Picture taken at SPE ACCE (Automotive composites conference and exhibition) 2018

2017-2018

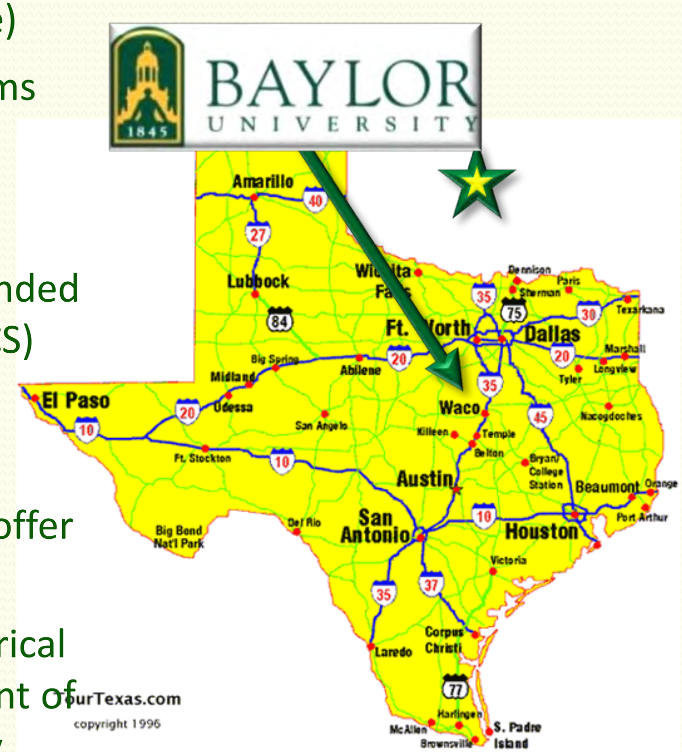
The Baylor SPE Chapter

The year in review

Baylor University

- Baylor University was chartered in 1845 by the Republic of Texas under the mission of Pro Ecclesia and Pro Texana
- Baylor has an enrollment of 17,000 students (14,300 undergraduate)
- Baylor has 142 undergraduate, 75 master's, and 42 doctoral programs
- Student to faculty ratio is 15 to 1 across the campus

- Baylor's School of Engineering and Computer Science (ECS) was founded in 1995 with two departments, Department of Computer Science (CS) and Department of Engineering
- The only graduate degree in 1995 was an M.S. in Computer Science
- The Department of Engineering was granted permission in 2004 to offer master's degrees
- In 2006 the Departments of Mechanical Engineering (ME) and Electrical and Computer Engineering (ECE) were formed out of the Department of Engineering. Currently the two departments have 14 and 16 faculty, respectively
- Dean Dennis O'Neal, has spearheaded the growth of the research programs in the school
- In 2017 Sarah Stair (an SPE member and former president) graduated as the first mechanical engineering Ph.D.

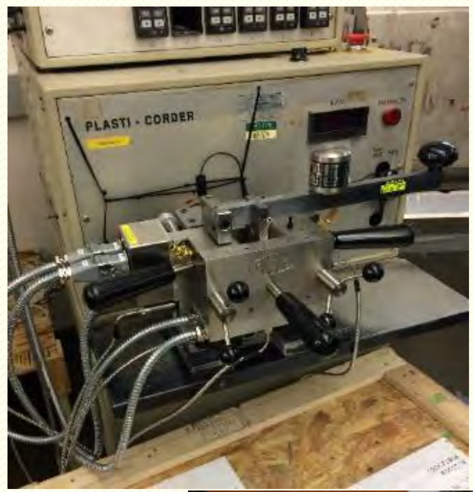


Baylor University

- There are 1,106 undergraduate students in ECS (2015-2016), with 5,100 new applications for the fall of 2014 (double that of 5 years ago)
- The student body in ECS is composed of 25% female and 30% minority
- ~80 graduate students in ECS, with ~40 of those in ME
- The materials group (self labeled Sic'em – Scientific Innovations in Complex Engineering Mateirals) has moved to the BRIC (Baylor Research Innovation Corporative) in 2013.
- Currently Sic'em has 4,600 sq. ft. of lab and office space
- Materials faculty have received funding from NSF, NASA, AFOSR, ONR, L-3 Communications, Hess Inc., Delta G, Sandia National Laboratory, Oak Ridge National Laboratory, DOE (Education), Leggett and Platt, the Kern Foundation and Axion Structural Innovations.

SPE Equipment

- Filabot
- Benchtop Injection Molder
- Solidoodle
- Carvey
- Vacuum Pump and resin trap
- Brabender Mixer
- Various material supplies



BAYLOR UNIVERSITY

Available Equipment

Imaging

- JEOL JSM Scanning Electron Microscope with 5,000 N tensile stage
- Panametrics 300 gallon, 200 MHz 3 ft x 4 ft x 6 ft NDT Immersion System
- Keyence VR-3200 – high resolution 3D, non-contact, surface measurements
- Custom C-Scan Immersion System, 5 - 25 MHz, 1/800th mm x-y-z resolution, 0.01^{o} resolution in rotation stage
- Custom C-Scan Out-of-tank System, 5 - 25 MHz, 1/800th mm x-y resolution
- Leica binocular/stereo microscope
- MZ7 Microzoom 10x-1000x magnification, 10 MP video imaging
- Multiple Dino-Lite Polarizing portable microscopes
- Non-contact 3D digitizer/scanner – NextEngine 3D

Materials Fabrication/Processing

- K-Lab Magnetron sputter system for Thin Film Electronic/Flexible Polymers
- Multiple vacuum pump systems (VARTM) for fabricating laminated composites
- CTE M7000 Constant Speed Mixer, API Spec 10
- ExOn 8, 12 lb/hr extruder with custom translation system for large volume additive manufacturing
- Custom CVD chamber for nanotube synthesis
- Arburg 70 ton injection molding machine with 5 molds
- Brabender single screw extruder
- Ross mixing unit
- Carbolite split tube furnace for MWNT CVD fabrication
- DSM X-Plore Injection molding machine
- Makerbot Replicator 2 and 2x, and SolidDoodle 3D Printers
- Objet and Dimension 3D printers (dept. resource)
- Compression molding 60 ton hot press
- CNC with 4 axis capability (dept. resource)

Available Equipment

Materials Characterization

- TA Instruments DMA Q800 – Dynamic Mechanical Analyzer
- TA Instruments TGA Q50 – Thermogravametric Analyzer
- TA Instruments M/DSC Q20 – Differential Scanning Calorimeter
- TA Instruments Q400 TMA – Thermomechanical Analyzer
- Malvern Bohlin Gemini II Rheometer
- Instron CEAST 9050 Charpy and Izod Impact Testor
- Desktop Instron with 10lb and 450lb cells
- Test Resources 810LE Tensile Stage – 15 kN static, 8.5 kN dynamic @ 15Hz
- MTS Qtest/100, 100kN tensile test load frame
- Custom 8 foot drop tower with 1 to 25 pound load tray
- Tinius Olsen Meltflow Indexer – MP600

Sample Preparation and Measurement Devices

- Blue M LO-225 Programmable Oven – Interrior Dims. 24” x 20” x 30”
- Plasma Etch PE50-HF
- Buehler EcoMet Grinder-Polisher and Buehler IsoMet Low Speed Saw
- Multiple National Instruments Data Acquisition cards and chassis
- Agilent Oscilloscopes and Programmable Power Supplies

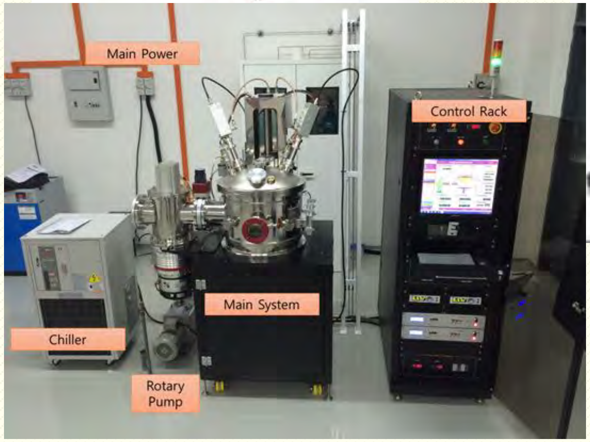
Computational Resources

- Twelve high performance workstations (most are Intel i7 or Xeon 8-core), each 3.06 GHz or higher, with 32, 64 or 256 GB of ram
- 6 node portable desktop cluster, 12 cores, CUDA cards
- Full access to Baylor’s HPC with 128 nodes of dual Xeon 5355s with 16 GB ram per blade (Baylor resource)
- 5 standard fume hoods (2 – 48” width, 2 – 60” width, 1 – 72” width) and one highly acidic fume hood with ultrafine (SWNT scale) particle filtration



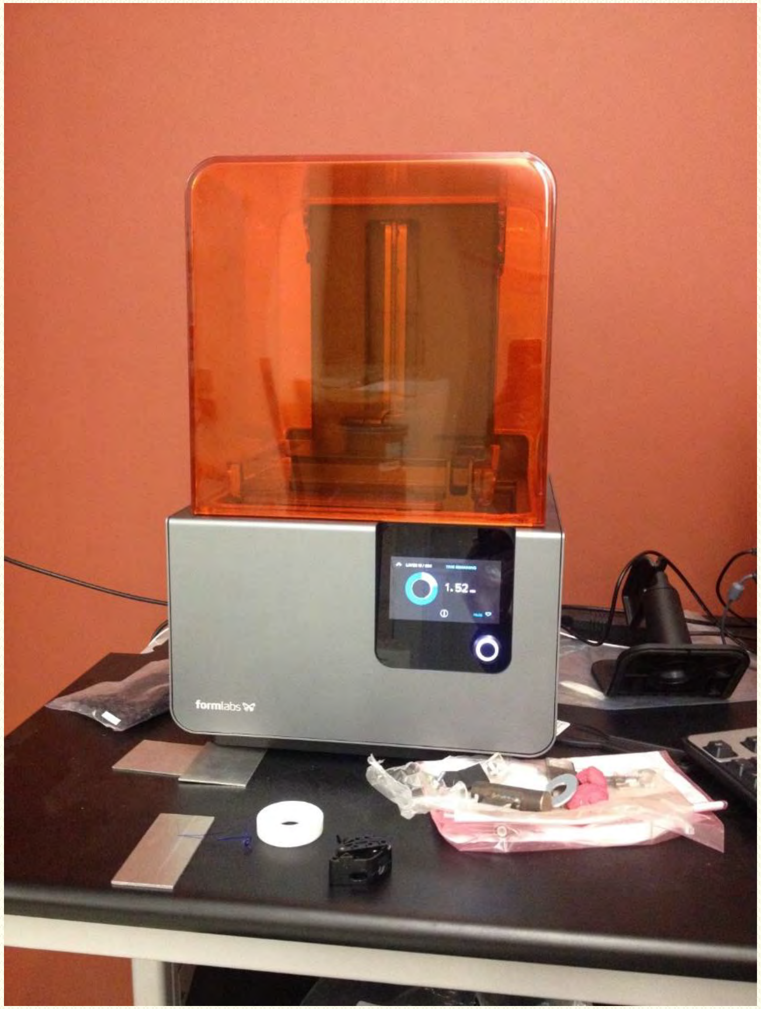


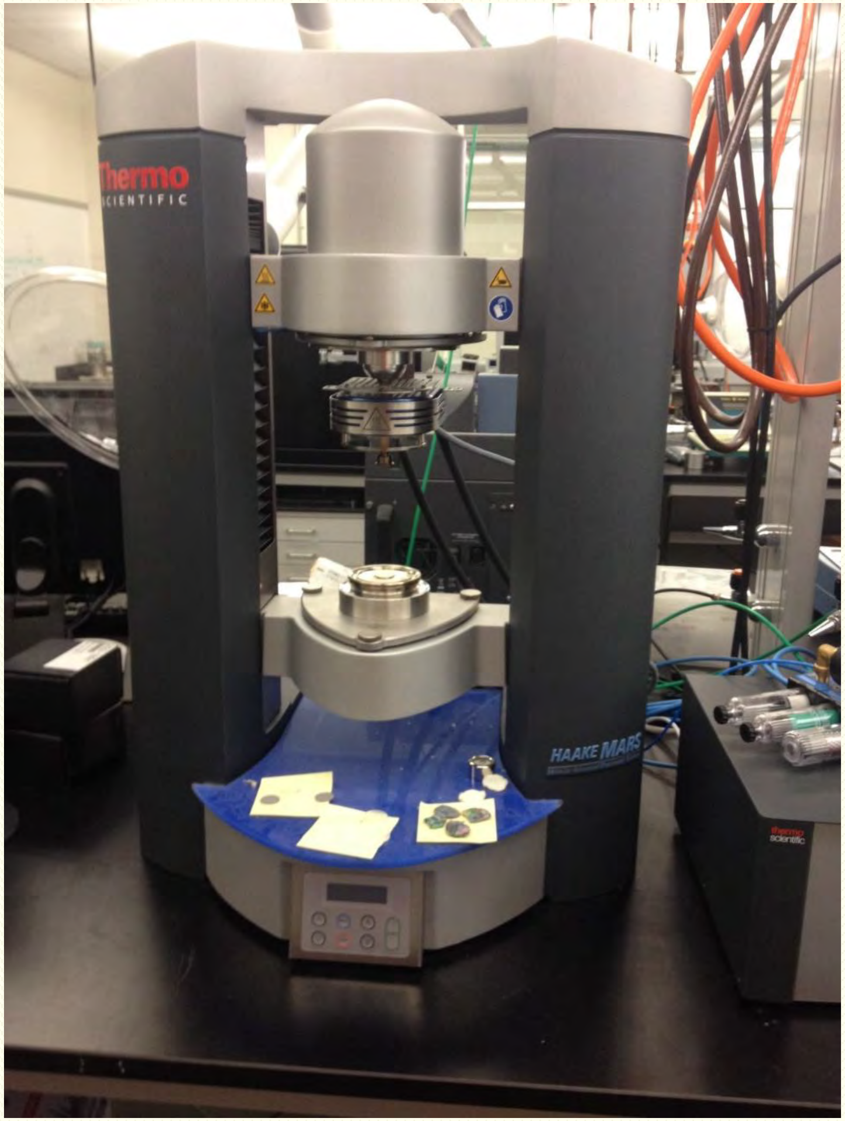




SPE Equipment - 2017

- Form 2 SLA 3D Printer
- Thermo Scientific Rheometer





SPE Equipment Purchased - 2018

- Freezer/Mill 6775
- Vertical Mill with Powerfeed & DRO

The Baylor SPE Chapter
2017-2018

The year in review

Student Officers

Daniel Pulipati

President
2017 - 2018

Jay Thomas

Vice President
2017 - 2018

John Moreton

Treasurer
2017 - 2018

Evan Wang

Secretary
2017 - 2018

Daniel Pulipati

President
2018 - 2019

Nate Blackman

Vice President
2018 - 2019

Timothy Russell

Treasurer
2018 - 2019

Dale Jiang

Secretary
2018 - 2019

Faculty Members in Polymers, and Composites

Dr. William Jordan

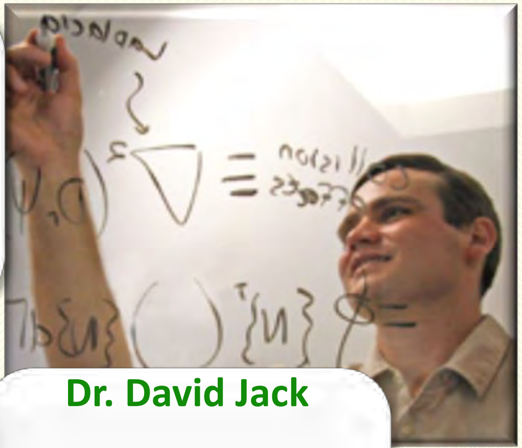
Professor and Chair of Mechanical Engineering

Dr. Douglas E. Smith

Associate Professor of Mechanical Engineering

Dr. Sunghwan Lee

Assistant Professor of Mechanical Engineering



Dr. David Jack

Associate Professor of Mechanical Engineering

Dr. Alex Yokochi

Professor of Mechanical Engineering

Student Members

- 25 current members
- 1 Post Doc
- 1 Facility Advisor
- 15+ Alumni

SPE Chapter and Member Awards

- Evan Wang received 1st place in the Graduate Student Poster Competition at the 2017 SPE-ACCE meeting
- Ben Blandford received the ACCE scholarship award in 2017.
- Ben Blandford also received the Harold Giles Award winner in 2017.
- Evan Wang received travel award for ANTEC 2017.
- Evan Wang also won the scholarship award at the Polyolefins conference 2018.

Evan Wang

Ben Blandford

Best Faculty Advisor – Baylor

Dr. David Jack won the best faculty advisor award among all the student organization advisors at Baylor.

