fiber material inside the composite is defined. Special fiber analysis software is then used to calculate the fiber orientation and fiber volume content.

While the pyrolysis, as described earlier, measures the fiber weight content, CT scanning measures the fiber volume content inside the sample region. The fiber volume content Φ_{vol} is described as the ratio of fiber volume V_f to the compound volume consisting of both the fiber V_f and the matrix V_m volume:

$$\Phi_{vol} = \frac{V_f}{V_f + V_m} \quad (5)$$

The fiber volume content Φ_{vol} can be correlated to the fiber weight content Φ_{wt} with the known densities of the matrix polymer ρ_m and the fiber material ρ_f. Therefore, all mentioned fiber contents in this paper refer to the fiber weight content.

$$\Phi_{vol} = \frac{1}{\left[1 + \frac{\rho_f}{\rho_m}\left(\frac{1}{\Phi_{wt}} - 1\right)\right]} \quad (6)$$

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Straight Rib

Figure 16 shows the original CT image of a straight rib with 6 cm height.

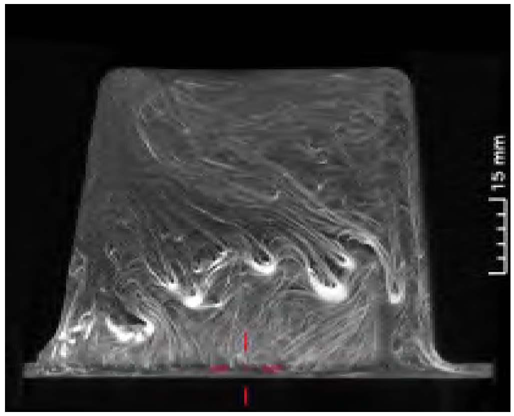

Figure 16: CT image of the straight rib showing excessive fiber bundling and change in fiber content

The reinforcement fibers in light grey are clearly visible in the matrix and show extensive bundling and entanglement. The image also shows the lighter regions at the rib entrance with higher fiber content. Fiber interactions over multiple component sections are visible. Figure 17 shows the results of the fiber parameters analysis of the same CT sample.

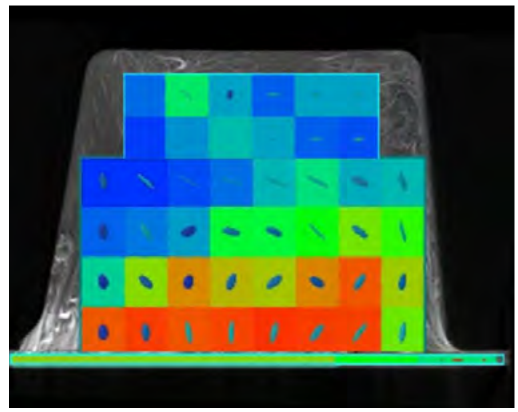

Figure 17: CT analysis of fiber content showing significant change of fiber content in straight rib

The fiber content in vol.-% is displayed in color. The CT fiber content analysis clearly shows a triangular shape of higher fiber content (red/orange) in the lower section of the rib. Towards the upper region of the rib, the fiber content decreases significantly (blue). Comparisons of the fiber content inside the rib with sections before the rib entrance (green) show that the fiber content is not impacted before the narrow rib entrance. This leads to the conclusion that the significant increase in fiber content happens due to the decrease in flow cross section and the resulting interaction with the fibers. When comparing the triangular shape of the high fiber content region at the rib entrance with the filling study (Figure 18) and the simulation (Figure 19), they are remarkably similar in shape.

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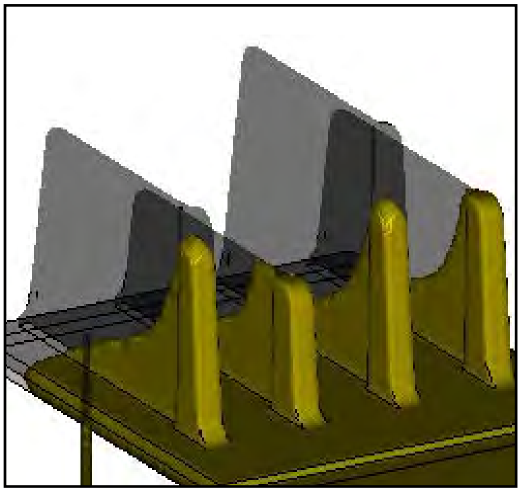

