Hardware Review 1

Biomechatronic Hip Exoskeleton Team (BHET) 19F13

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Section information: We 5:30PM - 8:00PM, Engineering, Rm 321

Introduction

The BHET Team has made many changes to the hip exoskeleton. Design changes were made with manufacturing in mind. The mechanical aspects are now simpler and more condensed to fit the dimensions of the belt. The belt is also more conformable to the subject wearing it. Later sections will go into more detail on the specific changes made. The team is still on schedule for the semester even with all these design changes because parts have been ordered prior, other parts will be quick to ship, parts are simple to manufacture by the team, and there should be no more major changes to the design.

Subsystems

The following sections describe the different subsystems of the current hip exoskeleton design.

Hip Belt

Shown below is the hip belt design represented in SolidWorks (Figure 1).

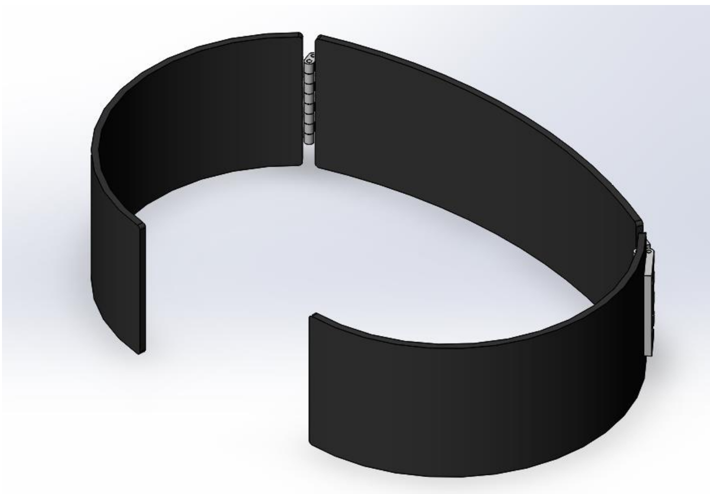

Figure 1: Hip Belt Design from SolidWorks

The current hip belt design is constructed from three 4-inch by 12-inch sheets of Kydex that are molded to the user’s body. Two hinges hold the three pieces together. A functional prototype of the cad model has been constructed and tested. The prototype proved that this design is very comfortable and conforms to the user’s body well. This design is also very easy to manufacture. The prototype is also lined on the inside with padded foam for better user comfort.

Motor Mount

The motor mount functions to secure the electric motors to the frame of the hip exo, allowing the torque to be transmitted through the Bowden cables. The previous revision (Figure 2) of the motor mount was designed as one piece, which clamped to the motor. This design did not support the end of the motor shaft, which could reduce the life of the motor/gearbox. Additionally, the single piece mounting solution had complex geometry which increased manufacturing cost.

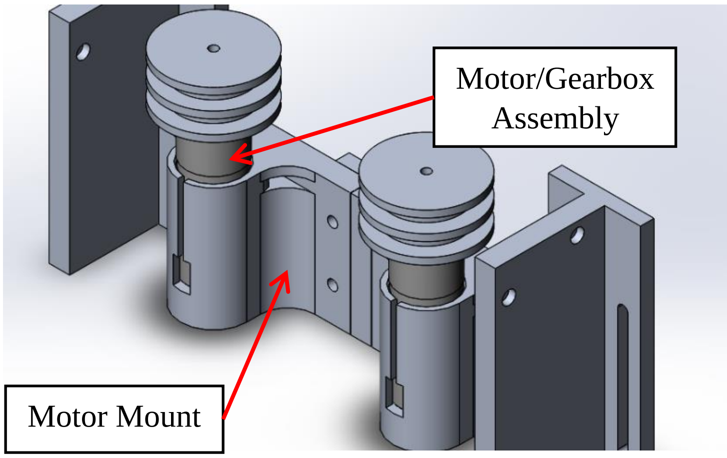

Figure 2 Previous motor mount assembly

The redesigned motor mount assembly is shown in Figure 3. The new design consists of three parts that secure the motor assembly to a mounting plate. The motor assembly is now secured via a plate which attaches to the face of the gearbox, with a support block to relieve the cantilever created by the length of the motor. The output shaft is supported by a bearing block. This version will be easier to manufacture and is a lower mass than the previous but increases the number of parts and makes the assembly more complex.

