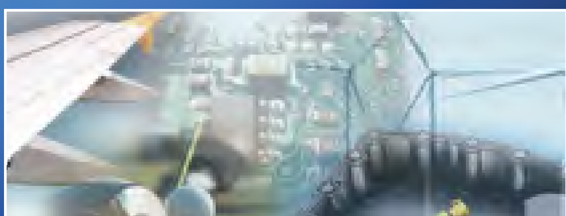
SPE COMPOSITES

AUGUST 2017



Composites Connection™

Official Newsletter of the SPE Composites Division

Reaching Over 1,000 Composites Professionals
In All Industries

Composites Connection™
Advancing Composites Technology Worldwide
SPE COMPOSITES
August 2016

Chairman's Message:

Ray Boeman, Ph.D.

As I write this message, I have yet to convene my first board meeting of the Composites Division. My term became effective at the end of ANTEC (May, 2017), and I will conduct the first meeting of my tenure in July. Although nothing earth shattering has occured during the past 2-3 months, I believe that there is news to share. First though, I would like to take this opportunity to thank our outgoing chair, Michael Connolly, for his effective leadership. Michael initiated activities that I believe will help the Division become more effective over the next several years. Revision of the Division's policy manual and establishing standard operating procedures (SOPs) for each board position are examples related to the governance of the Divsion.

I would also like to thank Ian Swentek for accepting the nomination of Chair-Elect – Ian was elected at ANTEC. I am sure that he will continue to serve with the same distinction that he did on the awards committee. Finally, our Councilor Crieg Bowland was named SPE Vice President for Divisions. According to SPE bylaws, Crieg cannot continue as councilor. Consequently, Dale Brosius has been elected to complete Crieg's term. The Division's loss is the Society's gain.

The Automotive Composites Conference and Exhibition (ACCE), held jointly with the Automotive Division, continues to be the Division's most important event. The growth and success of the ACCE, coupled with increased corporate sponsorship, has enabled us to increase the monetary awards for students and educators alike. Additionally, the Division awarded a grant in 2017 to Winona State University. The grant, cost shared with an equal amount from the university, will be used to establish a bench-scale 3D composite printer. We anticipate the trend of increased support for education will continue and suggest that those in education, whether student or teacher, closely monitor these opportunities and apply. More information can be obtained from the Division's Education Chair, Prof. Uday Vaidya (uvaidya@utk.edu).

Goals for my tenure are still in development, but among the items for the first 6 months, I would like to strengthen and link our membership and communications committees. Long term viability of the Division rests with our ability to offer value to our membership, and effective communication of that value is paramount. Over the past several years, including in 2017, the Division has achieved SPE's Pinnacle Gold Award for creating and delivering member value but I think we can do more, and do a better job of communicating the value of being a Composites Division member. Additionally, we will continue on the pathway that Michael has charted toward improving the Division's effectiveness.

I believe the Composites Division has a bright future. Please feel free to reach out to me or any of the board members to share your thoughts on where the future may take us.

Best Regards,
Ray

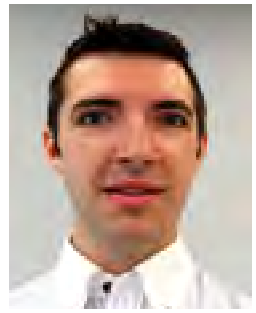
Board of Directors

Raymond G. Boeman, Chair

Ray Boeman has over twenty-five years of composites materials experience at Oak Ridge National Laboratory and currently holds a joint position with Michigan State University as an MSU-ORNL professor of composite materials and manufacturing. He is the associate director for the Institute for Advanced Composites Manufacturing Innovation (IACMI) Vehicle Technology Area where he is responsible for establishing an R&D facility with full-scale composites manufacturing equipment in the Corktown area of Detroit, and to develop partnerships and projects with industry.

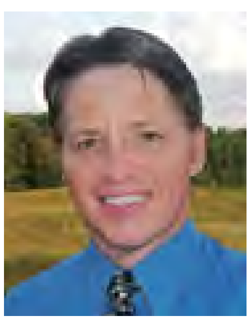
Boeman hold a Ph.D. in Engineering Mechanics from Virginia Tech and has assumed the role of Chair of the SPE Composites Division as of May 2018. He previously served as Membership Chair for the division.

Ian Swentek, Chair-Elect/ Awards Chair



Dr. Ian Swentek is an Applications Development Engineer at Hexion where he specializes in epoxy-based technology for high-volume automotive applications. His process expertise surrounds structural materials such as epoxy-carbon sheet molding compound, liquid compression molding, and high pressure resin transfer molding. He holds a doctoral degree in Mechanical and Materials Engineering from the University of Western Ontario where his dissertation was on the fracture mechanics of long-fiber polymer composites. Additionally, Dr. Swentek is an active member of the Professional Engineers of Ontario, the Society of Plastics Engineers – Composites Division, and the Society for the Advancement of Material and Process Engineering.

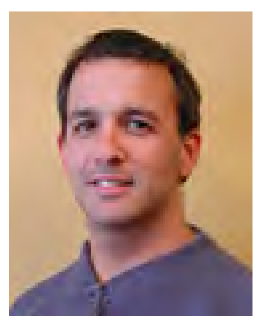
Michael Connolly, Past-Chair



Michael Connolly is Program Manager for Urethane Composites at Huntsman Polyurethanes where he has worked for 21 years. At Huntsman, Michael oversees product development of polyurethane composite resin and processing technology for industrial, automotive and wind energy applications using RTM, SMC, spray honeycomb and pultrusion processes. He holds a Ph. D. degree in Polymer Science from the University of Massachusetts-Amherst and has authored 13 conference papers on polyurethane composites.

Michael is current Past-Chair and Membership Chair of the SPE Composites Division and former Chair of the SPE Automotive Division (2003-2004). He is closely involved with the SPE Automotive Composites Conference and Exhibit (ACCE), twice serving as Chair and six times as Technical Program Chair. Michael has been a member of SPE since 1992 and is also member of SAMPE and ACS.