SPE Outstanding Student Chapter

- The Outstanding Student Chapter of the Year award seeks to recognize the top student SPE chapters each year that have demonstrated true excellence in the proliferation of plastics engineering education.
- Baylor's SPE chapter received 2nd place for SPE Outstanding Student Chapter of the Year Award (out of all SPE student organizations). Baylor's SPE chapter was placed as top three SPE student organizations every year since formation - 2018.

Monthly Guest Speakers

Society of Plastics Engineers (SPE) Meeting

Come join SPE as we host Dr. David Jack, Baylor Mechanical Engineering professor. He will be discussing an overview of materials research at Baylor University and the department of Mechanical Engineering with Hands on demonstrations.

Thursday, Sep 14th

6:30 p.m.

Rogers 106

FREE PIZZA and SODA

Society of Plastics Engineers (SPE) Meeting

Come join SPE as we host Mr. Don Roberts, from Lockheed Martin. He will be discussing some of his experience in Aeronautics and helping students to navigate in getting hired at Lockheed Martin.

Thursday, Oct 16th

6:30 p.m.

Rogers 109

FREE PIZZA and SODA

Society of Plastics Engineers (SPE) Meeting

Come join SPE as we host Dr. Valerie Thomas, from Georgia Tech University as she will be discussing on “Plastics: The immense, Eternal Footprint Humanity Leaves on Earth”.

Plastics: The Immense, Eternal Footprint Humanity Leaves on Earth

Dr. Valerie Thomas

Plastics have been in the news, and the news is not positive. The talk title is a quotation from a newspaper headline from July 2017, reporting on a widely cited study. Moreover, recycling rates are low, and it's not always clear that recycling plastics is beneficial. The talk will draw on recent research, assessments, and publications to provide an eclectic overview of costs, benefits, and challenges of recycling and managing plastics.

Valerie Thomas is the Anderson Interface Professor of Natural Systems at the Georgia Institute of Technology, with appointments in the School of Industrial and Systems Engineering and in the School of Public Policy.

FREE PIZZA!

Thursday, Nov 16th

6:30 p.m.

Rogers 106

FREE PIZZA and SODA

Society of Plastics Engineers (SPE) Meeting

SPE will be hosting Jennifer Latiolais this Thursday for a presentation on Injection Molding with an emphasis on Scientific Molding.

ALL-PLASTICS

Thursday, January 25th

6:30 p.m.

Rogers 106

FREE PIZZA and SODA

Society of Plastics Engineers (SPE) Meeting

SPE will be hosting Rick Pardun from L3 communcations also the co founder of Maker's Edge Makerspace this Thursday for a presentation on Plastics in Aircraft interiors and how learning different processes can be an edge in job search.

Thursday, February 20th

6:30 p.m.

Rogers 207

FREE PIZZA and SODA

Society of Plastics Engineers (SPE) Meeting

SPE will be hosting Kelsi Mcghee from L3 this Thursday. She will be discussing her experience in Munitions Directorate of the Air Force Research Lab doing weapons engineering (design/test) and on a weaponized military aircraft project.

L3 Technologies

Tuesday, March 20th

6:30 p.m.

Rogers 106

FREE PIZZA and SODA

Society of Plastics Engineers (SPE) Meeting

SPE will be hosting Dr. Alex Yokochi this Thursday for a presentation on advanced materials and energy solutions.

Thursday, April 19th

6:30 p.m.

Rogers 106

FREE PIZZA and SODA

Facility Tours and Equipment Demonstrations

Site Visit – All Plastics

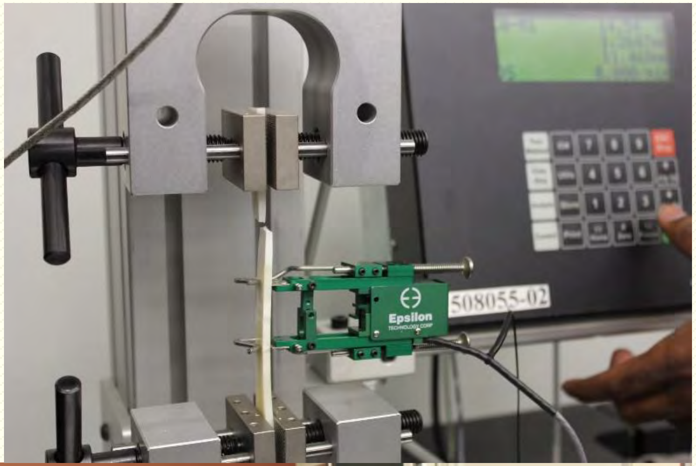
- All Plastics has their corporate office and a manufacturing plant in Dallas and San Antonio, Texas. They are involved in Pharmaceuticals, Industrial, Medical, packaging and consumer products.
- Students were able to tour the facility and see injection molding, automation, scientific molding as well as the product testing.

Site Visit – Exxon Mobil

- ExxonMobil's state-of-the-art campus north of Houston serves as home to its Upstream, Downstream, Chemicals and XTO Energy companies and their associated service groups. The facility opened in 2014 and accommodates more than 10,000 employees and visitors.
- Students were able to tour their work area’s, talk to Industry experts as well as recruitment officers.

Injection Molding and Tensile Testing

- Students learned the mold flow index machine, injection molding machines and Tensile testing as a part of equipment demonstrations.



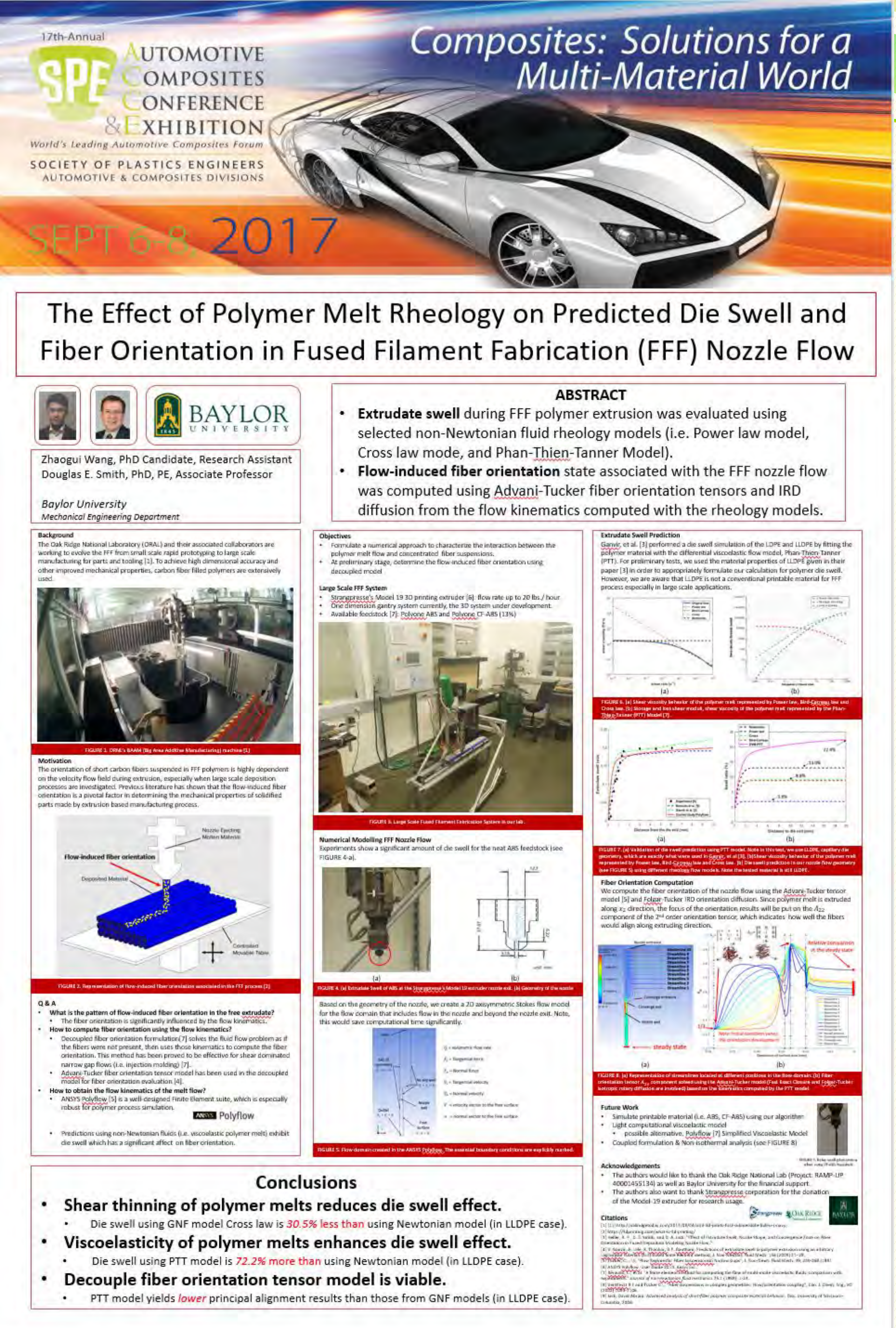
Student Posters and Presentations Given at SPE Conferences

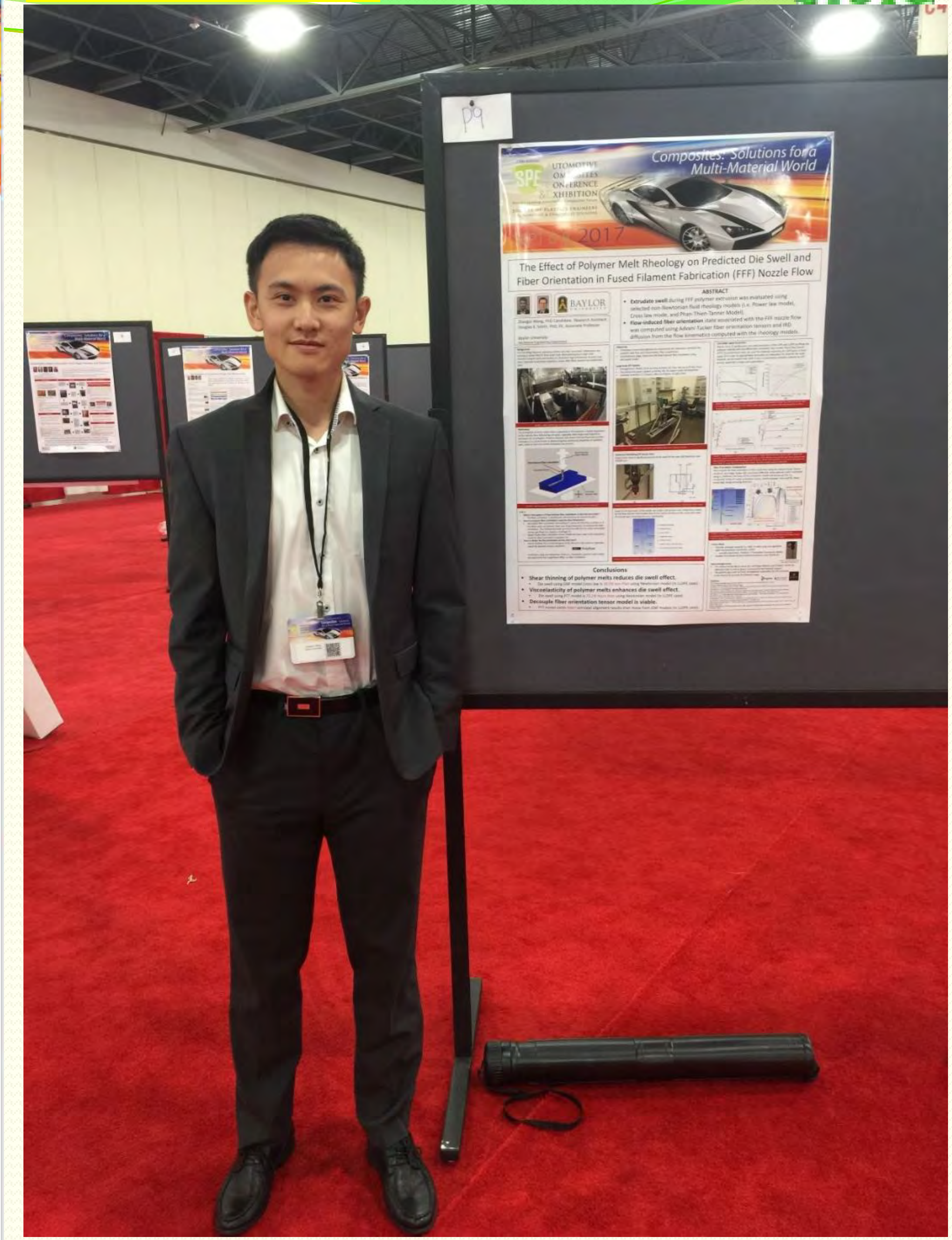
Conference Attendance – ACCE

- Students attended the Automotive Composites Conference and Exhibition in Novi, Michigan in the Fall of 2017. Students were able to interact with industry professionals and present their work.
- We had 7 poster presentations
- We had 2 podium presentations

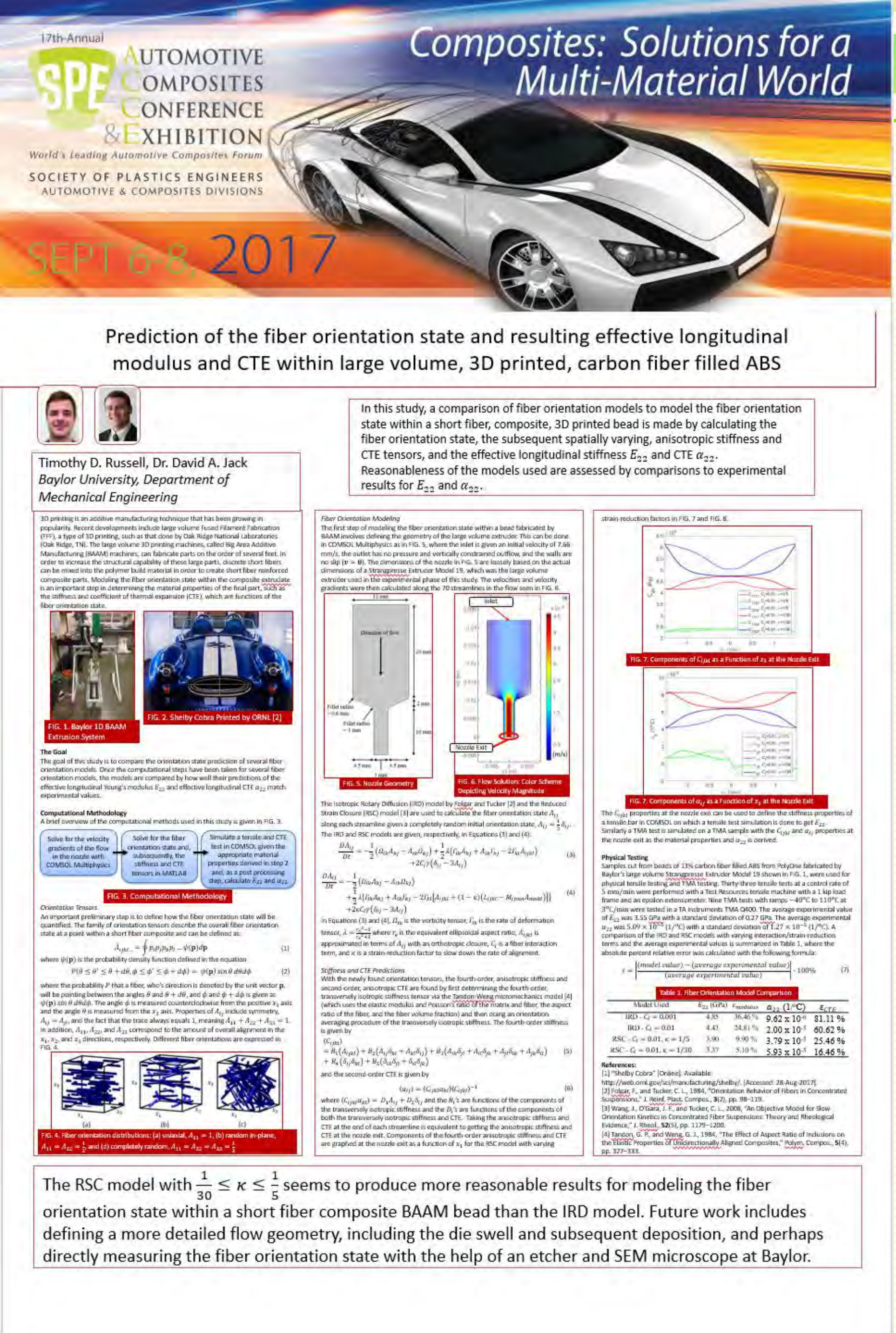
Evan Wang received 1st place in the graduate student poster competition

ACCE Poster


17th-Annual
SPE Automotive Composites Conference & Exhibition
World's Leading Automotive Composites Forum
SOCIETY OF PLASTICS ENGINEERS
AUTOMOTIVE & COMPOSITES DIVISIONS
Composites: Solutions for a Multi-Material World
SEPT 6-8, 2017
The Effect of Polymer Melt Rheology on Predicted Die Swell and Fiber Orientation in Fused Filament Fabrication (FFF) Nozzle Flow
BAYLOR UNIVERSITY
Zhaogui Wang, PhD Candidate, Research Assistant
Douglas E. Smith, PhD, PE, Associate Professor
Baylor University
Mechanical Engineering Department
ABSTRACT
Extrudate swell during FFF polymer extrusion was evaluated using selected non-Newtonian fluid rheology models (i.e. Power law model, Cross law mode, and Phan-Thien-Tanner Model).
Flow-induced fiber orientation state associated with the FFF nozzle flow was computed using Advani-Tucker fiber orientation tensors and IRD diffusion from the flow kinematics computed with the rheology models.
Background
Motivation
Objectives
Large Scale FFF System
Numerical Modelling FFF Nozzle Flow
Extrudate Swell Prediction
Fiber Orientation Computation
Q & A
Future Work
Acknowledgements
Citations
Conclusions
Shear thinning of polymer melts reduces die swell effect.
Die swell using GNF model Cross law is 30.5% less than using Newtonian model (in LLDPE case).
Viscoelasticity of polymer melts enhances die swell effect.
Die swell using PTT model is 72.2% more than using Newtonian model (in LLDPE case).
Decouple fiber orientation tensor model is viable.
PTT model yields lower principal alignment results than those from GNF models (in LLDPE case).



