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

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SPE® ACCE 2019 – Automotive Composites Conference & Expo (ACCE) Announces Call for Papers, Part Competition Nominations & Scholarship Applications

The SPE Automotive Composites Conference & Expo (ACCE) team is announcing its call for papers, part competition nominations, and scholarship applications for their 19th annual event September 4 - 6, 2019 at the Suburban Collection Showplace in Novi, Mich. in the Detroit suburbs. "Composites – Forming the Future of Transportation Worldwide," is the theme for this year's event reflecting the growing interest automotive, heavy truck, and other transportation OEMs have in learning about the latest plastic composites technologies.

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19th-Annual

AUTOMOTIVE COMPOSITES CONFERENCE & EXHIBITION
Novi, Michigan • September 4-6, 2019
Presented by SPE Automotive Division and SPE Composites Division

COMPOSITES: Forming the Future of Transportation Worldwide

SEPT 4-6, 2019

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MEETING SCHEDULE & SPECIAL EVENTS CALENDAR

ANTEC 2019
Marriott Detroit Renaissance — ALL DAY
Detroit, MI USA — March 18-21, 2019

4th Annual TPO Shanghai Conference
Shanghai Marriott City Center — ALL DAY
Shanghai, China — April 3-5, 2019

SPE Auto. Div. Board Meeting
American Chemistry Council - Auto. Ctr. — 5:30 - 7:30 p.m.
Troy, MI USA — April 15, 2019

ACCE Abtracts Deadline — April 30, 2019

14th Annual AutoEPCON
Detroit Marriott Troy — ALL DAY
Troy, MI USA — May 7, 2019

ACCE Papers Deadline — June15, 2019

SPE Auto. Div. Board Meeting
American Chemistry Council - Auto. Ctr. — 5:30 - 7:30 p.m.
Troy, MI USA — June 17, 2019

SPE Auto. Div. Board Meeting
American Chemistry Council - Auto. Ctr. — 5:30 - 7:30 p.m.
Troy, MI USA — August 19, 2019

SPE Ron Price Memorial Golf Outing — ALL DAY
Fieldstone Golf Club, Auburn Hills, MI USA — September 3, 2019

19th-Annual SPE Automotive Composites Conference & Exhibition (ACCE) — ALL DAY
Suburban Collection Showplace, Novi, MI USA — Sept 4-6, 2019

21st-Annual SPE TPO Automotive Engineered Polyolefins Conference (TPO) — ALL DAY
Detroit-Troy Marriott, Troy, MI USA — October 6-9, 2019

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

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

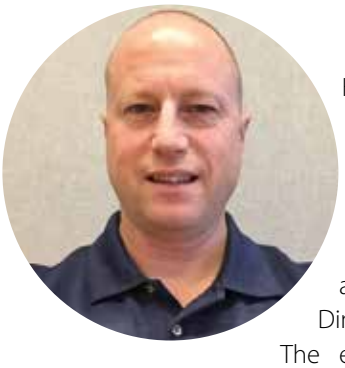
SPE Auto. Div. Board Meeting
American Chemistry Council - Auto. Ctr. — 5:30 - 7:30 p.m.
Troy, MI USA — December 9, 2019

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

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

CHAIR'S WELCOME

DAVE HELMER, SPE AUTOMOTIVE DIVISION CHAIR



Happy Spring or at least it warms up soon so that everyone can get outside to enjoy Spring.

In January of 2019, the SPE Automotive Division held its annual Sponsor Appreciation Dinner at Ruth's Chris Steak House. The event brought the Automotive Division together with the Sponsors to celebrate the past year's events. The celebration focused on student outreach, various scholarships, student involvement projects, and student competitions. Highlights include 4 ACCE scholarships at $2,000 each, Dr. Jackie Rehkopf Scholarship of $5,000, Student Poster Competition sponsorship totaling $21,800, and the ACCE Quiz Event sponsorship of $20,000. In total, the SPE Automotive Division, with support from the SPE Composites Division - our partner for ACCE, provided over $120,000 in student support in 2018! See page. 16 - 17 for more details. A big thank you to all the sponsors and Teri Chouinard's coordination for making this a possibility – without our sponsors it would not be possible to benefit so many students.

In 2019, PlastiVan® is planning to build on the success of 2018. PlastiVan® targets middle and high school students in a one day event at each school providing an interactive event on history of plastics, impact of plastics, what plastics professionals do, uses of plastics, and basic plastic chemistry. 2018 had 20 events at various schools in southeast Michigan. In 2019, we have budgeted for an additional 5 schools for a total of 25 school events. Thank you to the education team as well as Braskem for volunteering to make 2019 more successful.

ANTEC 2019 will be local this year at the Detroit Marriott on March 18-21st. The Automotive Session is well represented with 19 presentations in 3 sessions on Monday and Tuesday. Thank you to Dr. Norm Kakarala and Tom Pickett for being the Technical Co-Chairs and being the moderators. Thank you also to Dr. Suresh Shah, Dr. Alper Kiziltas, and Keith Siopes for recruiting presentations.

On May 7th, AutoEPCON will be held at the Troy Marriott. AutoEPCON focuses on the use of all plastic innovative applications in automotive. At this point, AutoEPCON is finalizing keynotes, preparing the Eblast, working on presentations, and finalizing the sponsors.

In April 2019, the Shanghai TPO Conference will be held at the Shanghai Marriott City Center on April 3-5th. Previously, the Shanghai TPO Conference was under the SPE Detroit Section but as it is held in Shanghai and focused on automotive, the SPE Automotive Division is the new sponsor. Thank you to all the effort by Dr. Norm Kakarala and Dr. Sassan Tarahomi to make the transition of sponsorship as well as make a successful event.

With 2019 well underway, I hope you find the time to participate in our upcoming events. Even though only a few people are mentioned above, thank you to all the volunteers involved to make SPE Automotive Division events. At any time, if you have ideas on how to make our section better or would like to volunteer, do not hesitate to contact me at **auto-div-chair@speautomotive.com**.

Thank you,

Dave Helmer

COMPOSITES: Forming the Future of Transportation Worldwide

SEPT 4-6, 2019

19th-Annual

AUTOMOTIVE COMPOSITES CONFERENCE & EXHIBITION

Novi, Michigan • September 4-6, 2019

Presented by SPE Automotive Division and SPE Composites Division

MATT CARROLL & ALPER KIZILTAS, ACCE CO-CHAIRS

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SPE® ACCE 2019 – Automotive Composites Conference & Expo (ACCE) Announces Call for Papers, Part Competition Nominations & Scholarship Applications

The ACCE features technical sessions, panel discussions, keynotes, and exhibits highlighting advances in materials, processes, and equipment for both thermoset and thermoplastic composites in a wide variety of transportation applications. Networking breakfasts, lunches, and receptions enhance the value of the event that attracts over 900 attendees worldwide. The Automotive and Composites Divisions of the Society of Plastics Engineers (SPE®) jointly produce the ACCE to educate the industry about the benefits of composites in transportation applications.

The 2019 ACCE will be co-chaired by 2018 ACCE co-chairs Dr. Alper Kiziltas, lead research scientist, Ford Motor Company, SPE Automotive Div. vice-chair & education committee chair and Matthew E. Carroll, materials engineering, General Motors Company and former SPE Automotive Div. chair. "The 2018 ACCE was the best one ever with over 1,000 attendees, close to 100 papers, increased student participation with an expanded Poster Competition, the addition of the Composites Quiz Event, PlastiVan® Program, and broadcasting key presentations live to colleges and universities," said Kiziltas. "We are continuously improving the ACCE, to provide our sponsors with added value, and the 2019 event will be even better," added Kiziltas. "Our engineering teams benefit tremendously from the lightweighting technologies presented at the ACCE," said Carroll. "Composites technology is important to our company and the industry as we innovate to reduce mass, meet emissions and fuel-economy standards, and improve styling," added Carroll.

THE 2019 ACCE TECHNICAL PROGRAM

The 2019 ACCE technical program will include 80 – 100 papers/presentations on industry advances (30 min. each) organized into the following categories: Thermoplastic Composites; Thermoset Composites; Virtual Prototyping & Testing; Reinforcement Technologies; Additive Manufacturing & 3D Printing; Nanocomposites; Enabling Technologies; Sustainable Composites; Bonding, Joining & Finishing; Carbon Composites; Fast Processing/High Performance Composites; and Business Trends/Technology Solutions. Paper ***abstracts*** are due ***April 30th, 2019*** and final papers or non-commercial ***presentations*** are due ***June 15th, 2019***. Authors who submit full papers (not presentations) in the proper format will be considered for the conference's Best Paper Awards, which are presented during the event's opening ceremony. A template for papers can be downloaded from the SPE ACCE website online via **http://speautomotive.com/acce-forms**. Abstracts can be submitted online via **http://SubmitACCEpapers.com**.