Antoine Rios, Secretary

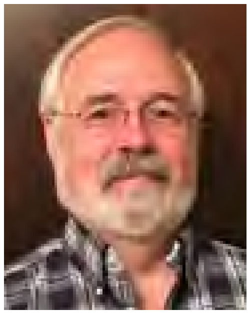


Antoine Rios is a Sr. project and consulting engineer working at The Madison Group since 1999. The Madison Group specializes in consulting and failure analysis for the plastics and composites industries. His areas of expertise are: failure analysis, molding simulation, FEA analysis, and design verification. Antoine Rios has a Ph.D. in mechanical engineering from the Polymer Engineering Center at The University of Wisconsin. Dr. Rios is a Senior member and Honored Service Member of the Society of Plastic Engineers where he serves in the Composites Division and the Failure Analysis SIG boards. He is fluent in English and Spanish.

This Issue:

Board of Directors continued...

Tim Johnson, Treasurer



Tim Johnson, is a Director for MatterWorks LLC, an Industrial Materials Technology company specializing in thermoplastic surfacing films. Tim is also President of TJohnsonLLC, providing independent consulting for clients developing composite materials and process automation. Tim has a BS in Mechanical Engineering from the University of Pennsylvania.

Tim has particular expertise in glass and carbon fiber production, textile processing including multiaxial fabric production, weaving, and nonwovens, as well as structural core materials including polymer honeycomb and foams, and fiber reinforced cores. He is a specialist of process technology and automation, instrumentation and control, composite structural analysis, graphic printing for composites, and has a dozen related patents. Tim has served on the Composites Division Board of SPE since 1997.

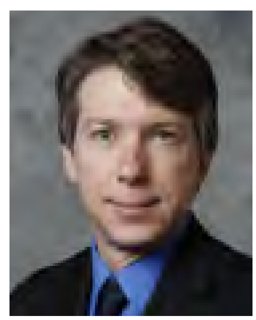
Dale Brosius, Councilor

Dale Brosius is Chief Commercialization Officer for the Institute for Advanced Composites Manufacturing Innovation (IACMI), He has a B.S. in Chemical Engineering from Texas A&M University, an M.B.A. and over 30 years of industrial experience in the composites industry. He is knowledgeable of all composite processes, from injection molding to textile preforming to autoclave, glass and carbon fibers and a wide range of thermoset and thermoplastic polymers. He served as Chair of SPE's Thermoset Division and Composites Division and four years as chair of SPE's Automotive Composites Conference and Exhibition. He has authored numerous technical papers for conferences in the U.S., Europe, Japan and Australia, and is the author of over eighty articles for High Performance Composites, Composites Technology and Composites World magazines.

Uday Vaidya, Education Chair

Uday Vaidya has a joint appointment with The University of Tennessee (UT), Knoxville and the Oak Ridge National Lab. He is the UT/ORNL Governor's Chair in Advanced Composites Manufacturing. Vaidya serves as the Chief Technology Officer for IACMI, where he has led the road mapping and actively engages in enabling technology development projects for the institute. Prior to joining UT/ORNL, Vaidya served as the Department Chair for Materials Science & Engineering and the Center Director for the Composites Center at the University of Alabama at Birmingham (UAB). Vaidya has 29 years of experience in a broad range of composites for defense, transportation and industrial applications. He has initiated and served as faculty mentor for SPE student chapters at Tuskegee University, North Dakota State University, UAB and UT. Vaidya is the author of the book 'Composites for Automotive, Mass Transit and Truck'.

Jim Griffing, Director/Ex-President

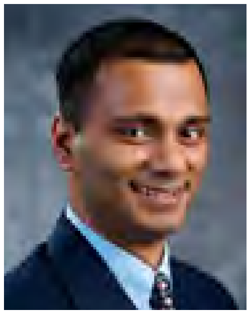


Jim Griffing holds a BS in Chemical Engineering from Rensselaer Polytechnic Institute and a MS in Chemical Engineering from the University of Washington. He worked as a process engineer at Chemical Fabrics Corporation in Vermont for two years before moving to Seattle where he has worked in Boeing's Material and Process Technology organization for the last 30 years. Jim is a Technical Fellow specializing in polymer and composite materials and processing for commercial airplanes. He is currently a Technology Focal in Boeing's 777X organization. He holds three patents for overhead stowage design & manufacturing techniques. Jim is a Past President of SPE.

This Issue:

Board of Directors continued...

Pritam Das, Newsletter Chair



Pritam Das holds a BE (Chemical Engineering) from NIT (Surat, India), MS (Polymer Engineering) from University of Akron, and MBA from University of Washington. Pritam Das has led state/ federal funded composite materials research programs for Dept. of Transportation, Dept. of Defense, State of Ohio, and Federal Transit Administration. He has pioneered pultrusion of polyurethane composites in the fenestration industry. Currently, Pritam is a Technical Manager at Toray Composites Materials America where he has been managing prepeg product development teams for space, aviation, and sports industry. Apart from being a BOD since 2008 at SPE Composites, Pritam has served the Composites on the Move Conference as the Technical Program Chair and Co-chaired technical sessions at the ACCE and SPE ANTEC.

Enamul Haque, Tech Program Chair

Enamul Haque is the Vice President and General Manager of Research & New Product Development at the Cooley/ Group. Previously, he has worked at GE Energy Management, Bostik, Inc., Owens Corning and AZDEL-A GE/PPG JV Company. Enamul Haque did his PhD in Chemical Engineering from Rice University, Houston, TX. Enamul has authored over 40 worldwide patents and thirty-four referred publications in the field of plastics and composites. He is a certified six- sigma champions. His areas of expertise include both thermoset and thermoplastics composites, adhesives and sealants and coated engineering fabrics. An SPE member since 1998 and currently a Fellow at SPE, Enamul has served as moderator at both ANTEC and ACCE conferences, TPC for Composites Division at ANTEC/ACCE.