ACCE Poster


17th-Annual
SPE
AUTOMOTIVE
COMPOSITES
CONFERENCE
& EXHIBITION
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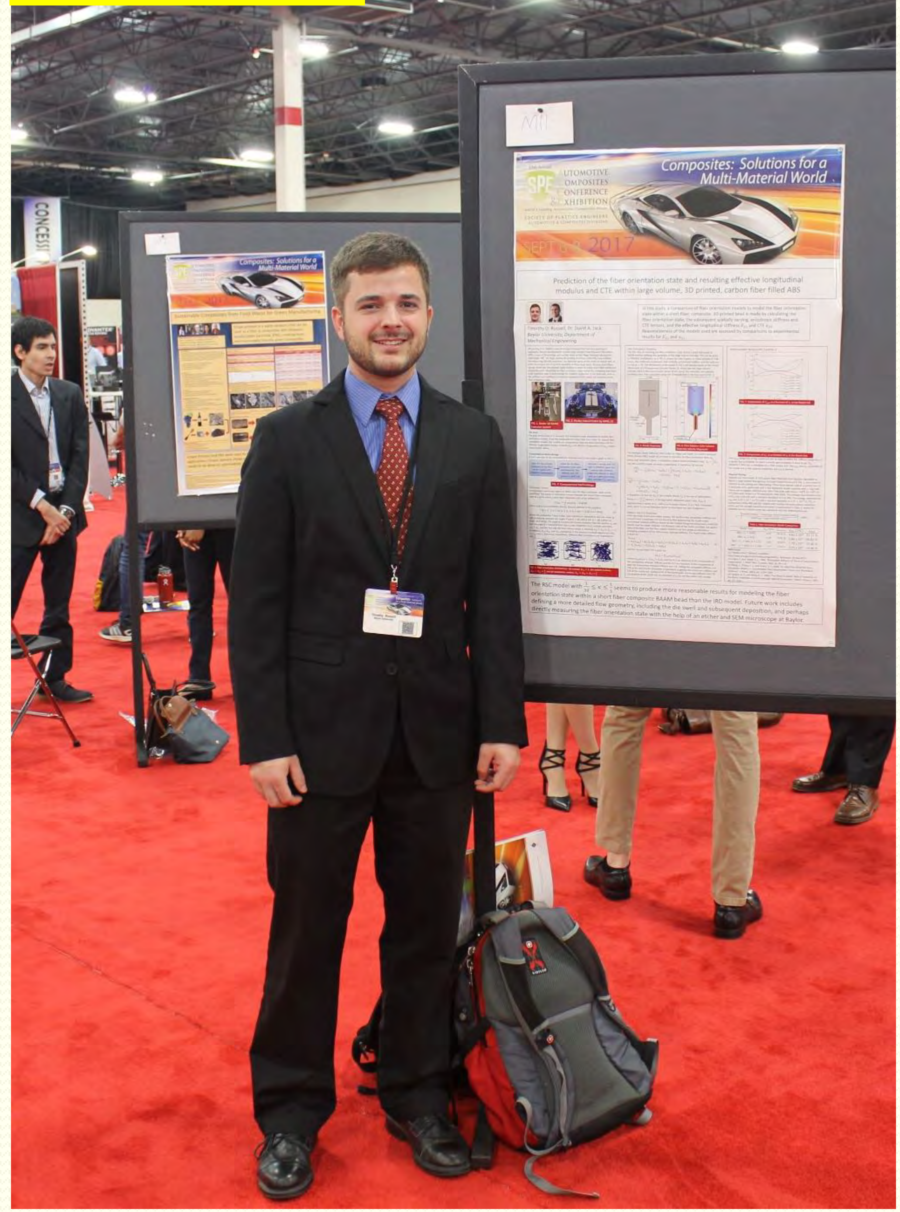
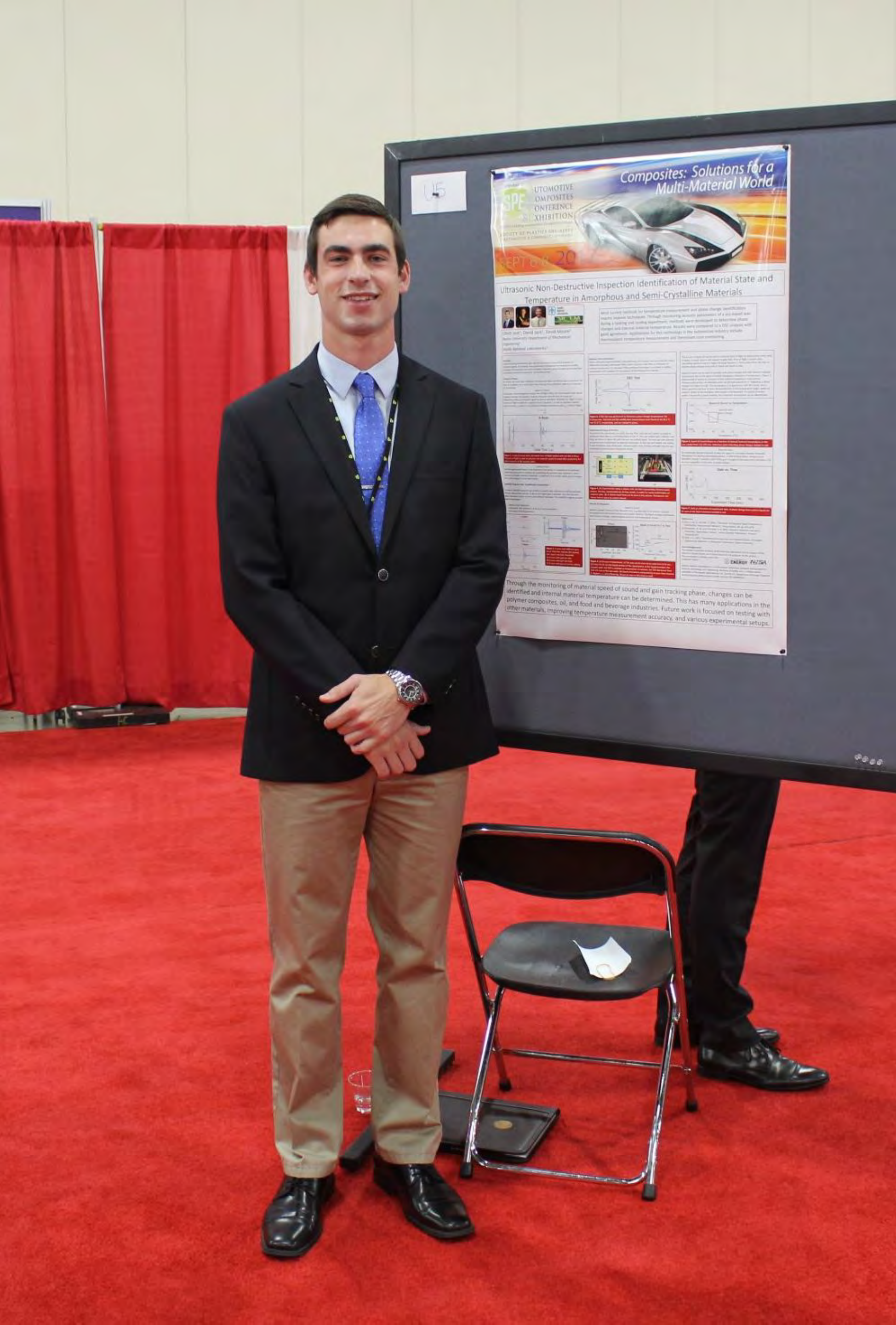
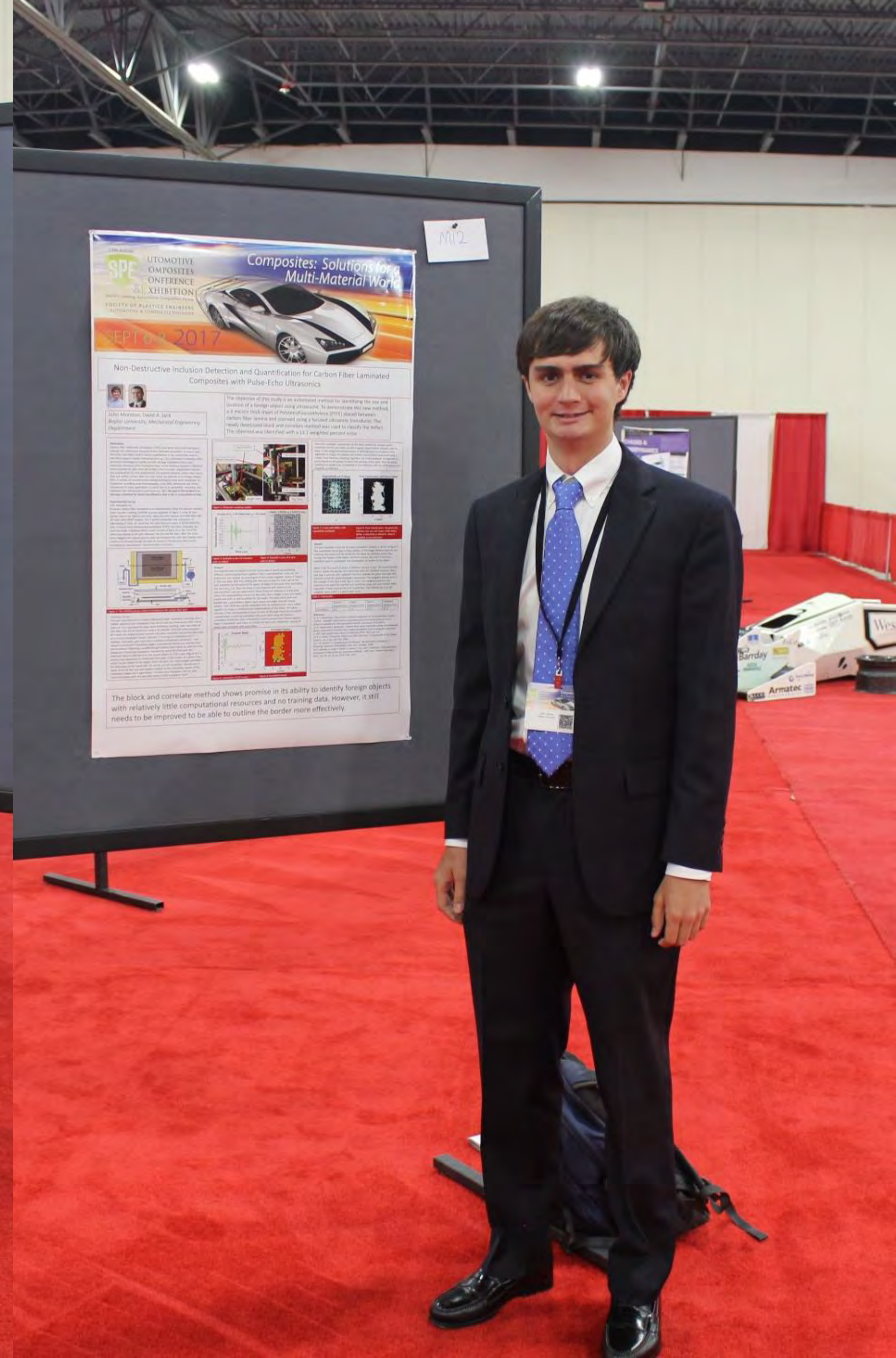
SOCIETY OF PLASTICS ENGINEERS
AUTOMOTIVE & COMPOSITES DIVISIONS
Composites: Solutions for a Multi-Material World
SEPT 6-8, 2017
Prediction of the fiber orientation state and resulting effective longitudinal modulus and CTE within large volume, 3D printed, carbon fiber filled ABS
Timothy D. Russell, Dr. David A. Jack
Baylor University, Department of Mechanical Engineering
In this study, a comparison of fiber orientation models to model the fiber orientation state within a short fiber, composite, 3D printed bead is made by calculating the fiber orientation state, the subsequent spatially varying, anisotropic stiffness and CTE tensors, and the effective longitudinal stiffness E_{22} and CTE α_{22}. Reasonableness of the models used are assessed by comparisons to experimental results for E_{22} and α_{22}.
FIG. 1. Baylor 1D BAAM Extrusion System
FIG. 2. Shelby Cobra Printed by ORNL [2]
FIG. 3. Computational Methodology
FIG. 5. Nozzle Geometry
FIG. 6. Flow Solution: Color Scheme Depicting Velocity Magnitude
FIG. 7. Components of C_{ijkl} as a Function of x_1 at the Nozzle Exit
FIG. 7. Components of α_{ij} as a Function of x_1 at the Nozzle Exit
Table 1. Fiber Orientation Model Comparison
The RSC model with $\frac{1}{30} \leq \kappa \leq \frac{1}{5}$ seems to produce more reasonable results for modeling the fiber orientation state within a short fiber composite BAAM bead than the IRD model. Future work includes defining a more detailed flow geometry, including the die swell and subsequent deposition, and perhaps directly measuring the fiber orientation state with the help of an etcher and SEM microscope at Baylor.





Composites: Solutions for a Multi-Material World
Ultrasonic Non-Destructive Inspection Identification of Material State and Temperature in Amorphous and Semi-Crystalline Materials
Through the monitoring of material speed of sound and gain tracking phase, changes can be identified and internal material temperature can be determined. This has many applications in the polymer composites, oil, and food and beverage industries. Future work is focused on testing with other materials, improving temperature measurement accuracy, and various experimental setups.



Composites: Solutions for a Multi-Material World
SEPT 6-8 2017
Non-Destructive Inclusion Detection and Quantification for Carbon Fiber Laminated Composites with Pulse-Echo Ultrasonics
The block and correlate method shows promise in its ability to identify foreign objects with relatively little computational resources and no training data. However, it still needs to be improved to be able to outline the border more effectively.

ACCE Poster

Implementation of LVDT to Decrease Time Associated with Ultrasonic Scans of Carbon Fiber Composites

L3 communications

SIC'EM

Nathaniel Blackman, M.S. (expected 2019)
Dr. David Jack (advisor)
Baylor University, Mechanical Engineering

ABSTRACT: Using a LVDT to track linear positioning, scan times associated with traditional C-scanning techniques can be dramatically reduced.

Objective

The current c-scanning techniques used to further research in the non-destructive testing (NDT) of carbon fiber composites often require large amounts of time, slowing the ability of researchers to make significant progress. Scan times used to find small defects and inclusions over a large area, or to identify the ply orientation of complex weaves can take a prohibitively long time. This high time-cost can make large and high-precision NDT scans prohibitive, and makes the furthering of research difficult. Such time-costs also make these advanced applications with ultrasonic scanning less appealing to those in industry. An example of the process used in NDT research can be seen in Figure 1.

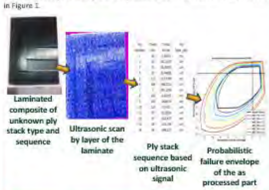


Figure 1: Example of Ultrasonic NDT

Formerly, in order to ensure that a scan was taken at the correct point, the motor would stop at each individual location to be scanned. A goal was set to allow the motor to move continuously through all locations to be included in a b-scan, and correctly scan when the ultrasonic transducer passed over each location to be included in the scan.

Methodology

1. The ultrasound c-scan system, did not initially have any methods installed that allowed the motors to move while tracking their position. First a rotary encoder was installed on the X2 axis to track positioning.

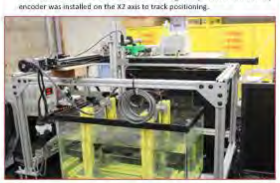


Figure 2: Scanning setup

2. After installing the rotary encoder, the software used for c-scanning was changed to read the digital outputs of the encoder. After testing, it was found that noise and the encoder's resolution created significant problems with use of the encoder.