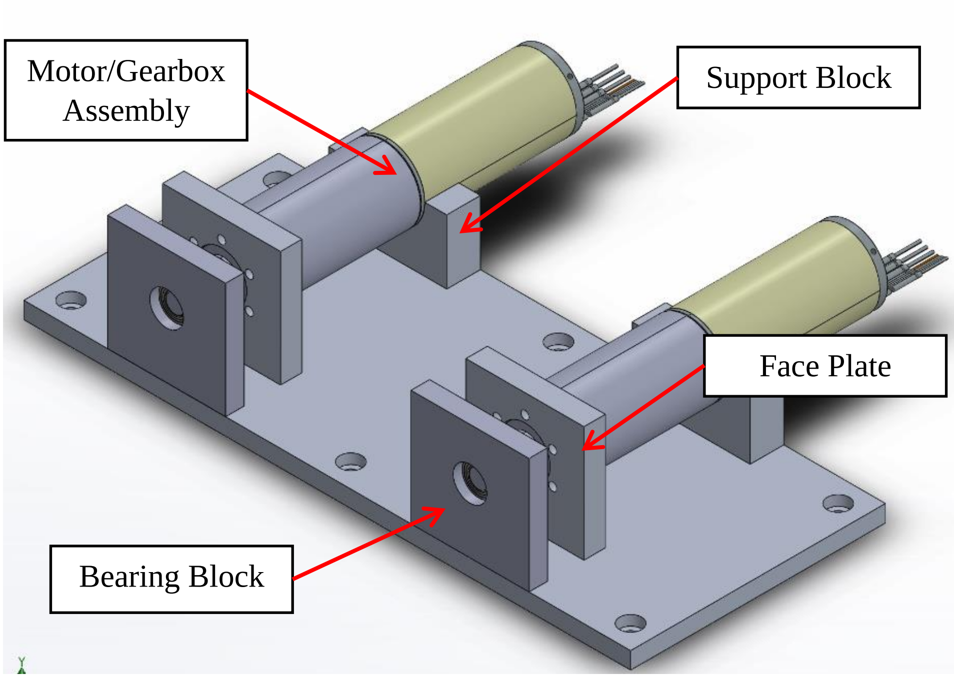

Figure 3 Redesigned Motor Mount

Further revision is required to complete the torque delivery module on the hip exo. In the previous revision, the cable actuators are wound on a pulley which is driven directly from the output of the gearbox. The required torque is greater than the selected motors can deliver and will require further reduction, which will be included in the final revision of the component.

The assembly will be 3D printed prior to manufacturing to test fitment with the motor/gearbox. Final manufacturing of the motor mount will be performed by the team at the NAU machine shop.

Knee Brace

The knee brace was redesigned to be more rigid. In the prior design the knee brace was completely soft, which results in a lot of deflection to the brace when force would be applied to the attached cord. The present design will be made of the same thermoplastic (Kydex) as the belt, and the complete design is shown below in Figure 2.

Figure 4 Knee Brace

The knee brace is made of the top portion which goes above the knee, and the bottom portion goes on the bottom of the knee. The back piece is the rigid portion for the back of the leg. The holes in the top piece and the back piece are meant to be places for the cables from the belt to attach to. The slots are where the straps will be, which encourages adjustability for different sizes. Overall, this system should be quick to manufacture because the thermoplastic is easy to manipulate. The process that might take the longest might be actually cutting the shape out of the thermoplastic. Cutting the thermoplastic is not difficult, though making the curves look clean might take longer.

Bowden Cable Clamps

The hip exoskeleton transmits torque from the electric motors via tension cables. The cables are routed through a Bowden tube, which terminates at a location coplanar with extension/flexion motion of the user's thigh. It is critical that the termination point of the Bowden tube be maintained at a known position deviation can cause fluctuation in the torque being applied to the user.

