Biomechatronic Hip Exoskeleton

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Abstract

The goal of this project was to design and build the mechanical portion of a biomechatronic hip exoskeleton. This hip exoskeleton will be used to reduce the metabolic cost of walking for children with cerebral palsy. The design that this capstone team implements will ultimately be used by our primary client, the Northern Arizona University Biomechatronics Laboratory. The key requirements for the design are for it to be as lightweight as possible, comfortable, and to allow for torque to be applied linearly in the direction of hip extension/flexion. The final concept is a Bowden cable design that utilizes electric motors with a timing belt system that actuates the extension/flexion movement.

Methods

Manufacturing

Components of the design were manufactured with a combination 6061-T6 aluminum and Kydex thermoplastic. Most aluminum parts were cut on a CNC machine and all Kydex parts were molded with a heat gun. Shown below is the CAM generated for one of the aluminum Parts.

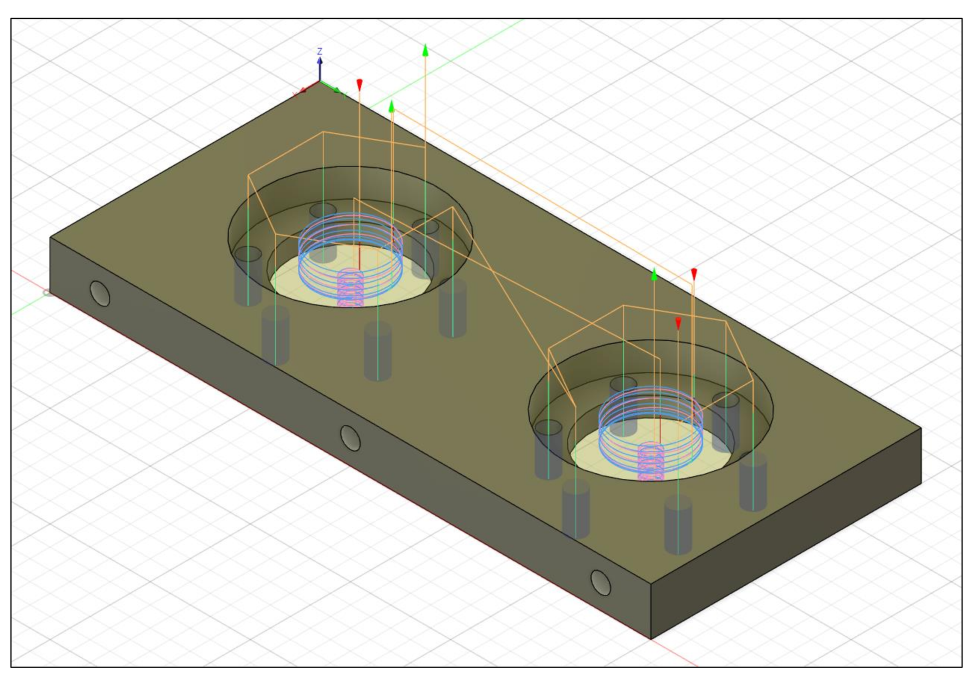

Figure 1: CAM of Motor Mount Component

Testing

Testing Procedure 1: Torque/Power Output

This testing procedure is used to record the torque/power output of the assembly. This is done by attaching it to a test fixture and using load cells for torque testing and weights for power testing.

Testing Procedure 2: User Comfort Rating/Survey

A random set of people would wear the exoskeleton and move around with it on, then they would fill out a survey rating it.

Testing Procedure 3: Fitment Tests

The BHET team would wear the system and take measurements such as: range of motion angle and waist measurement. Weight of the system would be taken by itself using a scale.

Testing Procedure 4: Fatigue Failure Modes

While using the same testing fixture as Testing Procedure 1, system will be run as if it's actuating movement. Record number of cycles when wear is shown on cables or motor mounts.