Figure 3: Rotary Encoder initially used to track position

3. While a decrease in the time of scans was achieved, the encoder was found to be unpredictable.
4. A linear variable differential transformer, LVDT, was installed on the X2 axis to track positioning.

Figure 4: Spring-assisted LVDT mounted to X2 axis

5. The LVDT was calibrated, and using a linear regression in MATLAB a relationship was established between changes in voltage and steps taken by the motor.
6. The software was changed to read the voltage output of the LVDT and fire when the voltage change corresponded to the desired change in steps.
7. Results of the scans were compared to those of scans taken with the old point by point logic.
8. Data was taken to identify the max speed the X2 motor can be operated while accurately tracking positioning.
9. Using the knowledge gained, a LVDT was installed on a portable scanner, see figure 7, to increase scans of composites that need to be scanned without using an immersion setup.

Results

1. Several successful c-scans have been taken using the LVDT and continuous scanning method, and data from continuous scans and scans taken with the old software have been compared to determine the continuous scanning works. Figures 5 and 6 compare a b-scan at the same location for each scanning method, and Figures 7 and 8 compare a c-scan image the same depth into the part.

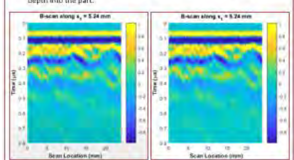


Figure 5: B-Scan Continuous Scan | Figure 6: B-Scan point by point Scan

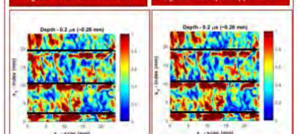


Figure 7: C-Scan Continuous Scan | Figure 8: C-scan point-by-point scan

2. Using the current LABVIEW software, the motor being tracked by the LVDT can be run at speeds up to 49 times greater than the step size per increment for the motor.
3. As shown in Table 1, the scanning software takes 20% of the scan time for the standard scan used to determine ply detection of carbon fiber composites. The new scanning method has been found to take as little as 10% of the time of highly intensive scans when run at max speed.

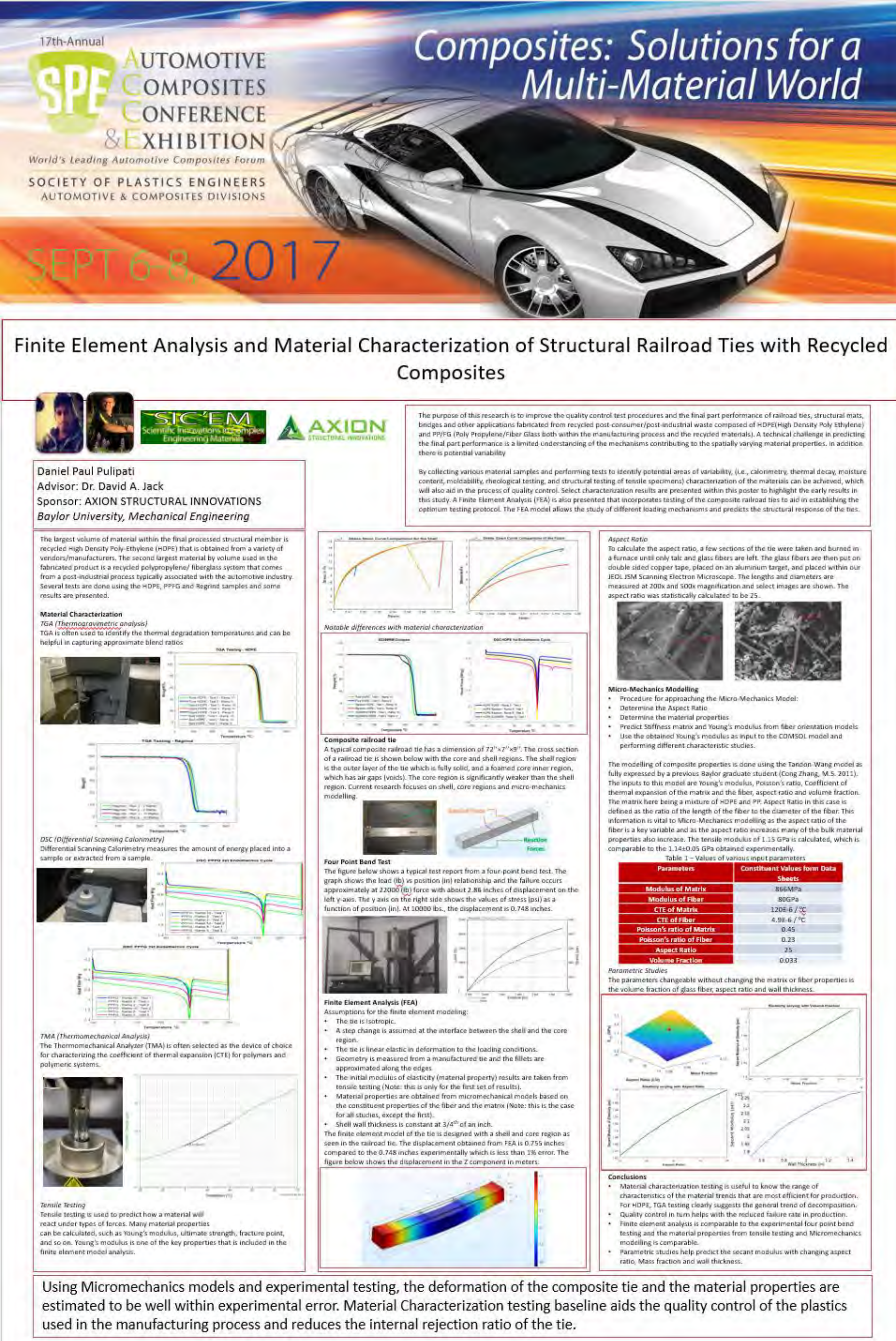
Table 1: Standard Ply Detection Scan Times

	Point-by-Point Scan	Continuous Scan
Time to Scan	6350.4 seconds	1264.32 seconds

Acknowledgements
I would like to thank my advisor Dr. Jack for his guidance and help. I would also like to thank Mr. Ben Blandford for his help in installing and calibrating the LVDTs. Finally, I would like to thank L-3 Communications and Baylor University for their support.

By using a LVDT to track the motion of the ultrasonic transducer during a c-scan, an accurate and fast c-scanning method was developed. This method of scanning consistently saves 80% to 90% of the time required using older scanning techniques, and is being used to further ultrasonic NDT research on carbon fiber composites.

ACCE Poster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SOCIETY OF PLASTICS ENGINEERS
AUTOMOTIVE & COMPOSITES DIVISIONS
Composites: Solutions for a Multi-Material World
SEPT 6-8, 2017
Finite Element Analysis and Material Characterization of Structural Railroad Ties with Recycled Composites
AXION STRUCTURAL INNOVATIONS
Daniel Paul Pulipati
Advisor: Dr. David A. Jack
Sponsor: AXION STRUCTURAL INNOVATIONS
Baylor University, Mechanical Engineering
The purpose of this research is to improve the quality control test procedures and the final part performance of railroad ties, structural mats, bridges and other applications fabricated from recycled post-consumer/post-industrial waste composed of HDPE(High Density Poly Ethylene) and PP/FG (Poly Propylene/Fiber Glass both within the manufacturing process and the recycled materials). A technical challenge in predicting the final part performance is a limited understanding of the mechanisms contributing to the spatially varying material properties. In addition there is potential variability
By collecting various material samples and performing tests to identify potential areas of variability, (i.e., calorimetry, thermal decay, moisture content, moldability, rheological testing, and structural testing of tensile specimens) characterization of the materials can be achieved, which will also aid in the process of quality control. Select characterization results are presented within this poster to highlight the early results in this study. A Finite Element Analysis (FEA) is also presented that incorporates testing of the composite railroad ties to aid in establishing the optimum testing protocol. The FEA model allows the study of different loading mechanisms and predicts the structural response of the ties.
The largest volume of material within the final processed structural member is recycled High Density Poly-Ethylene (HDPE) that is obtained from a variety of vendors/manufacturers. The second largest material by volume used in the fabricated product is a recycled polypropylene/ fiberglass system that comes from a post-industrial process typically associated with the automotive industry. Several tests are done using the HDPE, PPFG and Regrind samples and some results are presented.
Material Characterization
TGA (Thermogravimetric analysis)
TGA is often used to identify the thermal degradation temperatures and can be helpful in capturing approximate blend ratios
Aspect Ratio
To calculate the aspect ratio, a few sections of the tie were taken and burned in a furnace until only talc and glass fibers are left. The glass fibers are then put on double sided copper tape, placed on an aluminum target, and placed within our JEOL JSM Scanning Electron Microscope. The lengths and diameters are measured at 200x and 500x magnification and select images are shown. The aspect ratio was statistically calculated to be 25.
Conclusions
Material characterization testing is useful to know the range of characteristics of the material trends that are most efficient for production. For HDPE, TGA testing clearly suggests the general trend of decomposition.
Quality control in turn helps with the reduced failure rate in production.
Finite element analysis is comparable to the experimental four point bend testing and the material properties from tensile testing and Micromechanics modelling is comparable.
Parametric studies help predict the secant modulus with changing aspect ratio, Mass fraction and wall thickness.
Using Micromechanics models and experimental testing, the deformation of the composite tie and the material properties are estimated to be well within experimental error. Material Characterization testing baseline aids the quality control of the plastics used in the manufacturing process and reduces the internal rejection ratio of the tie.

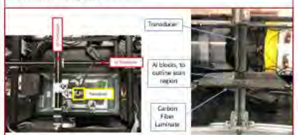
ACCE Poster

Determining Ply Orientation for Unidirectional Carbon Fiber Laminated Composites Utilizing an Ultrasonic Technique

Author: Benjamin Blandford
Advisor: Dr. David A. Jack
Sponsor: L3 Technologies
Baylor University, Mechanical Engineering

Carbon fiber composites are used extensively in the automotive industry, and have found popular use in the aerospace and athletic industries. However, due to the nature of carbon fiber manufacturing it is often not economical, and sometimes incorrect to use traditional destructive testing techniques. Destructive techniques are costly as they often ruin the finial component. To aid in the desire to prevent the destruction of the composite component being investigated, non-destructive testing techniques may be employed. This research uses a custom pulse-echo ultrasonic transducer and immersion system to scan and collect data from in-house fabricated unidirectional carbon fiber laminated composites. The unidirectional fabric used in this research contains a small weft fiber that runs perpendicular to the carbon fibers. The weft fiber makes fabrication easier, and does not provide structural support. Scanning and data collection is performed with an in house LabView code and data is post processed with a custom MATLAB code. Ply orientation is determined based off detecting the weft fibers using the peak signal information within a selected gate in the associated c-scan and recognizing that the weft fiber and carbon fiber are perpendicular to one another. Results presented show that ply orientation can be accurately predicted for the investigated unidirectional carbon fiber composites that incorporate a weft fiber perpendicular to the carbon fibers.

Scanning set up:
A Ultratek pulser/receiver is used in a pulse/echo configuration with a sampling rate of 160MHz. Various transducers are used in this research and include a 5MHz, 10MHz, 15MHz, and a 25MHz. A Velmex translation system is used to traverse the ultrasonic transducer. The scanning (X2) direction uses a coarse thread screw (200 steps/mm) and the index (X1) direction uses a finer screw (800 steps/mm). LabView is used to translate the transducer and capture the scan data.



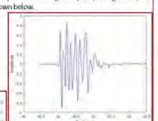
Part is placed inside a water tank on a custom built, adjustable, leveling stand. This ensures the scan region is in focus with the transducer.

Composite Fabrication:
Uni-directional composites are fabricated in house using 9oz. carbon fiber from Soller Composites with Proset INF-114 resin and Proset INF-221 hardener. A wet layup technique is used for fabrication. After the laminates are stacked on the aluminum tooling – with a generous about of resin – vacuum bagging is secured around the part and vacuum is pulled to remove the excess resin. The parts are cured in a furnace for 12 hours. This specific uni-directional carbon fiber contains a weft fiber. The weft fiber does not provide and mechanical improvements to the carbon fiber. The weft fiber is there to hold the individual carbon fibers in place to allow for easier manufacturing.
A total of (2) uni-directional parts were fabricated for this study. Both parts had 9 layers and they had identical sequencing. The only difference is one was manufactured with the weft fiber facing the tool side of the fabrication plate and the other part was fabricated with the weft fiber facing the bag side. Below are images of both parts. The sequencing for each part is as follows (in degrees off of X1) 0-30-45-60-90-60-45-30-0.

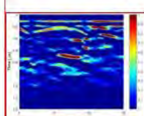
The composite on the left (Part A) was fabricated with weft fiber against tool. The right composite (Part B) was fabricated with the weft fiber against the bagging.

This image points out the weft fiber and the carbon fiber angle θ_F.

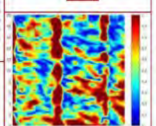
Scanning Procedure:
In house LabView code with Distance Amplitude Correction is used to control Velmex stepper motors, and fire the ultrasonic transducer. Our software is a continuous scanning system that does not have to stop to collect an A-scan (the system moves continuously in the scanning direction until the user defined limit is reached). A-scans are collected over the entire scan region. This research used scanning regions ranging from 15mm X 15mm to 20mm X 20mm. The A-scans are compiled to form a B-scan, which shows the cross section of the carbon fiber composite while you move in a specific direction(i.e the X1 cross section as you move through X2). C-scans are also developed and show the planar surface as you move though the part (through time). A sample A-scan, B-scan, and C scan are shown below.



A-Scan



B-Scan

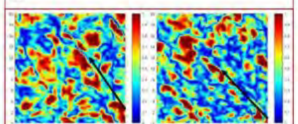


C-Scan: Fist layer of Part A (90° weft fiber, 0° CF)

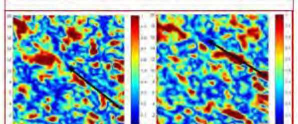
Analysis Techniques
Woven carbon fiber composites have very small height difference due to the nature of a weave. These height differences allow for visual interpretation of C-scans to determine ply orientation. Because uni-direction carbon fiber composites are flatter in plane, another technique must be used. The weft fiber runs perpendicular to the carbon fibers. There is a height difference between the weft fiber and carbon fiber as well as a material difference. Detecting the weft fiber allows us to determine ply orientation. Below is an A-scan that shows the 4 analysis techniques.

Four analysis techniques are used: maximum value, minimum value, absolute maximum value, and an absolute value integral average. The integral average is the sum of the absolute value within the shaded region divided by the distance between the two vertical dotted lines. This distance is the length of the gate, which is a time.

Results
Based on the results thus far we are able to identify the first, second, third, forth, and sixth layers. There is difficulty in identifying the middle (fifth layer) as well as the last three layers. Below are C-scans of the second, third, forth, and sixth layers. The results presented were obtained by using a 15MHz transducer and the absolute max analysis technique. In the four figures below, the black arrows point in the direction of the weft fiber.



The image on the left is the second layer of Part A (-60° weft fiber, 30° CF) and the image on the right is the third layer (-45° weft fiber, 45° CF) of Part A.

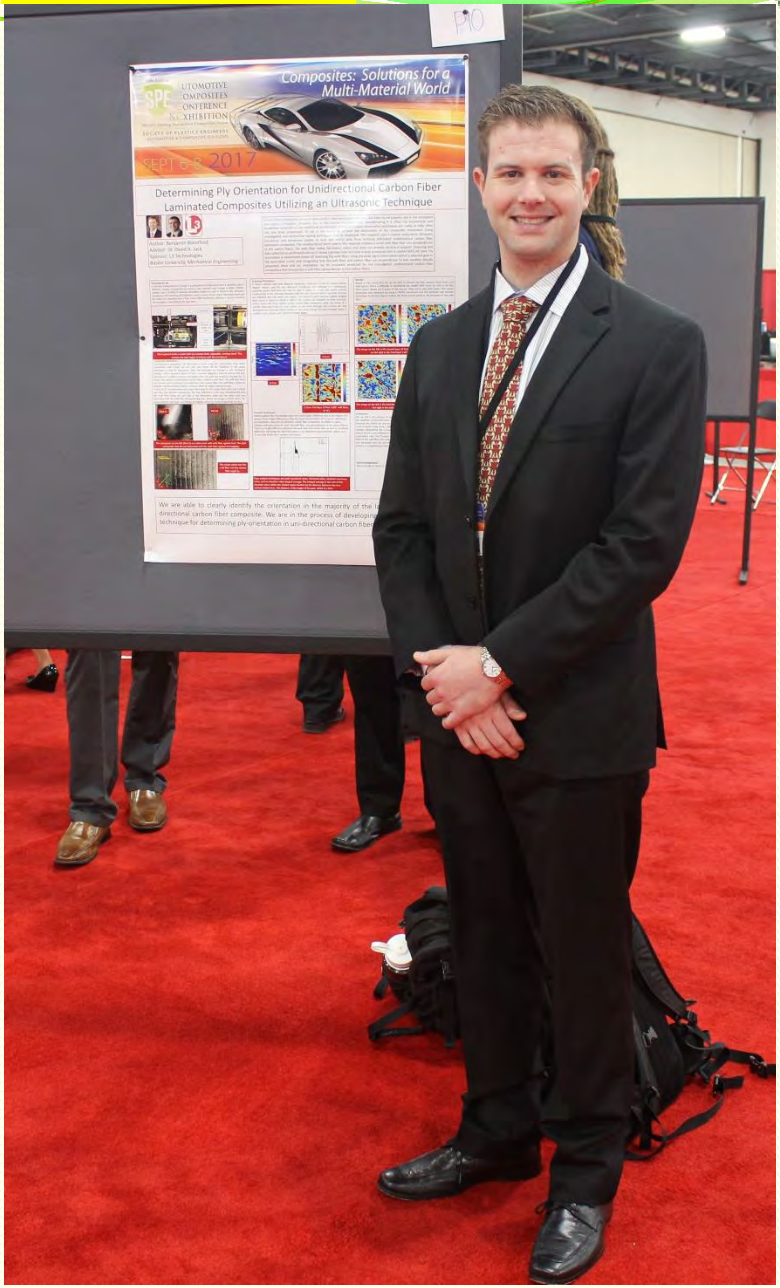


The image on the left is the forth layer of Part A (-30° weft fiber, 60° CF) and the image on the right is the sixth layer (-30° weft fiber, 60° CF) of Part A.