Board of Directors continued...

Andy Rich, Communications Chair

Andrew Rich has been working in Automotive Composites for more than 20 years. Before graduate school, he spent ten years as a prototype and mold maker for several composite vehicle projects, including the Solectria Sunrise. After receiving a double Masters degree from Boston University, his first experience was with DaimlerChrysler, in the research and development of carbon fiber and composite manufacturing processes, working extensively in the ACC, Automotive Composites Consortium.

He has over 7 years of experience in the Carbon Nanotube industry, developing automotive applications. Andy also has worked for Plasan Carbon Composites, where he helped develop their out of autoclave manufacturing process for carbon fiber. Currently, he is a Program Manager and Applications Development Engineer at Quantum Composites.

John Busel, Inter-Society Chair

John Busel is Vice President, Composites Growth Initiative of American Composites Manufacturers Association. Mr. Busel has over 30 years of experience in market development, standards development, composites design, tool engineering, manufacturing, and R&D of FRP composites. He is a Fellow of American Concrete Institute (ACI), and member of American Society of Civil Engineers (ASCE), SPE, SAMPE, and ASTM. He was the past chairman of ACI Committee 440. Mr. Busel has a BS Civil Engineering from Bradley University.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Board of Directors continued...

Frank Henning, European Liason

Prof. Frank Henning holds a Ph.D. (Composites Engineering) and Diploma (Mechanical Engineering) from the Universität Stuttgart (Germany). He has about 20 years of experience in polymer engineering with a special focus on composite processing. He published numerous articles in journals and owns patents in the field of polymer manufacturing.

Prof. Henning (Fellow at SPE) has held several positions and received recognitions including Managing Director of the Fraunhofer Project Centre for Composites Manufacturing (Korea) and Fraunhofer Project Center for Research (Canada), Faculty of Engineering at the University of Western Ontario (Canada), Deputy Director of the Fraunhofer Institute for Chemical Technology (ICT), Professor for Light-Weight Technologies at Karlsruhe Institute of Technology (Germany), CEO of the Fraunhofer innovation cluster KITe hyLITE, Director of the Competence Centre for Automotive Light-Weight Solutions, Vice-President of SAMPE Germany, and Director of Polymer Engineering at Fraunhofer ICT

Dan Buckley, Emeritus

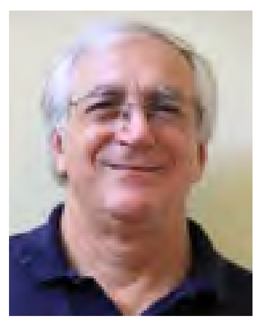
Dan Buckley is retired from American GFM where he was the Manager of R&D. Dan has 45+ years of experience in Composites, Plastics, and related fields. Dan received a BS in Chemistry (University of Massachusetts) and is the author of 100+ technical papers for Domestic and International publication. Dan has numerous patents in composites processing and related fields. Dan is currently active in Nano technology and 3D printing for medical applications.

Dan is a cofounder of the Composites Division of SPE, founder of the Nano/Micro Molding SIG, past Chair of both the Composites & Thermoset Div., served 5 terms as councilor for the Thermoset & Composites Div. of SPE, and cofounder of the ACCE. Dan is an Honored Service Member of SPE, Composites Division person of the year and Composites Division Lifetime Achievement award winner.

Creig Bowland, Director

Creig Bowland holds a B.S. degree in Chemistry from Colorado State University and an M.S. degree in Physical Chemistry from The University of New Mexico. Bowland has over three decades' experience in the design and production of composite materials for both the aerospace and automotive markets. He has been involved in nearly all aspects of the composites business, ranging from materials design and technical support, to production management, business development (including profit and loss responsibility), and marketing. He currently is a technical sales manager for Chongqing Polycomp International Corp. (CPIC®) North America, where he supports all markets, processes, and materials with special focus on long-fiber thermoplastics (LFT) and other thermoplastic composites. Bowland is a published author and regular speaker on composites-related topics at industry gatherings.

Rich Caruso, ANTEC Program Chair/ Director



Rich Caruso is the CEO of INTER/COMP, LLC, an international consulting firm coordinating the marketing and product development activities of advanced composite material and specialty fiber manufacturers by bridging technology gaps between aerospace, military, automotive, and commodity/consumer applications. Rich Caruso has been in the advanced materials, fibers, and composites industry for over 45 years having been involved in a wide range of engineering programs for military, aerospace, and commodity consumer and transportation applications.

Mr. Caruso previously worked at Goodrich, AVCO/ Textron Specialty Materials, Fiber Glass Industries and Gordon Composites/Polystrand. Specialties have included design and development of composite materials and structures for marine, aircraft and space vehicles, development and manufacturing of advanced fibers, and product and business development of CFRTP (Continuous Fiber Reinforced Thermoplastic) materials.

This Issue:

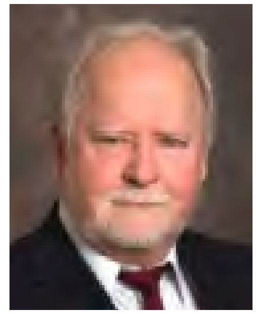
Board of Directors continued...

Fred Deans, Director

Frederick S. Deans holds a BS (Mechanical Engineering) from Valparaiso University and an MBA from University of Pittsburgh. Fred has expertise in composite materials, molding processes (compression, injection, open mold, pultrusion), application & specification development, contract negotiations, global sales & marketing development. Principal accomplishments include introducing 1st applications of monolithic tempered privacy glass for OE SUV's, developed 1st OE unidirectional GMT composites for new generation automotive bumper systems, and managed new generation long fiber thermoplastic developments for off-road vehicles.

Fred has held several positions and received recognition including SPE Automotive Division Lifetime Award Recipient, SPE Composites Person of the Year, SPE Honored Service Award, and past chairman for ACCE.

