MAKER: 3D Printing as an Alternative to Fabricate Motorsports Parts

Mr. Astrit Imeri, Tennessee Technological University

Mr. Astrit Imeri is a Masters student in the Mechanical Engineering Department at Tennessee Tech University. He is currently working as a graduate research assistant in the Center for Manufacturing Research under Dr. Fidan. Astrit has a BS degree in Mechanical Engineering from Middle East Technical University (METU). He is currently member of SME and Vice President of the Tennessee Tech University SME student chapter.

Mr. Nicholas Russell, Tennessee Technological University

Mr. Nick Russell is a senior in Mechanical Engineering at Tennessee Tech University. He is currently working as an undergraduate research assistant in the additive manufacturing laboratory under Dr. Fidan. Nick is the student trustee on the Tennessee Tech Board of Trustees and is formally the Tennessee Board of Regents Student Regent. He is also the recipient of the 2017 Rising Renaissance Engineer Spectrum Award. Nick enjoys spending time with his family and trading stocks in his free time.

Mr. James Reed Rust, Tennessee Technological University

Mr. Reed Rust is a senior in Manufacturing Engineering Technology at Tennessee Tech University. He is currently working as an undergraduate research assistant in the additive manufacturing laboratory under Dr. Fidan. He is also the build team director for the TTU Motorsports Formula SAE team. Reed is also the recipient of the 2017 Rising Renaissance Engineer Spectrum Award. He enjoys spending his time working in the machine shop and working on cars.

Mr. Serhat Sahin, Tennessee Technological University

Mr. Sahin is a Computer Science Master of Science student and graduate research assistant at TTU’s Center for Manufacturing Research under Dr. Fidan’s supervisory. His current research is on Additive Manufacturing security vulnerabilities. Before joining Tennessee Tech, Mr. Sahin worked as a researcher on security and speech processing related projects at The Scientific and Technological Research Council of Turkey. He has a BS in Electrical and Electronics Engineering from Bosphorus University, Turkey.

Dr. Ismail Fidan, Tennessee Technological University

Currently, Dr. Fidan serves as a Professor of the Department of Manufacturing and Engineering Technology and College of Engineering-Faculty Fellow in Innovation and Techno-Entrepreneurship at Tennessee Technological University. His research and teaching interests are in additive manufacturing, electronics manufacturing, distance learning, and STEM education. Dr. Fidan is a member and active participant of SME, ASEE, ABET, ASME, and IEEE. He is also the Associate Editor of IEEE Transactions on Components, Packaging, and Manufacturing Technology and International Journal of Rapid Manufacturing.

Dr. Hugh Jack P.E., Western Carolina University

Not an author
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1. Abstract
Today, saying Additive Manufacturing (AM) is changing our world is an understatement. Current applications include additively manufactured shoes, jewelry, prosthetics, and food products. In this study, a steering rack extension for Tennessee Tech’s Formula SAE (FSAE) car was replaced with various 3D printed alternatives. Numerous beta testing studies were performed to measure its sustainability. Utilization of a Steering Rack Extension is made to adapt a quick ratio steering rack to interface with the steering system designed for the TTU Motorsports FSAE car. The current study reports the design, analysis, and manufacturing studies performed to replace the steering rack extension with a 3D printed component. Various tests and 3D printing operations have been performed to show the improvements made to replace the currently used piece. This presentation will report the design, printing and testing studies performed for the newer steering rack extension. Student feedback received from the FSAE team and engineering students will be also presented.

2. Background
FSAE is the name of a student design competition organized by SAE International (previously known as the Society of Automotive Engineers, SAE). This competition was started initially in 1980 by the University of Texas-Austin SAE student branch. The main idea behind the FSAE is that an imaginary manufacturing company has contracted a student design team to develop a small Formula-style race car. The prototype race car is to be evaluated for its potential as a production item. The target marketing group for the race car is the non-professional weekend autocross racer. Each student team designs, builds and tests a prototype based on a series of rules, whose purpose is both ensuring on-track safety (the cars are driven by the students themselves) and promoting clever problem solving [1].
Tennessee Tech University has a very well established FSAE team that competes in the top FSAE competitions within the US. In the Spring, 2017 semester, one project was conducted to replace some of the FSAE parts with additively manufactured newer ones. In this paper, steering rack seen in Figure 1 will be presented, and studies performed will be reported.

![Figure 1: Location of the Steering Rack on FSAE](image)

This steering rack chosen to give the desired steering feel was too short to work with the system designed. In order to make the rack work a custom part was made to extend to rack out wide enough to connect the rest of the system together. This part was to be as light as possible while maintaining a strong reliable part. This piece extends the rack roughly 5 in out in each direction to connect to a sliding bearing in a vertical pitman arm. The extension experiences max forces of 300 pounds in a linear compression or extension during hard cornering. The finished design was a 78-gram machined piece of aluminum that allowed a firm solid feel in the steering system. As part of a National Science Foundation-Advanced Technological Education Project called AM-WATCH (Additive Manufacturing Workforce Advancement Training Coalition and Hub), this study has been performed in order to provide the capabilities and availabilities of composite 3D Printing as an alternative to conventional CNC (computer numerical control) practices.
3. Composite based Additive Manufacturing (CBAM)

Current steering rack is a CNC machined aluminum workpiece. In this study, MarkForged’s desktop 3D printer was used to perform an experimental study to show that a CBAM machine operating with carbon fiber, fiberglass and Kevlar components could produce reliable FSAE workpieces. Currently, MarkForged’s CBAM technology is not only capable of producing carbon fiber 3D printed parts with a higher strength-to-weight ratio than 6061-T6 Aluminum, it is also apparently able to do so up to 90% faster and 70% cheaper compared to traditional methods [2]. MarkForged’s patented CBAM technology relies on two print heads: one extrudes nylon filament, while the other continuously reinforces the nylon with proprietary reinforced composite materials, including carbon fiber, fiberglass, or even Kevlar. The result is cost-efficient CBAM parts that can displace components that would typically be machined in metal [2].

4. Testing Studies

Steering rack extensions have been printed in various fused deposition modeling machines available at the Tennessee Tech University. Then, produced samples were tested on a Tensile Test machine. It has been proven that the highest values of the results were received from the parts built via CBAM technology. Figure 2 shows a test part attached to Tensile Test machine.

Figure 2: Steering Rack made with CBAM under Tensile Testing Equipment
Table 1 presents the list of currently tested specimens. Figure 3 is various tensile test results from the specimens.

**Table 1: Specimens used in the Tensile Test**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Printer</th>
<th>Material</th>
<th>Infill</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MarkForged 1</td>
<td>Nylon+Carbon Fiber</td>
<td>CF-15.3cm³-Nylon-19.5cm³</td>
</tr>
<tr>
<td>2</td>
<td>Ultimaker 2+</td>
<td>PLA</td>
<td>25%</td>
</tr>
<tr>
<td>3</td>
<td>Ultimaker 2+</td>
<td>PLA</td>
<td>35%</td>
</tr>
<tr>
<td>4</td>
<td>Monoprice I3</td>
<td>PLA</td>
<td>35%</td>
</tr>
<tr>
<td>5</td>
<td>PrintrBot</td>
<td>PLA</td>
<td>35%</td>
</tr>
<tr>
<td>6</td>
<td>MarkForged 1</td>
<td>Nylon+Carbon Fiber</td>
<td>CF-11.20cm³-Nylon-23.93cm³</td>
</tr>
<tr>
<td>7</td>
<td>Ultimaker 2+</td>
<td>PLA</td>
<td>35%</td>
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<tr>
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</tr>
<tr>
<td>10</td>
<td>Ultimaker 2+</td>
<td>PLA</td>
<td>25%</td>
</tr>
</tbody>
</table>

**Figure 3: Tensile Test Results of Steering Racks made with Various AM Technologies**
5. Feedbacks received from Engineering Students

The following will provide a beneficial feedback about the impact of the current study to engineering education. The experience of two students will be shared here.

Undergraduate Student:

“Working on this project has provided useful feedback in how far AM has developed. During work on this project I have learned useful information about how to properly design parts that are additively made so that they will withstand the forces placed on them during use, while still being able to print them easily.”

Graduate Student:

“In a world where AM applications seem to be fitting everywhere, having the chance to work on one of them is a changing mindset experience. AM can be used to print things that would be unique not only because they were 3D printed, but also, they could be used in real life applications. This project provided an extra edge to my knowledge on how to think about designing and manufacturing a part that would not have the obstacles of subtracting manufacturing but in thinking of how to manufacture those parts for additive manufacturing.”

6. Conclusions

There are many studies on replacing the current automotive parts with 3D printed metal and non-metal components. In this study, one metallic component used in the FSAE car was replaced with various additively manufactured pieces. It was seen the parts produced with CBAM provide highest level of strengths compared to other conventional AM technologies. Also, students engaged to this study provided very enthusiastic and critical feedbacks indicating that such kind of experiential activities is a good way to help students retain in engineering programs and support their learning with real world experiences.

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References