Conclusion
We are still in the process of modifying the MATLAB code to more precisely determine the direction of the weft fiber. Only the 15MHz transducer results are presented here, however the 5MHz has proven to be produce decent results. The next step includes a more in depth study using a 5MHz transducer. The long term goal is to move away from visually interpreting the C-scan data to obtain the ply-orientation. Results have also shown that it is very difficult to detect repeat layers, that are not separated by a different orientation. Also, Part B tends to have small voids on the surface of the part, on either sides of the weft fiber; this makes it difficult to get good scans. Part A, the composite that was fabricated with the weft fiber against the bag, not only produces a much smoother surface, it is hypothesized that it yields much cleaner results.

Acknowledgements
We would like to thank L3 Technologies for their continual support.

We are able to clearly identify the orientation in the majority of the layers for a 9 layer uni-directional carbon fiber composite. We are in the process of developing a more robust analysis technique for determining ply-orientation in uni-directional carbon fiber composites.



ACCE Podium Presentation

The Applicability of Simplified Viscoelastic Fluid Model to Predict Extrudate Swell and Fiber Orientation in Fused Filament Fabrication Nozzle Flow

Zhaogui Wang
PhD Candidate, Research Assistant
Mechanical Engineering, Baylor University
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Douglas E. Smith, PhD, PE
Associate Professor, Graduate Program Director
Mechanical Engineering, Baylor University
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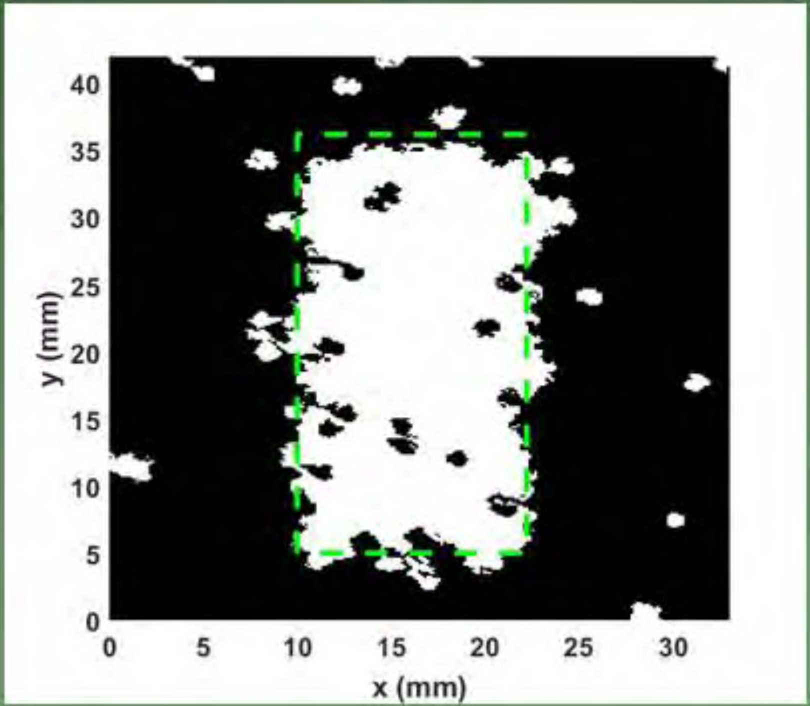
ACCE Podium Presentation

Non-Destructive Inclusion Detection and Quantification For Carbon Fiber Laminated Composites with Pulse Echo Ultrasonics



John Moreton, Master's Candidate

David A. Jack, Associate Professor

Given at the 2017 SPE ACCE Meeting, September 6, 2017

BAYLOR UNIVERSITY

L3 communications

Conference Attendance – Polyolefins

- We attended our Polyolefins conference 2018 in Houston, Texas.
- We had 5 students attend and help with the conference.

International Polyolefins Conference 2018

PREDICTION OF FIBER ORIENTATION STATE AND RESULTANT EFFECTIVE STRUCTURAL AND THERMAL PROPERTIES OF FIBER REINFORCED ADDITIVE MANUFACTURED COMPOSITES FABRICATED USING THE BIG AREA ADDITIVE MANUFACTURING PROCESS

PhD Student: Timothy Russell
Advisor: Dr. David Jack
Department of Mechanical Engineering
Baylor University, Waco, TX

ABSTRACT:
In this study, effective longitudinal stiffness E_1 and coefficient of thermal expansion α_1 are predicted for a short fiber filled polymer bead fabricated with a Big Area Additive Manufacturing (BAAM) extruder. Predictions are dependent on the spatially varying fiber orientation state and the model used to calculate the orientation state. Properties of a carbon fiber filled ABS composite, 13% carbon fiber by weight, are predicted using the Isotropic Rotary Diffusion (IRD) [1] and Reduced Strain Closure (RSC) [2] fiber orientation models.

INTRODUCTION

Additive Manufacturing (AM) is a method of manufacturing that involves selectively adding material, usually in a layer-by-layer fashion, to build a complete part. AM has grown dramatically in popularity in recent years and current advances include large volume 3D printing machines such as the Big Area Additive Manufacturing (BAAM) machines developed at Oak Ridge National Laboratories, which can print parts on the order of several feet. Short fibers can be added to the polymer feedstock used by BAAM in order to improve the structural ability of large volume parts. Carbon fibers are of particular interest since they can increase stiffness and, due to their low coefficient of thermal expansion (CTE), decrease the effective CTE of the final part and the resultant warpage of the part as its layers start cooling at different times during fabrication.

GOAL

The goal of this study is to predict the Young's modulus and CTE in the printed direction of a large volume, 3D printed, short fiber filled polymer bead and assess the sensitivity of the predictions to changes in fiber orientation model parameters.

COMPUTATIONAL METHODOLOGY

An overview of the computational methodology is shown in Figure 1.

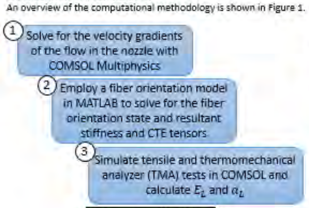


FIG. 1. Computational Methodology

STEP 1

COMSOL is used to simulate the polymer melt flowing through the 3D printer nozzle and onto a moving print bed. The velocity gradients along 61 streamlines are calculated and exported to text files to be used by MATLAB in Step 2. The COMSOL model used in this study is shown in Figure 2.

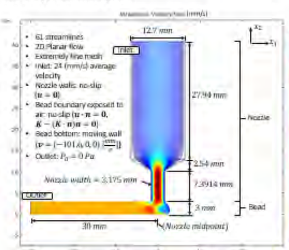


FIG. 2. COMSOL Multiphysics Modeling

STEP 2

The fiber orientation state is described in terms of orientation tensors. The second order orientation tensor is defined as

$$A_{ij} = \oint p_i p_j \psi(p)\, dp \tag{1}$$

where p is the unit vector and $\psi(p)$ is the probability density function. The diagonal components of A_{ij} describe the amount of fiber alignment in the x_1, x_2, and x_3 directions and sum up to unity. Examples of distributions are shown in Figure 3. The initial orientation state at the nozzle inlet is assumed to be perfectly random, i.e. $A_{ij} = \frac{1}{3}\delta_{ij}$. The IRD [1] and RSC [2] models are given by

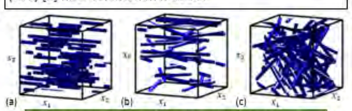


FIG. 3. Fiber orientation distributions: (a) uniaxial, $A_{11} = 1$, (b) random in plane, $A_{11} = A_{22} = \frac{1}{2}$ and (c) completely random, $A_{11} = A_{22} = A_{33} = \frac{1}{3}$

STEP 2 (CONTINUED)

Equations (2) and (3), respectively:

$$\frac{DA_{ij}}{Dt} = -\frac{1}{2}(\Omega_{ik}A_{kj} - A_{ik}\Omega_{kj}) + \frac{1}{2}\lambda(\Gamma_{ik}A_{kj} + A_{ik}\Gamma_{kj} - 2\Gamma_{kl}A_{ijkl}) + 2C_I\dot{\gamma}(\delta_{ij} - 3A_{ij}) \tag{2}$$

$$\frac{DA_{ij}}{Dt} = -\frac{1}{2}(\Omega_{ik}A_{kj} - A_{ik}\Omega_{kj}) + \frac{1}{2}\lambda\left(\Gamma_{ik}A_{kj} + A_{ik}\Gamma_{kj} - 2\Gamma_{kl}[A_{ijkl} + (1-\kappa)(L_{ijkl} - M_{ijmn}A_{mnkl})]\right) + 2\kappa C_I\dot{\gamma}(\delta_{ij} - 3A_{ij}) \tag{3}$$

The RSC model was invented to slow down the rate of alignment predicted by the IRD model by using a parameter $\kappa \leq 1$ to reduce the effects of strain. When $\kappa = 1$, the RSC model is equivalent to the IRD model.

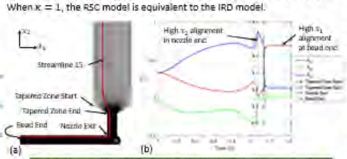


FIG. 4. (a) Streamline 15 highlighted in red. (b) Components of A_{ij} along streamline 15, predicted by the IRD model with $C_I = 0.01$.

STEP 2 (CONTINUED)

The homogenized stiffness and CTE tensors can be found as functions of the orientation tensors according to the following equations for stiffness (see, e.g. [3]) and CTE [4], respectively:

$$\langle C_{ijkl}\rangle = B_1(A_{ijkl}) + B_2(A_{ij}\delta_{kl} + A_{kl}\delta_{ij}) + B_3(A_{ik}\delta_{jl} + A_{il}\delta_{jk} + A_{jl}\delta_{ik} + A_{jk}\delta_{il}) + B_4(\delta_{ij}\delta_{kl}) + B_5(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}) \tag{4}$$

$$\langle \alpha_{ij}\rangle = \langle C_{ijkl}\alpha_{kl}\rangle\langle C_{ijkl}\rangle^{-1} \tag{5}$$

Components of the stiffness and CTE tensors can be plotted across a cross section of the flow domain as in Figures 5 and 6.

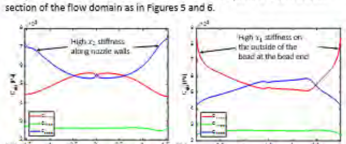


FIG. 5. Components of $\langle C_{ijkl}\rangle$ calculated with the RSC model with $C_I = 0.01$ and $\kappa = 1/30$ (a) as a function of x_1 at the nozzle exit, (b) as a function of x_2 at the bead end

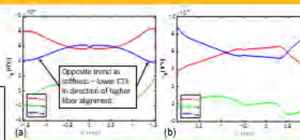


FIG. 6. Components of $\langle \alpha_{ij}\rangle$ calculated with the RSC model with $C_I = 0.01$ and $\kappa = 1/30$ (a) as a function of x_1 at the nozzle exit, (b) as a function of x_2 at the bead end

STEP 3

After Step 2 has been completed, the newly found stiffness tensors of the composite across the width of the bead at the bead end were used to define the stiffness properties of a tensile sample in COMSOL across the width of the tensile sample. Likewise, the stiffness and CTE tensors across the width of the bead at the bead end were used to define the stiffness and CTE properties of a TMA sample in COMSOL across the width of the TMA sample. Both samples had an initial width of 1.5 mm as if they were cut off the end of the bead in Figure 2. The boundary conditions for the samples are shown in Figure 7.

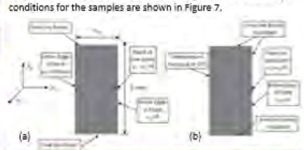


FIG. 7. COMSOL setup for (a) displacement-prescribed tensile test and (b) TMA test

STEP 3 (CONTINUED)

After the displacement-prescribed tensile test and the TMA test were simulated in COMSOL, the effective, longitudinal stiffness E_1 and CTE α_1 were calculated according to the equations

$$E_1 = \sigma_{11}/(u_1/w_0) \tag{6}$$

$$\alpha_1 = \frac{1}{w_0}\cdot\frac{dw}{dT} \tag{7}$$

Table 1 shows the results from several different fiber orientation model variations, the biggest difference happening when switching between the IRD and RSC models. The predictions are roughly in agreement with experimental results obtained by Duty *et al.* [5]

Table 1. Effective, Longitudinal Young's Modulus and CTE

	Model	C_I	κ	$E_1\,(GPa)$	$\alpha_1\,(1/^{\circ}C)\times 10^{-6}$
Deposited Bead – End	IRD	0.01	1	6.82	32.2
Deposited Bead – End	RSC	0.01	1/10	4.82	45.5
Deposited Bead – End	RSC	0.01	1/30	4.18	53.3
Deposited Bead – End	IRD	0.003	1	7.69	30.3
Deposited Bead – End	RSC	0.003	1/10	4.88	45.1
Deposited Bead – End	RSC	0.003	1/30	4.19	53.2
Nozzle Exit	IRD	0.01	1	7.10	31.3
Nozzle Exit	RSC	0.01	1/10	5.07	42.3
Nozzle Exit	RSC	0.01	1/30	4.40	49.5
Nozzle Exit	IRD	0.003	1	7.89	29.9
Nozzle Exit	RSC	0.003	1/10	5.20	41.7
Nozzle Exit	RSC	0.003	1/30	4.45	49.2

[1] Folgar, F., and Tucker, C. L., 1984, "Orientation Behavior of Fibers in Concentrated Suspensions," J. Reinf. Plast. Compos., 3(2), pp. 98–119.
[2] Wang, J., O'Gara, J. F., and Tucker, C. L., 2008, "An Objective Model for Slow Orientation Kinetics in Concentrated Fiber Suspensions: Theory and Rheological Evidence," J. Rheol., 52(5), pp. 1179–1200.
[3] Advani, S. G., and Tucker, C. L., 1987, "The Use of Tensors to Describe and Predict Fiber Orientation in Short Fiber Composites," J. Rheol., 31(8), pp. 751–784.
[4] Camacho, C. W., Tucker, C. L., Yalvaç, S., and McGee, R. L., 1990, "Stiffness and Thermal Expansion Predictions for Hybrid Short Fiber Composites," Polym. Compos., 11(4), pp. 229–239.
[5] Duty, C. E., Kunc, V., Compton, B., Post, B., Erdman, D., Smith, R., Lind, R., Lloyd, P., and Love, L., 2017, "Structure and Mechanical Behavior of Big Area Additive Manufacturing (BAAM) Materials," Rapid Prototyp. J., 23(1), pp. 181–189.

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International Polyolefins Conference 2018

MICRO-MECHANICS MODELING AND MODEL VALIDATION FOR COMPOSITE RAILROAD TIES MADE FROM RECYCLED POLYOLEFINS

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Advisor: Dr. David Jack
Department of Mechanical Engineering
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INTRODUCTION

Since the use of railroads in the US began, hardwood timbers were the primary choice of material for the crossties [1]. Wooden crossties have a short lifespan and have to be replaced often due to environmental exposure. To increase the lifespan of the crossties, preservatives such as creosote are used. Creosote being a hazard, causes skin rashes, lung cancer and various health related issues along with contaminating ground water and affecting plant life [1]. Therefore, various materials such as concrete, steel, and synthetic fiber reinforced composites have been studied as an alternative to wooden ties [2].

The primary focus of this research is related to the use of recycled polyolefins with fiber reinforcement manufactured with blow molding techniques to make crossties. HDPE and reinforced GFPP is used along with blowing agents and carbon black to make a crosstie. The blowing agent is activated under increasing temperature and pressure, which expands and leaves cells (air bubbles) in the core region as shown in Figure 1. The resulting product has a shell region that is nearly solid with few open cells and a foamed core region which contains cells.