Figure 18: *Flow front inside the straight rib section in simulation*

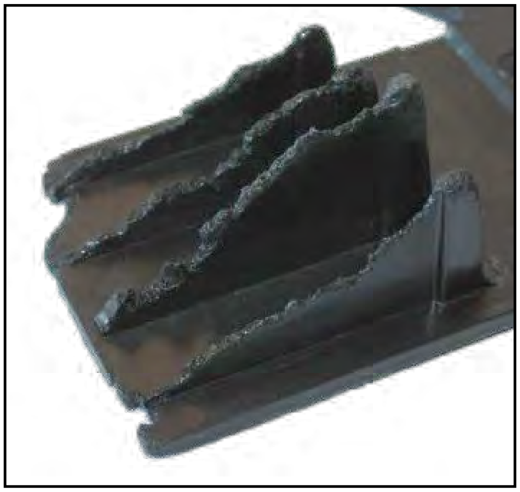

Figure 19: *Flow front during straight rib filling in experiments*

This supports the assumption that the fiber clogging appears in early stages of the rib filling process at the flow front, due to counteracting mechanisms of the fibers. In comparing the regions of low fiber content in the upper region with the high fiber content at the rib entrance, it appears that large entangled fiber bundles mark the border of the two regions (Figure 20). This leads to the assumption that the initial decrease in fiber content is due to fiber clogging effects when the rib front enters the smaller cross section of the rib. Evidently fibers get jammed at the rib entrance and create a "fiber dam", where oncoming fibers get stuck while the polymer matrix is able to pass. Eventually the "dam" is pushed into the rib due to increasing hydrodynamic forces, leading to the fiber content profiles in Figure 9 -Figure 14.

The observed effects of excessive fiber bundling and clogging in the lower rib area are also displayed in the fiber orientation analysis of the sample. The orientation tensors (blue) are displayed in Figure 21 and Figure 22.

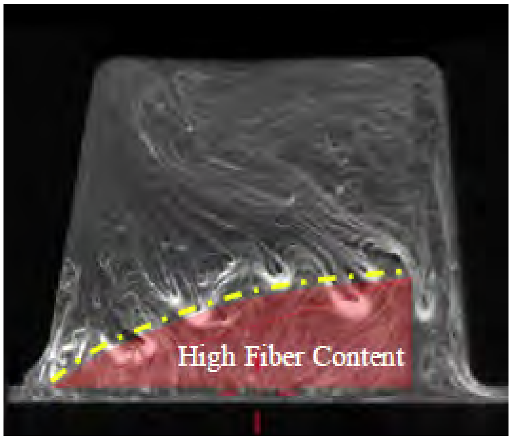

Figure 20: *Border region between high fiber content and low fiber content in a straight rib*

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Award Winning Paper continued...

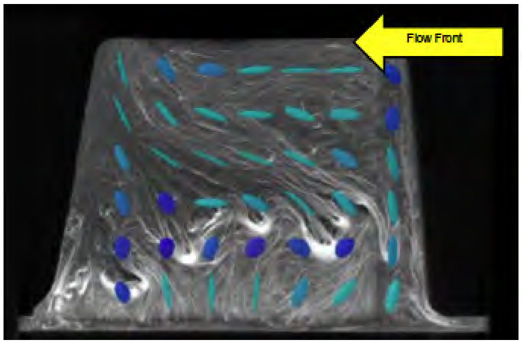

Figure 21: Fiber orientation in CT analysis of straight rib (side view)

Figure 22: Fiber orientation in CT analysis of straight rib (top view)

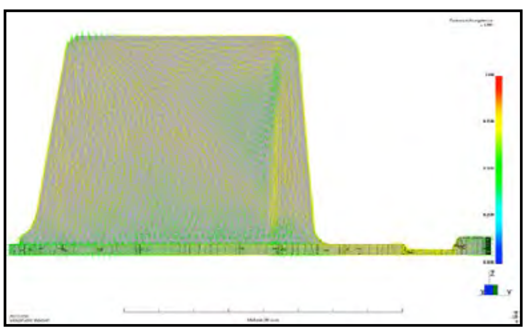

Figure 23: Fiber orientation of straight rib in Moldflow simulation (side view)

