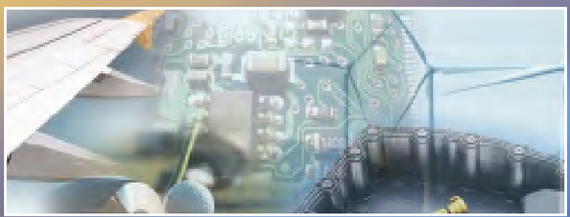
SPE COMPOSITES

WINTER 2024



Composites Connection™

Official Newsletter of the SPE Composites Division
Reaching Over 1,000 Composites Professionals
In All Industries

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spe COMPOSITES
WINTER 2024

Composites Connection™
Advancing Composites Technology Worldwide

Chairman's Message:

Oleksandr G. Kravchenko, Ph.D.

Dear All,

This past year has been a great year for innovation, learning and celebrating the successes of our membership within the Composites Division and across the SPE community.

2023 was off to a great start with the exciting ANTEC meeting in Denver, which allowed many the chance to reconnect with old colleagues and friends and make new connections. In September, we had a memorable time in Detroit during the Automotive Composites Conference and Exhibition that brought together experts in auto and air mobility for great discussions spawning new ideas and inspiration in our work.

Lastly, we celebrated the achievements of our colleagues. One of the most experienced scientists in our field, Dr. Uday Vaidya, was named SPE Fellow for his numerous contributions to composites. We also recognized the successes of our undergraduate and graduate students representing seven universities from across the country (see Fall edition of the Newsletter to read their amazing stories).

We welcomed new Composites Divion Board members, including Dr. Vipin Kumar, who joined the Board this year, while recognizing and thanking our former Division Board members, Jim Griffing and Shankar Srinivasan, who put many years of productive service to the community.

Building upon 2023, the Composites Division and SPE are looking forward to the new year and while we may not anticipate everything that will happen this year, one thing is sure, we will do everything we can to make it even more successful than 2023!

See page 31 for more details


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Award Report

By: Pritesh Yeole, Ph.D.

Part of the mandate of the Society of Plastics Engineers – Composites Division is to recognize excellence in composite materials development and proliferation. Several awards have been organized for this purpose to honor and recognize such individuals, both on academic and industrial levels. Every year the Composites Division issues these awards are based on rigorous competitions through solicitation of nominees and applicants. The awards are a) Harold Giles Award, b) Jackie Rehkpof Scholarship, c) Travel Award, and d) Educator of the Year Award. Other non-financial awards that are open to nominations as of January 1st are a) Honored Service Member / SPE Fellow and b) Composite Division Person of the Year Award. These two awards aim to recognize distinguished contributions from dedicated members of the society.

Harold Giles Scholarships

This award was created in honor of the late Harold Giles who was taken from this world too soon. Harold was one of the best Composite Division Awards Chairs that many of us worked with during his days at Azdel and at UNC. He would have been thrilled to know that we are honoring his name in awarding worthy students. This award is run through SPE International in their Foundation Program series. The Composites Division will select the winners from the pool of applicants in two categories, Graduate and Undergraduate students. The award is dispensed through SPE International to the winners.

The scoring criterion is based on twenty points for the category of scholastic achievements, community service, and other honors, up to ten points based on the strength of the recommendation letters, ten points for previous employment history particularly if this involved composite activity, up to five points for filling out the application form correctly and using good English, five points for providing their transcript and for getting good grades, and a final five points for the reason they applied for the scholarship.

Award Requirements:

- Two awards presented to one undergraduate and one graduate student, who will maintain the academic status for at least two semesters after award announcement.
- An essay documenting experience in the composites industry is required (courses taken, research conducted, or jobs held)
- Have not received the award in previous years.
- Winners are typically students who not only maintained a good grade point average but also served their community, had some experience in the composite area, and are backed by solid reference letters from former professors and employers

The award can be up to $3500 per student depending on funding availability.

Key Dates:

Issue call for nominations February 1st
Close call for nominations April 31st
Complete award adjudication June 30th
Notify recipients by July 30th
Present awards SPE ACCE

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Award Report continued...

Dr. Jackie Rehkopf Memorial Scholarships

This award is in honor of the late Jackie Rehkopf who was a recognized engineer who published books and was actively involved in the composites industry. The Automotive and Composites Divisions co-sponsor these awards and therefore co-coordinate. This award is presented annually at the SPE ACCE conference each fall and is a premiere award for exemplary performance.

Award Requirements

- A single full time grad student or two undergrad students if no grad students qualify
- Preference will be given to female students, but the best candidates will be selected
- Focus should be on research activities targeted to ground transportation composite technology
- Students must be in good academic standing and pursuing a degree in Polymer Science, Composites, Plastics, or a related Engineering discipline
- A 2-page essay is required showing planned work and how it will benefit composites in an automotive or other ground transportation application
- A letter of recommendation from the student's advisor or mentor is also required
- Scholarship recipients are required to present work at an SPE technical conference and/or have it published in an SPE technical journal

The award can be up to $5000 if one student is selected or up to $2500 per student if two are selected, depending on funding availability.

Key Dates

Issue call for nominations January 1st
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Complete award adjudication June 30th
Notify recipients by July 30th
Present awards SPE ACCE

Travel Award:

This is a two-year award where the applicant fills out an abstract form the first year and returns the second year to present a paper/poster to discuss how the topic has progressed. This reward is presented at ANTEC during the business meeting. Typically, scoring has been based on English, the novelty of the concept, and the strength of the research plan. This is a $2000 award, dispensed in two instalment payments over 2 years. This award is sponsored by industry partners every year. If any company like to sponsor this award, please reach out to the Awards Chair Dr. Pritesh Yeole (priteshyeole.mse@gmail.com).

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Award Report continued...

Award Requirements

- A two-part award presented annually to an undergraduate or graduate student.
- At the time of application, master's students must be in the first year of their program and doctoral students must be in the first two years of their program
- The winner is selected based on a 250-word abstract describing their composites research
- In the first year, the recipient receives a $1000 (USD) scholarship award and a plaque, presented at ANTEC
- To be eligible for the second $1000 installment, the research described in the winning abstract must be presented in a paper at ANTEC the following year

Key Dates

Issue call for nominations December 1st
Close call for nominations February 28th
Complete award adjudication March 14th
Notify recipients by March 31st
Present awards ANTEC

Educator of the Year Award:

The Educator of the Year Awards is an industry sponsored award. A certificate/ plaque combination will be presented at ANTEC during the business meeting. The present score sheet provides scoring of up to ten points for English at 1X, ten points for recommendation letters at 2X strength, and student support examples at 3X strength. This prestigious recognition is aimed to honor an Educator who have influenced his students to excel in the composite field and grow their composites careers.

Award Requirements

- Someone in the educational field (high school, university, or college-level)
- Has made a significant contribution to the training of students in the composites area. E.G.:
  - o the creation of new educational programs
  - o the development of new pedagogical tools
  - o motivating students to enter the composites sector
- Selection will be based on contributions made during the previous year.
- Must submit a nomination form and two letters of support

The award is $2500, covered by an industry sponsor. If any company like to sponsor this award, please reach out to the Awards Chair Dr. Pritesh Yeole (priteshyeole.mse@gmail.com).

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SPE® Automotive Names Winners for 52nd Annual Automotive Innovation Awards Competition

The Automotive Division of the Society of Plastics Engineers (SPE®) today announces the winners for its 52nd annual Automotive Innovation Awards Gala, the oldest and largest recognition event (established in 1970) in the automotive and plastics industries. The announcement was made on the evening of November 8, 2023, during the 52nd SPE Automotive Innovation Awards Gala held at Burton Manor in Livonia, Mich., USA. The Body Interior Category winner was also this year's Grand Award winner. The Grand Award winner is selected from the winners of each of the 8 categories by a panel of Blue Ribbon Judges who are industry experts. This year's winners are:

Grand Award & Body Interior
Mega Bin / Frunk

Aftermarket & Specialty Vehicles
Hybrid Battery Interconnect Board

Body Exterior
Thermoplastic Splitgate

Electric & Autonomous Vehicles
Battery Disconnect Unit

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Automotive Innovation Awards continued...