FIG. 1. Cross-section of the tie showing shell and foamed region

Polyolefins are widely used in many household and industrial applications. As shown in Figure 2, in 2015, HDPE accounts to 12.1% and PP to 18.8% of all the plastics manufactured. Therefore, recycled HDPE and PP is abundantly available.

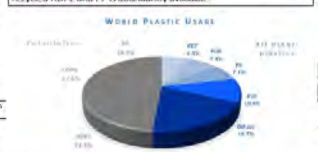

FIG. 2 Polyolefins account for 48.5% of plastics used [3]

GOAL

The goal of this study is to predict the Young's modulus using micromechanics models and homogenization methods for the shell and the foamed region. The predicted modulus will be used to validate four point bend test setup to a simulation using COMSOL.

An overview of the computational methodology is shown in Figure 3. The micro mechanics modeling and young's modulus calculations is outlined by the green boxes. The results are used in the COMSOL FEA model shown in the black text.

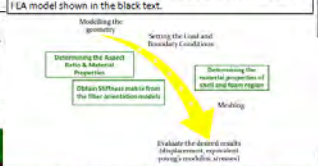

FIG. 3 Modeling (green) and FEA model using COMSOL

ABSTRACT:
The purpose of this research is to model the deflection behavior of railroad ties fabricated from recycled polyolefin post-consumer/post-industrial waste composed of HDPE (High Density Poly Ethylene) and GFPP (Glass Fiber Polypropylene). A technical challenge in predicting the final part performance is a limited understanding of the impact of microstructural variations due to processing variability on the final produced part's spatially varying material properties. The ties fabricated using extrusion molding techniques have a solid shell region on the outer surface and an inner foamed core. The foamed core region has cells of differing dimensions and the resulting effective material properties will vary as a function of the cell size and density. The shell and the foamed core regions are analyzed using micromechanics models for the prediction of the stiffness. The stiffness of the foamed core is calculated using the Monte Carlo method to investigate the macroscopic sensitivity to microstructural variations. The elastic moduli obtained from micromechanics is used for the shell and foam regions in a Finite Element model, and the computational results are compared to those obtained from experimental four point bend test results with a difference between the model and experiment being less than 2% for the predicted effective stiffness.

MODEL THE GEOMETRY

The dimensions of the tie are measured to be 0.2286 m × 0.1778 m × 1.8288 m (9" × 7" × 72"). A model was created in COMSOL, with a shell region on the outside and an inner region with the core as shown in Figure 4.

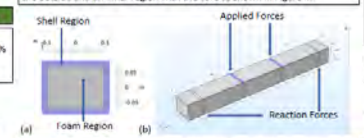

FIG. 4 (a) Cross-section (b) Tie geometry with prescribed forces

MATERIAL PROPERTIES AND ASPECT RATIO

Table 1. Material Properties [4]

Parameters	Constituent Values from Data Sheets
Modulus of Matrix	870 MPa
Modulus of Fiber	80 GPa
Poisson's ratio of Matrix	0.45
Poisson's ratio of Fiber	0.23
Aspect Ratio	25
Volume Fraction of Fiber	3.33%

ASPECT RATIO (A_R)

Sections of a tie are cut from the shell region. The pieces are put in a furnace and the tie sections are burned until only glass fibers and residue are left. The fibers and residue are put into a Scanning Electron Microscope and multiple measurements of the fibers are taken. A_R was measured to be 25. The effect of A_R for unidirectional properties is shown in Figure 5.b.

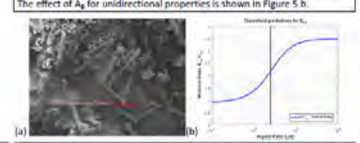

FIG. 5 (a) Glass Fiber measurement example (b) Effect of Aspect Ratio

MODELLING FOR SHELL AND FOAM MODULUS

Using the material properties and aspect ratio, the stiffness of a unidirectional composite can be calculated using Tandon-Weng [5] model. The closed form expression for Tandon-Weng was given be Tucker and Liang [6], and the full form expression is given by Caselman 2008.

Advani and Tucker [8] used orientation tensors to predict the stiffness tensor for a known orientation state. A_{ij} and A_{ijkl} are the second and fourth order orientation tensor. The fiber orientation state is described in terms of orientation tensors. The second order orientation tensor is defined

$$A_{ij} = \oint p_i p_j \psi(p)\, dp \tag{1}$$

where p is the unit vector and $\psi(p)$ is the probability density function. The diagonal components of A_{ij} describe the amount of fiber alignment in the x_1, x_2, and x_3 directions. The orientation state at is assumed to be perfectly random for the railroad tie, i.e. $A_{ij} = \frac{1}{3}\delta_{ij}$. The homogenized stiffness tensors can be found as functions of the orientation tensors according to the following equations for stiffness (see, e.g. [2]).

$$\langle C_{ijkl}\rangle = B_1(A_{ijkl}) + B_2(A_{ij}\delta_{kl} + A_{kl}\delta_{ij}) + B_3(A_{ik}\delta_{jl} + A_{il}\delta_{jk} + A_{jl}\delta_{ik} + A_{jk}\delta_{il}) + B_4(\delta_{ij}\delta_{kl}) + B_5(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}) \tag{2}$$

The four order stiffness tensor calculated is contracted to the second order stiffness tensor. The compliance tensor S_{ijkl} is calculated using as the inverse of the stiffness tensor. The Young's modulus is calculated using

$$E = \frac{1}{S_{11}} \tag{3}$$

The obtained result, E, is the modulus for the shell. To calculate the modulus of the foam [8], the equation used is.

$$\frac{E_f}{E} = \frac{2(7-5\nu)(1-f)}{(1+\nu)(13-15\nu)f + 2(7-5\nu)} \tag{4}$$

Where, f is the volume fraction of the voids in the foamed region and v is Poisson's ratio of the shell.

RESULTS

Table 2. Young's Modulus values

Parameters	Modulus Values
Young's Modulus of Shell	1.16 GPa
Young's Modulus of Foam	860 MPa

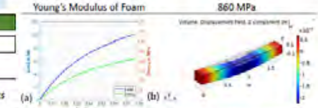

FIG. 6 (a) Stress Strain curve for a four point bend test (b) Results from COMSOL four point bend test simulation

Table 3. Displacement comparisons

Tools	Z displacement values
Four point bend test	0.7746 inches
COMSOL model simulation	0.7656 inches

The z displacements for the four point bend experiment and the COMSOL model have an error of 1.2%.

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[3] http://www.calrecycle.ca.gov/Publications/Documents/1574/20161574.pdf
[4] 2001, "E-Glass Fibre," AZoM.com; "Online Materials Information Resource - MatWeb" [Online]. Available: http://www.matweb.com/; "Modulus of Elasticity or Young's Modulus - and Tensile Modulus for Common Materials" [Online]. Available: https://www.engineeringtoolbox.com/young-modulus-d_417.html.
[5] Tandon, G. P., and Weng, G. J., 1984, "Effect of Aspect Ratio of Inclusions on the Elastic Properties of Unidirectionally Aligned Composites," Polym. Compos., 5(4), pp. 327–333.
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AXION STRUCTURAL INNOVATIONS
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Jingtao Shuang - Polyolefins Conference 2018 - Poster

International Polyolefins Conference 2018

BAYLOR UNIVERSITY

EXPERIMENT ON MECHANICAL PROPERTIES OF CHOPPED NATURAL FIBER REINFORCED COMPOSITE MATERIALS

Jingtao Shuang
Advisor: Dr. William Jordan
Department of Mechanical Engineering
Baylor University, Waco, TX

ABSTRACT:
Banana pseudo-stem fibers have potentials for applications requiring a high strength-to-weight ratio, and bear advantages of sustainability and low cost. However, the hydrophilic nature of the fibers and the hydrophobic nature of the polymer result in poor bonding between them and less composite properties. PLA is also among one of those most widely used biodegradable polymers, in various applications such as biomedical applications, bottle production, and compostable food packaging. This research investigates the mechanical properties of banana fiber reinforced PLA (Polylactic acid). It has been observed that ultimate tensile strength and Young's modulus of reinforced PLA increase with comparison to non-reinforced PLA.

Experimental Process – Fiber preparation

- banana fibers were stored in a humidity-controlled environment for twenty-four hours to ensure consistent moisture content for all fibers
- These fibers were then dried out in an oven at 60°, a temperature well below the decomposition temperature, for two hours
- A volume fraction of 10% was chosen for the fibers similar to previous experiment results

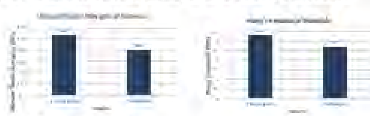
Experimental Process – Samples from Mixer and Injection Molding

- The Braebender mixer was used to obtain the composite mixture of PLA and banana fiber at 180°C
- the resulting mixture composite of PLA and banana fibers from the Braebender mixer was cut into small pieces
- Tensile bars (Type 1, "dog bone") conforming to the ASTM D638-14 for tensile properties of plastics were then made using the DSM Xplore micro 12cc injection moulding machine
- The melt temperature and barrel temperature were set at 180°C for the composite PLA and at 190°C for the PLA only

Experimental Process – Stress-strain Test

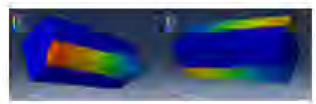
- tensile bars were tested to failure using the Test Resources DG.1000 Actuator under a 4.4 kN load cell
- The rate of 25 mm/min was chosen to run all these tests

RESULTS – Ultimate Tensile Strength and Young's modulus



Experiment Summarization:

Material	Ultimate Tensile Strength (MPa)	Standard Deviation(MPa)	Young's Modulus (GPa)	Standard Deviation(GPa)
PLA Composite	[illegible]	[illegible]	[illegible]	[illegible]
PLA	[illegible]	[illegible]	[illegible]	[illegible]



CONCLUSIONS

- Banana fiber reinforced PLA had a higher ultimate tensile strength when compared to clean PLA
- Reinforced PLA had an ultimate strength of 54.2 MPa whereas clean PLA had an ultimate strength of 40.2 Mpa
- Overall composite polymer had a median Young's modulus of 3.30 GPa, while clean PLA had a median of Young's modulus of 2.67 GPa
- PLA and banana fibers composite is a stronger material than raw material alone

FUTURE WORK

- Finite element method is capable of evaluating the mechanical properties of chopped natural fiber reinforced composite
- Various parameters, such as dimensions, geometries, aspect ratios, volume fraction, and interfaces, could be modeled effectively
- Python subprograms could be utilized to obtain further results of mechanical properties of composite material from the original data from Abaqus results
- To carry out numerical simulation with FEM program of chopped natural fiber reinforced thermoplastic composite materials
- To test the feasibility of numerical method through a comparison of experimental results of injection moulded parts
- To take into consideration of fiber orientations and fiber flexibility as well

ACKNOWLEDGMENTS

I would like to thank Baylor University for its financial support. In addition, I would like to thank my advisor Dr. William Jordan for his guidance.

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[1] Venkateshwaran, N., and A. Elayaperumal. "Banana Fiber Reinforced Polymer Composites - A Review." Journal of Reinforced Plastics and Composites 29, no. 15 (2010): 2387–96.

[2] Malkapuram, Ramakrishna, Vivek Kumar, and Yuvraj Singh Negi. "Recent Development in Natural Fiber Reinforced Polypropyl Composites." Journal of Reinforced Plastics and Composites 28, no. 10 (November 20, 2008): 1169–89.

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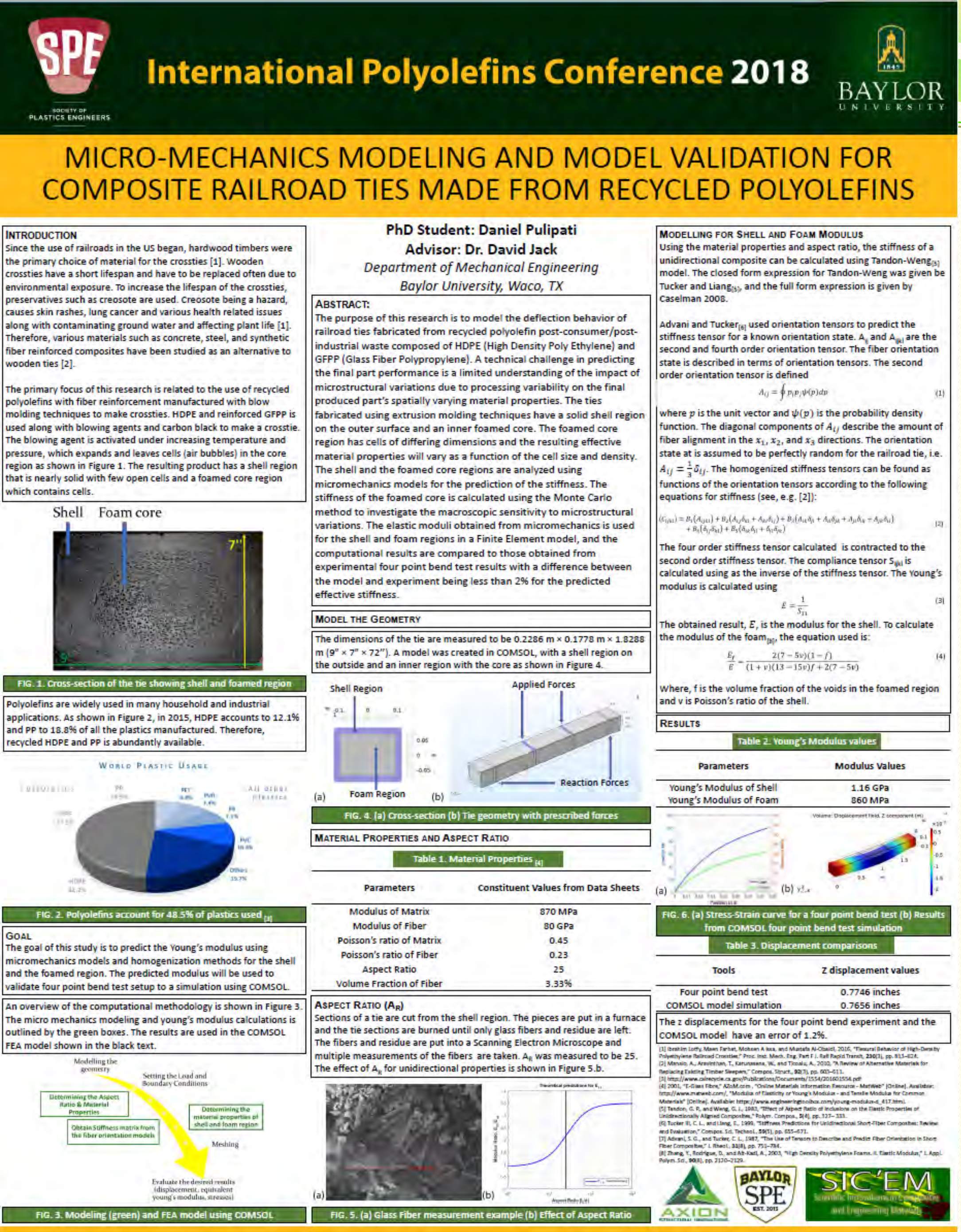

International Polyolefins Conference 2018

BAYLOR UNIVERSITY

MICRO-MECHANICS MODELING AND MODEL VALIDATION FOR COMPOSITE RAILROAD TIES MADE FROM RECYCLED POLYOLEFINS

PhD Student: Daniel Pulipati
Advisor: Dr. David Jack
Department of Mechanical Engineering
Baylor University, Waco, TX

Introduction

Since the use of railroads in the US began, hardwood timbers were the primary choice of material for the crossties [1]. Wooden crossties have a short lifespan and have to be replaced often due to environmental exposure. To increase the lifespan of the crossties, preservatives such as creosote are used. Creosote being a hazard, causes skin rashes, lung cancer and various health related issues along with contaminating ground water and affecting plant life [1]. Therefore, various materials such as concrete, steel, and synthetic fiber reinforced composites have been studied as an alternative to wooden ties [2].

The primary focus of this research is related to the use of recycled polyolefins with fiber reinforcement manufactured with blow molding techniques to make crossties. HDPE and reinforced GFPP is used along with blowing agents and carbon black to make a crosstie. The blowing agent is activated under increasing temperature and pressure, which expands and leaves cells (air bubbles) in the core region as shown in Figure 1. The resulting product has a shell region that is nearly solid with few open cells and a foamed core region which contains cells.

Shell Foam core

FIG. 1. Cross-section of the tie showing shell and foamed region

Polyolefins are widely used in many household and industrial applications. As shown in Figure 2, in 2015, HDPE accounts to 12.1% and PP to 18.8% of all the plastics manufactured. Therefore, recycled HDPE and PP is abundantly available.

World Plastic Usage

FIG. 2. Polyolefins account for 48.5% of plastics used [3]

Goal

The goal of this study is to predict the Young's modulus using micromechanics models and homogenization methods for the shell and the foamed region. The predicted modulus will be used to validate four point bend test setup to a simulation using COMSOL.

An overview of the computational methodology is shown in Figure 3. The micro mechanics modeling and young's modulus calculations is outlined by the green boxes. The results are used in the COMSOL FEA model shown in the black text.

Modelling the geometry; Setting the Load and Boundary Conditions; Determining the Aspects Ratio & Material Properties; Obtain Stiffness matrix from the fiber orientation models; Determining the material properties of shell and foam region; Meshing; Evaluate the desired results (displacement, equivalent young's modulus, stresses)

FIG. 3. Modeling (green) and FEA model using COMSOL

Abstract

The purpose of this research is to model the deflection behavior of railroad ties fabricated from recycled polyolefin post-consumer/post-industrial waste composed of HDPE (High Density Poly Ethylene) and GFPP (Glass Fiber Polypropylene). A technical challenge in predicting the final part performance is a limited understanding of the impact of microstructural variations due to processing variability on the final produced part's spatially varying material properties. The ties fabricated using extrusion molding techniques have a solid shell region on the outer surface and an inner foamed core. The foamed core region has cells of differing dimensions and the resulting effective material properties will vary as a function of the cell size and density. The shell and the foamed core regions are analyzed using micromechanics models for the prediction of the stiffness. The stiffness of the foamed core is calculated using the Monte Carlo method to investigate the macroscopic sensitivity to microstructural variations. The elastic moduli obtained from micromechanics is used for the shell and foam regions in a Finite Element model, and the computational results are compared to those obtained from experimental four point bend test results with a difference between the model and experiment being less than 2% for the predicted effective stiffness.

Model the Geometry

The dimensions of the tie are measured to be 0.2286 m × 0.1778 m × 1.8288 m (9" × 7" × 72"). A model was created in COMSOL, with a shell region on the outside and an inner region with the core as shown in Figure 4.

Shell Region; Foam Region; Applied Forces; Reaction Forces

FIG. 4. (a) Cross-section (b) Tie geometry with prescribed forces

Material Properties and Aspect Ratio

Table 1. Material Properties [4]

Parameters	Constituent Values from Data Sheets
Modulus of Matrix	870 MPa
Modulus of Fiber	80 GPa
Poisson's ratio of Matrix	0.45
Poisson's ratio of Fiber	0.23
Aspect Ratio	25
Volume Fraction of Fiber	3.33%

Aspect Ratio (A_R)

Sections of a tie are cut from the shell region. The pieces are put in a furnace and the tie sections are burned until only glass fibers and residue are left. The fibers and residue are put into a Scanning Electron Microscope and multiple measurements of the fibers are taken. A_R was measured to be 25. The effect of A_R for unidirectional properties is shown in Figure 5.b.

FIG. 5. (a) Glass Fiber measurement example (b) Effect of Aspect Ratio

Modelling for Shell and Foam Modulus

Using the material properties and aspect ratio, the stiffness of a unidirectional composite can be calculated using Tandon-Weng[5] model. The closed form expression for Tandon-Weng was given be Tucker and Liang[5], and the full form expression is given by Caselman 2008.

Advani and Tucker[6] used orientation tensors to predict the stiffness tensor for a known orientation state. A_{ij} and A_{ijkl} are the second and fourth order orientation tensor. The fiber orientation state is described in terms of orientation tensors. The second order orientation tensor is defined

$$A_{ij} = \oint p_i p_j \psi(p) dp \quad (1)$$

where p is the unit vector and $\psi(p)$ is the probability density function. The diagonal components of A_{ij} describe the amount of fiber alignment in the x_1, x_2, and x_3 directions. The orientation state at is assumed to be perfectly random for the railroad tie, i.e. $A_{ij} = \frac{1}{3}\delta_{ij}$. The homogenized stiffness tensors can be found as functions of the orientation tensors according to the following equations for stiffness (see, e.g. [2]):

$$\langle C_{ijkl}\rangle = B_1(A_{ijkl}) + B_2(A_{ij}\delta_{kl} + A_{kl}\delta_{ij}) + B_3(A_{ik}\delta_{jl} + A_{il}\delta_{jk} + A_{jl}\delta_{ik} + A_{jk}\delta_{il}) + B_4(\delta_{ij}\delta_{kl}) + B_5(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}) \quad (2)$$

The four order stiffness tensor calculated is contracted to the second order stiffness tensor. The compliance tensor S_{ijkl} is calculated using as the inverse of the stiffness tensor. The Young's modulus is calculated using

$$E = \frac{1}{S_{11}} \quad (3)$$

The obtained result, E, is the modulus for the shell. To calculate the modulus of the foam[8], the equation used is:

$$\frac{E_f}{E} = \frac{2(7-5\nu)(1-f)}{(1+\nu)(13-15\nu)f + 2(7-5\nu)} \quad (4)$$

Where, f is the volume fraction of the voids in the foamed region and ν is Poisson's ratio of the shell.

Results

Table 2. Young's Modulus values

Parameters	Modulus Values
Young's Modulus of Shell	1.16 GPa
Young's Modulus of Foam	860 MPa

FIG. 6. (a) Stress-Strain curve for a four point bend test (b) Results from COMSOL four point bend test simulation

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Daniel Pulipati- Polyolefins Conference 2018 - Poster

Polyolefins Podium Presentation

MICRO-MECHANICS MODELING AND MODEL VALIDATION FOR COMPOSITE RAILROAD TIES MADE FROM RECYCLED POLYOLEFINS

Daniel Pulipati, PhD Student

David A. Jack, Associate Professor

Given at the 2018 SPE Polyolefins Conference, February 28, 2018.

BAYLOR UNIVERSITY

AXION STRUCTURAL INNOVATIONS

Conference Attendance – ANTEC

- Baylor SPE was awarded 2nd place for SPE chapter of the year at ANTEC 2018.
- 1 Podium Presentations
- 4 Poster Presentations

ANTEC Poster

The Plastics Technology Conference

Nondestructive Testing Technique to Inspect Internal Delamination of Carbon Fib Polymer Matrix Laminates

Author: Benjamin M. Blandford

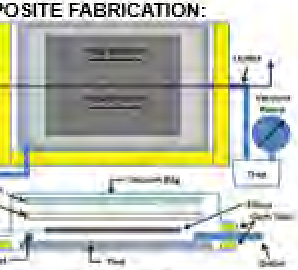
Advisor: Dr. David A. Jack

Department of Mechanical Engineering, Baylor University, Waco, TX

ODUCTION:

the nature of carbon fiber composite structures, damage can be present h the surface of the part without any visible signs of damage on the external s. Damage/delamination of any sort negatively impacts the composites material ies. This study uses an ultrasonic immersion system to visually determine the of internal damage caused by low-velocity impacts.

OSITE FABRICATION:

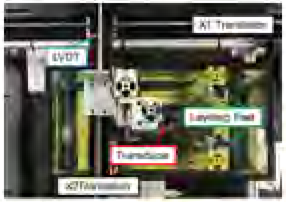


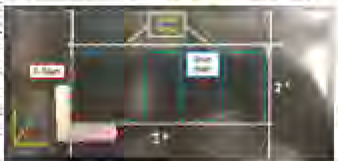
All composites are fabricated in house using a VARTM (Vacuum Assisted Resin Transfer Method) technique. A 3K/6oz plain weave carbon fiber is used with Proset INF 114 resin and Proset INF 211 hardener. Laminates (7-in x 10-in) are manufactured and then cut to approximately (3-in x 8-in) for drop tower testing. This study looks at an 8 lamina laminate [0/45/0/45].

A tile saw is used for cutting the carbon fiber laminates. Once laminates are cut to size they are scanned using a custom ultrasonic C-scan immersion system to get the baseline undamaged results. The laminates are then subject to low-velocity impacts and surface damage is minimized. The damaged laminates are then scanned again and the results are compared to the undamaged results.

RSION C-SCAN:

house LabView code has been ed to perform ultrasonic C-Scans. For udy a 15 MHz spherically focused cer was used in a pulse-echo ration. Other equipment include a US 160MHz pulser/receiver, Velmex ion stages, and an RDP LVDT. This sed a scan resolution of 0.2-mm per and has the capability to scan at m per A-Scan. The scan area is set in x 2-in and an aluminum L is placed bottom left corner, this marks the ng location of the scan. This ensures damaged and damaged scans are ed over the same region. A-scans are long the scan path.



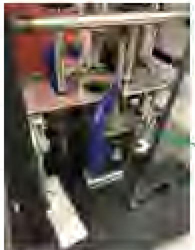


ABSTRACT:

Carbon fiber reinforced polymers have a wide range of applications, from the most advanced fighter jets to golf club shafts, and everything in-between. Carbon fiber composites provide a favorable strength to weight ratio compared to traditional metallic materials used to fabricate these same components. However, additional in-situ testing techniques need to be employed to evaluate carbon fiber components, specifically in regards to determining and quantifying damage. Damage, in the form of delamination, can arise form a host of reasons as varied as a technician dropping a wrench while performing maintenance or a minor flaw in the production process. Due to the layered structure of carbon fiber composites, damage may be present in an interior lamina with no visible sign of damage on the external surface. Traditional destructive testing procedures are not acceptable as not all damage results in a failed component, and there may be a desire to keep the carbon fiber component in service in order to lower production costs. This research uses a custom drop tower to impact carbon fiber laminates in a manner as to minimize surface damage, while at the same time producing internal damage to the laminate. An in house immersion system paired with a custom LabView code is used to perform ultrasonic scans on the laminates. Data is post processed in MATLAB to determine the extent of the damage that is not visible on the surface. Current results show an ability to see internal damage even when there is minimal to no surface damage, and the zone of identified internal damage is larger than that initially anticipated.

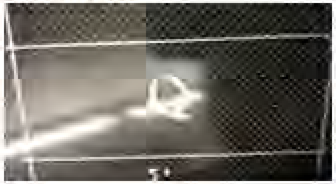
LOW VELOCITY IMPACT:

An in house drop tower is used to damage the carbon fiber laminate. The carbon fiber laminate is placed in the laminate holder and clamped in place. Pneumatic cylinders are used in conjunction with an Arduino controller to prevent subsequent impacts. The mass of the impactor and sled is 2.5Kg and the distance between the impactor and top surface of the laminate ranges from 0.1m to 0.15m. These values result in an impact velocity of $1.40\frac{m}{s}$ to $1.72\frac{m}{s}$.

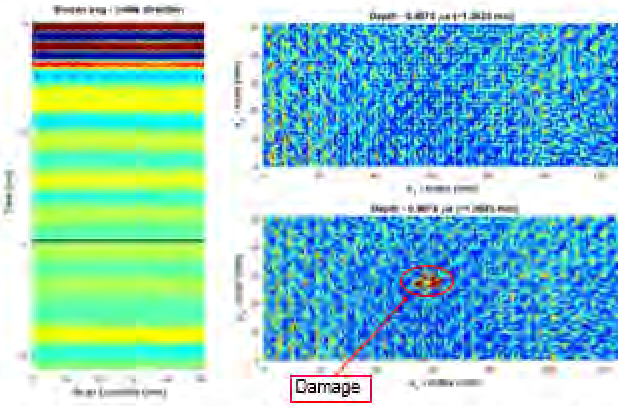


This study is interested in low velocity impacts for purposes of simulating events such as a technician dropping a wrench, or other blunt object, on to a carbon fiber component. The tip of the current impactor is flat and has a diameter of approximately 8.5mm.

RESULTS:



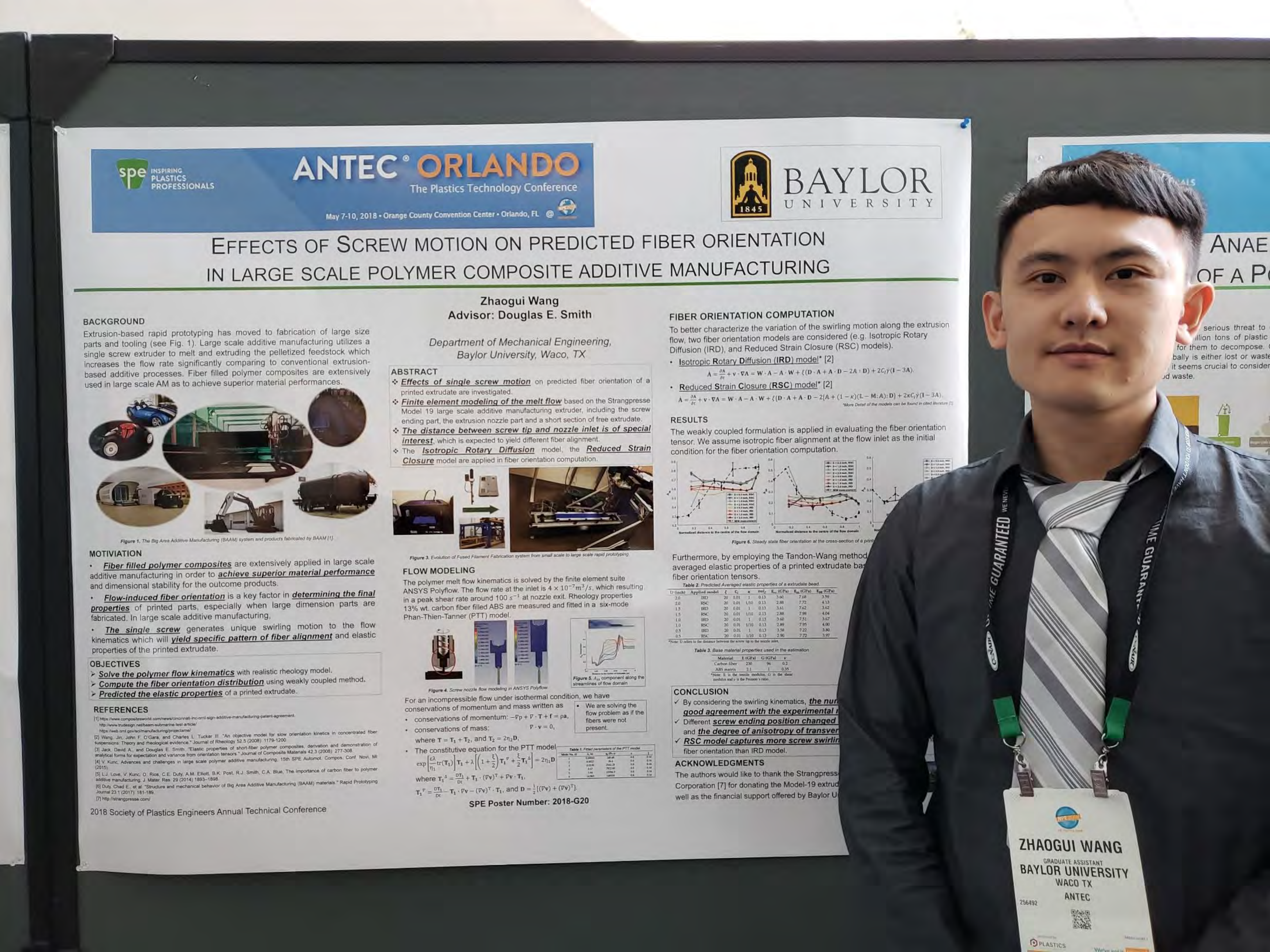
The image on the left shows the damage which resulted from an impa The impact zone is marked with a marker prior to impact. In this image is extremely difficult to see any damage. At just the correct angle and small dent is semi visible.



The images above are frames of a c-scan video. Both images are at the same with in the laminate. The depth is shown in the b-scan on the left of the c-scan i The top c-scan is taken prior to subjecting the laminae to impact damage. The c-scan is taken after the laminate is subjected to impact damage. By comparin images it is seen that there has been a change in the c-scan results. This cha circled in black on the damaged c-scan image. A depth more than half way thro laminate is chosen to show that damage is seen beyond just the first couple The damage width is measured to be approximately 10mm, which is just slightly than the diameter of the impactor (8.5mm).

CONCLUSIONS:

The current study shows that an immersion tank ultrasonic scanning procedu viable option for determining the extent of unseen damage in a carbon fiber lan composite. Due to the current drop tower configuration, it is believed that the from the drop tower is tearing the laminate due to bending of the carbon fiber la This is because there is nothing to support the back side of the laminate. In rea most aerospace/automotive composite structures there is honeycomb structure structure, or other rigid structures on the back side of the carbon fiber. There is metallic structure or more carbon fiber on the other side of the rigid structur creates at sandwich structure that is much more resistant to bending. Damage scanning this type of sandwich structure is the next step for this research.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EFFECTS OF SCREW MOTION ON PREDICTED FIBER ORIENTATION
IN LARGE SCALE POLYMER COMPOSITE ADDITIVE MANUFACTURING
Zhaogui Wang
Advisor: Douglas E. Smith
Department of Mechanical Engineering,
Baylor University, Waco, TX
BACKGROUND
Extrusion-based rapid prototyping has moved to fabrication of large size parts and tooling (see Fig. 1). Large scale additive manufacturing utilizes a single screw extruder to melt and extruding the pelletized feedstock which increases the flow rate significantly comparing to conventional extrusion-based additive processes. Fiber filled polymer composites are extensively used in large scale AM as to achieve superior material performances.
MOTIVIATION
Fiber filled polymer composites are extensively applied in large scale additive manufacturing in order to achieve superior material performance and dimensional stability for the outcome products.
Flow-induced fiber orientation is a key factor in determining the final properties of printed parts, especially when large dimension parts are fabricated. In large scale additive manufacturing,
The single screw generates unique swirling motion to the flow kinematics which will yield specific pattern of fiber alignment and elastic properties of the printed extrudate.
OBJECTIVES
Solve the polymer flow kinematics with realistic rheology model.
Compute the fiber orientation distribution using weakly coupled method.
Predicted the elastic properties of a printed extrudate.
REFERENCES
ABSTRACT
Effects of single screw motion on predicted fiber orientation of a printed extrudate are investigated.
Finite element modeling of the melt flow based on the Strangpresse Model 19 large scale additive manufacturing extruder, including the screw ending part, the extrusion nozzle part and a short section of free extrudate.
The distance between screw tip and nozzle inlet is of special interest, which is expected to yield different fiber alignment.
The Isotropic Rotary Diffusion model, the Reduced Strain Closure model are applied in fiber orientation computation.
FLOW MODELING
The polymer melt flow kinematics is solved by the finite element suite ANSYS Polyflow. The flow rate at the inlet is 4 × 10⁻⁷ m³/s, which resulting in a peak shear rate around 100 s⁻¹ at nozzle exit. Rheology properties 13% wt. carbon fiber filled ABS are measured and fitted in a six-mode Phan-Thien-Tanner (PTT) model.
For an incompressible flow under isothermal condition, we have conservations of momentum and mass written as
We are solving the flow problem as if the fibers were not present.
SPE Poster Number: 2018-G20
2018 Society of Plastics Engineers Annual Technical Conference
FIBER ORIENTATION COMPUTATION
To better characterize the variation of the swirling motion along the extrusion flow, two fiber orientation models are considered (e.g. Isotropic Rotary Diffusion (IRD), and Reduced Strain Closure (RSC) models).
Isotropic Rotary Diffusion (IRD) model* [2]
Reduced Strain Closure (RSC) model* [2]
RESULTS
The weakly coupled formulation is applied in evaluating the fiber orientation tensor. We assume isotropic fiber alignment at the flow inlet as the initial condition for the fiber orientation computation.
Furthermore, by employing the Tandon-Wang method
CONCLUSION
ACKNOWLEDGMENTS
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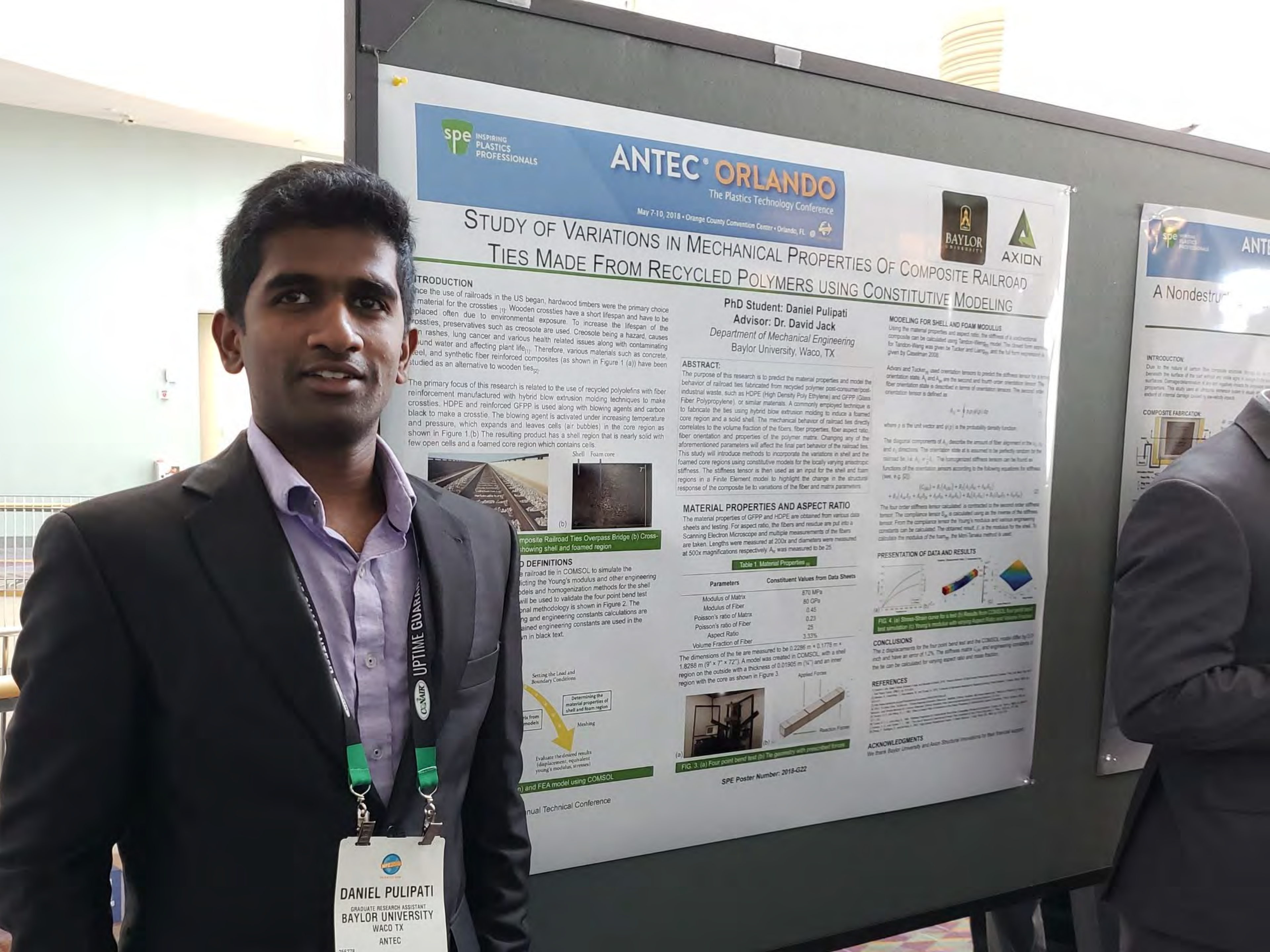
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AXION
STUDY OF VARIATIONS IN MECHANICAL PROPERTIES OF COMPOSITE RAILROAD TIES MADE FROM RECYCLED POLYMERS USING CONSTITUTIVE MODELING
INTRODUCTION
PhD Student: Daniel Pulipati
Advisor: Dr. David Jack
Department of Mechanical Engineering
Baylor University, Waco, TX
ABSTRACT:
MATERIAL PROPERTIES AND ASPECT RATIO
Table 1. Material Properties
Parameters
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SPE Poster Number: 2018-G22
A Nondestru
INTRODUCTION
COMPOSITE FABRICATION
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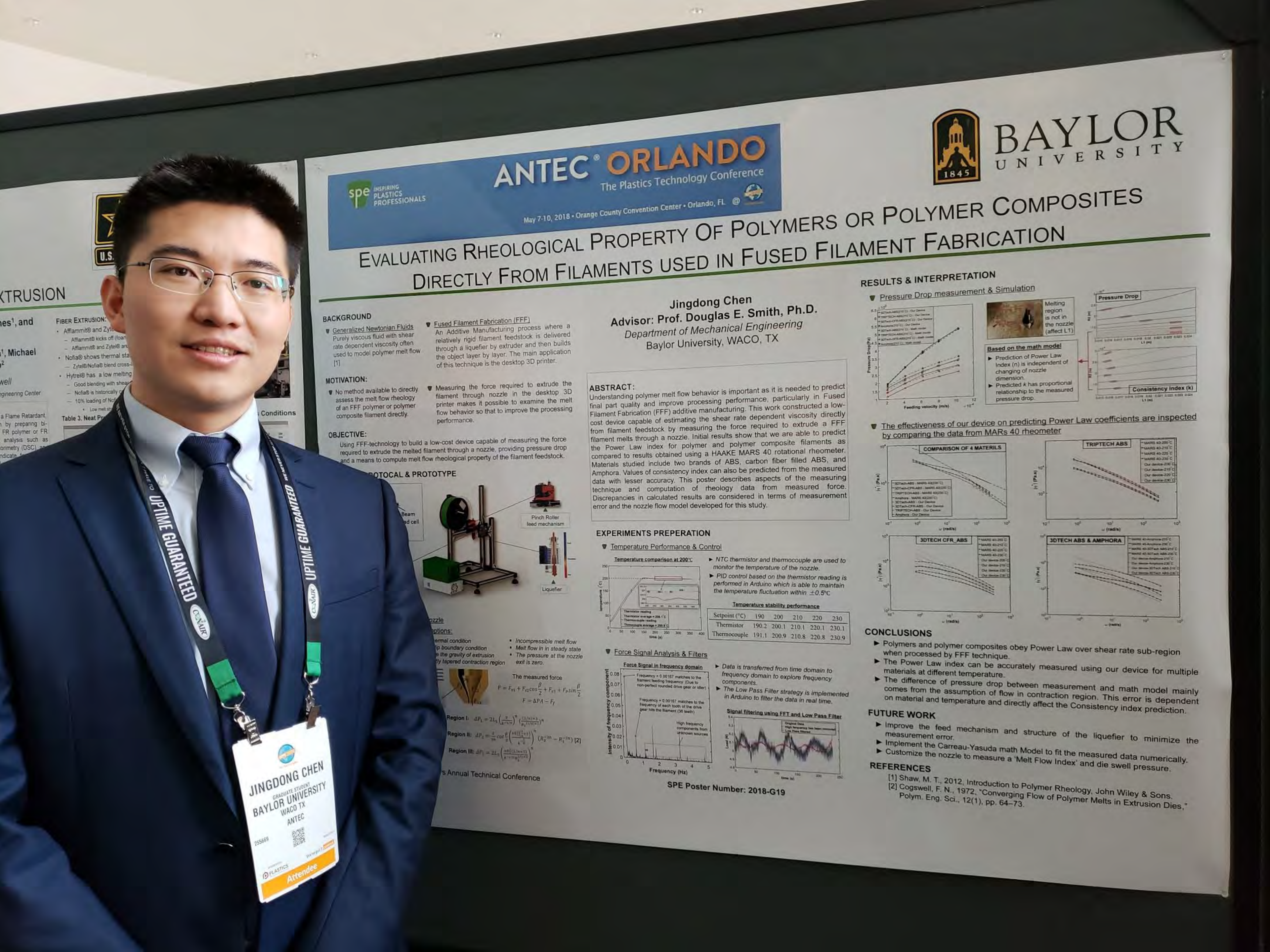
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EVALUATING RHEOLOGICAL PROPERTY OF POLYMERS OR POLYMER COMPOSITES DIRECTLY FROM FILAMENTS USED IN FUSED FILAMENT FABRICATION
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BACKGROUND
Generalized Newtonian Fluids
Purely viscous fluid with shear rate dependent viscosity often used to model polymer melt flow [1]
Fused Filament Fabrication (FFF)
An Additive Manufacturing process where a relatively rigid filament feedstock is delivered through a liquefier by extruder and then builds the object layer by layer. The main application of this technique is the desktop 3D printer.
MOTIVATION:
No method available to directly assess the melt flow rheology of an FFF polymer or polymer composite filament directly.
Measuring the force required to extrude the filament through nozzle in the desktop 3D printer makes it possible to examine the melt flow behavior so that to improve the processing performance.
OBJECTIVE:
Using FFF-technology to build a low-cost device capable of measuring the force required to extrude the melted filament through a nozzle, providing pressure drop and a means to compute melt flow rheological property of the filament feedstock.
ABSTRACT:
Understanding polymer melt flow behavior is important as it is needed to predict final part quality and improve processing performance, particularly in Fused Filament Fabrication (FFF) additive manufacturing. This work constructed a low-cost device capable of estimating the shear rate dependent viscosity directly from filament feedstock by measuring the force required to extrude a FFF filament melts through a nozzle. Initial results show that we are able to predict the Power Law index for polymer and polymer composite filaments as compared to results obtained using a HAAKE MARS 40 rotational rheometer. Materials studied include two brands of ABS, carbon fiber filled ABS, and Amphora. Values of consistency index can also be predicted from the measured data with lesser accuracy. This poster describes aspects of the measuring technique and computation of rheology data from measured force. Discrepancies in calculated results are considered in terms of measurement error and the nozzle flow model developed for this study.
Pinch Roller feed mechanism
Liquefier
EXPERIMENTS PREPERATION
Temperature Performance & Control
Temperature comparison at 200°C
NTC thermistor and thermocouple are used to monitor the temperature of the nozzle.
PID control based on the thermistor reading is performed in Arduino which is able to maintain the temperature fluctuation within ±0.5°C
Temperature stability performance
Setpoint (°C) 190 200 210 220 230
Thermistor 190.2 200.1 210.1 220.1 230.1
Thermocouple 191.1 200.9 210.8 220.8 230.9
Force Signal Analysis & Filters
Force Signal in frequency domain
Data is transferred from time domain to frequency domain to explore frequency components.
The Low Pass Filter strategy is implemented in Arduino to filter the data in real time.
Signal filtering using FFT and Low Pass Filter
Frequency (Hz)
Incompressible melt flow
Melt flow in in steady state
The pressure at the nozzle exit is zero.
The measured force
SPE Poster Number: 2018-G19
RESULTS & INTERPRETATION
Pressure Drop measurement & Simulation
Melting region is not in the nozzle (affect L1)
Based on the math model
Prediction of Power Law Index (n) is independent of changing of nozzle dimension.
Predicted k has proportional relationship to the measured pressure drop.
Pressure Drop
Consistency Index (k)
The effectiveness of our device on predicting Power Law coefficients are inspected by comparing the data from MARs 40 rheometer
COMPARISON OF 4 MATERILS
TRIPTECH ABS
3DTECH CFR_ABS
3DTECH ABS & AMPHORA
CONCLUSIONS
Polymers and polymer composites obey Power Law over shear rate sub-region when processed by FFF technique.
The Power Law index can be accurately measured using our device for multiple materials at different temperature.
The difference of pressure drop between measurement and math model mainly comes from the assumption of flow in contraction region. This error is dependent on material and temperature and directly affect the Consistency index prediction.
FUTURE WORK
Improve the feed mechanism and structure of the liquefier to minimize the measurement error.
Implement the Carreau-Yasuda math Model to fit the measured data numerically.
Customize the nozzle to measure a 'Melt Flow Index' and die swell pressure.
REFERENCES
[1] Shaw, M. T., 2012, Introduction to Polymer Rheology, John Wiley & Sons.
[2] Cogswell, F. N., 1972, "Converging Flow of Polymer Melts in Extrusion Dies," Polym. Eng. Sci., 12(1), pp. 64–73.
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ANTEC Podium Presentation

Effects of Polymer Rheology on Fiber Orientation in Large-Scale Polymer Additive Manufacturing

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ANTEC 2018 Orlando *May-07-2018* *09:30 AM – 10:00 AM*

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OAK RIDGE National Laboratory

Outreach with other organizations

- Baylor SPE helped host Beach bash at Baylor University
  - SPE talked about various research opportunities available in Baylor Mechanical Engineering.
- Baylor SPE assisted in planning a basketball tournament for the school of Engineering and Computer Science.
  - We partnered with ASME and SWE
  - 50 participants

Outreach with Community

- Members of Baylor SPE presented at the Hillsboro ISD Career Day
- We taught on the many types and various uses of plastics and did hands on demonstrations with the students.

PlastiVan – McGregor High School

- Baylor SPE chapter organized the PlastiVan event at McGregor High school.
- Over 200 high school students learned about plastics and various engineering opportunities. PlastiVan was sponsored by the SPE composites division.

PlastiVan – Connell Elementary

- Baylor SPE chapter organized the PlastiVan event at Connell Elementary school.
- Over 250 elementary school students learned about plastics and science opportunities. PlastiVan was sponsored by the SPE composites division.

Stepping Out

May 2017 – September 2018 Purchases

Expenditure	Amount
SPEX Freeze/Mill	$8,203.25
Grizzly Vertical Mill	$7,271.33
SPE Polo's	$80.91
Makerbot and Form 2 supplies	$671.77
Form 2 cure station	$700
Food for Meetings	$491.27
ACCE 2017 Scholarships	$786.20
Polyolefins Scholarships	$148.09
ANTEC 2018 Scholarships	$2075.59
Gas for Facility Tours	$150.14
NGAB Scholarship	$113.42
Events	$13.14
ACCE 2018 Scholarships	$225.15
Total Expenditures	$20,580.26

Thank you for supporting our student chapter!