Results

Completed Hip Exoskeleton

The final device consists of the different subsystems: The Motor Mount (1), Hip Belt (2), and Knee Brace (3). The wearer is secured by a semi-rigid hip belt and braces on each knee joint. Flexible cables connect the Hip Belt to the Knee Braces. Assistive torque is applied to the wearer by tensioning the cables in cadence with the wearer's walking gait cycle.

Subsystems of the Design

1. Motor Mount

The components which generate and transmit torque. Brushless DC motors generate torque, which is multiplied through an 89:1 planetary gearhead. Torque is then transmitted through a timing belt to a parallel shaft fixed to the cable spools.

2. Hip Belt Harness

The hip belt is molded from Kydex thermoplastic and is padded with foam. This is were the motor assembly, batteries, and control systems are mounted. The combination of molded Kydex and foam allows for the best possible user comfort.

3. Knee Brace

Similar to the hip belt, this portion of the design is molded from a Kydex thermoplastic and is padded on the interior with foam. The Bowden cables coming from the motor mount connect to the knee brace, allowing for the application of torque about the user's hips.

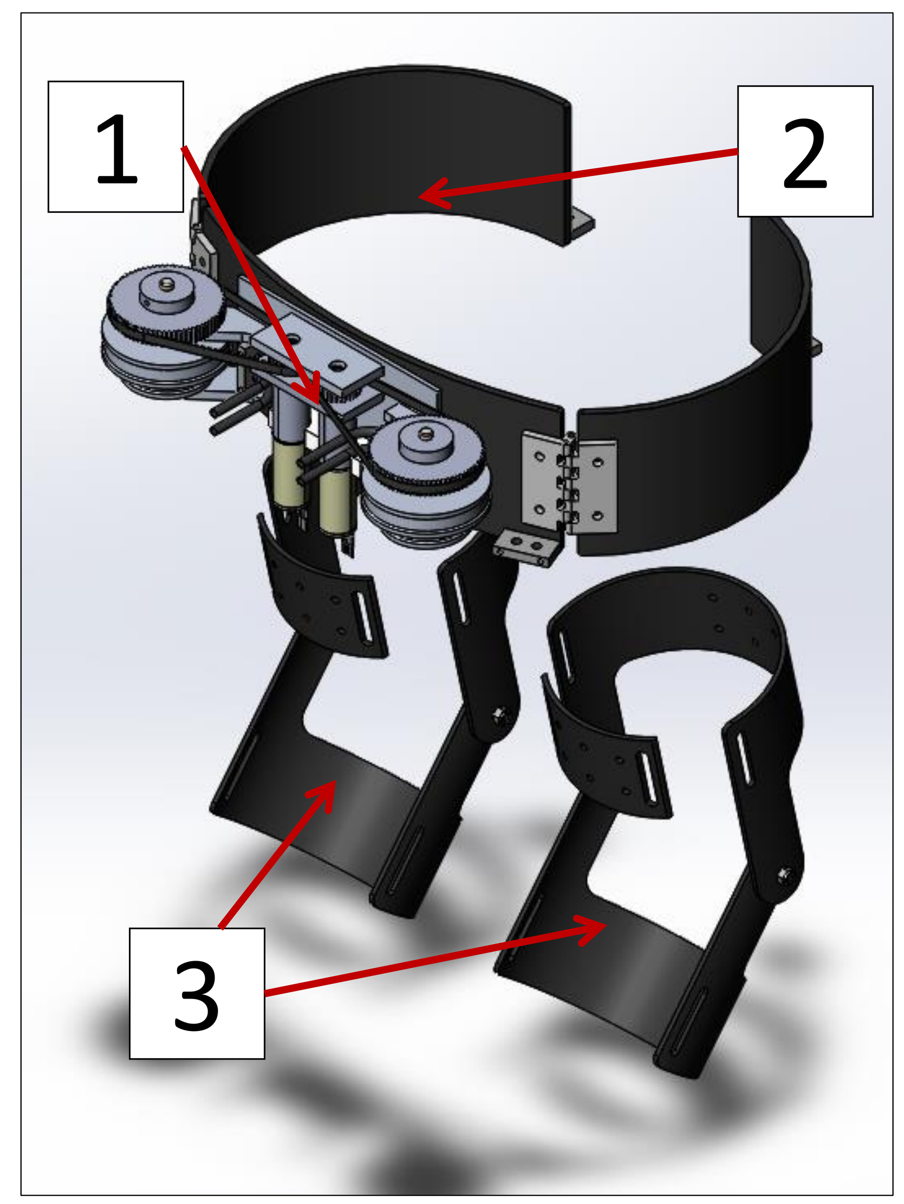

Figure 2: Full Assembly (Back)