Materials
Battery Module Sideplates

Process/Assembly/Enabling
Seat Module

Safety
Intumescent Terminal Covers

Sustainability
One-Piece Frunk

Vehicle Engineering Team Award (VETA)
2024 Chevrolet Corvette E-Ray

Hall of Fame - First Acrylic Rear Lens on 1948 Cadillac

Lifetime Achievement Award
Kevin N. Pageau

the high resolution pictures can be found atInnovation Awards Competition & Gala 2023 – SPE Automotive Division

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ACCE Best Paper Award

Enhancing Structural Performance of Recycled Fiber-Reinforced Thermoplastic Composites Through Incorporating Composite Laminate Precuts

Garam Kim, Sungjun Choi
The School of Aviation and Transportation Technology, Purdue University
Harry Lee, Eduardo Barocio
Composites Manufacturing and Simulation Center (CMSC), Purdue University

Abstract

Composite recycling has gained significant attention due to the increasing global sustainability problems. The mechanical recycling process of fiber-reinforced composite parts involves shredding long continuous fibers within the composite into shorter discontinuous fibers. Since the performance of the resulting short fibers is not as high as that of the original long fibers, the application of mechanically recycled composites is limited. The objective of this study is to enhance the structural performance of recycled composite parts by integrating of a set of continuous fiber composite precuts during the molding process. The 2-dimentional precuts were positioned in the structurally critical regions of the recycled composite part, and the remaining area was then filled with shredded composite material. An aircraft overhead bin door pin bracket was used as the part geometry. The mechanically recycled material and the precuts were made from 60% by weight carbon fiber reinforced polyetherketoneketone (PEKK) composite. Three different combinations of precuts were designed to create the pin bracket, and their performance was assessed by mechanical testing of the pin bracket. Additionally, digital image correlation (DIC) technology was used to analyze local strain changes and investigate the failure mechanisms of the parts throughout the testing process. The test results demonstrated that the inclusion of properly designed precuts significantly improved the performance of the recycled composite part. This research contributes to the advancement of composite recycling by providing insights into methods for enhancing the structural performance of mechanically recycled composites through the strategic integration of continuous fiber precuts into recycled composite part.

Garam Kim receiving
the Best Paper Award

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Introduction

The fiber-reinforced composite materials have widely used across various industries such as aerospace, aviation, automotive, wind energy, construction, and sporting goods [1]. The advanced composite materials offer advantageous mechanical and physical properties, including high strength-to-weight ratio, stiffness, and low coefficient of thermal expansion (CTE) [2]. As a result, their demand has been steadily increasing, with projections indicating substantial growth in the global composites market [3], [4]. However, along with the increased usage of composite materials comes the challenge of addressing their sustainability throughout their lifecycle [5], [6]. The management of end-of-life (EOL) composite parts has been a significant concern, as their disposal through traditional methods like landfilling has not only ineffective in terms of sustainability but also severe damage to environment [5], [7]. To solve this issue, many countries have begun implementing policies to encourage recycling or promote alternative waste management practices for composites [6].

Composite recycling methods generally fall into three categories: mechanical, pyrolysis, and chemical recycling [8]. Mechanical recycling is one of the most commonly used methods due to its simplicity and cost-effectiveness [7]. Composite mechanical recycling includes shredding and

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ACCE Best Paper Award continued...

grinding the composite material to reduce it into smaller fragments [9]. These shredded recycled composite materials are reused in new composite product or reinforcement additives. However, the mechanical recycling process may result in a reduction in the performance of the recycled composite compared to the original composite [6], [9]. The shorter fibers generated through mechanical recycling may have degraded mechanical strength and other desirable characteristics. Therefore, the applications of mechanically recycled composites are often limited [6], [9]. Therefore, it is important to find a way to enhance the performance of recycled composite parts and broaden the application range of them to enhance the sustainability and to promote the recycling of composite materials.

This study demonstrated an innovative approach to enhance the mechanical performance of recycled composite parts through the integration of two-dimensional continuous fiber composite precuts. These precuts are fabricated by cutting them from composite laminates. They are selectively placed in structurally critical areas to reinforce the parts and provide additional strength in mechanically demanding sections. Even the continuous fiber composite laminates themselves, which the precut is

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ACCE Best Paper continued...

cut from, can be sourced from EOL composite parts. Rather than shredding all composite parts in the composite recycling process, the suitable composite parts can be used for precut fabrication. To implement this approach successfully, careful planning and consideration are required regarding precut design and how they will be cut from the parts. Not all composite parts have a two-dimensional flat geometry. Additional processes, such as composite part flattening, may be necessary before the precut fabrication. However, by utilizing EOL composite parts to create precuts, the need for additional new continuous fiber composite materials can be eliminated. This approach represents a closed sustainability loop, where materials can be continually recycled and repurposed without the introduction of new resources as shown in Figure 1.

In this study, recycled composite parts were manufactured using mechanically recycled composite material. The load-critical areas were identified, and the precuts were specifically designed to reinforce those regions. Sets of precuts with different designs were fabricated and integrated into the recycled composite parts during the molding process. The mechanical performance of the recycled composite parts with precuts was then tested to assess how different precut designs improved their structural performance, and these results were compared to the performance of recycled composite parts without precuts. With the novel recycling approach, this study aims to contribute to the enhancement of sustainability by effectively utilizing EOL composite part and recycled composite materials, thereby creating additional applications and improving overall sustainability of the composite materials.

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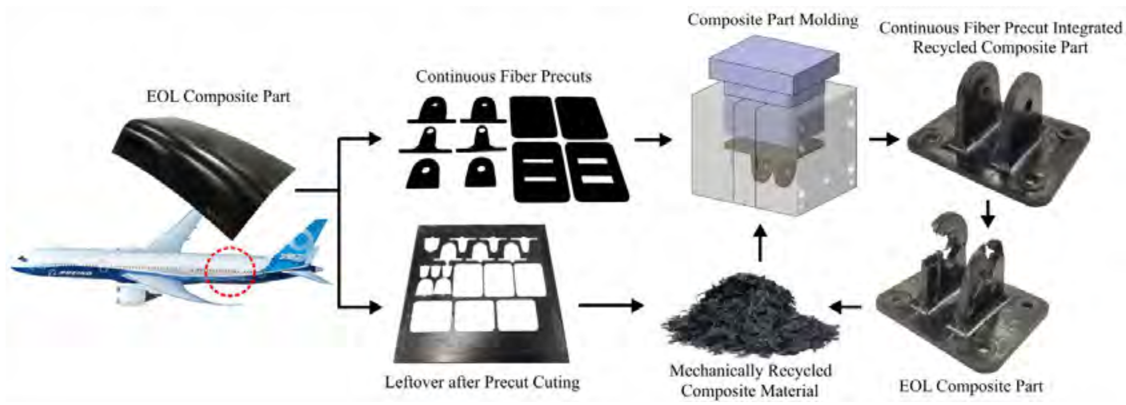

Figure 1: Closed composite material sustainability loop via continuous fiber precut integration approach

Methodology

An aircraft overhead bin door pin bracket was selected as a part geometry for this study. The pin bracket plays an essential role in providing strength and ensuring safety while maintaining a lightweight design. Furthermore, the manageable size of the pin bracket facilitated the production of multiple samples for testing purposes. The pin bracket consisted of two ears which have holes for pin insertion. The ears had an approximate height of 30.48 mm, with varying thicknesses. The thicker section measured approximately 5.08 mm. These ears were connected to a base with dimensions of around 63.40 mm by 50.70 mm and a thickness of approximately 2.54 mm. The base has four screw holes to which screws are fastened to install the pin bracket. Figure 2 shows the pin bracket design.

First, the continuous fiber precuts that was integrated into the pin bracket needed to be designed. The strategic design of the precuts was crucial to optimize the load distribution and maximize the structural performance of the part. The previous testing on sheet molding compound (SMC) pin brackets showed that failures occurred in the ear and base regions. In the ear section of the pin bracket, particularly in the areas above the pin hole and in the center where the load was applied was failed. During the compression molding process of manufacturing pin brackets using SMC, the material flow resulted in the formation of welding lines at the ear above the pin hole. Welding lines occur when the molten ma-

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Figure 2: Aircraft overhead bin door pin bracket design.

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terial flows around obstacles or merges with other material flow fronts, resulting in a line that can weaken the structural integrity of the pin bracket. In the base section, the failures occurred in the areas where screws were installed. This is due to the localized stress formation around the screw holes when the screws are installed and subjected to loading.