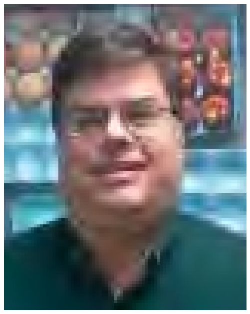
Jack Gillespie, Director



Jack Gillespie has 36 years of experience in composites research and education at the University of Delaware. Currently he is Named Professor in the College of Engineering and Director of the Center for Composite Materials. He has advised more than 100 graduate students (17 now teaching at other universities) and published more than 800 publications in composites science and technology including 18 book/book chapters and 20 patents. He has led four major DoD centers of excellence and the Center's University-Industry Consortium "Application of Composite Materials to Industrial Products". He has been a member of SPE since 1990.

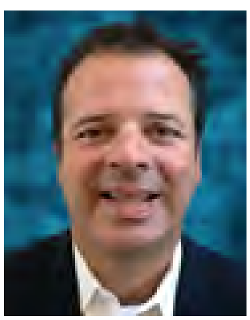
Board of Directors continued...

Dale Grove, Director



Dale Grove is a PhD Chemical Engineer with over 25 years of successful product launches and process developments with expertise in silica, filtration media, fibers, compounding, foamed packaging, composites, gypsum facers, coatings, long fiber thermoplastics, polymer analysis and formulation, molding, and lamination. His engineering skills include sourcing, specifying, and scaling up wet-lay and coating plants. Dale has over ten patents, a six sigma black belt, business case writing skills, and numerous papers including a chapter on composite processing. Dale has served the composite board since the early 1990s in various roles including councilor, Divisions Chair, Secretary, Newsletter editor, ANTEC TPC, Awards Chair, and President of the Georgia Tech Student Chapter.

Steve Bassetti, Director



Steven Bassetti is a Group Marketing Director at Michelman. His thirty plus years of commercial experience cover areas of engineering plastics, chemical intermediate manufacturing, fiberglass manufacturing, polymer composite component manufacturing, engineered wood release coatings, polymer science and commercialization of new products. He has worked for companies such as LNP Engineering Plastics, General Electric Plastics, Ticona, Celanese, Johns Manville, Arizona Chemical, and others. Steve completed his undergraduate studies at the Worcester Polytechnic Institute and his graduate Masters of Business Administration degree at Pace University's Lubin School of Business. He is an active member of Society of Plastics Engineers, American Composite Manufacturer Association, American Chemical Society, Institute for the Study of Business Markets, and few others. He is also a co-author of one patent in the field of polymer science.

Nippani Rao, Director

Nippani Rao, retired from Chrysler and is the president of RAO Associates, a consulting company in Farmington Hills, Michigan. Nippani is currently working part time at Asahi Kasei Plastics, Fowlerville, Michigan as an OEM Business development consultant.

For over 40 years, Nippani worked in the automotive industry in plastics and composite materials developments for interior, exterior and under hood applications. Nippani worked at Ford Motor Company, DeLorean Motor Company and Chrysler Corp.

Nippani has been active with SPE Detroit Section and the Automotive Division for over 35 years and Served as President and Chair, respectively in early 2000s.

Nippani has been on the Composite Division Board since about 2002 and served as Inter/Intra Society Committee Chair until 2014.

Nippani has 4 patents in composite manufacturing processes.

Nikhil Verghese, Director

SPE COMPOSITES

This Issue:

Treasury Report

By: Tim Johnson, Treasurer

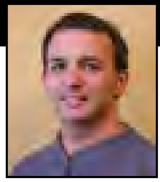
SPE Composites Division (D39) FINANCIAL REPORT

Financial Report for the Period: **July 1, 2016 to June 30, 2017**
Section/Division Name: **Composites Division D39**

Balance as of 7/01/2016	-1	$146,177.73	
Income: check the "Income"worksheet for details		**Actual**	**Budget**
Sponsorships for Newsletter	-2	$ 10,500.00	$ 7,500.00
Sponsorships ANTEC Reception	-3	$ -	
SPE Rebates	-4	$ -	
ACCE Earnings (after expenses, scholarships and payment to SPE)	-5	$ 42,084.21	$ 50,000.00
Sponsorship: Educator of the Year, SABIC	-6	$ 2,500.00	$ 2,500.00
Investment Earnings	-7	$ (73.11)	
Training programs	-8		
Sponsorship: Mettler-Toledo Award	-9	$ 1,000.00	$ 1,000.00
Cyclitech	-10		$ 5,000.00
	-11		
	-12		
Total Income for the period	-13	$ 56,011.10	$ 66,000.00
Total Funds Available (add lines 1 and 13)	-14	$ 202,188.83	$ 66,000.00
Expense: check the "Expense" worksheet for details		**Actual**	**Budget**
Website - CompHelp - 1&1.com	-15	$ 707.14	$ 1,000.00
Newsletter	-16	$ 9,003.00	$ 7,500.00
Mettler-Toledo Award	-17	$ 1,000.00	$ 4,500.00
BOD Meeting Expenses	-18	$ 1,468.66	$ 2,000.00
Educator of the Year Award	-19	$ 2,500.00	$ 2,500.00
Bank Service Fees	-20	$ 548.68	$ 500.00
Antec Suite / W&C Reception	-21	$ -	$ 2,000.00
ANTEC Other Expenses	-22	$ 2,565.69	$ 1,000.00
Council Travel	-23	$ 1,602.50	$ 3,000.00
Publicity	-24	$ -	$ 500.00
Cyclitech	-25	$ 3,839.21	$ 5,000.00
SPE Foundation: H. Giles Scholarship	-26	$ 8,000.00	$ 6,000.00
Student Activities at ANTEC	-27	$ 5,000.00	$ 5,000.00
Student Academics Program	-28	$ 7,500.00	
Office Supplies	-29	$ -	$ 75.00
ACCE expenses	-30	$ 384.69	$ 1,000.00
SPE Foundation: Jackie Rehkopf Scholarship	-31	$ 6,000.00	$ 6,000.00
Total Expenses (add lines 15 – 31)	-32	$ 50,119.57	$ 47,575.00
Investment Transfer	-33	$ -	
Ending Balance (subtract line 32 from line 14)	-34	$ 152,069.26	$ 18,425.00
Allocation of Funds on Line 34 (enter allocations as applicable)			
Checking Account	(A)	$ 77,142.37	
Savings Account 1	(B)	$ -	
Savings Account 2	(C)	$ -	
Investment 1	(D)	$ 74,926.89	
Investment 2	(E)	$ -	
Investment 3	(F)	$ -	
TOTAL	(G)	$ 152,069.26	
Amount on line G should equal amount reported on line 34			
Section / Division Treasurer's Name:		Timothy Johnson	
Audit Committee Attest:			