The technical program will be co-chaired by 2018 co-chairs Dr. David Jack, associate professor, Mechanical Engineering at Baylor University and Dr. Leonardo Simon, professor, Chemical Engineering at Waterloo University. "The education our students gain from ACCE greatly contributes to their success," said Jack. "The scholarship opportunities available from ACCE greatly help our students and the industry benefits from their innovative research," noted Simon.

THE INNOVATIVE COMPOSITE PART COMPETITION

The Innovative Composite Part Competition is open to all ACCE attendees. Parts may be OEM or aftermarket on a vehicle available for sale anywhere in the world or a development/prototype demonstrating a significant advancement in composites technology. Production parts and/or prototype parts can be for passenger cars, light trucks, heavy trucks, busses, race cars, concept vehicles, autonomous vehicles, or any unique ground transportation application. Parts must be available for display at the conference and will be judged by a group of industry experts from the SPE ACCE organizing committee. Up to five awards will be presented. ACCE judges will determine four of the winners, including a winner in Materials Innovation and Process Innovation in the Production part and Prototype part categories. An additional prize, the People's Choice award, will be selected by vote from conference attendees. Companies interested in showcasing their products and/or services and nominating an innovative composite part for the competition should contact Teri Chouinard at teri@intuitgroup.com and go to **www.speautomotive.com/acce-conference** for more info and a nomination form. ***Nominations are due June 30th, 2019***.

THE ACCE SCHOLARSHIP AWARDS

The ACCE Scholarship Awards are open to graduate, undergraduate, and community college students, anywhere in the world, pursuing degrees in: Polymer Science, Composites, Plastics, or a related Engineering discipline. Last year's program included four $2,000 USD awards ($8,000 USD total) sponsored by the Michigan Economic Development Corporation (MEDC). One of the $2,000 USD awards was targeted for a student attending a college or university in the state of Michigan. This year's program will likely follow the same format. In addition to a letter of recommendation from an advisor or mentor (and other SPE foundation requirements), students must provide a succinct two-page essay explaining how their planned work or research will benefit polymer composites usage in the automotive or other ground transportation industries.

THE DR. JACKIE REHKOPF ENDOWED SCHOLARSHIP

The Dr. Jackie Rehkopf endowed scholarship includes up to $5,000 USD for a full-time graduate student studying engineering or science with plans to work in the field of transportation composites. If there are no qualified graduate applicants, two $2,500 USD awards may be awarded to suitable undergraduate applicants. As with the ACCE scholarships, a letter of recommendation from the student's advisor or mentor (in addition to other SPE foundation requirements) and a two-page essay is required showing planned work and how it benefits composites usage in the transportation industry.

Applications for both scholarships are due April 1, 2019. Students interested in submitting applications should visit **SPEAutomotive.com/acce-conference.**

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

For more information see **http://speautomotive.com** and **https://composites.4spe.org**. For more information on the

19th-Annual

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Novi, Michigan • September 4-6, 2019

Presented by SPE Automotive Division and SPE Composites Division

DR. UDAY VAIDYA, 2019 SPE ACCE POSTER COMPETITION CHAIR, UNIVERSITY OF TENNESSEE-KNOXVILLE

CALL FOR ABSTRACTS FOR SPE® ACCE STUDENT POSTER SCHOLARSHIP COMPETITION ABSTRACTS DUE JULY 1, 2019

Societyof Plastics Engineers, see **www.4spe.org.**

The organizing committee for the SPE® Automotive Composites Conference & Expo (ACCE) invites graduate, undergraduate, community college, and high school students to submit abstracts on innovative composites technologies, for automotive and ground transportation, for its tenth annual student poster scholarship competition. The competition will be held during the ACCE at the Suburban Collection Showplace in Novi, Michigan (in the Detroit suburbs) September 4-6, 2019. Judges who are industry experts, SPE board members, and members of the media will review all posters with student authors on the first day of the conference, September 4, 2019. First-, second-, and third-place awards will be presented to winners in graduate, undergraduate and high school categories during a special ceremony after lunch on the event's second day, September 5, 2019.

Students interested in participating in the scholarship competition should contact Dr. Uday Vaidya, ACCE student poster competition chair as well as chief technology officer, Institute for Advanced Composites Manufacturing Innovation (IACMI) and professor and governor's chair – Advanced Composites Manufacturing at University of Tennessee-Knoxville via **ACCEposters@speautomotive.com**.

Abstracts are due by July 1, 2019. Digital copies of posters are due by August 20, 2019 for pre-review by judges. Students will need to bring printed copies of their posters to the conference, which they can attend free of charge. All students in the competition will also receive a partial travel stipend and a shared hotel room provided by SPE, as well as free student membership in SPE. Large multi-poster panels and push pins for displaying the posters in the Student Poster Display area will be provided. The show also provides excellent networking opportunities for those close to graduating who are starting to look for a job. The poster template is online via **http://speautomotive.com/acce-forms**.

Poster topics may include subjects such as:

- Automotive Composites
- Composites and lightweight materials for trucks
- Bio-composites
- Nanocomposites
- Glass, carbon, and hybrid fibers
- Thermoset and thermoplastic technologies
- Recycling and green technologies
- Multi-materials
- Joining technologies
- Modeling and analysis of lightweight materials
- CAFÉ standards and mandates
- Cost-effective manufacturing
- Use of advanced materials in innovative applications
- Virtual prototyping and design
- Microstructure, failure and fracture
- Failure envelopes and theories
- Additive manufacturing of composite

Students and their posters are ranked according to the following criteria:

- Content (student and poster demonstrate clarity of topic, objectives, and background);
- Motivation for research and technical relevance to conference theme;
- Methodology and approach to problem;

- Quality of proposed research results/findings;
- Conclusions are supported by information presented;
- Presentation (display aesthetics are pleasing and there is a logical flow between sections);
- Knowledgeable (presenter has a good grasp of the subject);
- Understandability (poster is effective even without student being present to explain it); and
- Overall rank vs. other posters and presenters.

For more information on the ACCE Student Poster Competition, contact:

- **Dr. Uday Vaidya,** University of Tennessee-Knoxville, +1.205.410.2898, uvaidya@utk.edu
- **Dr. David Jack**, Baylor University, +1.254.710.3347, David_Jack@baylor.edu
- **Dr. Douglas Gardner,** University of Maine, +1.201.581.2846, douglasg@maine.edu

Please include in the subject line – **2019 SPE ACCE Student Poster Competition**

ABOUT THE SPE ACCE

Held annually in suburban Detroit, the ACCE draws over 900 speakers, exhibitors, sponsors and attendees and provides an environment dedicated solely to discussion, education and networking about advances in transportation composites. Its global appeal is evident in the diversity of exhibitors, speakers, and attendees who come to the conference from Europe, the Middle East, Africa, and Asia/Pacific as well as North America. About one-third of attendees work for automotive and light truck, agriculture, tuck & bus or aviation OEMs and another 25% represent tier suppliers. Attendees also work for composite materials processing equipment, additives, or reinforcement suppliers; trade associations, consultancies, university and government labs; media; and investment banks. The show has been jointly produced by the SPE Automotive and Composites Divisions since 2001.

THE MISSION OF SPE

The mission of SPE is to promote scientific and engineering knowledge relating to plastics worldwide and to educate industry, academia, and the public about these advances. SPE's Automotive Division is active in educating, promoting, recognizing, and communicating technical accomplishments in all phases of plastics and plastic-based composite developments in the global transportation industry. Topic areas include applications, materials, processing, equipment, tooling, design, and development. For more information see **www.speautomotive.com** and **www.specomposites.org**. For more information on the ***Society of Plastics Engineers***, see **www.4spe.org**.

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COMPOSITES: Forming the Future of Transportation Worldwide

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CALL FOR PAPERS

ATTEND THE WORLD'S LEADING AUTOMOTIVE COMPOSITES FORUM You're invited to attend the 19th Annual SPE Automotive Composites Conference and Exhibition (ACCE), **September 4-6, 2019** at the Suburban Collection Showplace in Novi, MI. The show features technical sessions, panel discussions, keynotes, receptions, and exhibits highlighting advances in materials, processes, and equipment for both thermoset and thermoplastic composites in a wide variety of transportation applications.