To address this issue, it was essential to reinforce the ear section, specifically the upper portion above the pin hole, with continuous fiber. The precut had an ear-shaped with a pin hole, allowing for the simultaneous molding with the pin during the manufacturing process was designed. This design approach eliminated potential welding lines and enabled the precise placement of continuous fiber around the pin hole area. To improve the performance of the base section, a continuous fiber precut of the same size as the base was integrated into the design. The base design aimed to reinforce the base and distribute the load more evenly, reducing stress concentration and the risk of failure in the screw-fastened areas Figure 3(a) shows the precut design set 1.

In the primitive experiment, the pin bracket with the precut design 1 was mechanically tested. The test result showed that the pin bracket no longer experienced failure at the ears or the base. However, it failed at the area where the ears were connected to the base. The test result addressed the need to develop a precut design that would effectively connect the ears and base sections with continuous fiber. The new precut design was developed to have slots in the base and allowed the ear to pass through the slot. The ear precuts had a wider section on the bottom that enabled the ear to withstand the pulling load without simply slipping through the slot. This precut design concept is similar to three-dimensional puzzle, where the components interlock and provide structural integrity. Figure 3(b) shows the precut design set 2

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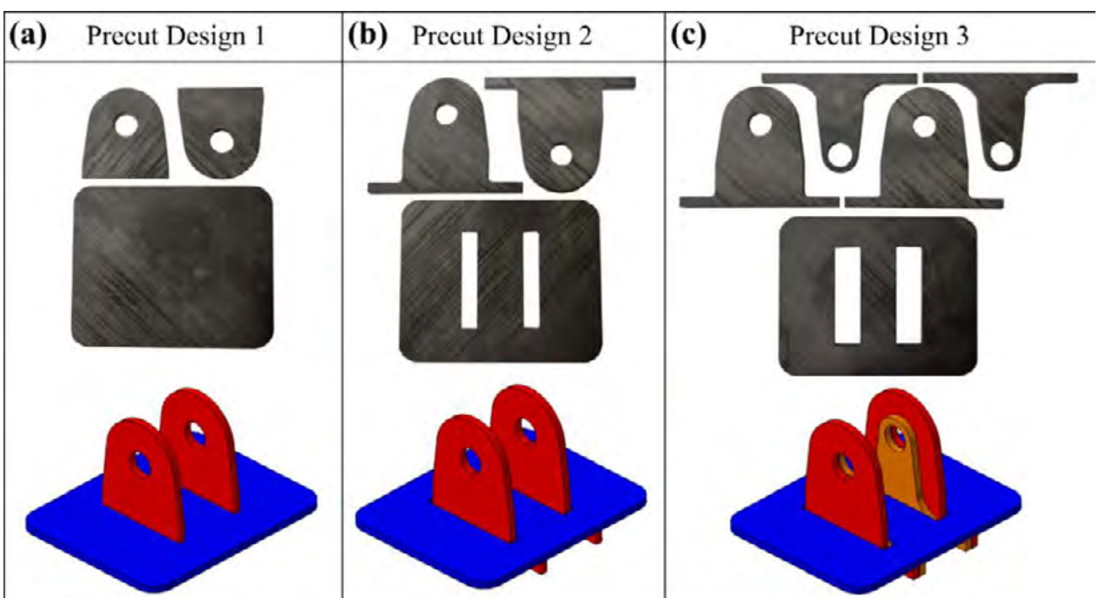

Figure 3: Precut set and assembled precut image for (a) the precut design 1, (b) the precut design 2, and (c) the precut design 3.

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As a final iteration of the precut design, additional layers of precuts were added each ear, while the basic design of the ear and base were same as the previous three-dimensional puzzle design. This designed aimed to enhance the load-carrying capacity by increasing the amount of continuous fiber within the pin bracket. Through these design refinements, the study aimed to achieve a more robust and effective precuts design that would contribute to the overall improvement of the recycled composite part's mechanical performance. Figure 3(c) shows the precut design set 3.

For both precut and mechanically recycled material, 60% by weight carbon fiber reinforced polyetherketoneketone (PEKK) composite was used. The precut was fabricated from a 20-ply thick quasi-isotropic laminate, approximately 2.54 mm thick, with a fiber orientation of [45/90/-45/0/90/0/0/45/90/-45]s. The precuts were cut from the laminate with an abrasive waterjet. After the cutting, the surface of the precut was lightly sandblasted to clean any remaining release agents or grease and to enhance bonding with the recycled material. The precut design set 1 was 16.67 g, and the precut design set 2 was 19.37 g, and the precut design set 3 was 22.17 g. To investigate the fiber length of the recycled composite material, the shredded material was thermally decomposed in a furnace to remove the polymer matrix. The remained fiber was collected and microscopic analysis was performed to measure the fiber lengths. By measuring 100 individual fibers, the average fiber length was 4.7 mm. Figure 4 shows the mechanically recycled composite material and the fiber length distribution.

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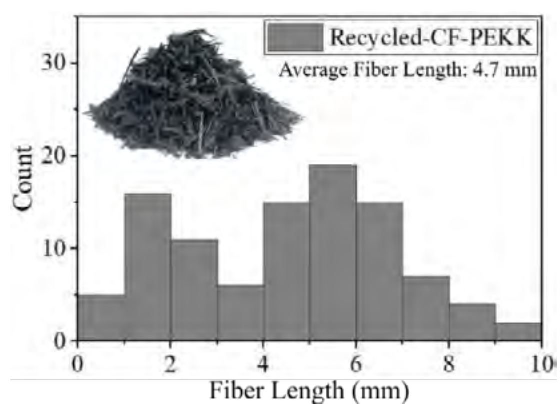

Figure 4: The mechanically recycled CF-PEKK and the fiber length distribution.

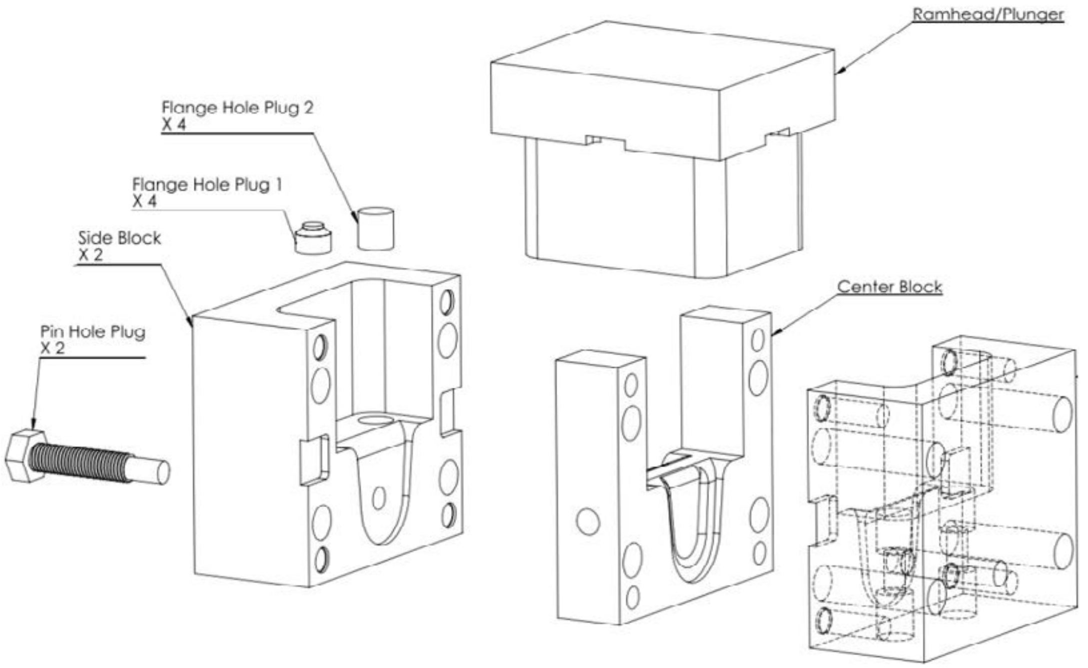

Figure 5: Compression molding tool used to fabricate the pin bracket [10].

A compression molding tool made from H13 tool steel was used to fabricate the pin bracket geometry. The exploded view of the compression molding tool shown in Figure 5 provides an overview of the different sections of the tool and the inserts used to mold the pin hole and the screw holes at the base of the bracket. The tool is equipped with a thermocouple well to record temperature during manufacturing.