This Issue:

Board Meeting Minutes March 27, 2017



By: Antoine Rios

Conference Call
Monday, March 27, 2017

Attendees:

Michael Connolly	Nippani Rao
Dan Houston	Andy Rich
Jack Gillespie	Dale Brosius
Pritam Das	Ray Boeman
Mingfu Zhang	Klaus Gleich
Christoph Kuhn	Ian Swentek
Craig Bowland	Jim Griffing
Enamul	Antoine Rios
Ray Boeman	

Meeting started at 12:04pm EST

Chair: Michael Connolly

- Discussion on Composites Division Policy Manual update: only two have given feedback so far.
- SOP's: still waiting for feedback from some committee chairs, define time line.
- ***Action (All):*** send MC feedback in regards to the policy manual and SOPs

Secretary: Antoine Rios

- Approval of last meeting minutes (done by Email)
- Upcoming elections:
  - "Change of guard" needed
  - Inactivity to be cause of dismissal
  - Klaus opted not to be reelected
  - Membership chair: Michael Connolly interested in this position once his chair term is over
- **Action (AR):** send email to current BOD members that are up for reelection and volunteers

Chair-Elect: Ray Boeman

- Pinnacle Award 2017 outcome: COMDIV reached Pinnacle again for this year
  - Craig Bowland to receive award at ANTEC
- Chair-Elect search for 2017-2019
  - Asking for nominees
  - **Action (RB):** reach out to possible candidates

continued on page 13...

This Issue:

Board Meeting Minutes continued...

Inter/Intra-Society: Michael Connolly o/b/o John Busel

- CAMX 2017: search for papers
  - Ian Swentek and Jack Gillespie to volunteer a paper
- Cyclitech 2017: relatively successful in 2016.
  - Financial value, branding, branching out
  - Expanding to sporting goods
  - **Action (MC):** to request and find more information. Prepare report

Membership: Ray Boeman

- Current status including e-members
  - Gain 84 in November
  - Currently at 714 as of 3/27/17; COMDIV ranks 5th within SPE.
- Membership Chair replacement: Michael Connolly volunteered

Councilor Report: Creig Bowland

- Latest Council reports
  - New president elect for SPE: Brian Grady
  - SPE's 75th anniversary
  - DeVos resigned as CEO, CEO search underway
- CB running for VP of SPE. If he gets the VP position the COMDIV will have to search for a new councilor.

continued on page 14...

Board Meeting Minutes continued...

Technical Conference Reports:

- Thermosets 2017 (March 21-22, 2017, Phoenix, AZ) – **Dale Brosius**
  - Successful conference
  - Attendees: 125-150
  - CPMDIV to consider being a co-organizer

- ANTEC 2017 (May 8-11, 2017, Anaheim, CA) – ***Jim Griffing***
  - 10 technical sessions
  - 50 papers presented

- JEC Building & Construction Forum 2017 – Summer 2017 – ***Michael Connolly***
  - SPE is listed as a "partner" for this conference. Research what this means.
  - **Action (MC):** to contact Russell Broom to find out SPE's involvement

- ACCE 2017 (September 5-8, 2017, Novi, MI) – **Dale Brosius**
  - Conference moving forward
  - 10 abstracts this far
  - **Action (All):** seek for submissions

Awards: Ian Swantek

- Sabic EOTY: Tim Osswald from University of Wisconsin – Madison
- Mettler-Toledo: Munetaka Kubota from the University of Delaware
- Honored Member program: HSM and Fellow nominations
  - Fellow candidates: Jack Gillespie
  - HSM candidates: Uday Vaidya

Communications: Andy Rich

- Not receiving enough feedback
  - **Action (All):** read Andy's email about the new website development and give feedback
- New website currently live under SPE's web
- Old website is still live
- We should combine both websites soon
- It is important to maintain traffic analytics for the website
- Retake control of LinkedIn page

Meeting adjourned at 1:29 pm EST

This Issue:

Newsletter Chair's Message

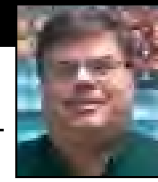
By: Pritam Das

"You write to communicate to the hearts and minds of others what's burning inside you, and we edit to let the fire show through the smoke." - Arthur Plotnik

At the Composites Division of the Society of Plastics Engineers, the newsletter committee's primary role is to stimulate the fiery flow of information in the field of Composites for the Division and the Composites Industry as a whole. Apart from informing the Composites members how the SPE Composites Board of Directors communicate, collaborate, and co-ordinate, we try to feature scholarship opportunities for students, recognize the achievements of students, and highlight award winning papers. The newsletter also provides a forum for our sponsors to showcase new products to the divison's members. The August edition of the newsletter includes a special section providing the detailed background of the Board of Directors to show the vast and varied experience in the Composites Division. Members are more than welcome to interact with the board of directors. As always, we are excited to hear back from members for any improvements you would like to see in the newsletters.

