MECH 6303 Computer Aided Design

Final Project Report

Wearable Inertial Measurement (IMU) Shoe for Gait Analysis

Group 10

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Background

Inertial measurement units (IMU) are electronic devices that contain accelerometers and gyroscopes to measure acceleration, angular rates, and orientation. IMU-based gait analysis uses this data to identify phases of the gait cycle during walking or running [2]. This technology is not only helpful in the field of sports analysis but also the detection of early onset Parkinson's disease. The goal of this project was to design, analyze and develop a CAD model of a 3D-printable shoe with a mount for the Inertial Measurement Unit. Another objective of the project is to make the design modular, so the shoe could accommodate different foot sizes. This was done by including adjustable supports on the sides using sliding mechanisms. The design assumed the use of a wireless IMU to avoid wiring and other electronic components. Based on the CAD model, a life-size model of the shoe was produced using the Fused Deposition Modeling (FDM) additive manufacturing technique. The shoe itself is made of thermoplastic polyurethane (TPU) while the mount and moving parts for the Inertial Measurement Unit are made of acrylonitrile butadiene styrene (ABS).

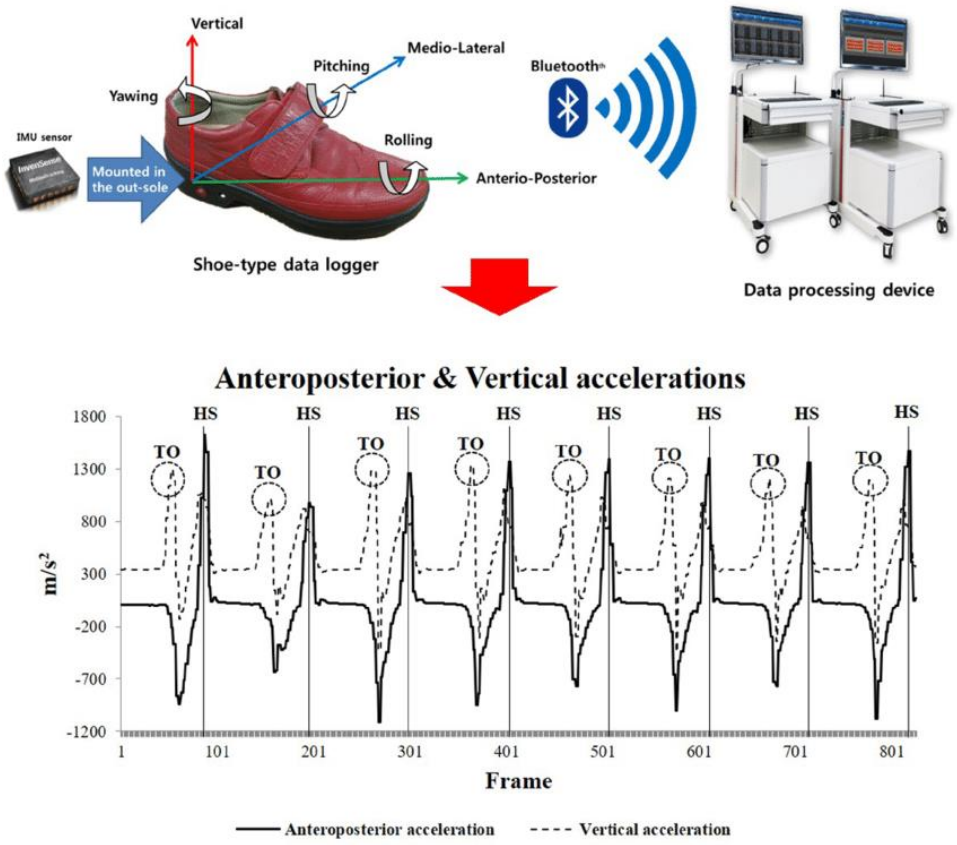

Figure 1. Schematic diagram for the working system [1]