PRESENT BEFORE A GLOBAL AUDIENCE The SPE ACCE draws over 900 attendees from 15 countries on 5 continents who are interested in learning about the latest composites technologies. Few conferences of any size offer such an engaged, global audience vitally interested in hearing the latest composites advances. Interested in presenting your latest research? Abstracts are due ***April 30, 2019*** and papers on ***June15, 2019*** to allow time for peer review. Submit abstracts via **www.SubmitACCEPapers.com.**

EXHIBIT / SPONSORSHIP OPPORTUNITIES A variety of sponsorship packages are available. Companies interested in showcasing their products and / or services should contact Teri Chouinard of Intuit Group at **teri@intuitgroup.com.**

FOR MORE INFORMATION **SPEautomotive.com/acce-conference** **+1.248.701.8003**

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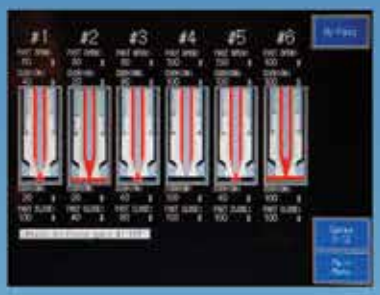

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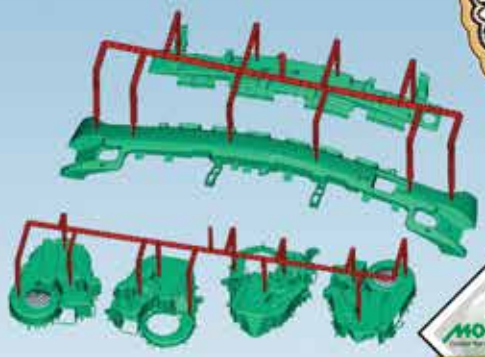

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Submit now at
4spe.org/AutoEpcon

REGISTRATION IS OPEN!

The SPE Detroit Section, the SPE Automotive Division, and the SPE Injection Molding Division are pleased to announce the fourteenth annual Automotive Engineering Plastics Conference and Exhibition (Auto EPCON) on May 7, 2019 at the Detroit Marriott Troy located in Troy, MI.

There is no more effective event to meet, network, and learn with the most influential engineers and scientists involved in specifying, designing, and recommending engineering plastics.

Sponsorship and exhibitor opportunities are also available!

More information:
4spe.org/AutoEpcon

JEFF HELMS, 2019 SPE AUTOMOTIVE INNOVATION AWARDS CHAIR

SPE® ANNOUNCES CALL FOR NOMINATIONS FOR 49TH ANNUAL AUTOMOTIVE INNOVATION AWARDS COMPETITION & GALA

–> HALL OF FAME AWARD NOMINATIONS (DUE MAY 31, 2019)

–> MOST INNOVATIVE USE OF PLASTICS AWARD NOMINATIONS (DUE SEPTEMBER 6, 2019)

The Automotive Division of the Society of Plastics Engineers (SPE®) is announcing a "Call for Nominations" for its 49th annual ***Automotive Innovation Awards Gala,*** the oldest and largest recognition event in the automotive and plastics industries, and due dates for the event's annual Parts Competition and Hall of Fame Award nominations. This year's Awards Gala will be held **Wednesday, November 6, 2019** at the Burton Manor (www.burtonmanor.net) in Livonia, Mich. Winning part nominations ***(due by September 6, 2019)*** in 10 different categories, and the teams that developed them, will be honored with a "Most Innovative Use of Plastics" award. A "Grand Award" will be presented to the winning team from all category award winners. An application that has been in continuous use for 15 years or more, and has made a significant and lasting contribution to the application of plastics in automotive vehicles, ***(nominations due by May 31, 2019)*** will be honored with a "Hall of Fame" award. Nominations must be submitted online via: **http://speautomotive.com/innovation-awards-gala**

"Polymer technologies are advancing mobility by enabling mass savings, greater design flexibility, enhanced performance and more," said Jeffrey Helms, global automotive director, Celanese Corp. who returns as the 2019 ***SPE Automotive Innovation Awards*** chair. "This led to the selection of ***Plastics –> Advancing Mobility*** as our 2019 program theme. Plastics technologies are enabling automakers to provide the advanced performance and comfort features their customers want while meeting global regulatory and affordability targets. Plastics and composites are the leading material solution for automotive applications today and will be used even more in the future with the growth of autonomous vehicles with advanced communications and connectivity."

Since 1970, the ***SPE Automotive Innovation Awards Competition*** has highlighted the positive changes that polymeric materials have brought to automotive and ground-transportation industries, such as weight and cost reduction, parts consolidation, increased safety, and enhanced aesthetics and design freedom. At the time the competition started, in 1970, many OEM designers and engineers thought of plastics as inexpensive replacements for more "traditional" materials. To help communicate that plastics were capable of far more functionality than their typical use as decorative knobs and ashtrays indicated, members of the board of directors of SPE's Automotive Division created the competition to recognize successful and innovative plastics applications and to communicate their benefits to OEMs, media, and the public.

Over the years, the competition drew attention to plastics as an underutilized design tool and made industry aware of more progressive ways of designing, engineering, and manufacturing automotive components. From its humble

beginnings, the competition has grown to be one of the most fiercely contested recognition events in the automotive and plastics industries. Today, polymeric materials are no longer substitutes for more expensive materials, but rather are the materials of choice in hundreds of different applications throughout the vehicle. Without plastics, many of the auto industry's most common comfort, control, and safety applications would not be possible.

During the competition phase of the event, dozens of teams made up of OEMs and suppliers work for months to hone submission forms and presentations describing their part, system, or complete vehicle module to support claims that it is the year's ***"Most Innovative Use of Plastics."*** To win, teams must survive a pre-competition review and two rounds of presentations before industry and media judges.

There is no cost to nominate parts, however, nominations that are accepted into the competition need to be presented (in person or via webinar) by their nominating teams during the first round of ***Automotive Innovation Awards Competition*** judging, **September 26 – 27, 2019 at Celanese in Auburn Hills, Michigan. Finalists from that round advance to a second presentation before a panel of Blue Ribbon judges made up of media, retired chief engineers, and other industry experts on October 4, 2019 at Celanese.**

Winners of each part category, the Grand Award, Hall of Fame, and Lifetime Achievement winner will all be honored during the ***Automotive Innovation Awards Gala*** on November 6, 2019. This annual event currently draws over 800 OEM engineers, automotive and plastics industry executives, and media. Funds raised from the event are used to support SPE educational programs including technical seminars and conferences, which help educate and secure the role of plastics in the advancement of the automobile.

Current competition categories include:

- Additive Manufacturing
- Limited Edition/Specialty Vehicles and Aftermarket
- Body Exterior
- Body Interior
- Chassis/Hardware
- Environmental
- Hall of Fame
- Materials
- Process, Assembly & Enabling Technologies
- Powertrain
- Safety

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

For more information about the SPE Automotive Innovation Awards Competition and Gala see **www.speautomotive.com**.

For more information on the Society of Plastics Engineers, see **www.4spe.org**.

49TH ANNUAL

AUTOMOTIVE INNOVATION AWARDS COMPETITION & GALA

HONORING THE BEST IN AUTOMOTIVE PLASTICS

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NOVEMBER 6 2019

CALL FOR NOMINATIONS

–> MOST INNOVATIVE USE OF PLASTICS AWARDS

The Automotive Division of the Society of Plastics Engineers (SPE®) is announcing a "Call for Nominations" for its 49th-annual ***Automotive Innovation Awards Gala,*** the oldest and largest recognition event in the automotive and plastics industries. This year's Awards Gala will be held Wednesday, **November 6, 2019** at the Burton Manor in Livonia, Mich. Winning part nominations ***(due by September, 6, 2019)*** in 10 different categories, and the teams that developed them, will be honored with a **Most Innovative Use of Plastics** award. A **Grand Award** will be presented to the winning team from all category award winners.

SPONSORSHIP OPPORTUNITIES

This annual event currently draws over 800 OEM engineers, automotive and plastics industry executives, and media. A variety of sponsorship packages - including tables at the banquet, networking receptions, advertising in the program book, signage at the event and more are available. Contact Teri Chouinard of Intuit Group at **teri@intuitgroup.com**.

For more info and to submit nominations, go to: **www.speautomotive.com/innovation-awards-gala.**

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- Environmental
- Materials
- Process, Assembly & Enabling Technologies
- Powertrain
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SOCIAL REPORT

TERI CHOUINARD, SPE AUTOMOTIVE DIVISION SOCIAL CHAIR

SPONSOR APPRECIATION THANK YOU & CELEBRATION EVENT HELD JANUARY 24

50 SPE Automotive Div. members and Sponsors attended our Sponsor Appreciation Event Held on January 24th, 2019 at Ruth's Chris Steak House in Troy, MI.