2016 Harold Giles Award Winners

By: Dr. Dale Grove



Harold Giles Scholarship

The 2017 Harold Giles Scholarship award winners are Ms. Emma Adams and Mr. Benjamin Blandford. Thirteen applications were received this year. It is always a difficult job to select winners based on the many talented applications that the judges received.

Ms. Adams presently attends Auburn University and is expected to graduate in May of 2018 with dual degrees in Polymer & Fiber Engineering and Chemical Engineering. Active in many societies including SPE, AICHE, Society of Women Engineers, Society of Hispanic Engineers—not to mention local Campus and Community groups such as STEM—Emma stood out amongst the other candidates. In addition to reaching out beyond herself, Ms. Adams maintained a high GPA (3.8/4.0), performed nano-composite testing with a drug delivery system during her undergraduate research, and experienced composite processes such as pultrusion, filament winding, and CRTM when she worked at PolyOne Corporation. Nothing

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has been handed to this candidate. On the contrary, Ms. Adams has had to simultaneously work part time and taken out sizeable student loans to obtain her Bachelors of Science degree. It is amazing under the circumstances and time restraints, that Ms. Adams regularly obtained the Dean's list, is a member of the Phi Kappa Phi Honor Society, was nominated for the Phi Kappa Phi Susan Stacy Entrenkin Yates Award, and is a member of the Alpha Lambda Delta Honor Society. The Composite Division Award Committee is delighted to augment her education costs with scholarship funding. You'll likely hear this candidates name again in whatever area she chooses to work from in the future.

Mr. Benjamin Blandford is pursuing a PhD in Mechanical Engineering from Baylor University. As the president of the Baylor University SPE student Chapter his leadership skills paired with live composite equipment demonstrations and direct student contact sessions with nearby businesses have caused that chapter to receive several outstanding society recognized awards. In addition to his leadership in SPE, Ben is also a member of the American Society of Mechanical Engineers, the Honor Council of Baylor University, and Kappa Sigma fraternity. With a high GPA (3.9/4.0) and various awards including the TPM&F scholarship, Baylor University Graduate School Fellowship Scholarship, and SPE Color and Appearance Division Endowment Scholarship, Ben has already made several marks in the plastic

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society world. His investigative work employs non-destructive testing techniques to manage reliability in carbon fiber and other composite components for the aircraft and automobile industries, and has presented his work at ANTEC and will be presenting his work at ACCE this fall. In addition to these outstanding achievements, Ben came up with answers quickly for a critical fracture mechanical problem, as demonstrated by his work with Delta-G Aerospace Design. Like Emma, Ben has also had to go deep into debt to obtain his degrees, and the Composite Division is pleased to help him in this endeavor. Benjamin Blandford displays a number of admirable traits that will take him far in his future endeavors.

The Composite Division will continue to offer the Harold Giles Scholarship to worthy candidates in the future; the scholarship was developed to honor the late Dr. Harold Giles, a past Composite Division Awards Chair. As a former University Professor at the University of North Carolina, Azdel employee, and GE employee, Harold knew full well the value of scholarships to students. He was always a proponent of awarding worthy students and served the society well in this capacity. Harold would have been pleased to know that students like Emma Adams and Benjamin Blandford received this award. So if you believe that you know of other worthy candidates, please apply in 2017.

Humbly submitted by,
Dr. Dale Grove
Composite Division Awards
Committee Member

Award Winning Paper

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

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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 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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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	LF-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.

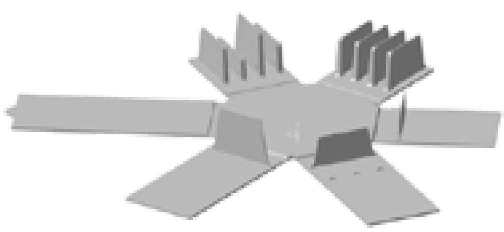

Figure 3: Star-shaped tool geometry with straight ribs, cross ribs and a free flow region

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].

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.

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

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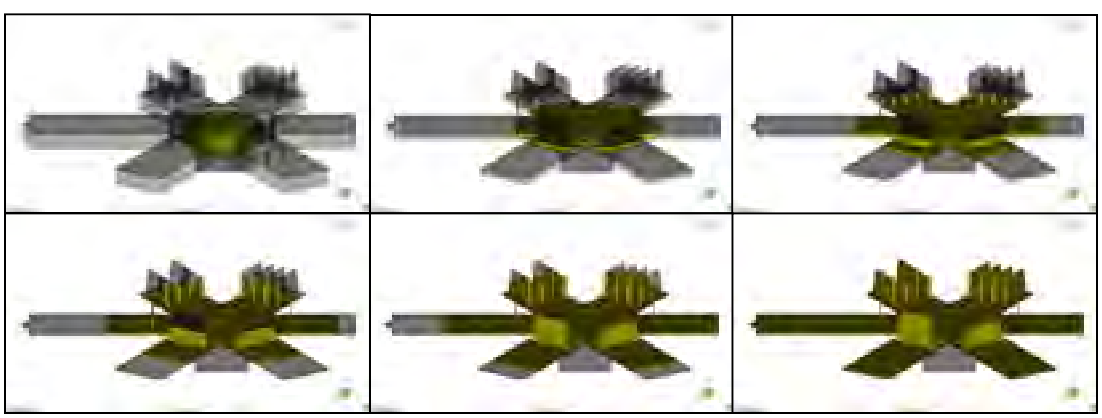
Figure 4: Mold filling simulation in compression molding at different time steps



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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.

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 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.