Sketch to Final Concept

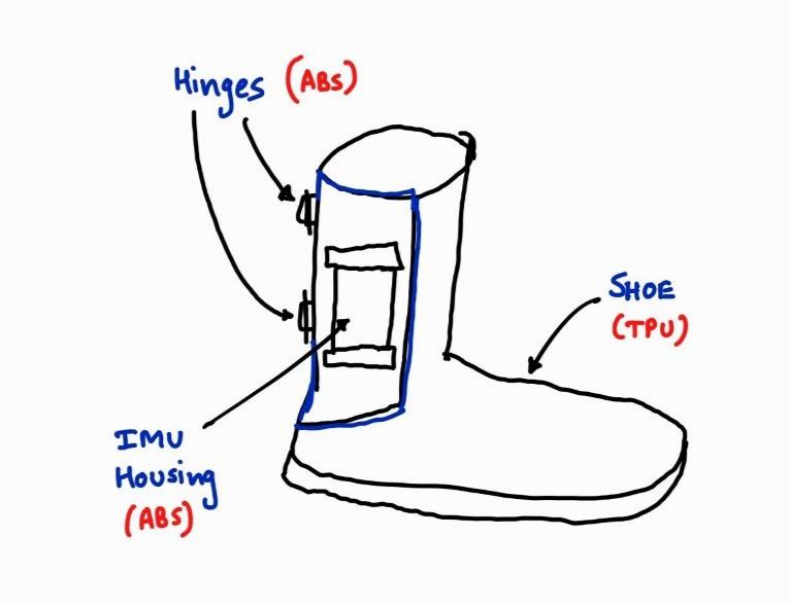

Figure 2. Initial sketch

Figure 3. Final rendering

Due to the volume constraint in the project specifications (<8 in^3), several changes had to be made to the design. These included the following:

- Shoe could not be enclosed
- Slots and holes were created in each part
- The entire assembly had to be scaled down
- A mount for the IMU was used rather than a housing and moved to the rear

Overall Assembly

There are a total of eight parts in the assembly. Many parts were combined during the design phase to allow for easier printing and assembly. In the end, three subassemblies were printed: the sole in TPU, the top/bottom in TPU, and the center in ABS.