We had a great showing of attendees from General Motors, Ford, FCA Group, ABC Group, Amcor, Ashland, Borealis Group, BASF, Celanese, DSM, EMS Grivory, Grupo Antolin, Incoe, Intuit Group, JSP, JPI Creative, Lotte Advanced Materials, MacLean-Fogg, Magna, Marubeni USA, Miller-Cole, Mitsubishi Chemical, PCS Company, Ravago Americas, Sabic, Sirrus Chemistry, Techno-UMG America, The Materials Group, Toray Resin, Trinseo and more.

Great beverages and hors d'oeuvres were enjoyed with a presentation on scholarships and student programs supported in 2018 with sponsorship support and SPE Automotive Div. leadership.

Total 2018 Scholarships and Student Support Contributions were over $120,000. This includes a $54,000 contribution at the ACCE event which is produced by both the SPE Automotive Div. and the SPE Composites Div.

The following is the **2018 Scholarships & Student Support** presentation:

THANK YOU SPE SPONSORS AND LEADERSHIP!

Your support helps us to educate the automotive industry to the benefits of polymer technologies in automotive applications and to provide scholarships and additional support to students interested in careers in the industry. This helps to grow the industry now and into the future! Your support is greatly appreciated!

SPE AUTOMOTIVE DIV. GOLF OUTING SUPPORTS SPE STUDENT CHAPTERS

$1,000 Awarded to Each of the Following Michigan student chapters:

- Ferris State University
- Kettering University
- Michigan State University
- Mid-Michigan Community College
- Schoolcraft College
- University of Michigan – Ann Arbor
- Western Michigan University
- Oakland University

Total Contributionfrom Golf Outing and SPE Automotive Div.: $8,000

SPE AUTOMOTIVE DIV. SUPPORTS PLASTIVAN® PROGRAM EDUCATING MIDDLE AND HIGH SCHOOL STUDENTS ABOUT PLASTICS

- Total 2018 Visits Jan–Dec. 2018: 25
- Total 2018 School year budget:..... $39,375
- Sponsorship is $1,750/day (Automotive Div. discount $1,575/day)
- Plus 100 Students from Clarkston and South Lion High Schools attended PlastiVan® presentations at SPE ACCE in Sept. 2018

2018 Schools Visited/3,304 Students served:

- Warren Mott High School ..... 2 visits
- Detroit Leadership Academy..... 5 visits
- Cousino High School, Warren..... 2 visits
- West Middle School, Troy ..... 1 visit
- Larson Middle School, Troy ..... 2 visits
- Hoover Middle School, Taylor ..... 2 visits
- AAUW Explorathon, Bloomfield Hills ..... 1 visit
- Clarkston High School..... 1 visit
- Clarkston Junior High School ..... 3 visits
- Durant-Tuuri-Mott School, Flint..... 1 visit
- Bates Academy, Detroit ..... 1 visit
- ACS STEM Stew Camp, Saginaw ..... 1 visit
- J• efferson Middle School, Midland ..... 1 visit
- Handy Middle School, Bay City..... 1 visit
- St. Clair Middle School ..... 1 visit

SPE AUTOMOTIVE COMPOSITES CONFERENCE & EXPO (ACCE) SUPPORTS STUDENTS VIA SCHOLARSHIPS, TRAVEL STIPENDS & MORE

- 4 ACCE Scholarships ($2,000 ea.) (Sponsored by MEDC in 2018, 2017).....$8,000
- Dr. Jackie Rehkopf Scholarship (Sponsored by SPE Automotive & Composites Div.) $5,000
- Student Poster Competition Participation (Sponsored by Ford Motor Company) .....$15,000 ($6,000 for Travel Stipends & $9,000 for Lodging serving 68 Students/$220.60 ea.)
- Student Poster Competition Prizes $6,800 in Awards to 20 Students ($200 - $750 ea.) $6,800
- ACCE Composites Quiz Event - 20 Teams of 2-4 Students with Industry Leaders $20,000

Total Contribution: $54,800

THE SPE AUTOMOTIVE DIVISION CONTRIBUTES TO ADDITIONAL SCHOLARSHIPS - AWARDED ANNUALLY AT ANTEC

- The Fred E. Schwab Education Award (for Distinguished Professors/Educators) $2,500
- The SPE International Award (recognizes Lifetime Achievements in Polymer Science)..... $2,500
- MAIN Event - Lawrence Technological University Scholarships for Design Students ..... $5,000 ($10,000 pledged toward event and Scholarships in 2019)

Total Contribution: $10,000

SUMMARY OF SPE AUTOMOTIVE DIVISION 2018 SCHOLARSHIP & STUDENT SUPPORT

- Summary of SPE Automotive Division 2018 Scholarship & Student Support Golf Outing/SPE Automotive Div. SPE Student Chapter Support: $8,000
- PlastiVan® Program 2018 School Year (25 visits): $39,375
- SPE Automotive Composites Conference & Expo (ACCE):.....$54,800
- Additional Scholarships for Antec & MAIN Event:..... $10,000
- The SPE Automotive Div. also Sponsors 40 Students to attend the Innovation Awards Gala annually. At a $200 value for each ticket, which represents an additional: $8,000

  (Faurecia Sponsored this program in 2018, 2017)

  (Celanese has been the leading sponsor of IAG f or many years)

Total 2018 Scholarships & Student Support Contributions:..... $120,175

4TH-ANNUAL

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FOR MORE INFORMATION

Conference Chair: Dr. Sassan Tarahomi
+1. 201.887.7635 | sassan@shanghaitpo.com

Technical Program Co Chair: Dr. Norm Kakarala
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Technical Program Co Chair: Dr. Shiyao Huang, Ford – Nanjing
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Sponsorship & Registration: Karen Rhodes-Parker
+1.248.244.8993 Ext 3 | karen@shanghaitpo.com

> 2019 TECHNICAL SESSIONS

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TREASURER'S REPORT

Bonnie Bennyhoff,
SPE Automotive Div. Treasurer

AS OF MARCH 13, 2019, THE DIVISION'S ACCOUNT BALANCES WERE:

Checking:	$513,895.67
Savings:	$ 27,475.52
Total:	$541,371.19

2018 SPE TPO AUTOMOTIVE ENGINEERED POLYOLEFINS CONFERENCE SPONSORS:

PLATINUM & EXHIBITOR

Advanced Composites, Braskem, 台塑關係企業, SUMITOMO CHEMICAL, LG Hausys, Washington Penn Plastic

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A. Schulman, Adell, AESSE, americhem, AMFINE CHEMICAL CORPORATION, ALDIA ELASTOMERS, BRANSON, BYK, ChasePlastics, CRODA, Datapoint Labs, elastion, ENTEC, EXTEEX, Jowat, JSR Corporation, Kal-Polymers, KRATON, KRÜSS, LOTTE CHEMICAL ALABAMA, MRC, MARION GROUP, MONARK, nexeo solutions, NOBLE polymers, NOF CORPORATION, RA RELIABLE ANALYSIS INC, RheTech, RTP, Specialty, struktol, SUNSTAR, TECHMER PM, UCC

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Abstract Due: April 8, 2019 • Presentations Due: July 12, 2019

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The SPE TPO *Automotive Engineered Polyolefins Conference* typically draws over 900 attendees from 20 countries on 4 continents who are vitally interested in learning about the latest in rigid and elastomeric TPO as well as TPE and TPV technologies. Fully a third of conference attendees work for a transportation OEM, and nearly 20% work for a tier integrator. Few conferences of any size can provide this type of networking opportunity or put you before such an engaged, global audience interested in hearing the latest olefin advances. Interested in presenting your latest research? Abstracts are due ***April 8, 2019*** and Papers/Presentations on ***July 12, 2019.*** Email abstracts/papers to **TPOpapers@auto-tpo.com**.