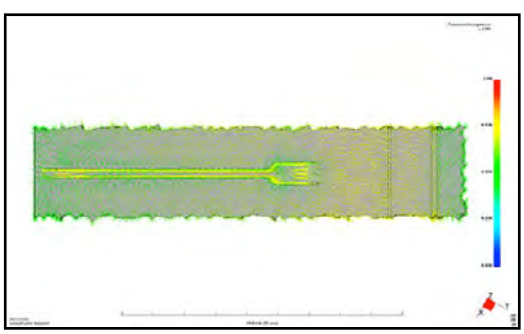

Figure 24: Fiber orientation of straight rib in Moldflow simulation (top view)

It is visible that the fibers align with the flow, but show random orientation in the regions of excessive fiber bundling. Worth noting is the high alignment of fibers, especially in the rib entrance area in the lower rib section. Observing the fiber orientation in the base of the rib (Figure 22), it appears that the fibers change orientation when entering the rib, leading to high fiber interaction. Furthermore, it is visible that the long fibers expand over multiple component sections. This shows that with increasing fiber length, the fibers interact over multiple component regions. It also shows that the glass fibers are able to deform heavily to enter the rib, leading to excessive bundling and fiber interaction.

Comparing the fiber orientation of the CT sample to the simulation results in Figure 23 and Figure 24, it is obvious that complex fiber effects are not portrayed in the continuum simulation.

The high degree of fiber orientation in the lower rib region is not depicted, since it appears to be caused by fiber interaction of long fibers spanning from the outside of the rib into the lower rib region. Figure 24 shows the fiber orientation as seen from the top view. Moreover the simulation describes the general change of orientation in the flow, the actual orientation values are not matching due to long fiber effects not covered by continuum simulation.

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This Issue:

Award Winning Paper continued...

Cross Rib

Figure 27 and Figure 26 show the CT image of the 6 cm cross rib. As seen before in the straight rib, complex fiber bundling and entanglement are visible, but especially in the lower rib section not as excessive and large as in the straight rib. Again, fibers spreading from the base of the rib towards the upper regions are visible, leading to complex fiber interaction over multiple geometry regions.

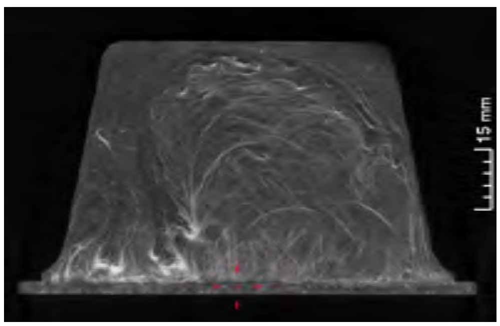

Figure 25: CT image of the cross rib (6cm), front view

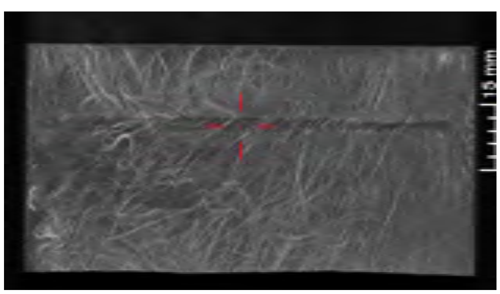

Figure 26: CT image of the cross rib (6cm), top view

Analysis of fiber content and orientation with the analysis software is displayed in Figure 27. The increase in fiber content at the rib entrance is not as large in size as compared to the straight rib and is mainly visible in the center of the rib. The decrease of fiber content is especially visible in the sides of the top rib section.

Regarding the CT analysis of the fiber orientation, a generally horizontal orientation in the rib plane is visible. Towards the upper regions the fibers tend to orient sideways, following the rib geometry. Compared to the simulation results (Figure 28), the fiber orientation of the long fibers cannot be displayed accurately.