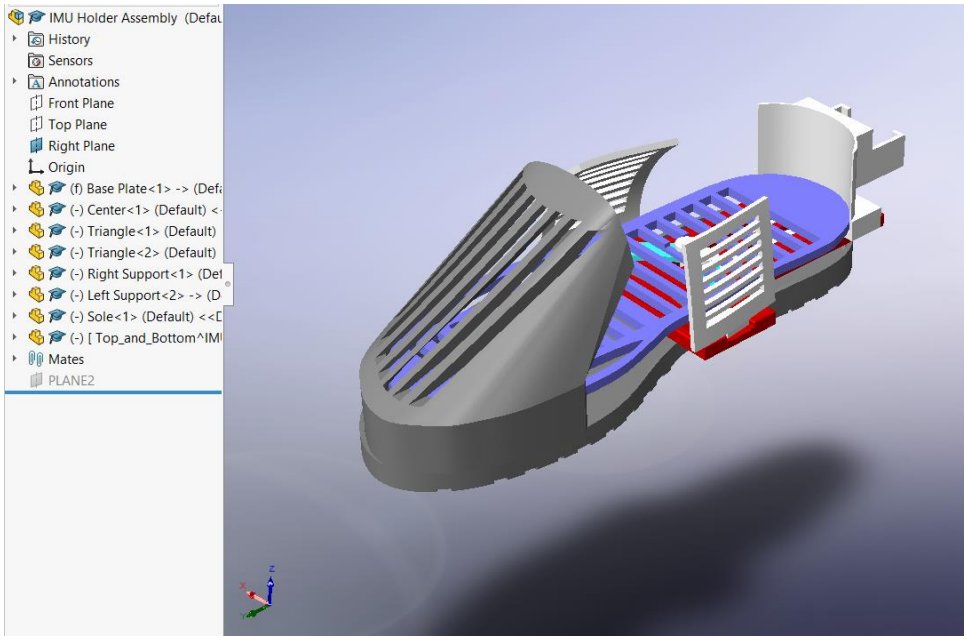

Figure 4. Isometric view

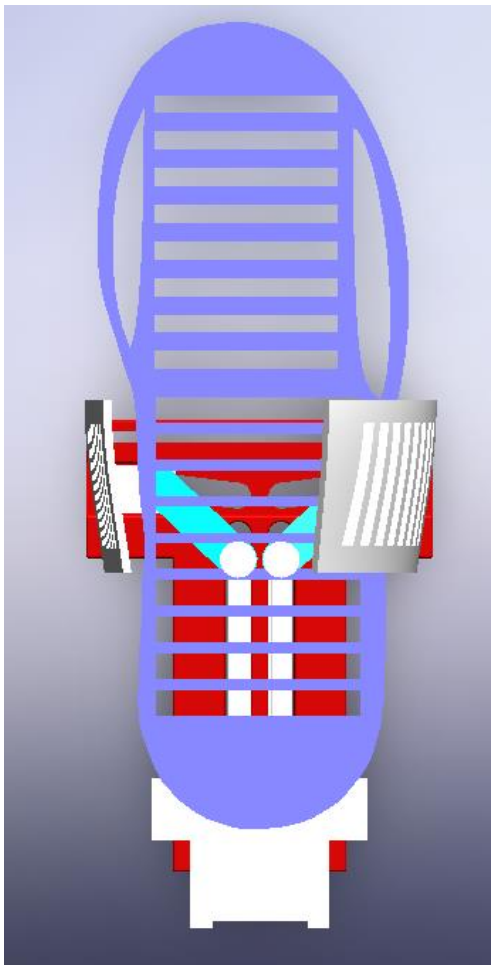

Figure 5. Top view with top and bottom parts removed

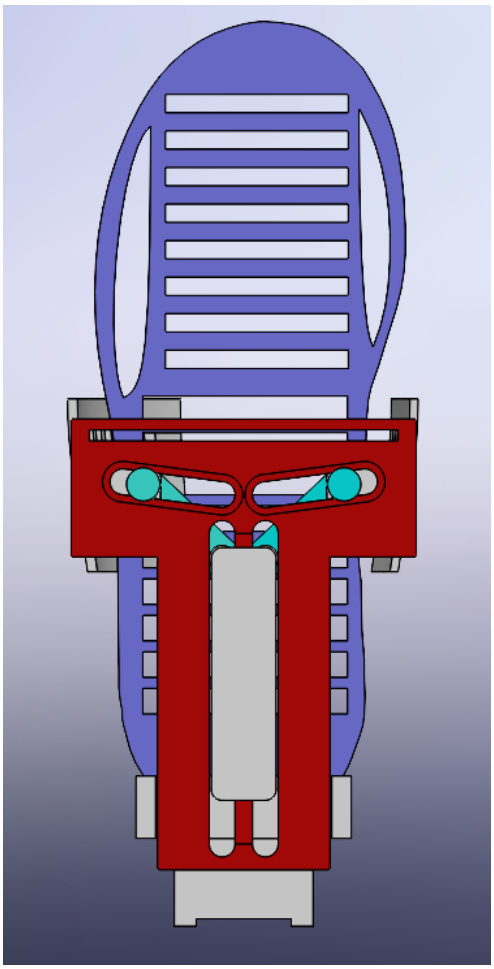

Figure 6. Bottom view with top and bottom parts removed