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FOR MORE INFORMATION

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FOR ADVERTISEMENT PLEASE CONTACT

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TPO® 2019 AUTOMOTIVE ENGINEERED POLYOLEFINS CONFERENCE

Troy, MI • October 6-9, 2019

Presented by SPE Detroit Section

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ABSTRACT DEADLINE: APRIL 8, 2019
PAPERS/PRESENTATIONS (COMPLETED PAPERS): JULY 12, 2019
EMAIL TO: TPOPAPERS@AUTO-TPO.COM

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TPO 2019 CONFERENCE TECHNICAL PROGRAM SESSIONS & CHAIRS:

Scope of each session and suggested topic areas are provided on conference website: **www.auto-tpo.com**

MATERIALS DEVELOPMENT
- Mike Balow, Asahi Kasei Plastics North America
- Mark Jablonka, The Dow Chemical Company
- Peter Glenister, LyondellBasell

SURFACE ENHANCEMENTS
- Dr. Rose Ryntz, Ryntz & Associates
- Jim Keller, Mankiewicz Coatings
- Jeff Crist, Ford Motor Company

INTERIOR APPLICATIONS & LAMINATING ADHESIVES
- Dr. Pravin Sitaram, Haartz Corporation
- Sarah Gatzek, Ford Motor Company
- Hoa Pham, Freudenberg Performance Materials

PROCESS DEVELOPMENTS & SIMULATIONS
- Kurt Anthony, Washington Penn Plastic Co., Inc.
- Dr. Suresh Shah, SPE Fellow
- Dr. Li Lu, Ford Motor Company

LIGHTWEIGHTING OF POLYOLEFIN PARTS
- Mike Shoemaker, Borealis Compounds
- Dr. Nadeem Bokhari, Sumitomo Chemical
- Normand Miron, Washington Penn Plastic Co., Inc.

BIO BASED & RECYCLED MATERIALS
- Susan Kozora, IAC Group
- Dr. Alper Kiziltas, Ford Motor Company

INTERIOR EMISSIONS
- Dr. Laura Shereda, Asahi Kasei Plastics North America

ADDITIVE MANUFACTURING (3D PRINTING)
- Kurt Anthony, Washington Penn Plastic Co., Inc.
- Dr. Suresh Shah, SPE Fellow
- Nihir Bhuva, Asahi Kasei Plastics North America

SUNDAY, OCTOBER 6, 2019 – TWO TECHNICAL WORKSHOPS: 3:00PM & 4:00PM

KEY CONFERENCE CONTACTS

CONFERENCE CO-CHAIRS

Neil Fuenmayor, LyondellBasell
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SPONSORSHIP/EXHIBIT CO-CHAIRS

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David Okonski, General Motors
dokonski@auto-tpo.com

For information and registration visit our website at auto-tpo.com or call Karen at +1.248.244.8993, Ext 3, karen@auto-tpo.com

A block of rooms has been reserved at the Marriott Troy for the SPE TPO Automotive Engineered Polyolefins Conference.

SECRETARY'S REPORT

SPE Automotive Division Board Meeting Minutes February 18th, 2019, by Crystal VanHouten

Dave Helmer, Sanjay Patel, Dhahendra Nagwanshi, Matt Carroll, Alper Kiziltas, Bonnie Bennyhoff, Chuck Jarrett, Crystal VanHouten, Rodrigo Orozc, Brian Grosser, Fred Deans, Gary Kogowski, Nippani Rao, Norm Kakarala, Steve Van Loozen , Teri Chouinard, Tom Pickett, Mark Bahm, Suresh Shah, Keith Siopes, Paula Kruger, Neil Fuenmayor, Sanjay Patel, *ph: Jeff Helms*

Meeting was held at the ACC Office (American Chemistry Council) in Troy, 5:34pm – 7:31pm

OPENING – Dave Helmer
Review of Agenda for Meeting

FINANCIAL – Bonnie Bennyhoff
Reviewed Accounts Receivable/Accounts Payable and Balance sheet.

We are on target to Budget vs Actual spending allocations.

Fiscal year ends, June 30th

ANTEC – Norm Kakarala, Tom Pickett
75th Anniversary of ANTEC to be held in Detroit, MI

13 concurrent sessions with 400 presentation

Suresh, Keith and Alper have help tremendously with the recruitment of papers.

UofM students contacted to volunteer at ANTEC

COUNCILOR REPORT – Suresh Shah
Meeting held on 12/13/2018. Please see the COUNCILOR REPORT in the newsletter for details of this meeting.

WEBSITE ANALYTICS – Mark Bahm
New banner has been integrated onto the Website

2018 ACCE REPORT – Alper Kiziltas, Matt Carroll, Teri Chouinard, Bonnie Bennyhoff
Working on Keynote and Panel Discussion

Targeting 100 students for 2019 attendance

2 abstracts submitted as of current. All abstracts are due April 30th, with papers due May 15th.

DESIGN IN PLASTICS / The MAIN Event – Steve Van Loozen
2nd year of sponsoring this event. It is very well received and appreciated by the students and staff of LTU.

Several students received scholarships for participating in this event.

In 2020, the event will be moved to June 2020 as it corresponds with the NAIAS. Details of year 3 will be presented in April 2020.

EDUCATION – Alper Kiziltas
Review of PlastiVan® school visits

SPE Auto Division currently has 17 visits. We have committed to 25.

MEMBERSHIP – Samar Teli
Currently there are 915 members registered with 798 that are active

CHAIR REPORT – Dave Helmer
Liability Insurance Coverage has been renewed

Need a copy of bylaws

Sponsorship Appreciation Dinner will be held in January for sponsor for all events.

AUTO EPCON REPORT – Gary Kogowski
9 Abstracts submitted / Need 20

Would like additional sponsors this year

IAG – Jeff Helms
Theme: Plastics –> Advancing Mobility

Sponsorship rates will increase 20% this year due to economic inflation

Initial judging will be September 26 and 27th, 2019

Blue Ribbon Judging date to be confirmed.

INTERSOCIETY REPORT – Dhanendra Nagwanshi
FSD Global Award Recognition to be held March 20th, 2019

SAE World Congress 2019 will be held April 9th-11th, 2019 in Detroit. Focus of this years event is Leading Mobility Through Innovation

TPO SHANGHAI – Norm Kakarala
4th annual SPE TPO conference held @ Shanghai, Marriott

NEW DATE – April 3-5th, 2019

2 Keynotes & 18 Technical Papers are scheduled

TPO TROY, MI – Neil Fuenmayor
Will be held October 7-9th, 2019 in Troy, Mi

43 Sponsors signed up as of 2/13/2019

4 out of 4 Keynote Speakers secured

Targeting 64 papers

Abstracts are Due April 8th and Papers are due July 12th, 2019

NEW BUSINESS
SPE Auto Division and Detroit Section have created a College Student Presentation Committee. We are all looking forward to the end results.

Bylaws are being worked on. Rough draft to be presented soon.

Meeting adjourned at 7:31pm.

AUTOMOTIVE

TECHNICAL REPORT

SANDEEP TAMRAKAR, CENTER FOR COMPOSITE MATERIALS (UD-CCM), DEPT. OF CIVIL & ENVIRONMENTAL ENGINEERING, THE UNIV. OF DELAWARE

CO-AUTHORS: RAJA GANESH, RAMANI SOCKALINGAM, JOHN W. GILLESPIE JR.,

ABOUT SANDEEP TAMRAKER

After earning his undergraduate degree in Civil Engineering from Tribhuvan University, Nepal in 2007, Tamrakar attended the University of Maine, where he earned his Master's degree in Civil Engineering in 2011 under the supervision of Prof. Roberto Lopez-Anido. He then earned a doctorate in Civil Engineering from the University of Delaware under the supervision of Prof. John W. Gillespie, Jr. He is currently a post-doctoral research associate at Ford Research and Innovation Center. His research interest includes composite interfaces, rate dependent behavior of polymer composites and viscoelasticity. His work has been featured in numerous peer-reviewed journal papers and presentations.

DETERMINATION OF MODE II TRACTION SEPARATION LAW FOR S-2 GLASS/EPOXY INTERFACE UNDER DIFFERENT LOADING RATES USING A MICRODROPLET TEST METHOD

ABSTRACT

This paper presents a methodology to extract the rate dependent traction separation law for composite interface through iterative method by simulating all the physically observed mechanisms in a microdroplet experiment. Experimentally obtained rate dependent interfacial shear strength (1 μm/s to 1 m/s), large strain resin properties (0.001/s to 12,000/s) and information on crack initiation at the interface obtained from carbon nanotube sensors are used as model input. Through simulation of microdroplet experiments, unique set of traction separation laws were determined for a given loading rate by narrowing down the range based on IFSS prediction for different droplet sizes and the associated failure modes. Both traction law parameters, i.e. peak traction and the fracture energy increase with the increase in the rate of loading. Partitioning of energy absorption contribution by the constituents suggests resin plasticity and strain energy stored in the fiber play an important role up to failure.