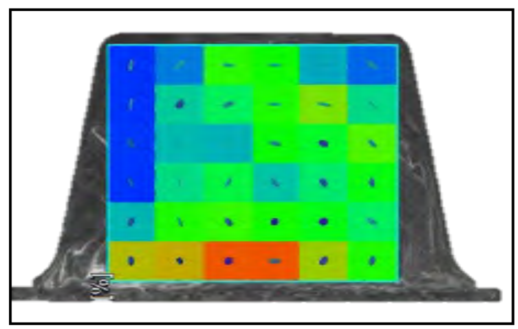

Figure 27: CT analysis of cross with fiber content (color) and fiber orientation analysis (tensor balls)

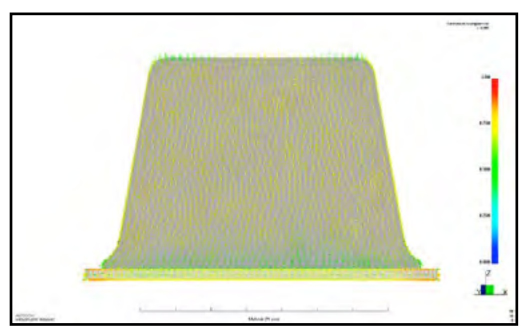

Figure 28: Fiber orientation of the cross rib in Moldflow simulation

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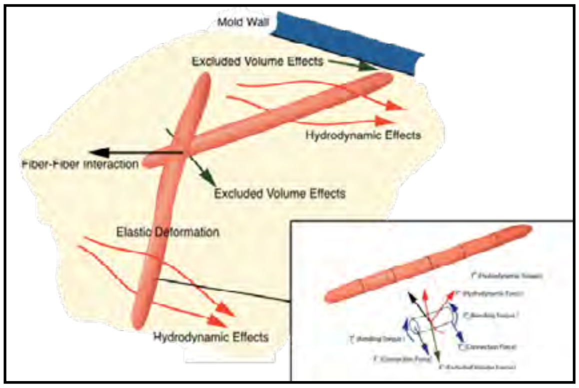

Figure 29: Direct Fiber Simulation with a micromechanistic model [11]

Conclusion & Future Work

The experiments show numerous effects caused by the complex interaction of long fibers with the polymer matrix. Fiber Matrix Separation occurs in all regarded component sections and is of tremendous importance to the application of long fiber reinforced polymers. The influence of the rib geometry and orientation was analyzed in combination with material and processing parameters. Furthermore, the governing interactive mechanisms between fibers and matrix during rib filling were underlined.

The experimental results support the basic approach of Londoño, while the exact interaction between fibers and polymer matrix are in need of a more detailed approach.

Due to complex fiber interactions, a simulative approach by the Polymer Engineering Center at the University of Wisconsin-Madison [12] is applied to determine the influence of the fiber and polymer properties on Fiber Matrix Separation. With the help of direct fiber simulation in the micro-mechanistic scale (Figure 29), the influential parameters of the governing equation for a suggested continuum model (Figure 2) can be generated.

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This Issue:

Communications Report

By: Andrew Rich

Changes to the website:

The current website was set up at least 8 or 10 years ago, and it has been difficult to keep it up to date, due to the effort required to keep it populated. To make matters worse, in the past several years, the market has seen a much wider variety of devices, and web browsers that the website must work on. The type of website template that was used when the site was originally set up, does not adapt to the OS on many devices, and does not look good on certain web browsers, and/or cell phones.

After speaking to Peggy Malnati, I was totally confused by the wide variety of options that we have. Apparently, we have an unlimited number of options.

After speaking to two different website builders, and (hopefully) the SPE website guru, Pedro, I have narrowed down to three different options:

Peggy is the one who built the original website all those years ago, with Dawn Stephens. In fact, because of the age, the type of template that was used, and the general chunkiness of that style of web service, Dawn is still needed to make monthly updates. She can update our whole look and rebuild a new website on an up-to-date template and web service for $2500, and repopulating it with all new content for another $900. Total estimate $3400.

The SPE really wants all the Divisions to move our websites on to the SPE website service, but at last check it was expensive, but that may have changed. I have spoken to Pedro and the story from SPE is not complete. They looked at our site to charge the divisions $1,500 to rebuild our website, and $500/yr. to maintain it. But we don't have the new pricing yet.

Other services vary in cost from $1,000 to $5,000, with the lower cost ones requiring us to put a lot of time and effort into it, and the higher cost services giving us a more complete turn-key service, which would be easy for us to take over from there. I received another estimate for the transportation of the website to a new more modern template, of $1200, with any additional pages repopulated for $125 per page. Basically, the estimate was about $1800.