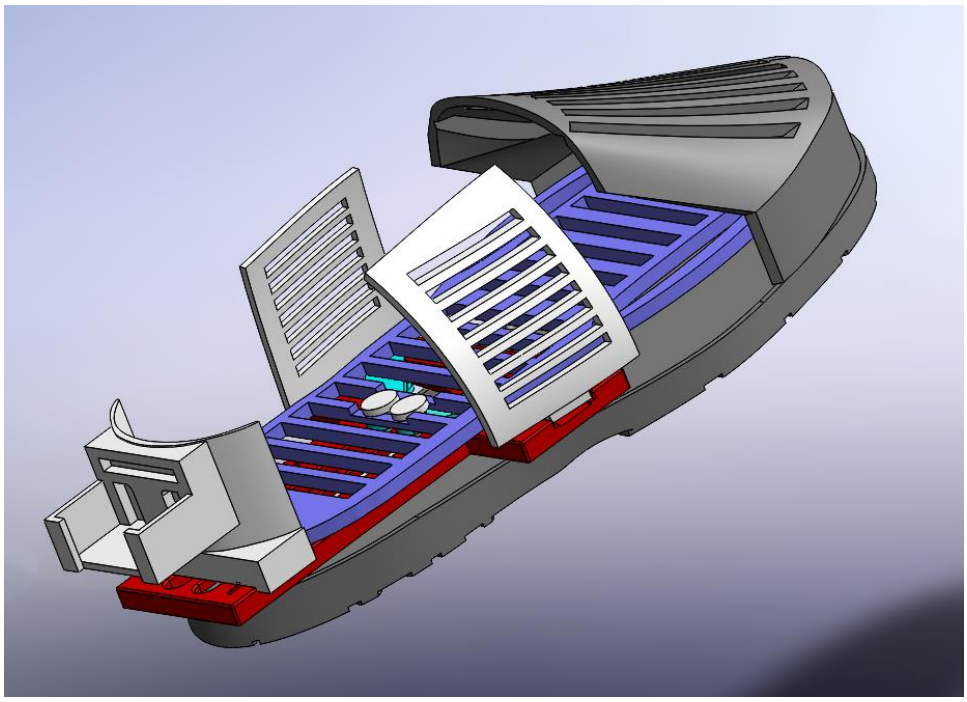

Figure 7. Rear view

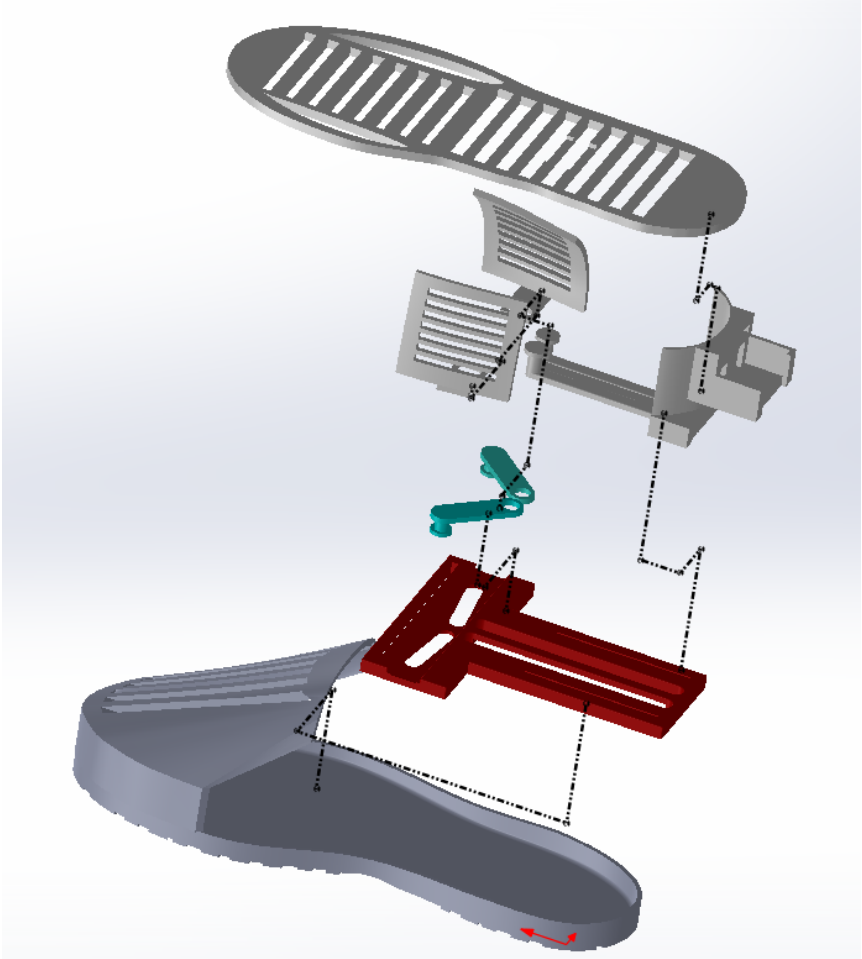

Figure 8. Exploded view

Parts with Parametric Curves

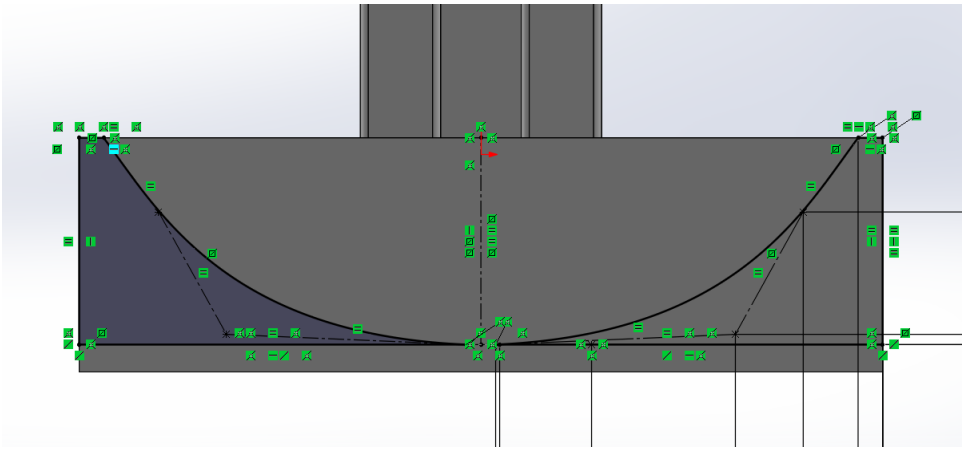

Figure 9. Center part with parametric curves