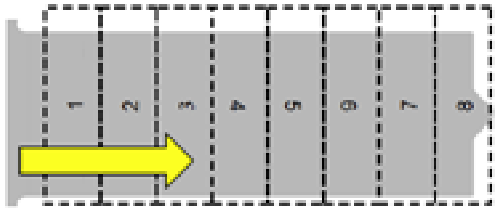

Figure 5: Sections in the free flow region used for fiber content analysis

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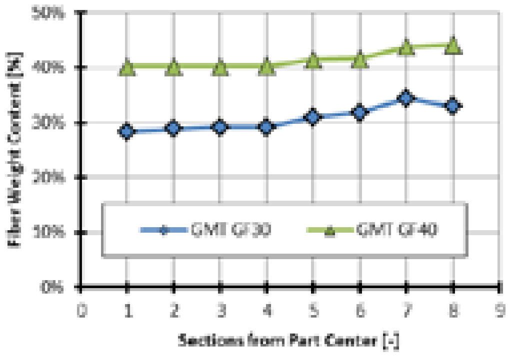

Figure 6: Fiber content over free flow area

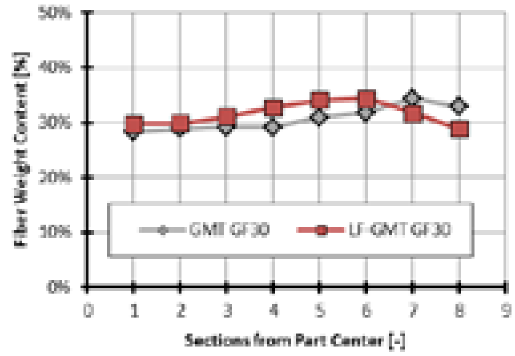

Figure 7: Fiber content over free flow area, comparison of Standard GMT (grey) and LF-GMT (red)

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 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.

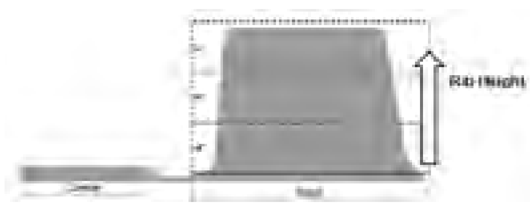

Figure 8: Overview of component selection for pyrolysis

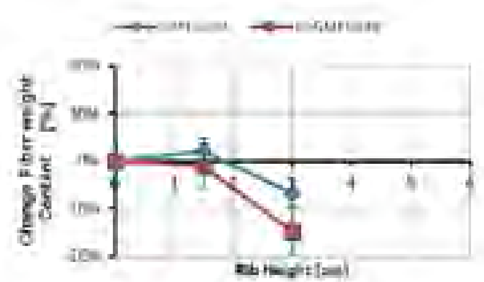

Figure 9: Change of fiber content in a straight rib (3cm)

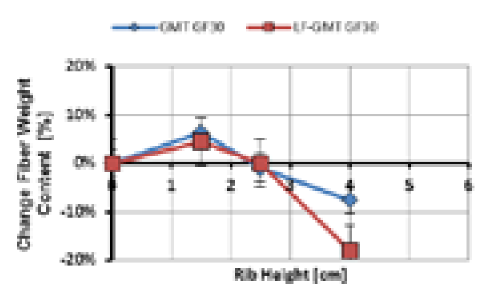

Figure 10: Change of fiber content in a straight rib (4cm)

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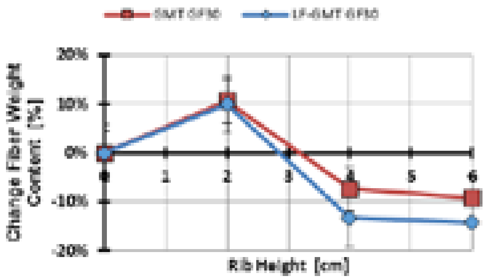

Figure 11: Change of fiber content in a straight rib (6cm)

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.

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.

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.

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.

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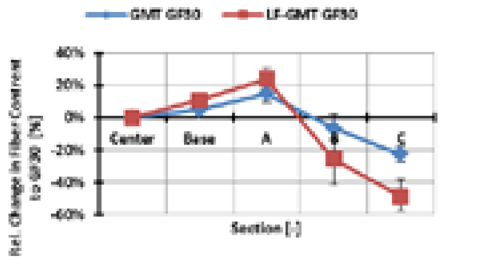

Figure 12: *Change of fiber content in straight rib* (5cm) *with both* GMT *and* LF-GMT GF30 *samples*

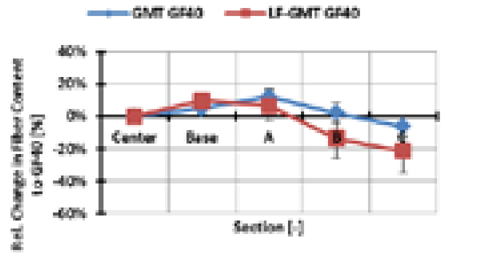

Figure 13: *Change of fiber content in straight rib* (5cm) *with both* GMT *and* LF-GMT GF40 *samples*

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

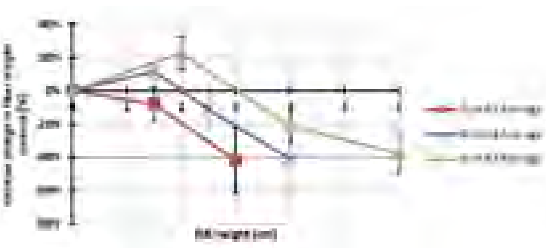

Figure 14: Change of fiber content in straight ribs with different heights

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.

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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:

$$\phi_{vol} = \frac{V_f}{V_f + V_m} \qquad (5)$$

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.