1. INTRODUCTION

In the automotive industry, there is a demand for lightweight composite structure with enhanced energy dissipation capability during an event of crash or impact. Under dynamic loading, energy is dissipated through various mechanism such as delamination, matrix cracking at higher length scale and fiber matrix debonding, frictional sliding and fiber breakage at lower length scale. Studies have shown that the damage mechanisms pertaining to lower length scales absorb more energy [1]. The interaction between fiber and matrix at the interface determines the overall energy absorption capability of the fiber reinforced composite material [1]. A coating on the surface of the fiber called sizing, which is in the nanometer length scale, consists of film former and silane coupling agents [2,3]. The chemical formulation of the sizing and its compatibility with the resin significantly affects the degree of adhesion between fiber and matrix and ultimately the energy absorbing capability of the composite [4,5]. This opens an opportunity to maximize the composite properties by studying the energy dissipation and failure mechanisms during interface debonding and design lightweight automotive parts. An ideal case for maximum energy absorption would be to have resin deform plastically near the interface with the ultimate failure occurring along the interface. Since this is a dynamic event, it become important to consider the rate dependent properties of the matrix as well as the interface.

One approach to optimize the interaction between constituents for maximum energy absorption is by studying a model composite through finite element simulation (FEA). This requires accurate rate dependent properties for fiber, resin and interface. In FEA simulation, cohesive zone models are generally used to simulate the interface between two dissimilar materials. Dependence of traction law parameters on the rate of loading has been reported in the literature [6–8]. For instance, traction law obtained through direct approach for steel adherends bonded with polyurea exhibited strong dependence on the rate of loading [8]. Rahulkumar et al. [9] modeled fracture in viscoelastic materials by combining viscoelastic adhesive model with a rate independent cohesive zone model. Xu et al. [10] modeled rate dependent failure behavior of adhesive bonds by introducing a Maxwell element to a rate independent cohesive zone model. Model parameters were determined by simulating DCB tests conducted at different strain rates. Wang et al. [11] employed spring and dashpots to introduce viscoelastic factor in the cohesive zone model and simulated DCB tests with metal adhesive (elastic) and rubber adhesive (hyperelastic) structure. Marzi et al. [12] used a rate dependent extension of bilinear cohesive model and implemented in commercial FE code LS-DYNA via a user-defined subroutine. Butt joint and tapered DCB tests were conducted at velocities ranging from 10-2 mm/s to 102 mm/s to determine the Mode I model parameters. Gowrishankar et al. [7] adopted an iterative approach in which the toughness of silicon/epoxy interface was estimated by comparing the crack length in a DCB specimen, and then the peak traction was adjusted to match the experimental results. These parameters were in good agreement with the ones extracted directly.

In this study, traction law parameters are iteratively determined by accurately simulating and matching the experiments [13,14]. This route, in conjunction with the novel test methods developed for characterization of rate dependent interface and resin properties in our previous studies [15,16] and in-situ sensing of crack initiation, is the approach used.

2. MICRODROPLET TEST

S-2 glass fibers with (3-glycidoxypropyl) trimethoxy silane coupling agent and epoxy film former sizing obtained from Owens Corning Corporation were used. Epoxy resin DER 353 (Dow Chemical Company) was mixed with bis (p-aminocyclohexyl) methane (PACM-20) curing agent (Air Products and Chemicals, Inc.) at stoichiometric ratio of 100:28 (weight ratio) to form the droplets which is then allowed to gel at room temperature for 5 h, followed by curing at 80 and 150 °C for 2 h each. At least 10 valid microdroplet tests were used for each loading rate. The nominal diameter of the S-2 glass fibers considered in this study was 10 µm. The embedded length of the droplet ranged from 70 to 200 µm. Fiber gauge lengths (top of drop to load cell) between 1 mm and 2 mm were maintained. Tests were conducted at 1 um/s, 0.1 mm/s and 1 m/s [17]. A modified tensile Hopkinson bar was used for 1 m/s loading rate. Details on this test setup can be found in [15].

Experimental results exhibited size effects showing lower IFSS for higher embedded length, which are accounted for in the simulation. The average IFSS increased by a factor of 1.6 when the displacement rate was increased from 1 µm/s to 1 m/s (See Figure 1 and Table 1). Resin plasticity in the droplet is observed at the location of knife edge contact. Finite element simulation of the microdroplet experiments incorporates accurate rate dependent resin properties to partition the resin and interface energy contributions.

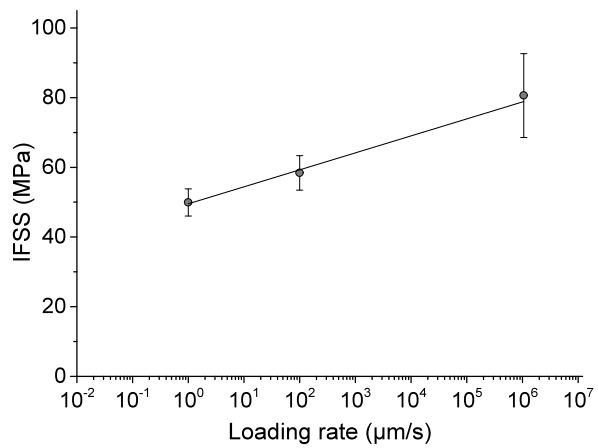

Figure 1 Average IFSS vs. loading rate for microdroplet specimens with embedded length ranging from 70 µm to 125 µm show a linear increase when plotted on a log scale

Table 1 Rate dependent IFSS and specific energy up to debond

Loading Rate	IFSS (MPa)	Specific energy debond (J/m²)
1 µm/s	49.9 ± 4.7	670 ± 220
0.1 mm/s	58.4 ± 4.9	880 ± 350
1 m/s	80.6 ± 12.1	1950 ± 860

 Continued from Page 25

3. PROPOSED METHODOLOGY FOR THE DETERMINATION OF TRACTION SEPARATION LAW

Our proposed methodology to determine rate dependent traction separation law for composite interfaces includes characterizing the rate dependent response of fiber, matrix and interface separately. Then, by accurately simulating all the physically observed mechanisms in the specimen, unique traction law can be determined. Parametric studies on a bilinear traction law conducted by Tamrakar et al. [24] demonstrated a non-unique nature of the traction law where there are more than one combinations of peak traction and relative displacement for crack separation traction law parameters that accurately predict the maximum load. Two different combinations of peak traction and fracture energy resulted in very similar force displacement response. However, the point at which crack initiation occurs varies. For the traction law with 160 J/m^2 and 120 MPa peak traction, the crack initiates at around 88% of the peak load, whereas for the one with 200 J/m^2 and 75 MPa, crack initiation occurs right after reaching the peak load. These parametric studies suggest that additional experimental information such as load at the initiation of debonding along the interface is important to establish uniqueness. For this purpose, the authors developed CNT sensors at sub-micron length scale to monitor the onset of crack initiation at the interface, where the CNT sensors act as on/off switch [17]. Measurements on change in electrical resistance during microdroplet test showed that the crack initiation occurs at the peak load and becomes unstable and failure occurs. Information on crack onset and its corresponding load level is used as an input in the FE simulation to extract traction separation law.

Resin plasticity is another factor that that must be accounted for in simulations of the microdroplet experiments for accurate traction law determination. During the experiments, large plastic deformation has been observed at the tip of the droplet where knife edge comes in contact. When only the elastic response of the resin is considered, interface debonding is assumed to be the only energy absorption mechanism. However, when resin yield stress is exceeded additional energy absorption occurs through resin plasticity. Rate dependent yield stress and stress strain response for DER 353 epoxy resin serve as input in the model [17].

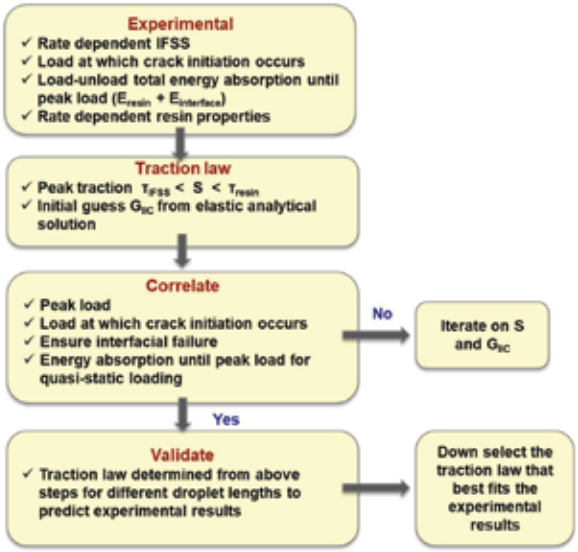

Figure 2 Methodology for determination of traction separation law for composite interface

The first step is to conduct the microdroplet experiments under different loading rates (Figure 2). During the experiment, cured specimens are placed on a specimen holder, which is attached to a load cell. Knife edges induce compression in the resin droplet resulting in large local deformation. This force is transferred to the fiber through shearing shear of the resin of and the interface, which results in the fiber being loaded in tension and is measured by the load cell.