Design of this component has been changed to favor simple manufacturing. The previous design was a singly piece block which secures the tube using set screws. The client was concerned that this design might cause excessive mechanical wear to the cables, as they will rub against the black prior to exiting.

The redesigned clamp will hold the outer sheath of the Bowden cable. The inner sheath will extend beyond the clamp, ensuring the cord only directly contact the inner sheathe before exiting the tube. The new design is two pieces that achieve clamping pressure by being bolted together. This design simplifies the manufacturing process, allowing for numerous parts to be made quickly and easily, ensuring an iterative process may occur to refine the design.

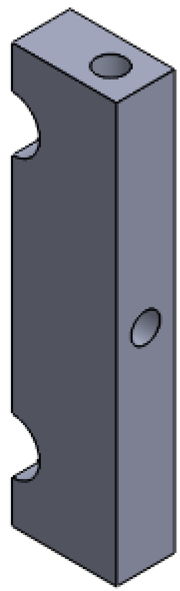

Figure 5 Bowden Sheath Design

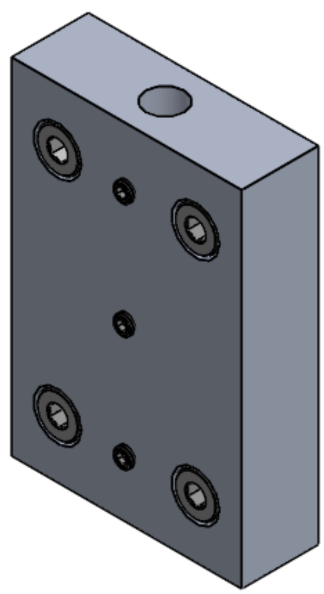

Figure 6 Old Cable Clamp Design

Full CAD Assembly

Shown below is a representation of the fully assembled design in SolidWorks.

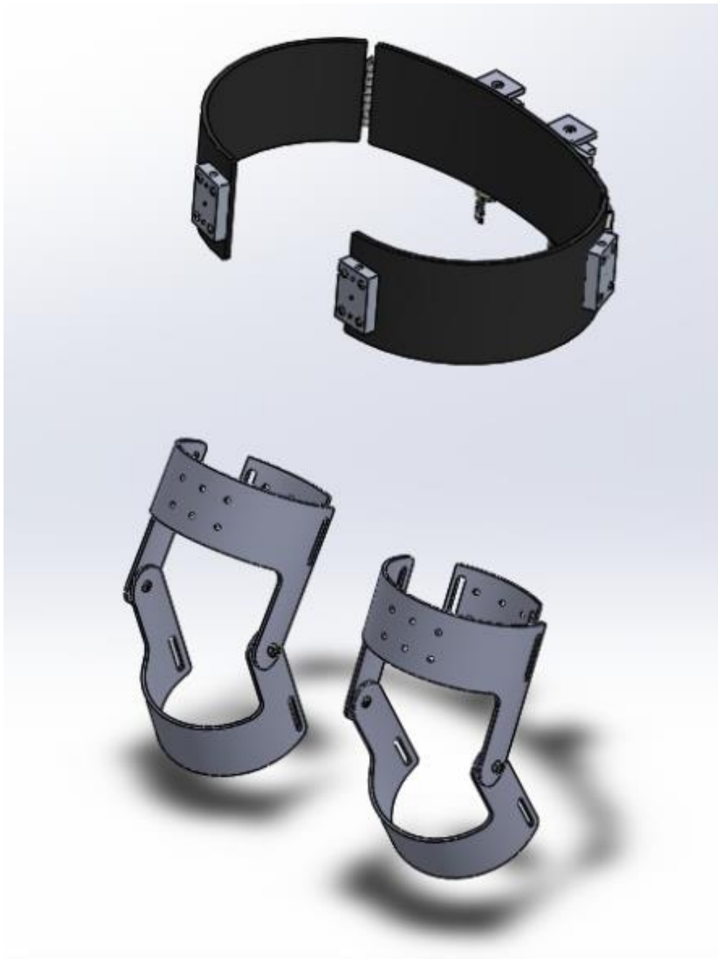

Figure 7: Full Assembly of Exoskeleton in SolidWorks

This representation of the fully assembled design does omit the Bowden cables running down to the knee braces, this was done for simplicity in SolidWorks. It is very likely that the final design will look similar to the design shown in the above figure.