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

Straight Rib

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

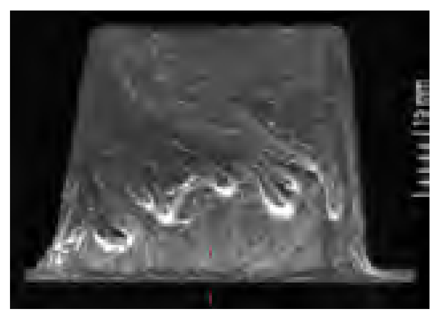

Figure 16: CT image of the straight rib showing excessive fiber bundling and change in fiber content

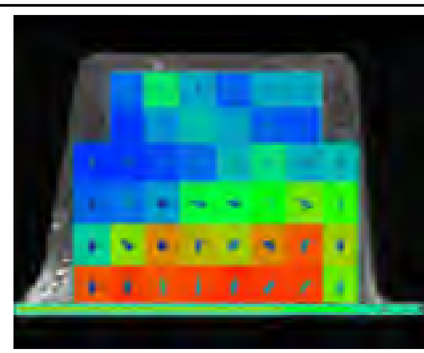

Figure 17: CT analysis of fiber content showing significant change of fiber content in straight rib

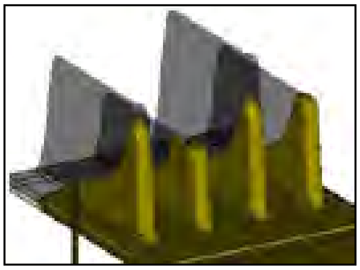

Figure 18: Flow front inside the straight rib section in simulation

Figure 19: Flow front during straight rib filling in experiments

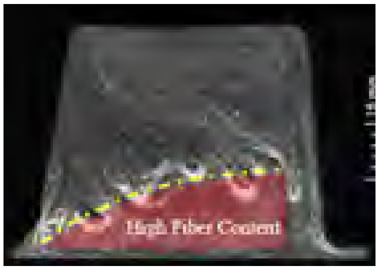

Figure 20: Border region between high fiber content and low fiber content in a straight rib

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.

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.

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.

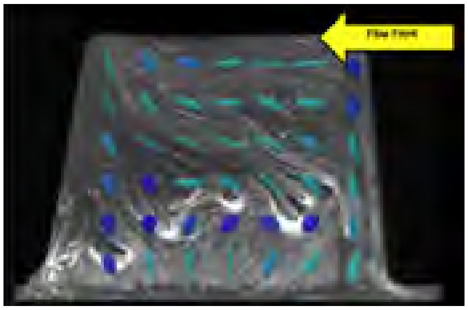

Figure 21: Fiber orientation in CT analysis of straight rib (side view)

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

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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.

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.

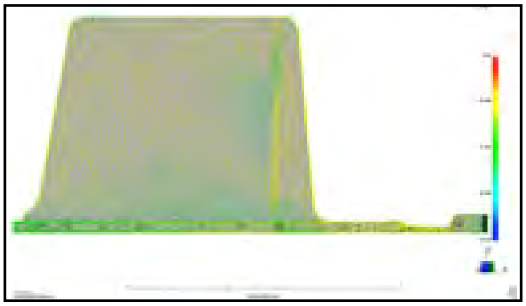

Figure 23: Fiber orientation of straight rib in Moldflow simulation (side view)

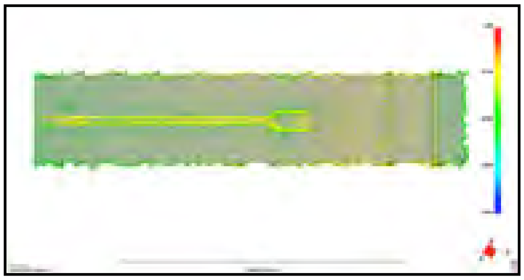

Figure 24: Fiber orientation of straight rib in Moldflow simulation (top view)

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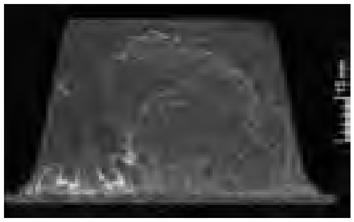

Figure 25: CT image of the cross rib (6cm), front view

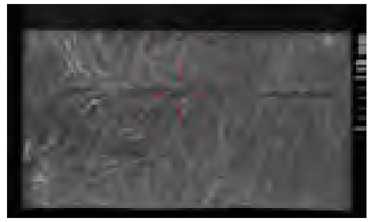

Figure 26: CT image of the cross rib (6cm), top view

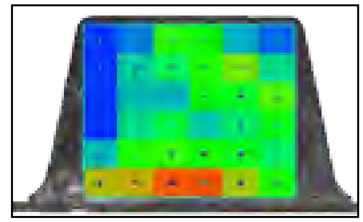

Figure 27: CT analysis of cross with fiber content (color) and fiber orientation analysis (tensor balls)

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.

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.

continued on page 32...

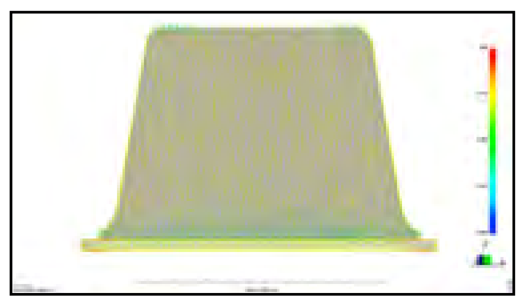

Figure 28: Fiber orientation of the cross rib in Moldflow simulation

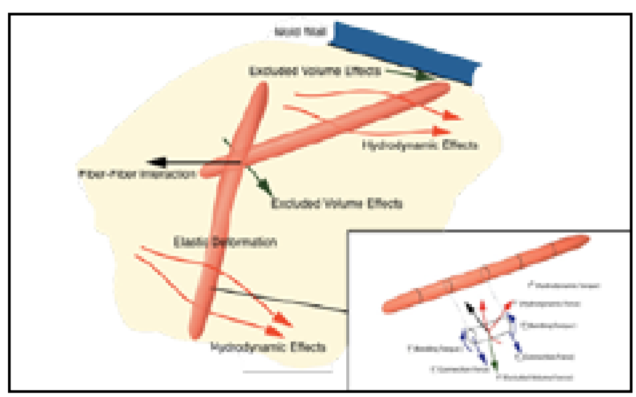

Figure 29: Direct Fiber Simulation with a micromechanistic model [11]

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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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