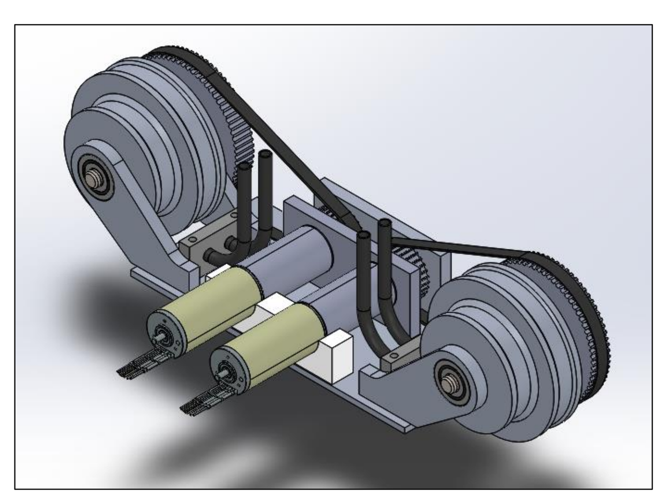

Figure 3: ISO View of Motor Mount

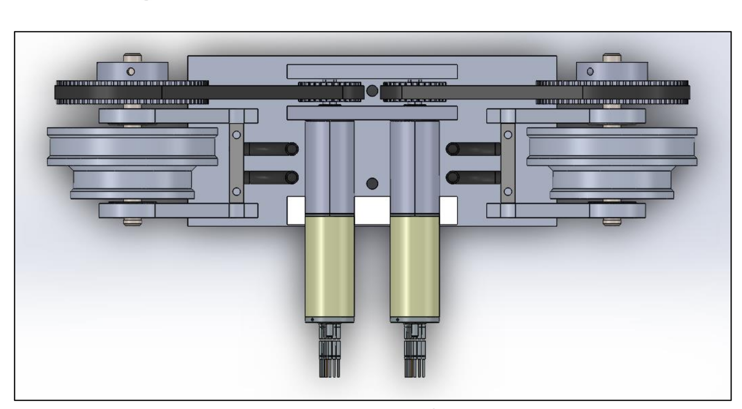

Figure 4: Top View of Motor Mount

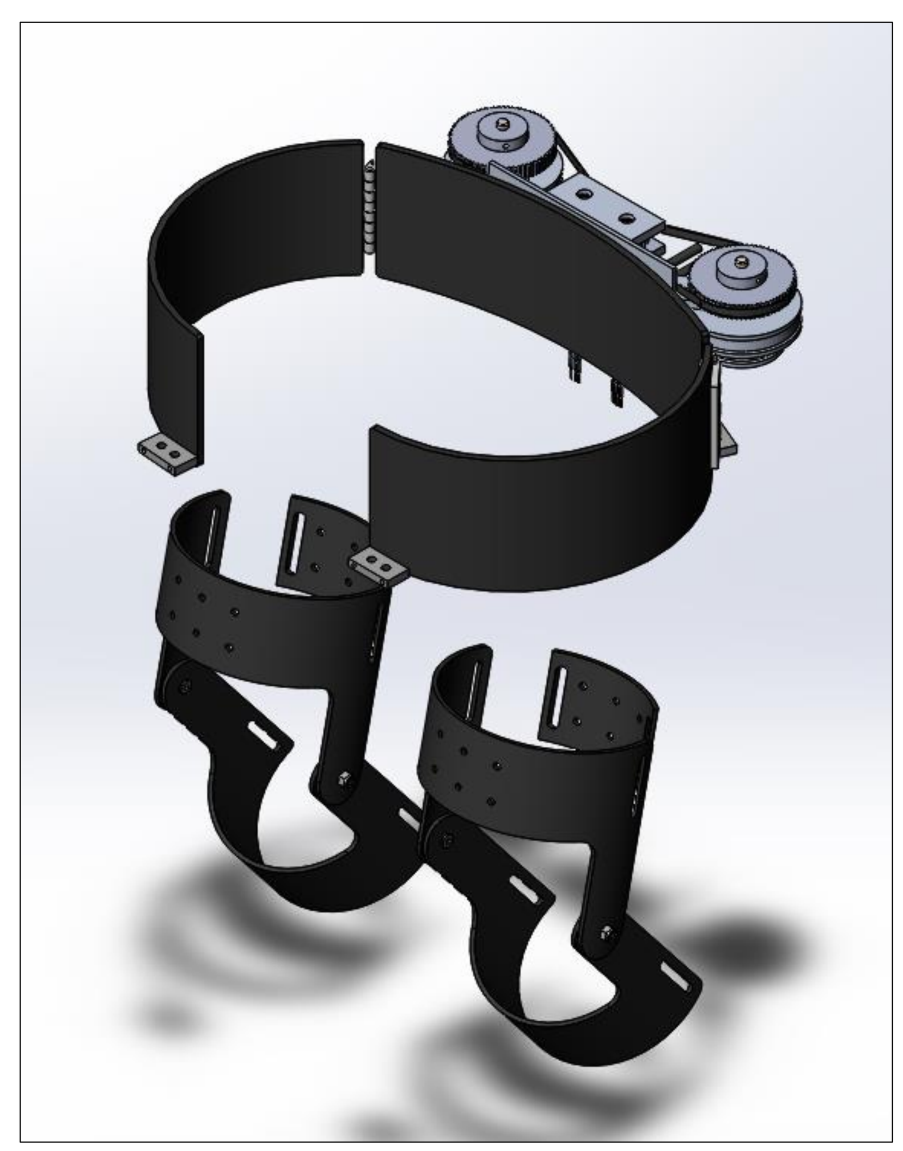

Figure 5: Full Assembly (Front)

Customer Requirements

The main objective of our design is to actuate movement in the hip. The movement is assisted in extension/flexion but needs to be passive in all other directions. The team's design also needs to sense the torque applied within the system. These three requirements are a priority in the design which is why they are ranked the highest out of all the customer needs. All of the customer needs identified last semester are listed in the below table.

Table 1: Customer Requirements

Customer Requirements	Weights
Hip Actuation	5
Full Range of Motion	5
Sense Torque	5
Minimize Metabolic Cost	4
Safe to Operate	4
Untethered	4
Durable	3
Easy to don and doff	2
Comfortable	2
Reliable	2
Within Budget	1
Fit small to medium build	1

Future Work

There are a few aspects of this project that will need to be conducted by both the NAU Biomechatronics Lab and future capstone projects. This includes finalizing the manufacturing and testing of the finished design. Currently, the hip belt, 1 knee brace and half the components of the motor mount assembly have been completed. The other knee brace and remaining components of the motor mount assembly will have to be completed by future parties. The focus of this team for the remainder of the semester will be refining the design in CAD and creating a detailed operation and assembly manual for the future parties that work on and improve this design. The goal of this capstone project for the remainder of this semester is to lay the groundwork for future iterations of the hip exoskeleton design.

References

M. O. Bair, "The Design and Testing of a Powered Exoskeleton to Reduce the Metabolic Cost of Walking in Individuals with Cerebral Palsy," Northern Arizona University, Flagstaff, 2018.

A. T. Asbeck, K. Schmidt and C. J. Walsh, "Soft exosuit for hip assistance," Elsevier: Robotics and Autonomous Systems, no. 73, pp. 102-110, 2014.

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