Society of Plastics Engineers • Upper Midwest Section

JULY 2017 • *Volume 42*

THE SPECIALIST

UPPER MIDWEST SPE 2017 ANNUAL GOLF OUTING

August 1, 2017

OAK MARCH GOLF COURSE – 526 Inwood Ave. N. • Oakdale, MN 55128

START TIME: 10:00 AM Shotgun Start

COST: $95 per SPE Member and $110 per NON-SPE Members

If you sign up as a full foursome, you pay the $95 rate for ALL players whether SPE member or non-member

Includes 18 holes with cart, lunch at the turn, awards and prizes.

REGISTER FOR GOLF http://www.wpgolf.com/oakmarsh/spe.aspx

REGISTER FOR SPONSORSHIPS AT http://www.uppermidwestspe.org

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President's Remarks *by Eric Hall*

Hello to everyone in the Upper Midwest Section of SPE! You may be noticing a new picture in the President's Remarks section. My name is Eric Hall, and I'm taking over the role of President of Section 22 from the capable and creative leadership of Shilpa Manjure. Shilpa had generously served as President for almost 3 years, one year longer than the typical term of 2 years. Please join me in thanking Shilpa for her service to SPE, and for setting an example that will be hard to match in leadership, hard work and attention to detail. Thankfully she is not going far, and will remain active in Section 22, just in a different capacity.

I'd like to thank the board members for giving me the opportunity to serve the section in this new role. I have really enjoyed my time in SPE, and am looking forward to a great rest of 2017 and 2018. I'd like everyone to know that I am always interested in feedback and ideas or just discussion about how we can help you in your business, career or project. My door is always open, and I love to talk, (as some of you may already know!). Tell me what you like about our programs, and what you'd like to see in future Minitec's and Megatec's. We are always interested in what our members need from SPE- after all, that is what we are here for, to serve YOU.

It's been a busy, successful, and fun year for Section 22. We've already had two Minitec's. The spring Minitec was on failure analysis, and was given by Jeff Jansen with The Madison Group, and the summer Minitec was on Computational Modeling of polymer extrusion processes and product design, presented by ANSYS. Both were very well attended, and very educational. Thanks to Sean Mertes and the rest of the board for all their hard work in putting together such great programs. Thanks also to everyone who attended. We're in the process of putting our program together for the Fall Megatec. The topic this year will be injection molding related. Stay tuned and watch your inboxes for more details.

Our summer golf outing is just around the corner, August 1st, at Oak March Golf Course in Oakdale. Join us for a day of golf, socializing and fun. Get out of the office, plant or lab for a day, bring a couple colleagues or friends, and get to know other polymer professionals from the area.

The activities- Golf Outing, Minitec's and Megatec's- are our primary income source for funding our Scholarships, which are a cornerstone of the mission of SPE- Education. At our Spring Minitec we were pleased to award scholarships to two very deserving students in the Polymer program at Hennepin Tech. Read more about them and their awards in the Education Chair report.

We are always looking for folks who are interested in getting involved in our section. If you'd like to work a few hours a month with a great group of people, and have an impact on the activities and direction of the section, please contact me or anyone else on the board- we have several openings for chairs and co-chairs on the board, and need folks with all kinds of skills and backgrounds- no specific experience required! It's a great opportunity to meet and network with other local polymer professionals from a very diverse background.

Best Regards, and have a great rest of the Summer!

SPE Education Committee

– Tom McNamara & Joshua Weed

Once again, our Section has supported local Plastics Engineering students with financial support towards their education. This Spring we gave two Tony Norris Scholarships to worthy students in the Plastics Engineering Technology Program at Hennepin Technology College. Upper Midwest Section President, Shilpa Manjure, made the presentation at the Spring MiniTech. See photos below. We encourage all students in the Plastics Engineering programs at the colleges in our Section to keep abreast of our scholarship offerings on our Upper Midwest Section website (www.uppermidwestspe.org). We will be announcing available scholarships in the fall.

Our Section also supported the student activities at ANTEC program with a sponsorship at the bronze level. If you are a student and want to take advantage of the travel assistance and would like to have an opportunity to win cash awards, you should start preparing now for a presentation at next year's ANTEC in Orlando, FL. It will also be a great ANTEC to attend as it is a joint event with the National Plastics Exposition (NPE), which only takes place every three years

Tony Norris Scholarship recipient - Shelton Jones Jr.

From left to right: Tom McNamara, Shilpa Manjure, Shelton Jones Jr., Dan Ralph – Plastics Engineering Technology Instructor

Tony Norris Scholarship Award Recipient – Eric Bakke

From left to right: Tom McNamara, Shilpa Manjure, Eric Bakke, Dan Ralph – Plastics Engineering Technology Instructor

Combined Birefringence-Tensile Testing of Medical Plastics and Comparison to Finite Element Analysis

Robert J. Klein, Nilesh S. Billade, Steven D. Lince, and Matthew T. Bryant, Stress Engineering Services, Mason, OH

Abstract

Combined birefringence-tensile testing was used to characterize stress development in medical-grade polycarbonate (PC) of four specimen geometries, which included un-notched samples and notched samples with various radii of curvature. Finite Element Analysis (FEA) was also performed to characterize the same geometries. The experimental birefringence stress maps of standard and notched tensile specimens were shown to correlate very well to contour stress maps generated from Finite Element Analysis (FEA) for the same geometries. Depending on the radius of curvature of the notch, the stress maps exhibited slightly different patterns; with sharper notches there were much higher local stress concentrations, which led to yielding and failure at lower displacements. This investigation shows the potential for combining birefringence analysis with mechanical testing, especially when inspecting parts, evaluating residual stress, performing screening studies of stresses, or for comparison to FEA results.

Introduction

The use of crossed polarizers and birefringence patterns to visualize stress patterns in transparent plastics is a well-known and historic technique. In the mid-20th century, prior to the widespread use of computers to model stresses, transparent plastic parts and models were often used with birefringence imaging to visualize stress patterns. The classic example is a miniature, scaled model of a cathedral or a bridge with birefringence patterns showing stress distribution.

Birefringence analysis is still used today, most commonly as a qualitative technique for identification of high local stresses or for manufacturing inspections of parts. [1-7] It is less often used for quantitative analysis and quantitative mapping, although there is a strong body of literature on how to perform this for selected cases, such as monitoring of film manufacturing [6] or characterization of optical plastics such as lenses. [7]

In recent years, FEA modeling has become the most widely used tool for understanding stress-strain distributions during component assembly, operation, etc. With improvements in computing power and software packages, FEA allows quantification of stresses and strains for complex geometries and non-linear material models. However, the historic birefringence methods still offer some advantages over FEA, especially when used for inspection, evaluating residual stresses, as a screening tool for clear parts, or for a parallel comparison to FEA models. Also, in some cases such as poorly defined boundary conditions, FEA simulations can struggle with properly predicting stresses, and birefringence analysis can help fill in these gaps.

In this paper, we utilize a combined birefringence- tensile approach where tensile frame, crossed polarizers, digital camera, and data acquisition software are used to record video of polycarbonate (PC) tensile bars as they are pulled to failure. Analysis of the video, in comparison to the tensile results, allows for quantification of the birefringence/stress patterns. Standard tensile bars and tensile bars with various notches were tested. For the same configurations, Finite Element Analysis was also performed and compared directly to the birefringence results.

Stress-Optics Background

There are multiple potential causes for birefringence, but for a single plastic material with parallel surfaces, the birefringence can be directly related to microstructural anisotropy. [1-4] Molecular anisotropy can be developed either from local orientation built into the material, or from applied stresses. For applied stresses, birefringence $(n_2 - n_1)$ is typically quantified as follows [2]:

$$(n_2 - n_1) = \mathrm{d}/t = C\,(\mathrm{s}_2 - \mathrm{s}_1) = k\,(\mathrm{e}_2 - \mathrm{e}_1)$$

with retardation d, thickness t, stress-optic activity constant C, strain-optic activity constant k, local stress $(\mathrm{s}_2 - \mathrm{s}_1)$, and local strain $(\mathrm{e}_2 - \mathrm{e}_1)$.

The stress-optic value C is highly dependent on the material chemistry and microstructure, and therefore needs to be measured for each specific resin type.

As light retardation increases, the colors visible through crossed polarizers go through a series of fringes, and for visible light every complete fringe shift represents ~570 nm of retardation. The colors are represented in Figure 1 for 90° crossed polarizers using in-plane polarization mode.

Relevance to Medical Plastics

Medical plastics are often amorphous and optically transparent, which lend themselves to birefringence-stress analysis. The authors have observed birefringence-stress patterns in clarified polypropylene, low density polyethylene, polyvinyl chloride, ethylene vinyl acetate, copolyester, PC, PC-copolymers, cyclic olefin, polyethersulfone, crosslinked acrylics, and other resins. For some of these materials, the birefringence pattern does not follow the same coloration patterns as in Figure 1, but is still visible with increasing stress. Highly crystalline materials such as PP homopolymer or HDPE, on the other hand, do not typically show strong birefringence. .

Materials and Methods

In this case we utilized a medical grade of PC, Sabic Lexan PC 141R, that had been molded into ASTM D638 Type I tensile bars. Birefringence of PC is well-known and well-characterized, allowing us to verify our measurement of

SCIENCE CORNER continued on page 6

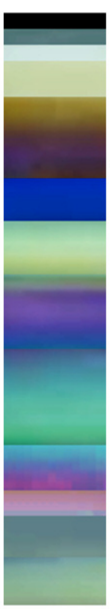
the PC strain-optic coefficient.

After molding, the PC was annealed at ~148 C for at least 1 hour to remove most of the residual molding stresses. Slow heating and slow cooling rates were critical to prevent the addition of new thermal stresses. Note that the annealing process also physically aged the PC, leading to a modified modulus, higher yield stress, and lower elongation at break

Notches were machined into the tensile bars using steel milling bits. Notches were machined 50% through the specimen, and had radii of curvature of 0.25”, 0.03125”, and ~0.001”.

For birefringence-tensile testing, the StrainOptics PS-100-SF was orientated perpendicular to the tensile frame so that the crossed polarizers were behind and in front of the tensile frame, and a digital camera was focused on the tensile bar being tested. Polarizers were oriented in “plane polarization mode”. Tensile bars were tested per ASTM D638 with the following test criteria: 0.2”/min crosshead speed, 4.50” crosshead gap, 50 Hz acquisition rate, 1124 lbf load cell, 72 °F, 25-35% RH, and load cell and test frame within calibration. For one of the tests, a 1.0” extensometer was used in order to correlate crosshead-based strain to extensometer-based strain.

The ABAQUS software package (version 6.14-1) was used for the Finite Element Analysis. The tensile test specimens were modeled using 3D geometry for ASTM Type I tensile bars. The material properties were defined using a nonlinear elastic-plastic material model based on test data obtained from testing physical specimens, which is included in this paper in Figure 2.



Color	Approximate Retardation (nm)
Black (zero-order fringe)	0
Gray	150
Yellow-White	250
Yellow	300
Orange Yellow	450
Red	500
Violet-Red (first-order fringe)	570
Blue	600
Blue-Green	650
Greenish Yellow	720
Pale Yellow	850
Violet (second-order fringe)	1140
Green	1300
Violet (third-order fringe)	1710
Green	1750

Figure 1: Fringe colors as a function of retardation, for the first 3 fringes. The color bar was generated by the authors, and color names and retardation levels were obtained from reference [1] and ASTM F218-13.

Results and Discussion

Stress-Strain Curves and Birefringence Evaluation

Median tensile stress-strain curves for as-molded and annealed tensile bars are plotted in Figure 2. The annealing modifies the modulus and yield stress as noted previously. It should also be noted that an extensometer could not be used, because it would interfere with the birefringence imaging, but previous investigations have shown that for strains below ~2.5% the crosshead and extensometer data match up very well.

The stress-strain behavior in Figure 2 was combined with the development of birefringence fringes to generate the dataset in Figure 3 as a function of crosshead displacement. The slope in Figure 3, 6.3 x 10^{-7} nm retardation / nm thickness / psi, matches closely with values of 5.8 to 5.9 x 10^{-7} nm/nm/psi that were published previously by and Bayer [4] and Eastman [8]. For the four geometries investigated here (standard, ¼” round hole, notch with 1/32” tip radius, and notch with 0.001” tip radius), load-crosshead displacement plots are included in Figure 4. As would be expected, the general load-displacement behavior is similar between samples, but as the notches get sharper, failure occurs at lower displacements.

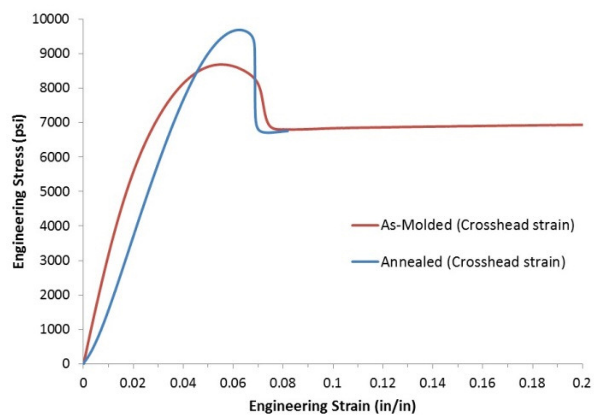


Figure 2: Engineering stress-strain curves for as- molded PC and annealed PC. Annealed PC parts were used for all birefringence investigations.

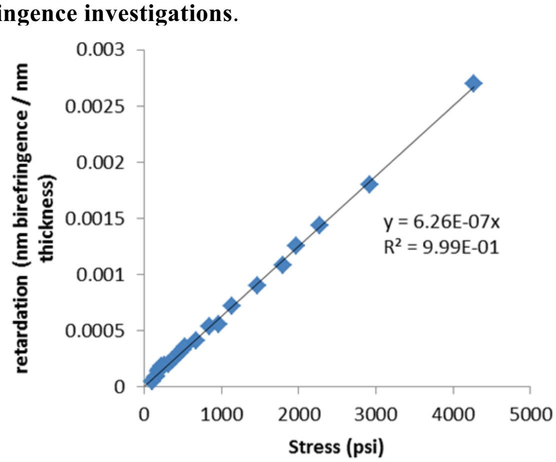


Figure 3: Optical birefringence at the center of the bar versus stress for the standard tensile bar case.

SCIENCE CORNER *continued on page 7*

Birefringence Maps and Comparison to FEA Results

Images of the notched tensile bars at various crosshead extension levels are included in Figure 5, Figure 6, Figure 7, and Figure 8. Directly below the images are FEA models at the same crosshead extensions. Contour maps are provided in both birefringence images and FEA contour maps. (The FEA is shown in gray-scale to help visualize the intermediate stress levels.) Therefore, it is straightforward to make a direct comparison between the experimental and modeling results. As shown by Figures 5-8, agreement between the overall patterns is excellent for all four cases. The stress patterns are very similar in terms of local high-stress regions and low-stress regions and how these regions propagate across the specimens with increasing crosshead displacement.

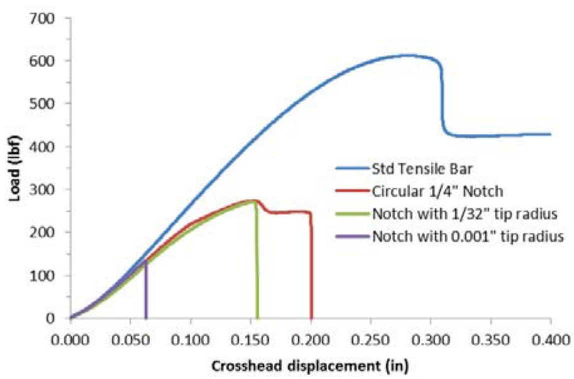


Figure 4: Load-displacement test results for the four tensile bar cases.

In terms of quantifying stresses, it is also possible to evaluate the fringes in the birefringence images and compare them to the contour maps generated by the FEA. The stresses at different time points agree fairly well between the two approaches; for example, 1400 psi, or 5 fringes, appears at ~0.03-0.04" crosshead displacement in the standard tensile case. For sharper notches, there are high fringe densities near the notch, which can make it more difficult to experimentally determine the highest stress at a particular crosshead displacement.

From both experimental and modeling results, it was evident that the sharper the notch, the higher the local stress concentration. With a sharper notch, samples exhibited higher local stress near the notch and plastic (yielding) deformation initiated earlier. In addition, experimental results indicated that ultimate failure (crack propagation) occurred much earlier for sharper notches.

Conclusions

This paper utilized combined birefringence-tensile testing to characterize stress development in medical grade PC. Several specimen geometries were tested, including un-notched and notched samples with various radii of curvature. Results were compared with FEA results to verify the stress maps, and an excellent correlation between the two techniques was observed. From these results, it is evident that birefringence imaging can be a helpful technique for visualizing stress patterns in clear medical-grade (and other grade) plastics. By tracking birefringence patterns with video and mechanical stress-strain behavior with load frames, it was straightforward to obtain experimental contour maps of stress generation.

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This paper was presented at ANTEC 2017.

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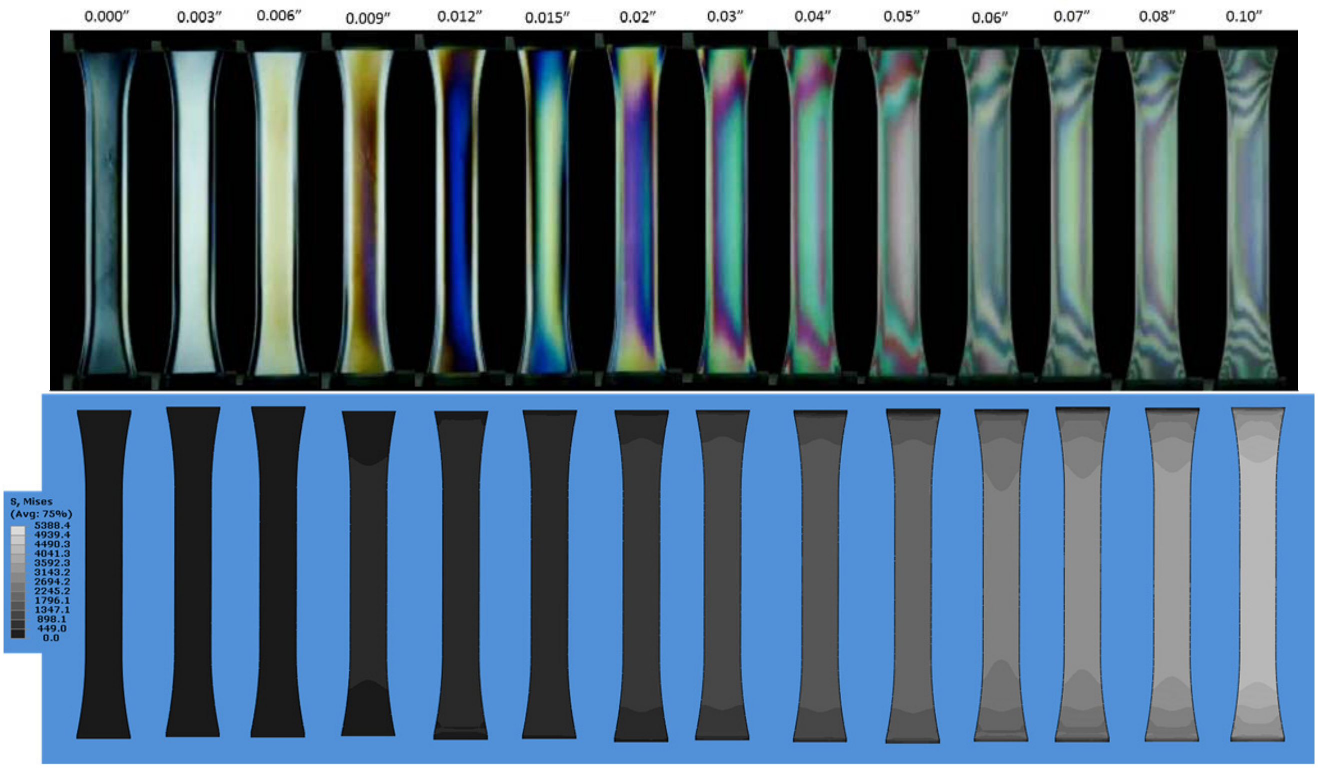

Figure 5: Standard Type I tensile bar: (Top) birefringence + tensile testing and (Bottom) FEA. Both sets of images were evaluated at the same crosshead displacements, shown above as text.

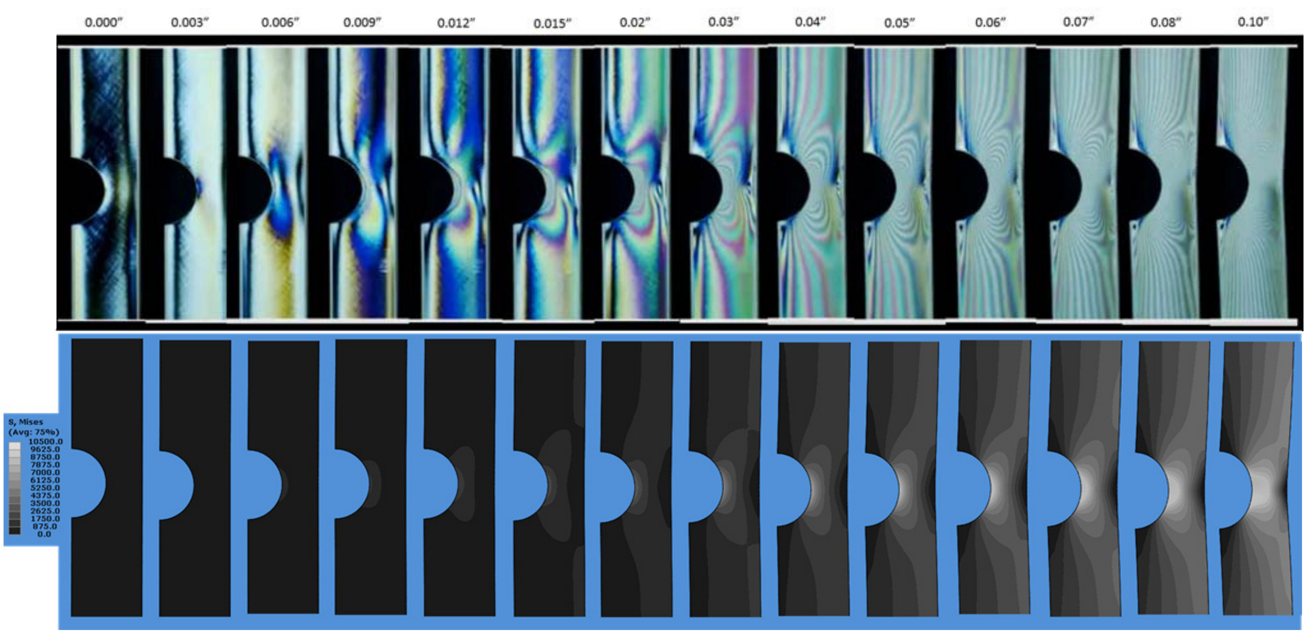

Figure 6: Type I tensile bar with circular ¼" notch: (Top) birefringence + tensile testing and (Bottom) FEA. Both sets of images were evaluated at the same crosshead displacements, shown above as text.

SCIENCE CORNER continued on page 10

Councilor's Corner

by Tom McNamara - Councilor - Upper Midwest Section

At this year's main Council meeting at ANTEC was the introduction and implementation of the new governance model for our Society. Two-year terms for all VP positions along with formal job descriptions has been adopted into our bylaws with four of the VP positions starting as of the Council II meeting this year with the other three VP positions to be filled at next year's ANTEC council meeting to allow a staggered transition of the Governance Board (GB) in all future years. The new slate of VP's is:

VP of Marketing and Communications – Conor Carlin

VP of Events – Jaime Gomez

VP of Business – Jeremy Dworshak

VP of Divisions – Creig Bowland

Our current President is Dr. Raed Al Zubi and our President-Elect is Brian Grady

Another significant change is the resignation of our current CEO, Wim DeVoss, and the introduction of our new CEO, Patrick Farrey. Wim lead our Society for 5 years but chose not to renew his contract. Patrick comes to us with a 23-year career in publication and association management. He has 15+ years in managing societies and associations. We welcome Patrick and wish Wim all the best in his future endeavors.

Financially SPE is showing a YTD gain of $1.9M (as of the end of May) but that number is somewhat skewed by a $1.5M windfall from a renewal signing bonus from Wiley Publications. ANTEC revenues exceeded budget by $70K but exhibit sales and sponsorships had a shortfall of $150K. Also, some of the expenses from ANTEC will not show up until June.

If you did not make it to ANTEC, you missed a good one. Many exciting papers introduced several new technologies. Attendance is a must if you want to stay current on the latest developments. If you attend next year's ANTEC, you will have a double benefit in making the trip to Orlando as it is a joint event with the National Plastics Exposition (NPE).

The Next Generation Advisory Board (NGAB) hosted another successful Plastics Race at ANTEC. For those unfamiliar with the Plastics Race, it is a fun event that provides information & knowledge transfer, networking, and give back to the industry. Teams of 3-4 people use an APP to guide them through the exhibit hall. They scan a QR code at participating booths and the QR code prompts the team with questions. The team with the most correct answers wins a monetary prize.

Also successful was the Students Activities @ ANTEC program. This year the sponsors set a record by donating a total of $52,850. These funds go in support of travel, prizes, and social events during ANTEC. Our Section was one of many sponsors with our Section sponsoring at the Bronze level.

Be sure to tell your friends about the benefits of being a member of SPE. It is the largest technical resource of plastics information and expert network in the world. In 2016, 12,453 publications were loaded into the resource library. Year-to-date 2017, 13,574 were loaded for an increase of about 10%. Also, for Plastics Insights, 2016 saw 319 customizations while YTD 2017, there have been 545 - - almost a 70% increase. Membership also provides discounts on conferences, webinars, and other SPE sponsored events. Please inform your colleagues.

WELCOME TO OUR NEW MEMBERS - Michael Arney, Dick Bopp and Hamid Quraishi

We are pleased to welcome our newest members of the SPE Upper Midwest Section. As of June 30, 2017, there are 536 people in the Upper Midwest area who are members of SPE; 188 people who are also members of the Upper Midwest Section. Please join our section for the best education and networking opportunities!
Check out our website, www.uppermidwestspe.org, and the national website, www.4spe.org, to know all that SPE and this section has to offer.

New Member	Affiliation
Janice Bennett	Match Point Strategies, LLC
Matt Dachel	
Patrick Farrey	Society of Plastics Engineers
Alex Jordan	University of Minnesota
Andrew Ortquist	Uponor
Diana Smirnova	Uponor
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Charles Stone	3M
Bruce Van Clay	MOCON
Ian Walter	University of Wisconsin Madison
Rick Burnton	Aspen Research
Matt Weber	Advance Extrusion

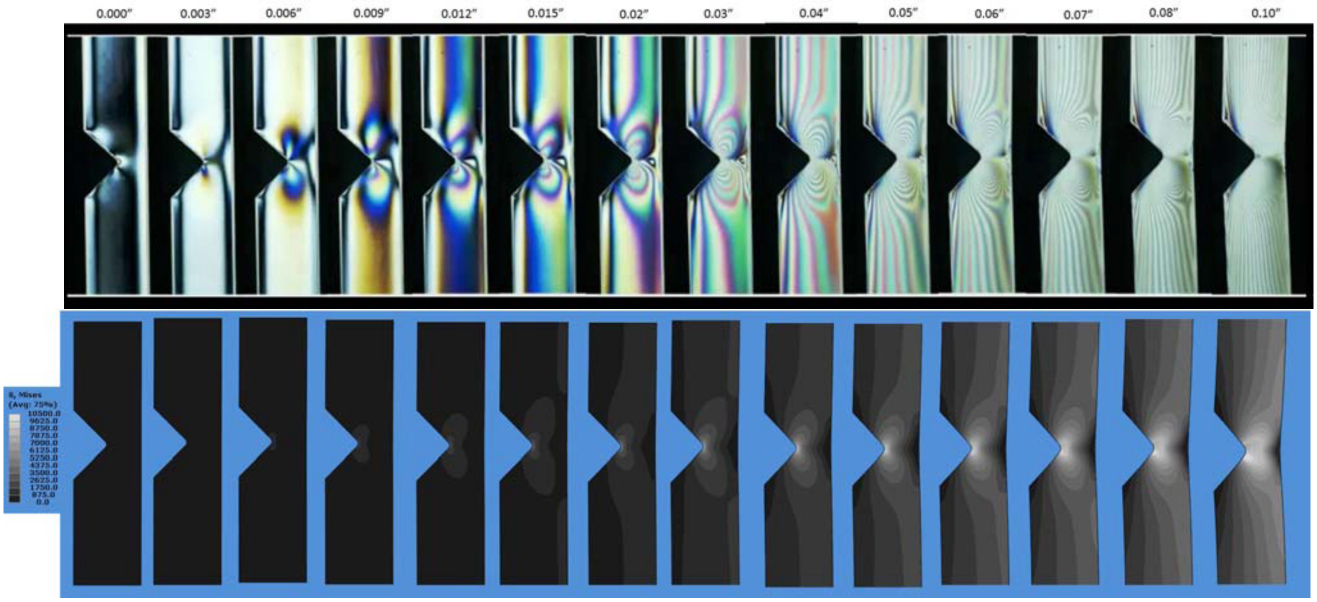

Figure 7: Type I tensile bar with notch with 1/32" tip radius: (Top) birefringence + tensile testing and (Bottom) FEA. Both sets of images were evaluated at the same crosshead displacements, shown above as text.

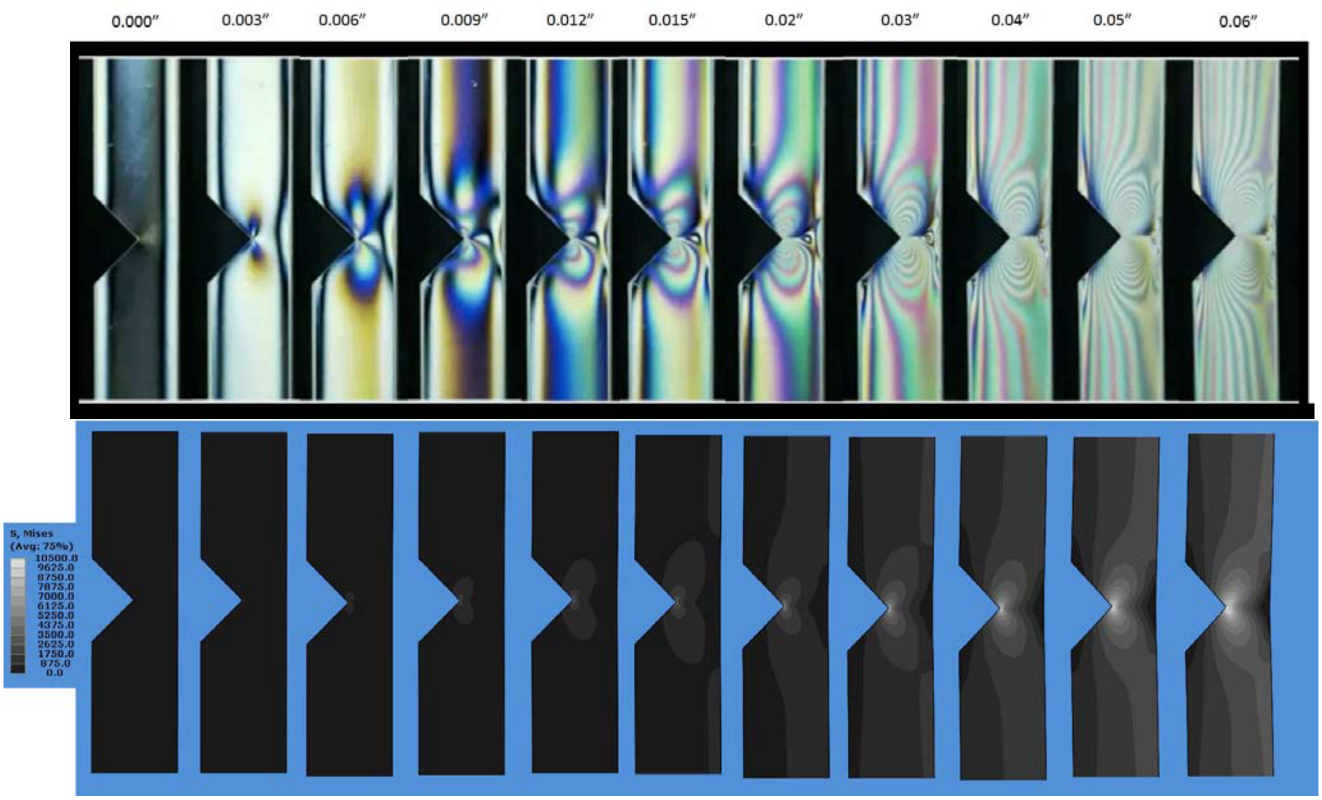

Figure 8: Type I tensile bar with notch with 0.001" tip radius: (Top) birefringence + tensile testing and (Bottom) FEA. Both sets of images were evaluated at the same crosshead displacements, shown above as text.

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Newsletter

JULY 2017

Upper Midwest Section Board of Directors 2016 - 2017

CALENDAR OF EVENTS

Golf Outing .... August 1, 2017

Plant Tour .... October 2017

Megatech .... October-November 2017

ANTEC 2018 .... May 7-10 2018

Upper Midwest Section (S22)
Membership
June 30, 2017

Section Total

536