Each precut design had a unique method for installation. For the first precut design, the ear precuts could be easily installed to the tool during the tool assembly process as shown in Figure 6(a). Then, the recycled material was poured into the tool, and the base precut was placed on the top of the recycled material as shown in Figure 6(b). The second and third precut designs had more challenges since the ear and base precut were interlocked, prohibiting separate installation. Therefore, the ear and base precuts were assembled together and integrated into the tool while the tools were assembled as shown in Figure 6(c) (precut design 2). Then, the recycled material was poured into the tool. To ensure that there was an enough material to fill the ear cavities fully, some recycled material was pushed into the ear cavities through the slots on the base precut while the recycled material was poured as shown in Figure 6(d). All pin brackets were fabricated with the same amount of composite material. The total amount of composite material including both continuous fiber precuts and the recycled material in the pin bracket was 31.4 g.

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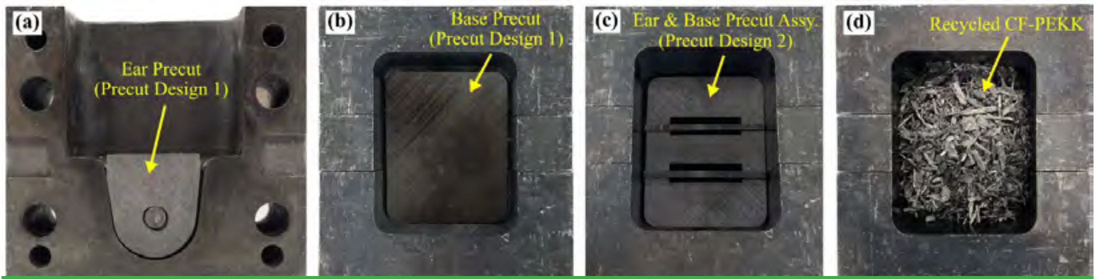

Figure 6: Manufacturing of the pin bracket including continuous fiber precuts. (a) The placement of the ear precut of the precut design 1 and (b) the placement of the base precut of the precut design 1. (c) The placement of the assembled ear and base precuts into the tool while the tools were assembled, and (d) the tool cavity filled with the recycled materials.

Following the preparation of the compression molding charge, the tool's plunger was installed, and the tool assembly was heated to the processing temperature in a forced convection oven. Upon reaching the processing temperature, the tool assembly was transferred to a hot press for the flow and consolidation of the molding charge into the tool cavity. A pressure of 124.1 Bar was applied while the tool cooled down to below the glass transition temperature of the polymer. The platens of the hot press were preheated to reduce the cooling rate and allowed the development of crystallinity in the polymer. Table 1 lists the process conditions used for the compression molding.

Process Parameter	Value
Material	CF-PEKK
Process Temperature (°C)	390
Consolidation Pressure (Bar)	124.1
Demolding Temperature (°C)	150
Platens Temperature (°C)	220

Table I: Process conditions for c ompression molding [10].

Quasistatic tests of the pin brackets were conducted with a universal test machine MTS 810 equipped with a 100 kN load cell. A displacement control procedure was carried out at a rate of 2 mm/min until the ultimate failure of the bracket was reached. A custom-made fixture was utilized to load the pin bracket in tension as shown in Figure 7(a). The pin bracket was installed on the test fixture with four 10-32 screws torqued to 40.67 Nm. Digital Image Correlation (DIC) was used to record the strain field developed at the surface of the pin bracket's ear during loading. Figure 7(b) shows the strain field in the load direction developed before and after ultimate failure of a pin bracket reinforced with continuous fibers. Three pin brackets for each precut design and four pin brackets with only recycled material for the baseline were tested.

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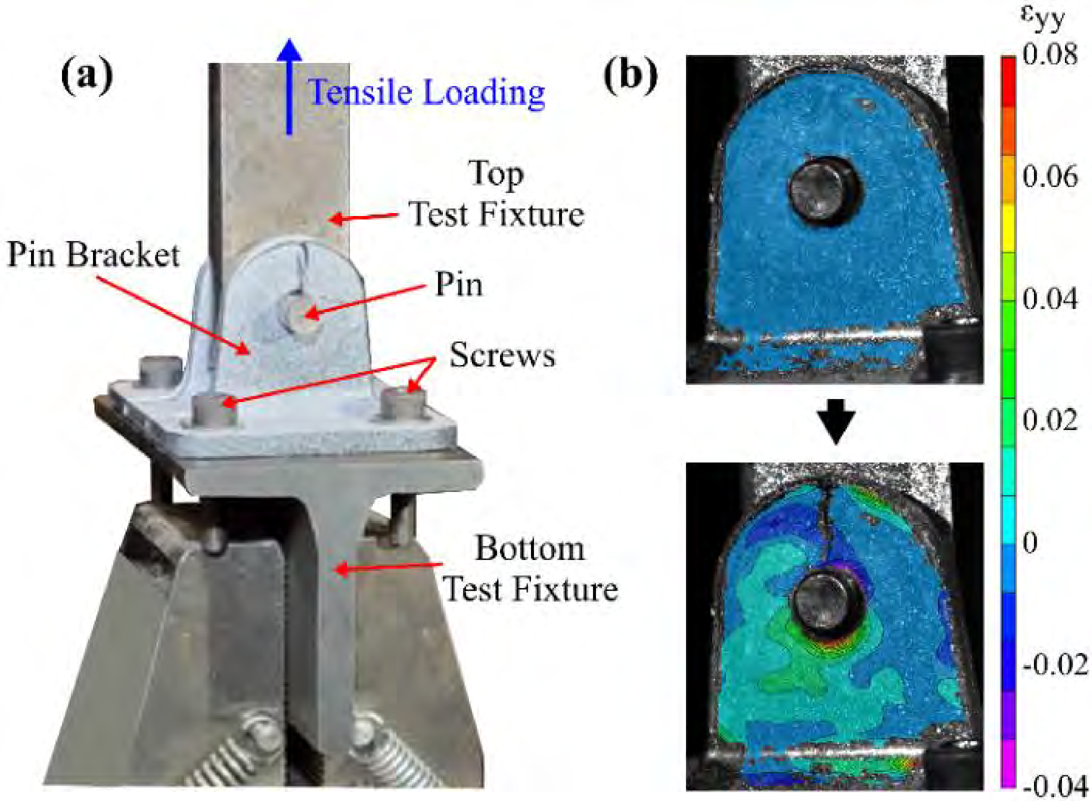

Figure 7: (a) Mechanical testing setup for the pin brackets. (b) Strain field in the load direction obtained from DIC analysis before and after failure in the pin bracket.

Results

The pin brackets with three different precut designs and the pin brackets without precuts, only with the recycled composite material, were successfully fabricated. Three pin brackets were manufactured for each precut design, and four pin brackets were fabricated without any precut, making a total of 13 pin brackets. There was no evidence of any defects such as void or crack on the surface of the pin brackets. After manufacturing the pin brackets, the pin holes on the ears and screw holes on the base were finished, as well as sanding to remove any burrs. To observe the fiber distribution within the molded pin brackets and to observe any defects, such as void, inside of the pin brackets, microscopic image of the cross-section of the pin bracket with different precut were made as shown in Figure 8. The microscopic images demonstrated that the fibers were effectively placed along the boundaries of the ear and pin hole sections. Similarly, in the base sections, the fibers adequately covered the screw holes. For the precut design 1, it was found that the ear precut were pushed inside of the ear cavity and it made a noticeable gap between the ear precut and base precut. The gap between the precuts was filled with the recycled composite materials. In the precut design 2 & 3, the ear precut held its position during the forming process. The continuous fiber was observed across of entire ear, and the wider bottom section of the ear preform positioned properly underneath of the base precut. For all the precut designs,

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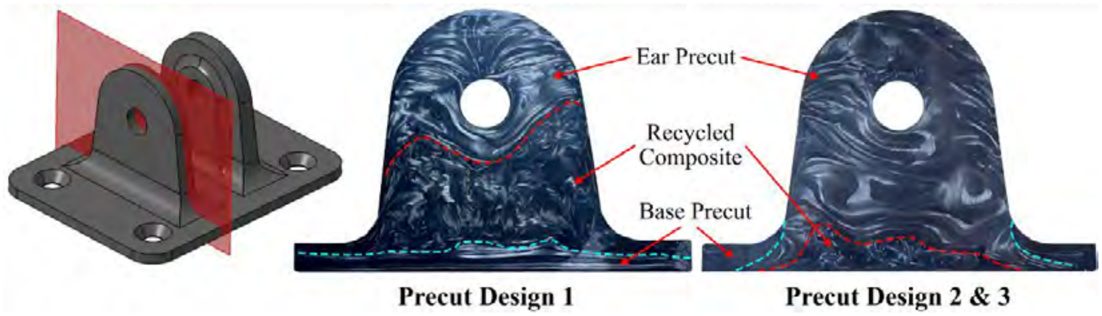

Figure 8: The microscopic image of cross-sectional area of the pin brackets fabricated with the precut design 1 and 2 & 3.

it was found that the quasi-isotropic fiber orientation of the ear precut did not maintained during the forming process, resulting many wavy fiber orientations and buckling were observed in the precut. The base precut relatively remained same location where it was installed during the precut placement process. No defects were observed on the cross-sectional area of the pin bracket in the microscopic image.

The mechanical test results compared the maximum load, onset failure load, and displacement at failure for each pin bracket with different precut designs. The maximum load represents the highest load experienced by the pin bracket during the test. While some pin brackets reached the maximum load and failed immediately, others demonstrated a gradual decrease in load due to crack propagation before experiencing complete failure. The pin brackets without any precut, that is only made with the recycled material, had an average maximum load of 10.5 kN. The pin brackets fabricated with precut design 1 had an average maximum load of 12.8 kN, which is 22% higher than the average maximum load of pin brackets fabricated only with the recycled material. The pin brackets with the precut design 2 had an average maximum load of 13.6 kN, which is 30% higher than the average maximum load of the recycled pin brackets. The pin brackets fabricated with precut design 3 had an average maximum load of 14.1 kN, which is 34% higher than the average maximum load of the recycled pin brackets without the precuts.

The onset failure load refers to the load at which the pin bracket begins to show signs of failure or damage. For the pin brackets made only with the recycled composite material, the onset failure load was 8.4 kN. The pin brackets made with the precut design 1 had the average onset failure load of 10.2 kN, indicating a 23% increase compared to the pin bracket without any precut. The pin brackets with the precut design 2 showed the average onset failure load of 11.3 kN, which is 35% higher than the recycled pin brackets. The pin brackets with the precut design 3 had the average onset failure load of 9.1 kN, which is 9% higher than the pin brackets without any

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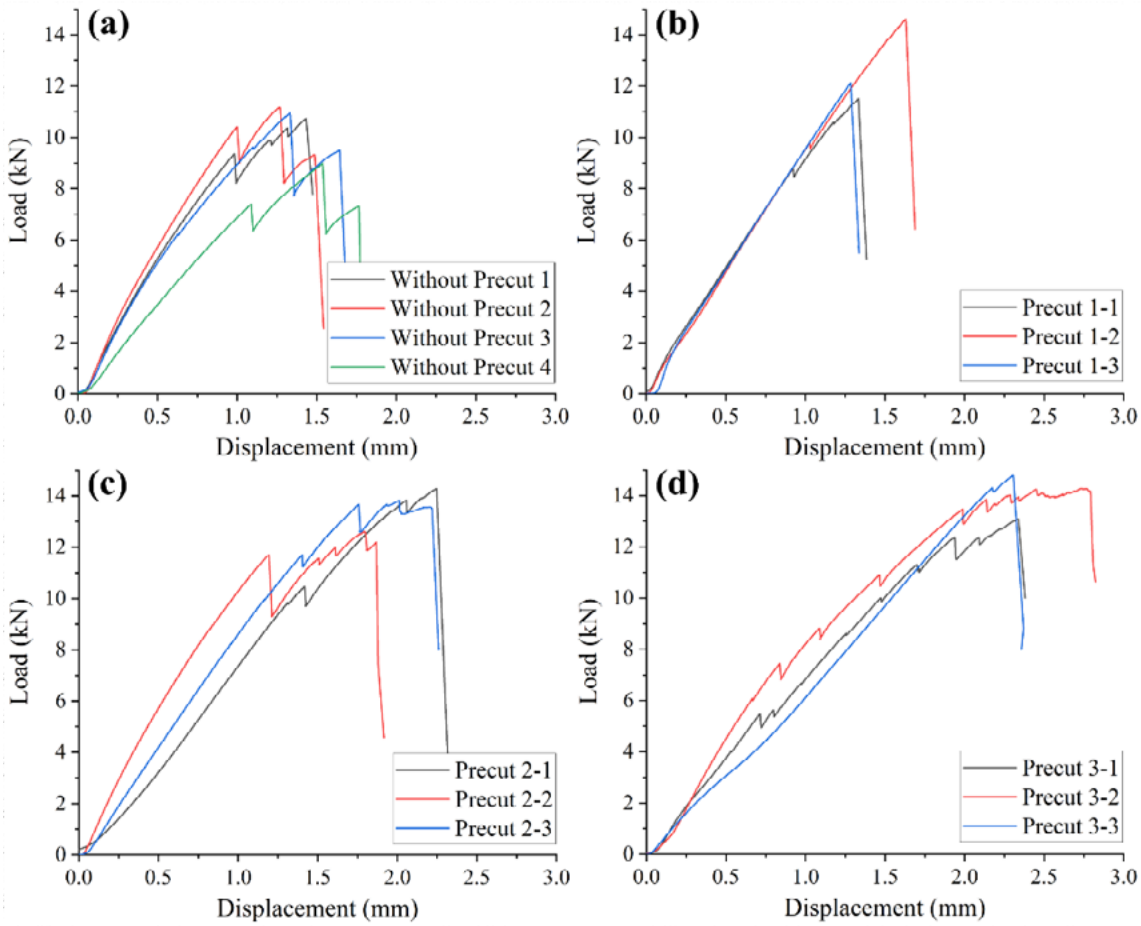

Figure 9: Load-displacement plot during the mechanical testing of the pin bracket (a) without precut, (b) with the precut design 1, (c) with the precut design 2, and (d) with the precut design 3.

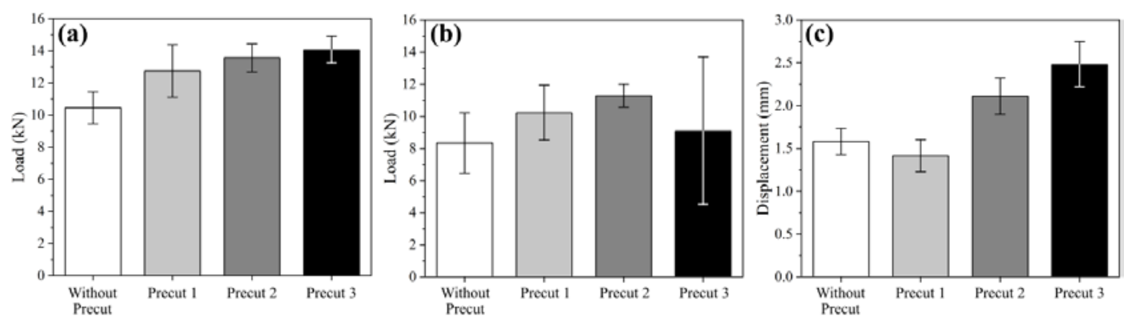

Figure 10: Average (a) maximum load, (b) onset failure load, and (c) displacement at failure of the pin brackets fabricated without precut and with the precut design 1, 2, and 3.

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precut. While the pin brackets fabricated with the precut design 1 and precut design 2 showed significant increases on onset failure load, the precut design 3 did not show a significant increase. The pin brackets fabricated with the precut design 3 showed large variation on the onset failure load. While two pin brackets out of three had an onset failure at low loads (5.5 kN and 7.5 kN), one pin bracket had highest onset failure load among all the pin brackets tested (14.3 kN).

The pin brackets fabricated with different precut designs yielded various displacement at failure values. The pin brackets without the precut had the average displacement at failure of 1.58 mm. The pin bracket made with the precut design 1 had the average displacement at failure of 1.42 mm, which was 10% lower than the recycled pin brackets value. The pin bracket fabricated with the precut design 2 and 3 showed higher average displacement at failure values, 2.11 mm (33.5% higher than recycled material) and 2.48 mm (56.7% higher), respectively. The load-displacement plot of the pin bracket mechanical testing showed that the pin bracket without the precuts had two or three major failures before the complete failure of the pin brackets. The pin brackets with the precut design 1 tended to have a single complete failure, while the pin brackets made with the precut design 2 and 3 had numerous minor load drops before the complete failure.

DIC analysis was conducted to observe local strain changes and the failure behavior of the pin brackets. The pin brackets without precuts showed significant strain changes, particularly in the upper portion of the pin hole during the test. The strain did not show a distinct pattern, but the cracks occurred in the upper region of the pin hole toward the load was applied. The failed pin bracket fabricated without precut and the DIC analysis are shown in Figure 11(a). All pin brackets made only with the recycled composite material without precuts failed in the same way.

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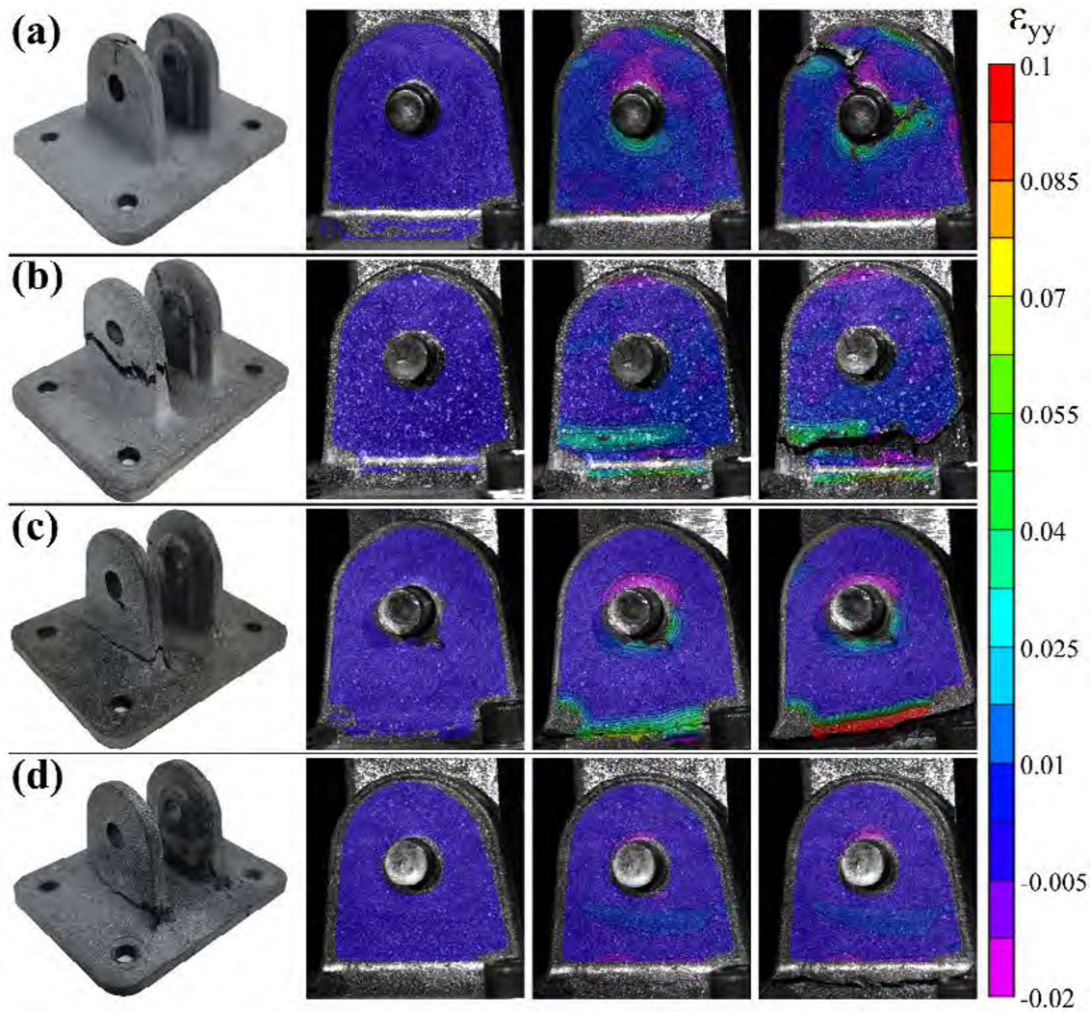

Figure 11: Images of the pin bracket after failure and local strain changes via DIC analysis for each design: (a) without precuts, (b) with the precut design 1, (c) with the precut design 2, and (d) with the precut design 3.

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The pin brackets fabricated with the precut design 1 initially experienced strain changes at the flange where the ear and base connected. During testing, a drastic strain change occurred at the bottom of the ear region, where the recycled composite material was filled. The strain change in this region gradually increased and led to failure. When one side failed at the bottom of the ear region, the pin tilted, and the strain on the opposite side at the bottom of the ear was relieved. Eventually, the angled pin failed the ear pin hole region of the opposite side ear. The failed pin bracket fabricated with the precut design 1 and the DIC analysis are shown in Figure 11(b). All pin brackets fabricated with the precut design 1 had the same failure behavior.

For the pin brackets with the precut design 2, the failure occurred at the flange where the ear and base were connected. The failure in the pin brackets with the precut design 2 did not happen suddenly like in the precut design 1. Instead, it occurred gradually as the ear was slowly pulled out from the base through the slots. Similar to the pin brackets with the precut design 1,

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when one side failed at the ear-base connection region, the pin tilted, and the ear on the opposite side failed.

The pin brackets with the precut design 3 had a similar failure behavior to those with the precut design 2. However, the strain changes in the ear region were less significant compared to the precut design 2 due to the greater amount of continuous fiber in the ear region. The strain changes at the flange occurred at a slower and more gradual pace compared to the precut design 2. Unlike the precut designs 1 and 2, the pin brackets with the precut design 3 experienced failures at the flange area for both ears.

Discussion

The precut design 1 had a weight of 16.67 g which was approximately 53% of the total weight of the pin bracket. Integration of the precut design 1 resulted in an increase in the average maximum load, from 10.5 kN to 12.8 kN, increasing by 2.3 kN which is approximately 22% compared to the pin bracket without precuts. The precut design 2 had a weight of 19.37 g which represents that the 62% by weight of the pin bracket is continuous fiber. The average maximum load was 13.6 kN which was 3.1 kN (30%) higher than the pin bracket without precuts. The precut design 3 had a weight of 22.17 g which is 71% of the total weight of the pin bracket. The average maximum load increased by 3.6 kN (34%), reached to 14.1 kN, compared to the pin bracket without precuts. The test results showed a positive relationship between the amount of continuous fiber integrated through precuts inside of the pin brackets and the corresponding increase in maximum load. Performance enhancement-to-continuous fiber content ratio also can be calculated by dividing the increased maximum load value by weight of the continuous fiber precuts for each precut design. The performance enhancement-to-continuous fiber content ratio of the precut design 1, 2, and 3 was 0.137 kN/g, 0.161 kN/g, and 0.162 kN/g respectively. Although the results in this study showed a positive relationship between the amount of continuous fiber and both the average maximum load and the performance enhancement-to-continuous fiber content ratio, it may vary depending on the specific precut design. Therefore, depending on the application and conditions, the prioritization can be aiming to develop the precut design that yields the highest performance enhancement-to-continuous fiber content ratio, prioritizing maximum load capacity without considering of the weight of the continuous fiber, or a combination of both factors.

Through the innovative precut approach introduced in this paper, the integration of various continuous fiber precuts into mechanically recycled materials has demonstrated significant potential. This study contributes to promoting the recycling of EOL composite parts, improving the overall sustainability of composite materials, and providing valuable insights for the industry on effective ways to expand the application of recycled composite parts. However, this approach has several considerations that need to be addressed for industrial application. Firstly, not all EOL composite parts are flat. Therefore, a flattening process may be necessary. While the flattening process may be simple for parts with simple curve shapes, there are also parts where flattening poses challenges. Therefore, careful selection of composite parts suitable for precuts is required. Also, considering the varying thicknesses

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of the EOL parts, a strategic planning for precut design and incorporation is required. Moreover, continuous fiber precut integration approach does not always offer the optimal utilization of continuous fibers inside of the recycled composite part. Although efforts were made to design the most suitable precuts for the part, achieving the ideal fiber orientation for the structure may not always be possible. Further research is necessary to explore more effective precut designs, strategic planning for precut processing from EOL composite part, and methods to achieve optimal fiber orientation for maximize the structural performance of the part through precuts.

Conclusion

In this study, an innovative method to enhance the structural performance of mechanically recycled composite materials by integrating continuous fiber-reinforced composite precuts was demonstrated. Through the strategic design of various precut to reinforce critical load-bearing areas of the composite parts, significant improvements on structural performance were achieved. Three different precut designs were developed and their performance were evaluated by comparing them to the pin bracket without any precut. The microscopic image of the pin brackets indicated the location and shape of the continuous fiber in the pin brackets when they were fabricated with the different precut designs.

The pin brackets featuring various precut designs showed notable structural enhancements. The precut design 1, which incorporated separate precuts for the ear and base, showed a 22% increase in maximum load compared to the pin bracket without any precuts. For the precut designs 2 and 3, the base precut featured slots for the insertion and interlocking of the ear precuts. In Precut Design 3, two ear precuts were used in each ear to increase the amount of continuous fiber within the pin bracket. As a result, the maximum load of the pin brackets increased by 30% and 34% with Precut Designs 2 and 3 respectively. Also, not only the maximum load, but the onset failure load and displacement at failure also increased. The precuts inside of the pin brackets also affected the failure behavior of the pin brackets. Without any precuts, the pin bracket failed at the top of the pin hole in the direction of the applied load due to the localized stress in that specific region. The integrated ear precuts reinforced the top of the pin hole and transferred the load to the ear and base. Overall, the precuts integrated in the pin brackets enhanced the load-bearing capacity of the pin bracket.

The integration of continuous fiber precuts to enhance the structural performance of the recycled composite part showed a promising approach to overcome the limitations associated with mechanical recycling of composite materials. By strategically designing precuts, it is possible to maximize the utilization of continuous fiber within EOL composite parts and redirect their application towards continuous fiber precuts for recycled composite part, rather than shredding them all to short fibers. This study contributes to the advancement of sustainable fiber-reinforced composite materials and introduces an innovative approach to recycling composite materials to establish an environmentally friendly and economically sustainable loop.

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AT THE MONONA TERRACE COMMUNITY AND CONVENTION CENTER

SPE THERMOSET TOPCON

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Presented by SPE Thermoset Division

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SPE® Automotive Composites Conference & Expo (ACCE) Succeeds Again!

Expanded Focus on Composites in Electric Vehicles and Sustainability Enhanced the Event 52 Technical Presentations, 25 Student Posters, 65 Sponsorships, 45 Exhibits, 6 Keynotes

TROY (DETROIT), MICH. -

The 23rd annual SPE® Automotive Composites Conference & Expo (ACCE), produced by the SPE Automotive and Composites Divisions, was a very valuable event according to exhibitors/sponsors and attendees representing OEMs, Tier Suppliers, Academia and other composites industry professionals. "The ACCE provided us with the opportunity to feature our technology with a technical presentation and exhibit resulting in new business opportunities and new interest in our products and services – we're already signed up for next year," said Jonathon Spiegel, Senior Engineer at Avient Corporation.

"We're proud to sponsor the ACCE as it's a proven event for reaching OEMs interested in the benefits composites enable in automotive applications including electric vehicle batteries and components," said Eric Haiss, Global Director, Automotive Business Development at IDI Composites International. "I look forward to the ACCE every year to meet with suppliers and learn about the latest composites technologies," said Amanda Nummy, Senior Materials Engineer at Hyundai-Kia. "ACCE offers a great combination of educational presentations and exhibits with networking opportunities for follow-up and new connections."

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ACCE Leadership & Summary

"Our ACCE 2023 theme 'Composites The Key to EV Auto and Air Mobility,' was expanded from last year (Composites: The Key to EV) to continue emphasizing how composites are essential to automotive electric vehicles and also highlight how composites are essential in the next wave of transportation – electric air mobility – including eVTOLS and more," said Dr. Christoph Kuhn, Quality Satisfaction Strategy Manager at Volkswagen Group of America and ACCE 2023 and 2022 Co-Chair. "The 2023 ACCE was successful in attracting attendees who have attended the event for many years and new attendees eager to contribute to composites innovation in transportation as it progresses into the future," said Dr. David Jack, Professor – Department of Mechanical Engineering at Baylor University and ACCE 2023 and 2024 Co-Chair.

The ACCE 2023 event was held September 6 – 8, 2022 at the Suburban Collection Showplace Diamond Banquet and Conference Center in Novi, Michigan. In addition to Dr. Jack and Dr. Kuhn who provided leadership as Event Chairs, a number of composites leaders from industry and academia provided support. The Technical Program, including 52 presentations, was led by Dr. Dana Gabriela Miloaga, Nonwovens Technology Leader at Johns Manville and Dr.

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Mehdi Tajvidi, Associate Professor of Renewable Nanomaterials School of Forest Resources, Advanced Structures and Composites Center and Forest Bioproducts Institute at University of Maine with support from Kim Hoodin, Program Administrator, SPE Automotive Div. Hoodin also managed registration, including over 450 attendees, with support from Jitesh Desai, Program Treasurer, SPE Automotive Division. Dr. Leonardo Simon, Professor, University of Waterloo, led the ACCE Parts Competition that included 9 nominations. Dr. Douglas Smith, Professor at Baylor University, led the Student Poster Competition including 25 presentations with sponsorship support provided by Dassault Systèmes. Executive committee member Dr. Sara Simon, Project Engineering Manager atForward Engineering North America, led a Special Session on Sustainability including 2 keynotes and a panel discussion. Teri Chouinard, President of Intuit Group provided leadership as ACCE Sponsorship Chair with 65 sponsorships and 45 exhibits and support with Event Management overall.

Keynotes presented at the ACCE 2023 event included: "Journey to the World's First Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composite 100% Recyclable Door Assembly" by Dr. Ryan Hahnlen Principal Engineer and Lead of Strategic Research Operations at Honda Development & Manufacturing of America, LLC & Dr. Srikanth Pilla, Director of The Center For Composite Materials at The University of Delaware (UD_CCM) and Founding Director of 'Aim For Composites' a DOE Energy Frontier Research Center; "An Overview of Transportation Trends and Related Opportunities" by Gregory E. Peterson – Chief Engineer at Airspace Experience Technologies (ASX), "A Role for Composites In GM's Vision for Simulation-Driven & Sustainable Material Impact" by Jason Coryell, P.E., FASM – Engineering Group Manager of Advanced Materials Technology at General Motors Company and "What Does Disruptive Electrification of Transport Mean For Industrialization of Composites?" by Dr. Jamie Snudden, Business Development Manager at Airborne UK.

A Special Session on "End of Vehicle Life Today and Sustainability Solutions for the Future" featured the keynote presentations "Circularity for End Of Life Vehicles" by Kari Bliss, Principal Sustainability at PADNOS and "Recycling Plastics from End Of Life Vehicles: The Final Frontier?" by Dr. David L. Wagger, Chief Scientist and Director of Environmental Management at the Institute of Scrap Recycling Industries (ISRI) and a Panel Discussion including Amar Mohanty, Professor and Research Chair of Sustainable Biomaterials at University of Guelph; Mehdi Tajvidi, Associate Professor of Renewable Nanomaterials School of Forest Resources, Advanced Structures and Composites Center and Forest Bioproducts Research Institute at University of Maine; Dan Dowdell, Business Development Manager at INEOS Composites and keynote presenters Eric Walker from Honda, Kari Bliss from PADNOS and David Wagger from ISRI. The Special Session was led and moderated by Dr. Sara Simon, Project Engineer with Forward Engineering and ACCE Executive Committee member and moderated by Dr. Christoph Kuhn, Quality Satisfaction Strategy Manager at Volkswagen Group of America, Inc. and ACCE Co-Chair.

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The ACCE 2023 technical program included 52 presentations on advances in the following categories:

Composites in Electric Vehicles; Advances in Thermoplastic Composites; Advances in Thermoset Composites; Modeling of Composites; Additive Manufacturing/3D Printing; Enabling Technologies; Sustainable Composites; Bonding/Joining/Finishing; Carbon Composites and Reinforcements; and a special session on Partnerships Advancing Composites in Automotive Applications including Honda North America and Clemson University.

Best Paper Awards

Excellence in technical writing is recognized annually at ACCE by honoring those who have presented the best papers at the conference. The 2023 Best Paper Award winners received the highest average ratings by conference peer reviewers including members of the ACCE planning committee and other industry experts. One winner and two honorable mentions were recognized in the program guide and honored at the event in the "Best Paper Award" competition. Garam Kim, Assistant Professor at Purdue University, won the Best Paper Award for his paper "Enhancing Recycled Thermoplastic Composite Parts Using Recycled Composite Laminate Cutouts." Honorable Mention recognitions were awarded to Chandra Kishore Reddy Emani, Postdoctoral Researcher at University of Michigan – Dearborn for his paper titled, "Press Forming of E-Glass Fabric Reinforced Polypropylene: A Numerical Study" and Jacob Montrose, Graduate Researcher at Purdue University for his paper titled, "Influence of Waterjet Cut Quality for Fabrication of Test Specimen on Mechanical Testing Results." The authors were presented with certificates at the conference and their papers were highlighted in the ACCE program schedule and will be published in SPE Automotive and Composites Division newsletters and other industry publications.

Student Poster Competition:

Students from the U.S.A. and Canada featured innovative research related to polymer composite materials and manufacturing technologies for automotive applications via the annual ACCE Poster Competition. This yearly event enables students to meet with people in the industry and learn about career opportunities as a scientist, engineer, researcher and other professions in the field. Automotive OEMs, tier suppliers, and others appreciate the introduction to the next generation of automotive composites engineering professionals and opportunity to potentially hire them in the future. The 2023 ACCE Student Poster Competition, sponsored by Dassault Systèmes, included 25 posters from 9 different universities. The 2023 ACCE Student Poster Competition winners were:

Graduate Category

1st Place: "Manufacturing and Validation of a Carbon Fiber Reinforced Thermoplastic Composite Door"
Amit Deshpande, University of Delaware

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2nd Place: "Material Property Prediction of Recycled Polypropylene via Data-Driven Modeling"
John Estela-Garcia, University of Wisconsin - Madison

3rd Place: "X-Ray Micro Computed Tomography Characterization of Void and Carbon Fiber Correlation within the Bead Microstructure of Large Area Additive Manufacturing (LAAM) Polymer Composites"
Neshat Sayah, Baylor University

Undergraduate Category

1st Place: "Ultra-lightweight Carbon Foams from Lignin for High-temperature Thermal Insulation Applications"
Johnathan Behr, Clemson University

2nd Place: "Sustainable Lightweight Biocomposites from Engineering Plastic and Hemp-Hurd Pyrolyzed Biocarbon"
Hugh MacFarlane, University of Guelph

3rd Place: "Investigation of crystalline Degradation in Ultra-High Molecular Weight Polyethylene (UHMWPE) Composites"
James Tallman, University of Delaware

Scholarship Awards:

The organizing committee for the SPE Automotive Composites Conference & Exhibition (ACCE) honored winners of the SPE ACCE Scholarships and Dr. Jackie Rehkopf Scholarships at this year's event. The SPE ACCE Scholarships are sponsored by the SPE Automotive and SPE Composites Divisions. The Dr. Jackie Rehkopf Scholarships are sponsored by the SPE Automotive and Composites Divisions and generous donations of friends and family to honor the memory of the late long-time SPE ACCE committee member, SPE Automotive Division board member, and automotive composites researcher. Both scholarship programs are administered as part of the SPE Foundation.

The ACCE scholarships ($2,000 USD each) are awarded to students pursuing advanced studies in a composites related field. The three winners of the ACCE Scholarships are: Amit Makarand Deshpande, a graduate student pursuing a PhD in Mechanical Engineering at the Center for Composite Materials at the University of Delaware; Md Nayeem Hasan Kashem, a graduate student pursuing a PhD In Chemical Engineering at Texas Tech University; and Suyash Oka, a graduate student pursuing a PhD in Chemical Engineering at Texas A&M University.

Additional ACCE scholarships ($1,000 USD each) are being awarded to Orville Tackett, a sophomore majoring in Plastics Engineering and minoring in CAD and Electromechanical Engineering at Shawnee State University; and Youyi Zhou, a student majoring in Composite Materials Engineering and Minoring in Mathematics, Chemistry and Polymer Chemistry.

The two winners of the 2023 Dr. Jackie Rehkopf Scholarships ($2,500 USD each) are Amy Kurr, a PhD candidate pursuing a doctoral degree in Energy Science and Engineering from the University of Tennessee's Bredesen Center; and Rachel Van Lear, a PhD candidate pursuing a doctoral degree in Mechanical Engineering at Baylor University.

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The SPE ACCE SCHOLARSHIP COMMITTEE was led by Dr. Alper Kiziltas, Amazon Advanced Materials, and included Dr. Leonardo Simon, University of Waterloo; Dr. Christoph Kuhn, Volkswagen Group of America; Dr. Oleksandr Kravenchenko, Old Dominion University; Dr. John Gillespie, Jr., University of Delaware; Dr. Akshay Trivedi, General Motors Co.; Dr. Zeynep Iyigundogdu, Adana Alparslan Turkes Science and Technology University; Drew Geda, Hyundai-Kia America Technical Center; Chuck Jarrett, The Materials Group; and Keith Siopes, EMS-CHEMIE North America and Dr. Prasad Soman, Amazon Lab126.

Part Competition:

This year's ACCE Part Competition was led by Dr. Leonardo Simon from the University of Waterloo who previously served as the 2021 and 2022 ACCE Co-Chair. A panel of automotive composites industry experts, from industry and academia, studied the 9 nominations that were submitted in advance of the event and reviewed the parts onsite and voted for the Most Innovative Material and/or Process Applications in Production Part and Prototype Part Categories. Nominations were judged on the impact and trendsetting nature of the application, including materials of construction, processing methods, assembly methods, and other enabling technologies that made the application possible. Nominations emphasized the benefits of design, weight and cost reduction, functional integration, and improved performance. A separate prize, the People's Choice award, was selected by vote of conference attendees.

Here are the winners:

Most Innovative Material in the Production Part Category:
Organ Sheet Battery Casings on the 2020 Daimler Class S
Nominated by: Valeo

Most Innovative Material in the Prototype Part Category:
Recycled Paper and Recycled Polypropylene Interior Trim
Nominated by: Volkswagen Group of America

Most Innovative Process in the Prototype Part Category:
Ultra Lightweight Carbon Fiber Reinforced Thermoplastic Door Assembly
Nominated by: Clemson University and Center for Composites Materials at University of Delaware

People's Choice Award:
Thermoplastic Composites Sandwich Panel for Truck Bed
Nominated by: Johns Manville

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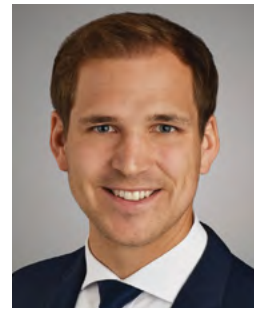

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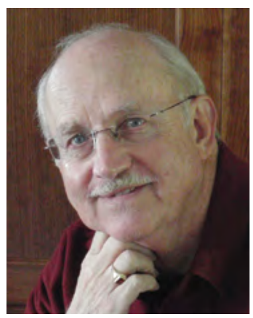

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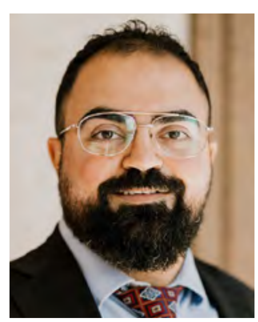

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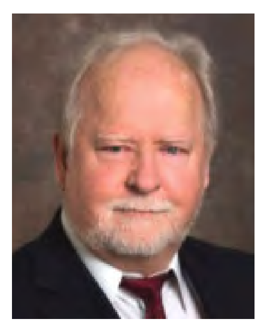

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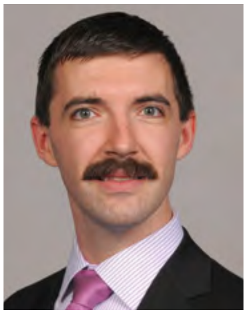

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