We should assume some time ($) will be spent on some better graphics design, $500.

In my opinion, after speaking to these people: Peggy Malnati, Dawn Stephens, Extrusion Division (has used the new SPE web service), SPE – Pedro Matos, Bill Arnold, (the other website designer)

The two independent options, Dawn Stephens, and Bill Arnold. Both are IT professionals doing website design and management as a side job. Both have about the same availability, and would take about the same amount of time. After speaking to both of them, more than once, and looking at websites that they have done for others, I would have to say that the price difference between Bill and Dawn is roughly equivalent to the quality difference, with Bill Arnold being the slightly better deal for the money, and Dawn being the better overall quality of service.

The surprise was that SPE Headquarters gave us a better price than anyone else. This also has several advantages, like the Membership link, the unified format, and maintenance. (Price of Maintenance TBD).

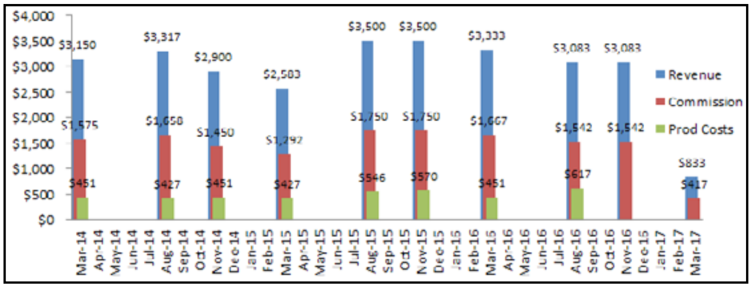
Projected cost for SPE.org: $1,500 - $2,000
Projected cost from independent website designers: $2,000 - $3,500
Projected time to completion: 2-3 weeks

This Issue:

Newsletter Update

By: Pritam Das

Financial analysis for newsletter:



Since March'14:
Total Revenue: $32,700
Cost (Commission at 50% and prod costs): $20,082
Profit: $12,618 (38.5%)

New sponsors signed in the last 3 months:

- Chomarat
- Siemens
- Intertek
- Polyscope
- Globe Machine

BOD members are requested to submit their reports in the next couple of days (by 11/22/16 – last date extended) to m by email as I will start preparing the composites newsletter. Thanks for those who have already provided their reports.
Thanks, Pritam Das

Sponsor the Newsletter

The best advertising value in the Composites Industry

Quarter page ad or logo ad:
3.75" x 5" $500

Half page ad:
7.5" x 5.5", 5" x 7.5", 4" x 8.5"..................$750

Full page ad:
7" x 10", 8.5" x 11" $1,250

Contact: Teri Chouinard CBC, APR
SPE Composites Division
Sponsorship Chair
C/O Intuit Group, Inc.
phone 248.701.8003
Teri@IntuitGroup.com

Please provide Logos as JPG and EPS files (send both if possible)
Please provide Ads as High Resolution PDF files
Advertising with the SPE Composites Division is inexpensive and easy. Please help us to promote the benefits of Composites in Industry.

Sponsoring the Newsletter enables the SPE to communicate the benefits of the composites in many industries, which fortifies your marketing efforts.

- **Support your SPE Composites Division**
- **Reach 1,000 Composites Professionals 3 Times a year via the E-Newsletter**
- **Also reach 1,070 SPE Composites Division Linked In Members 3 times a year and an additional 11,492 COMPOSITES Linked In Members Secondary group where the link to the newsletter is posted year-round**
- **Reach many more as a sponsorship also includes your logo on our website, www.specomposites.org with a link to your company**
- **Maximize your exposure to the customers & the trade**
- **Stay informed on the latest composites activity**

Increase your presence on the web leading to more sales by sponsoring our Electronic Newsletter which is published on the SPE Composites Division Website and emailed to all Division Members (1,000 approx.) 3 times annually. Rates include 3 issues (not on calendar basis - published approx. Nov/Dec, Mar/April, July/August). All ads include a link to your website increasing your exposure on the worldwide web exponentially. Sponsorship also includes your logo ad with a link to your website on www.specomposites.org further increasing your presence on the Web as a Leader in Composites Technology.

This Issue: