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ENGINEERING SUCCESS ON THE FIELD:

A Reflection on the EPICS Ironman Pediatric Prosthetic Project

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STUDENT AUTHOR BIO SKETCH

Glynn Gallaway is a student in the Purdue Mechanical Engineering Class of 2020 with interests in the health care, assistive technology, and medical device industries. Glynn is from Dallas, Texas, and was inspired to pursue this career path through her interactions with youth with special needs. She joined the EPICS Ironman team in the fall of 2016 during her first year at Purdue as a part of the learning community. In this article, she discusses her experiences on the Ironman team creating a pediatric prosthetic for a young local athlete. The goal of the Ironman team is to create a low-cost pediatric prosthetic that students can use in sports.

INTRODUCTION

I joined the Ironman EPICS team during the first semester of my freshman year as part of a learning community. EPICS is a service-learning program at Purdue that began over 20 years ago to promote student development through community projects. Through the learning community, I was placed in the Mobility (MOBI) lab, and from there I joined the Ironman team.

The Ironman project started in 2015 with the goal of providing a durable prosthetic ankle for use by young athletic amputees. We worked with a student from Harrison High School, Alex Morgan, who had a transtibial amputation. Alex was born with a birth defect that resulted in a foot and ankle amputation when he was an infant. He enjoys playing basketball, baseball, and wrestling, but his current prosthetic consistently breaks from stress encountered during his athletic activities.

A senior design team from mechanical engineering was involved in the initial development of the first version of the prosthetic. The team developed a two-piece aluminum device consisting of a reverse ball and socket. They completed extensive market and customer research, in

addition to a gait analysis of Alex. The team's work set the foundation for the Ironman project.

DESCRIPTION OF THE PROBLEM

Alex and several other users of pediatric prosthetics are fitted with an L-Bar prosthetic. This type of prosthetic consists of two pieces of metal joined together at a 90-degree angle. The device is stiff and allows little flexibility or response. Little flexibility is offered in other pediatric prosthetics as well. For the initial Ironman project, Alex was fitted with a more flexible prosthetic ankle, but it still broke frequently at the attachment to the prosthetic socket.

The Ironman team spoke with Alex's prosthetic technician to determine why it was breaking. He noted that prosthetics are rated for approximately two to three million cycles, and after that time, they are often replaced. This threshold is typical for manufacturers, as it aligns to when a user generally grows out of their prosthetic. A new prosthetic is made every two or three years. Alex's situation, however, is unusual because

Figure 1 (banner image, above). The testing rig manufactured by the team.

of his activity level and the concurrent stress on the prosthetic.

Without rotational movement at the ankle, the device experiences stress, and the user compensates with their hip and knee. For example, when walking on uneven terrain, an anatomical ankle has the ability to flex or rotate to adapt to the situation. However, in the case of Alex and other prosthetic users, these forces are rerouted to the hip and knee. While this does not cause short-term problems, it can lead to joint problems in the future.

THE SOLUTION

The senior design team from spring 2016 was inspired by a variety of products currently on the market. However, none of these met all of the goals of the project (flexible, durable, and affordable). The ball and socket joint consisted of two metal plates that mated together to form the joint. The mating surface was created out of a polymer material, and the two plates were connected by a screw. An exploded view of the first version of the product is seen in Figure 2.

During the spring and fall of 2017, the team aimed to reduce the weight of the device. While the device worked, its high metal volume made it bulky, and the technician was hesitant. In addition, the team aimed to increase the flexibility in the foot, specifically the balance provided by the toes. With influence from the current prosthetic market, the team created a split-toe, or two-toe, design. The metal tongue of the device was replaced with two carbon fiber “toes” that are able to move independently. This drastically reduced the weight of the device and allowed us to simplify the metal portion of the device for simple manufacturing. We then made the decision to change the way the two pieces were

Figure 3. Updated version of bottom plate and carbon fiber toes.

attached. Through research and tools like a decision matrix, the team came to the decision to attach the plates using Kevlar thread or cables. A modified version of the design is seen in Figure 3.

STUDENT STRUGGLES

The Ironman team made great strides in moving forward to create a better prosthetic device for Alex; however, we have not been without struggles. The fall 2016 semester focused on creating an active prosthetic, one powered by electricity and capable of sensing and adapting to and enhancing Alex’s movements. The focus was developing an actuation method that would provide a downward force with each forward stride and then pull the foot back to the resting state. The team investigated several actuation methods and landed on a linear actuator. We spent the rest of the semester toying with the linear actuator, trying to determine how to attach the actuator to the prosthetic and how to use sensors to activate the prosthetic. While this would be a great device to deliver, it was not within the initial goals of the project. Our team never got off the ground with actuators as we were unable to find any device that would fit our weight and output force requirements. In addition, our team had yet to deliver the device created during the first year. While an active prosthetic is the best solution for Alex, it would be incredibly expensive, and our team of undergraduate college students did not have the skills to make the device in a timely and efficient manner. At the end of the semester, the team sat down as a group and set new goals that focused on developing the device we inherited from the senior design team. Our goal was to continue to develop a mechanical solution we could deliver to Alex. From there, we had more discussion with Alex’s

Figure 2. Exploded view of the first version of the prosthetic.

prosthetic technician to determine what changes needed to be made. In addition, we started a testing team during the fall 2017 semester to develop a machine to ensure the validity and safety of our device. Our current outlook is to deliver a device to Alex sometime in 2018.

While our idea of an active prosthetic was set aside for the time being, our EPICS team accepts students from all disciplines. Understanding electronics is a large part of the future of engineering. With this in mind, we maintained an electronics team for every semester. This team focused on creating sensors that provide our team with feedback on the movement and stress on the device so we can make informed decisions on how to change it. This team is open to helping students employ what they have learned in their electrical engineering and computer science classes or those with a desire to learn about electronics.

In the spring 2017 semester, we consulted with Alex's prosthetic technician to determine what was and was not working in the passive prosthetic component we had (primarily from senior design). He advised us to reduce the weight and add more flexibility in the toes. With this in mind, we added two carbon fiber toes to the device (two would increase flexibility and decrease the number of fatigue points). This redesign allowed for a greater simplification of the hub or bottom plate.

In fall 2017, the team went through another redesign to replace the pin that connects the top and bottom plates of the device. The team made use of several campus resources. Dr. Nauman and the use of several decision matrices helped us decide to use Kevlar cables in addition to a rubber pad to connect the two plates, which would provide the needed flexibility. The team has moved forward with this idea at the time of writing and is working to manufacture the device.

In addition to the redesign in fall 2017, the Ironman team started a testing team to develop a testing rig that matched industry standards. This would be used to validate and verify our device. The team developed a testing rig similar to but lower-cost than those used in the industry. The rig, shown in Figure 3, is in the process of being manufactured at the time of writing.

STUDENT IMPACT

Each semester we learned lessons. We now know the importance of investing time into new members, which aids their skill and knowledge development. We continuously learned the value of effectively communicating with each other, as well as with Alex's prosthetic

technician and experts for advice. The beauty of EPICS is that it allows students to learn lessons vital to success in the corporate world.

In the four semesters I have been on the Ironman EPICS team, I have gained numerous skills. I learned how to approach solving engineering problems, how to work on a team with peers, how to sew, how to program, how to lead a team of my peers, and how to delegate. I received my first internship offer due to my involvement with EPICS, which ultimately led to a second internship offer.

I personally experienced the EPICS program's influence on my professional and personal development, but I have also seen it in our freshmen team members. When a freshman enters the team, they have little experience with the design process. EPICS provides professional development lectures on human-centered design, ethics, and the design process. In addition, freshmen go through several mini projects to increase their computer-aided design (CAD) and coding skills. During the first semester, most freshmen are nervous, but by the second semester, they gain confidence and begin to lead parts of the project. Several freshmen have taken on leadership roles. While EPICS has a steep learning curve, it gives you a leg up on your peers—not only in design, but also with communication, teamwork, professionalism, critical thinking, and problem-solving skills.

COMMUNITY IMPACT AND CONCLUSION

Alex's current prosthetic causes an awkward gait cycle. When Alex walks or runs, his leg swings out. Once a better device is delivered, we expect Alex's health and performance to improve. The proposed solution should resolve stress on his joints, help prevent further joint damage, and reduce the likelihood that Alex develops arthritis. The Ironman team has begun to get the word out to new project partners and industries to help give end users an increased activity level and a healthier lifestyle.

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