In our methodology, we create specimens with a minimum of three embedded lengths (75 µm, 100 µm and 125 µm). We ensure that the failure mode is along the interface and not within the resin. Our study using CNT sensors indicate that the interface debonding occurs at the maximum load in our S glass/epoxy specimens [17]. The IFSS data for each embedded length is used to correlate with the numerical predictions.

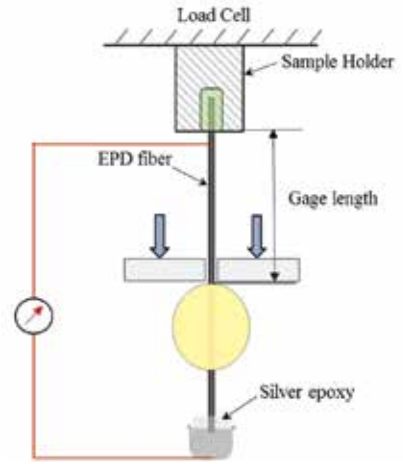

Figure 3 Quasi-static microdroplet test setup

A bilinear traction separation law is assumed for the interface under Mode II loading. The key parameters associated with the traction law are the peak shear stress (S) and the critical energy release rate, GIIc (the critical shear displacement is calculated using the other parameters). It is important to note that the IFSS is an average value and that there are significant gradients along the droplet interface (highest near the knife-edge loading surface). Hence, IFSS is much lower than the peak shear stress defined in the traction law.

The simulation based iteration process using known properties of the fiber and epoxy resin begins by choosing a value for peak traction that is equal or higher than the average interfacial shear strength. Since the failure mode is confirmed experimentally to debond within the interphase, the peak stress should also not significantly exceed the yield stress of the resin (otherwise failure will occur in the resin and not be consistent with interfacial failure mode). Initial estimates for the critical energy release rate is calculated by using the critical opening displacement from the previous studies by Sockalingam et al. [13] assuming an elastic resin response for the same S glass (GPS sized)/epoxy constituents.

Simulations with different combinations of peak traction and critical energy release rate within this range are carried out for a 75 µm droplet. Combinations that cannot reach the maximum load are eliminated. Those combinations that match the peak experimental load are then checked for failure mode (interfacial or resin). Resin failure modes (extensive resin plasticity near the interface) and the associated traction law parameters are also eliminated. This sequence significantly narrows the range of admissible parameters.

This range of acceptable traction law parameters are then used to predict the IFSS for the next larger droplet sizes (100 µm and then 125 µm). This sequence is repeated and further narrowing of the range is achieved. Three drop sizes provide convergence of the traction law parameters that provides the correct failure mode and failure loads for all embedded lengths. The simulation results also allow the partitioning of energy absorbing mechanisms (interface and resin plasticity) and prediction of cohesive zone sizes for all loading rates. Incorporating resin plasticity ensures energy absorption of the interface softening is accurate. Assuming elastic response (for a resin with extensive resin plasticity) will result in an overestimation of the interfacial energy absorption.

This procedure also works well for droplets tested at higher rates of loading, where only the maximum load can be measured accurately. This methodology provides a unique critical peak shear stress and energy absorption parameters for the Mode II traction law as a function of loading rate that can be used in other micromechanical simulations [18].

4. FINITE ELEMENT MODEL

A quarter-symmetric FE Model was used to simulate the microdroplet experiment. S glass fiber (10 µm diameter), steel knife blade and epoxy resin droplet (with spherical shape) were modeled using 8-noded linear reduced-integration 3D Brick elements (C3D8R in ABAQUS), with enhanced hourglass control. Zero-thickness 3D cohesive elements (COH3D8) represent the fiber-matrix interface. The thermal preload during the curing of the droplet was modeled as an initial quasi-static step [13], while the subsequent knife edge loading was simulated as a dynamic explicit load step and solved using the double-precision ABAQUS Explicit solver.

The fiber is modeled as isotropic linear elastic material. The matrix is modeled isotropic linear elastic up to yield. Rate dependent post yield behavior of the epoxy resin obtained from compression experiments serves as model input. The resin exhibits post yield softening, plastic flow followed by strain hardening at large strain. Element deletion occurs at the failure strain of 70%. Post yield stress strain curve is used for 0.001/s strain rate. For higher strain rates, the entire curve is shifted vertically using the strain rate dependent yield stress. Details on curve fitting and yield stress prediction using Eyring equation are presented in our previous work [16]. Details regarding meshing and boundary conditions in the model can be found elsewhere [17].

Table 2 Properties of fiber and matrix

Property	S-glass fiber	Epoxy resin DER 353
Young's modulus (GPa)	90.0	3.2
Poisson's ratio	0.17	0.36
CTE (ppm/°C)	3.4	70.0

5. DETERMINATION OF TRACTION SEPARATION LAW

5.1. HIGH RATE LOADING

For high loading rate of 1 m/s, the average IFSS for a 75 µm droplet was 88 MPa. So, a peak traction greater than 88 MPa was chosen based on our methodology. A series of parametric studies were conducted for a droplet with 75 µm embedded length to generate a family of IFSS vs. peak traction and fracture energy curves (Figure 4). In general, simulations with lower peak tractions showed delayed crack initiation at interface and higher peak traction showed resin failure. This trend is consistent with all the loading rates used in this study.

 Continued from Page 27

For 1 m/s, peak tractions ranging from 110 MPa to 150 MPa match the experimental IFSS and failure modes are carried forward to predict the IFSS for different droplet sizes as part of the procedure. Traction parameters that do not predict the experimental peak loads or failure modes are eliminated.

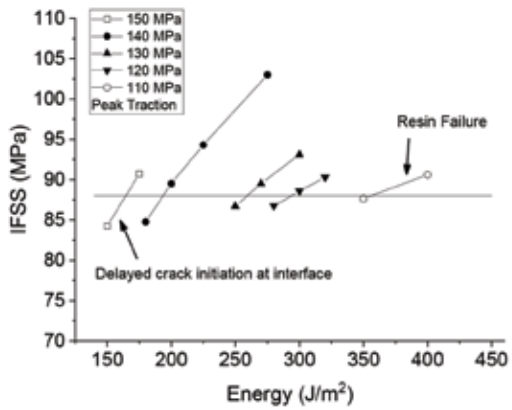

Figure 4 Parametric study on peak traction and fracture energy for the determination of traction separation law for 75 µm droplet at 1 m/s loading rate. Traction laws with peak shear stress of 110 MPa and 150 MPa are eliminated

Traction laws (120 MPa-300 J/m^2 and 130 MPa-270 J/m^2) exhibited correct failure modes for both 100 µm and 125 µm droplets. Size effects on the interfacial shear strength was also observed from simulation results (consistent with experimental observations), where larger droplet sizes showed lower IFSS. The traction law 120 MPa - 300 J/m^2 results in less error compared to the line fit to the experimental results. Hence this combination is chosen as the unique parameters for the loading rate of 1 m/s. It should be noted that our methodology to determine unique traction separation law is limited by the variability in experimental data.

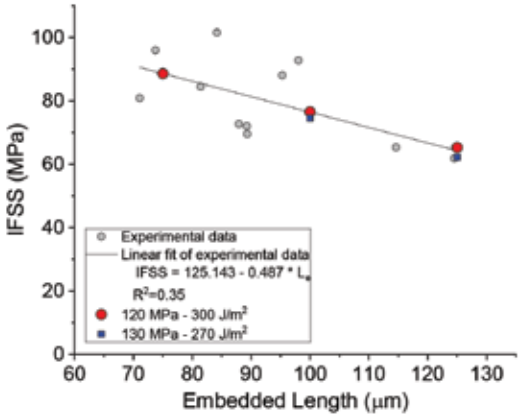

Figure 5 Average interfacial shear strength from microdroplet experiments and FE model showing size effects for 1 m/s loading rate

Table 3 Goodness of fit for the predicted IFSS at 1 m/s

Traction law	Error*
120 MPa and 300 J/m^2	0.54 %
130 MPa and 270 J/m^2	1.95 %

$$^{*}Error = \left|\frac{IFSS_{exp} - IFSS_{model}}{IFSS_{exp}}\right| \times 100\ \%$$

5.2. INTERMEDIATE LOADING RATE

For the intermediate loading rate of 100 µm/s microdroplet tests, the IFSS was 61 MPa for a nominal 75 µm droplet. Following the methodology, results from a parametric study done with peak traction ranging from 70 MPa to 90 MPa with a wide range of fracture energies are shown in Figure 6. For peak traction between 75 MPa and 85 MPa, failure occurred along the interface and the traction laws 75 MPa – 120 J/m^2, 75 MPa – 150 J/m^2, 80 MPa – 100 J/m^2, 80 MPa – 120 J/m^2 and 85 MPa and 90 J/m^2 predicted IFSS within the experimental error. However, when the peak traction of 70 MPa and 90 MPa exhibited delayed crack initiation at the interface and resin failure, respectively. Following our methodology, the traction law was narrowed down to 75 MPa – 150 J/m^2, which showed interfacial failure for both 75 µm and 125 µm droplets. Comparison of the simulation with the linear fit to the experimental results show an excellent correlation including size effect with an average absolute relative error of 5.9%.

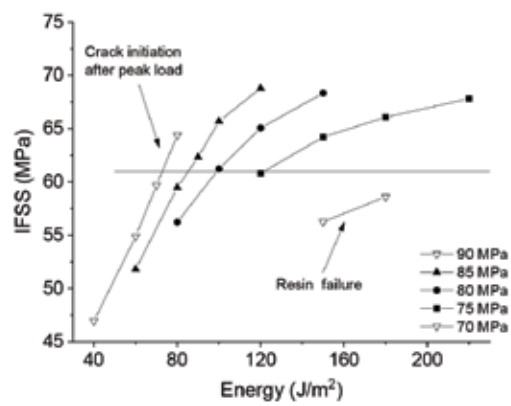

Figure 6 Parametric study on peak traction and fracture energy for the determination of traction separation law for 75 µm droplet at 100 µm/s loading rate

5.3. QUASI-STATIC LOADING RATES

For quasi-static loading rate of 1 µm/s, the average IFSS for a 75 µm droplet was 54 MPa. Traction laws with peak traction 60 MPa did not reach the experimental IFSS (Figure 7). The ones that matched the experimental IFSS (65 MPa - 100 J/m^2 and 70 MPa – 80 J/m^2) are carried forward and used to predict the IFSS for different droplet sizes.

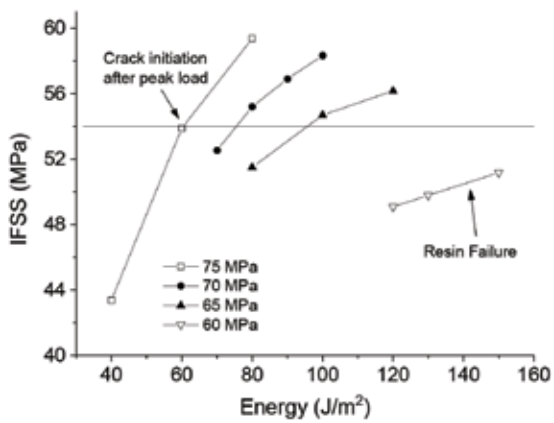

Figure 7 Parametric study on peak traction and fracture energy for the determination of traction separation law for 75 µm droplet at 1 µm/s loading rate. Traction laws with peak traction 60 MPa and 75 MPa are eliminated from further study

Simulations run with 70 MPa traction law exhibited delayed crack growth at the interface for droplet size of 125 µm and consequently was eliminated from further analysis. The FE predictions using the downselected traction law 65 MPa – 100 J/m^2 are within 2.9% of the line fit to the experimental data (Table 4).

Table 4 Goodness of fit for the predicted IFSS at 1 µm/s

Traction law	Error*
165 MPa and 100 J/m^2	2.9 %
70 MPa and 80 J/m^2	5.1 %

6. CONCLUSIONS

A methodology has been developed to extract the rate dependent traction separation law for composite interface through iterative method by simulating microdroplet experiment. Experimental results show the interfacial properties are dependent on rate of loading and on the geometry of the specimen. Rate dependent inelastic resin properties were considered, which is critical for accurate determination of traction law. Use of only elastic properties for resin droplet tend to overestimate the traction law parameters of the interface. Crack initiation occurs at peak load, which correlates well with the experimental results obtained from CNT sensors. A range of traction separation laws were determined for different loading rates by simulating the microdroplet experiments with a certain embedded length. Then, unique rate dependent traction laws were determined by narrowing down the range by simulating microdroplets with different droplet sizes. The simulations showed a general trend where a lower peak traction exhibited resin failure and higher peak traction showed a brittle failure. These failure modes are associated with the crack opening displacements assumed in the traction law. These results showed the overall energy absorption capability and failure modes depend on the rate dependent peak traction stress and resin yield stress. Interfacial traction separation laws (both peak traction and the fracture energy) were found to be dependent on the rate of loading (Figure 8 and Table 5). The range of shear strain rates presented in Table 5 have been calculated by assuming interface thickness of 10 – 100 nm. Peak traction and fracture energy exhibit a fairly linear relation with shear strain rate when plotted on a semi log scale (Figure 9).

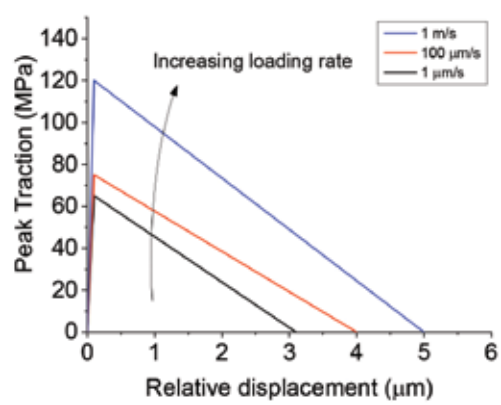

Figure 8 Traction separation law for different loading rates

Table 5 Rate dependent traction separation laws

Loading rate	Relative nodal velocity	Shear strain rate range	Peak traction	Fracture energy	Relative displacement
1 µm/s	0.9 µm/s	9/s – 90 /s	65 MPa	100 J/m^2	3.1 µm
100 µm/s	90 µm/s	900/s – 9000/s	75 MPa	150 J/m^2	4.0 µm
1 m/s	1 m/s	107 /s - 108 /s	120 MPa	300 J/m^2	5.0 µm

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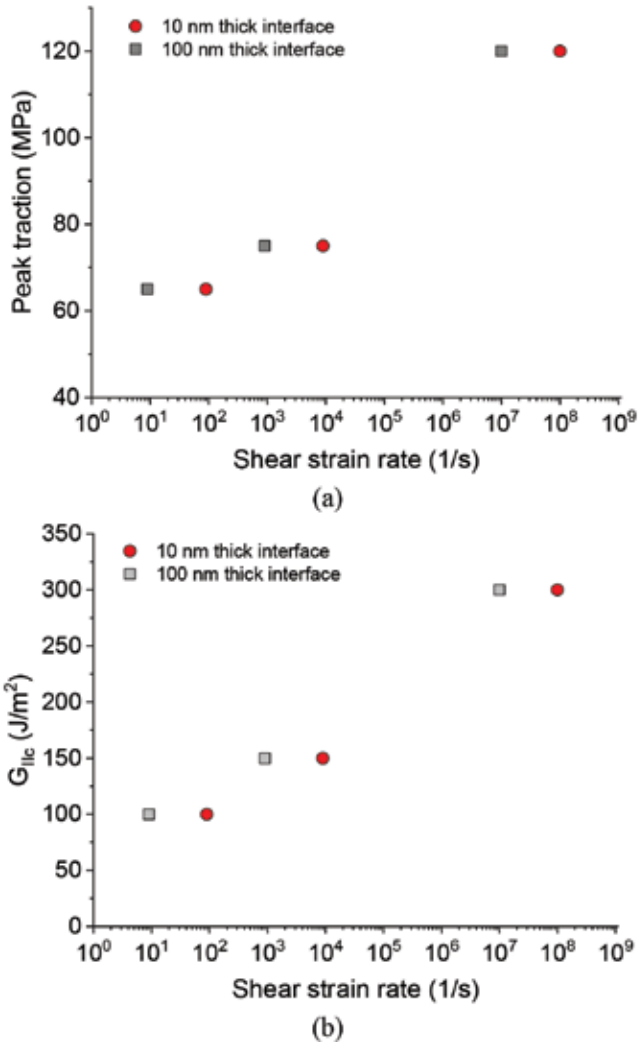

Figure 9 (a) Peak traction and (b) fracture energy as a function of shear strain rate for interface with 10 nm and 100 nm thickness

7. ACKNOWLEDGEMENTS

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