Bill of Materials

Shown below is the bill of materials that was put together for the first hardware review.

Table 1: Bill of Materials for Hardware Review

PART (SOLIDWORKS PART NAME)	MATERIAL	DIMENSIONS (in.)	SUPPLIER	QTY.	COST/UNIT	COST
Base_Plate_V1	6061 T6 AL	0.25 x 3 x 12	OnlineMetals	1	$6.30	$6.30
Bearing_Block_V1 Housing Clamps (At motor assembly) Housing Clamps (At cable termination) Face_Plate_V2	6061 T6 AL	0.25 x 1.5 x 48	OnlineMetals	1	$10.05	$10.05
Mounting_Bracket_V5	6061 T6 AL	0.5 x 1.5 x 12	OnlineMetals	2	$6.29	$12.58
KneeBraceTop_V2 KneeBraceTop-Back_V2 KneeBraceBottom_V2	Kydex	0.125 x 12 x 12	McMaster-Carr	2	$10.16	$20.32
Motors	N/A	N/A	Maxxon	2	$815.73	$1,631.46
					Total	**$1,680.71**

HARDWARE	MATERIAL	DIMENSIONS (in.)	SUPPLIER	QTY.	COST/UNIT	COST
M4 x 20mm (100 pack)	SS A2-70	N/A	Copper State	1	$8.76	$8.76
M4 x 10mm (100 pack)	SS A2-70	N/A	Copper State	1	$6.20	$6.20
M3 x 10mm (100 pack)	SS A2-70	N/A	Copper State	1	$4.09	$4.09
M3 x 20mm (100 pack)	SS A2-70	N/A	Copper State	1	$5.77	$5.77
Shoulder screw	316 SS	0.25 Shoulder, 10-32	McMaster-Carr	2	$5.32	$10.64
Nylon Insert Locknut (50 Pack)	316 SS	10-32 Thread Size	McMaster-Carr	1	$4.71	$4.71
Bearings for Bearing_Block_V1	Steel	3mm W, ID 6mm, OD 10mm	McMaster-Carr	2	$12.06	$24.12
					Total	**$64.29**

As shown in the above table, the final design will be made primarily of 6061 T6 aluminum and Kydex. 6061 T6 aluminum was chosen for its low cost, low weight, and appropriate strength. Additionally, current exoskeletons in the biomechatronics lab use 6061 T6 with no issues. The aluminum will be purchased in the form of rectangular bar stock so it can be machined into the appropriate components. Kydex was selected for the hip belt and knee brace for its low weight, low cost, and ease of molding to the shape of the user's body. The Kydex will be purchased in flat sheets that can be easily cut to shape prior to molding. Total cost of the hip exoskeleton is projected to be roughly $1745.00. This leaves roughly $505 to cover shipping, manufacturing and testing. Manufacturing costs should be relatively low since the exoskeleton will be produced by the capstone team. At this point the project is well bellow the allotted budget.

Conclusion

As shown, the hip exoskeleton has gone through many iterations. This final iteration is the strongest because the parts are simple to manufacture. Also, since many of the mechanical aspects are made of aluminum, shipping the raw material is not going to be an issue. In regards to the conformable aspects of the exoskeleton, the belt and knee brace are simple to manipulate. The thermoplastic (Kydex) is simple to form which will save us a lot of time. The only thing from fully completing this exoskeleton is the pulley dimensions. Depending on the pulley dimensions the other mechanical dimensions may change. Though, at the moment this form of the exoskeleton is the final one, with maybe only minor changes being made in the future. Now the team is going to move on to practical testing to conform the size of the pulley dimensions.