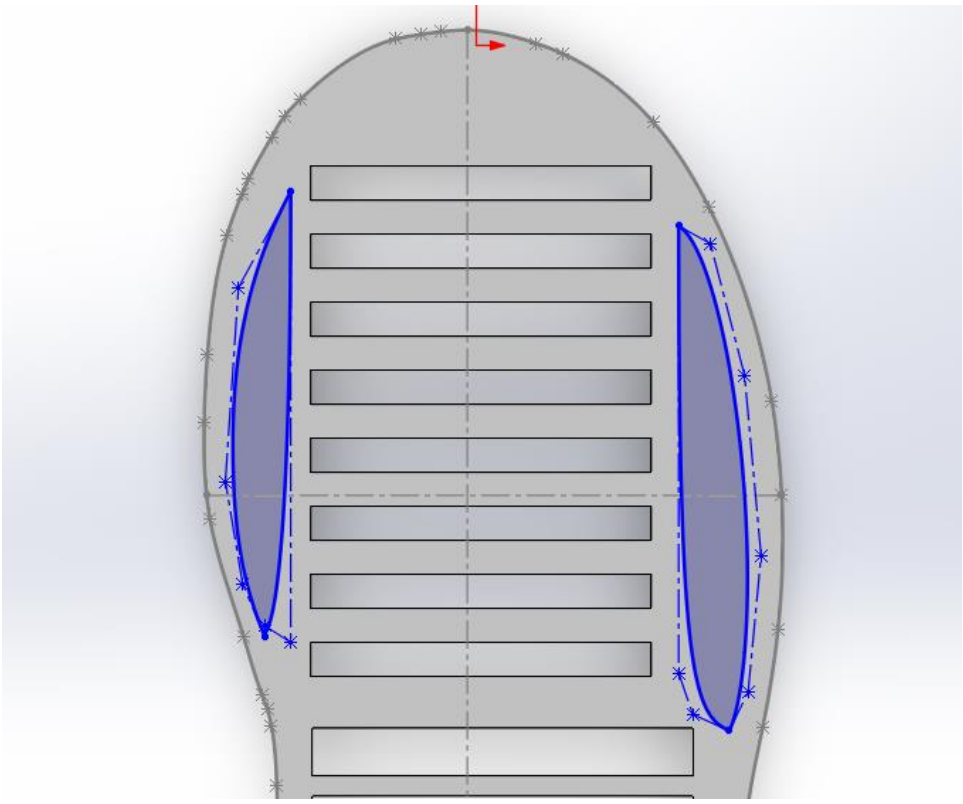

Figure 10. Sole with parametric curves

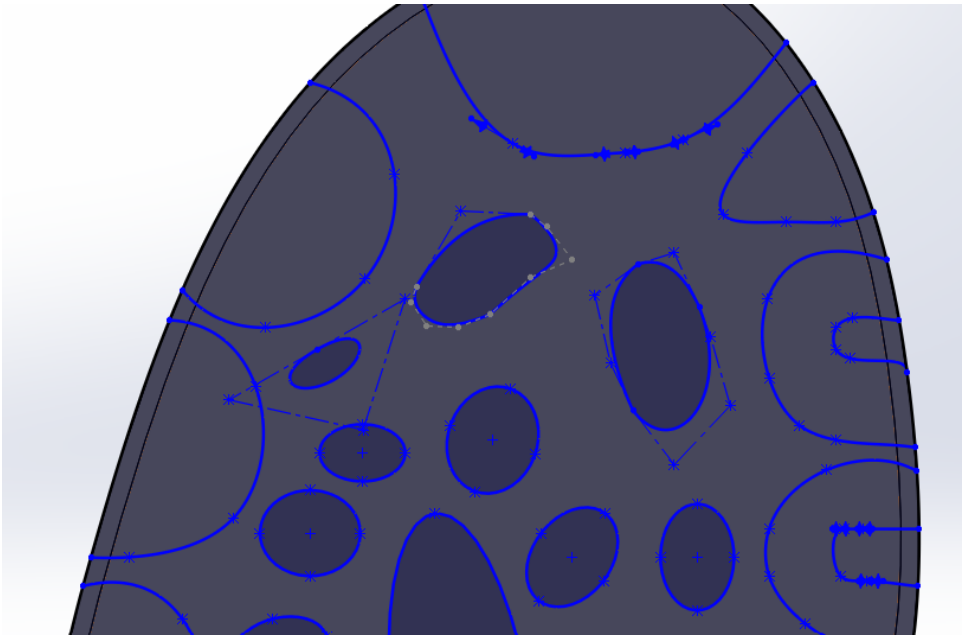

Figure 11. Bottom of shoe with parametric curves

Engineering Drawings

All dimensions are in inches.

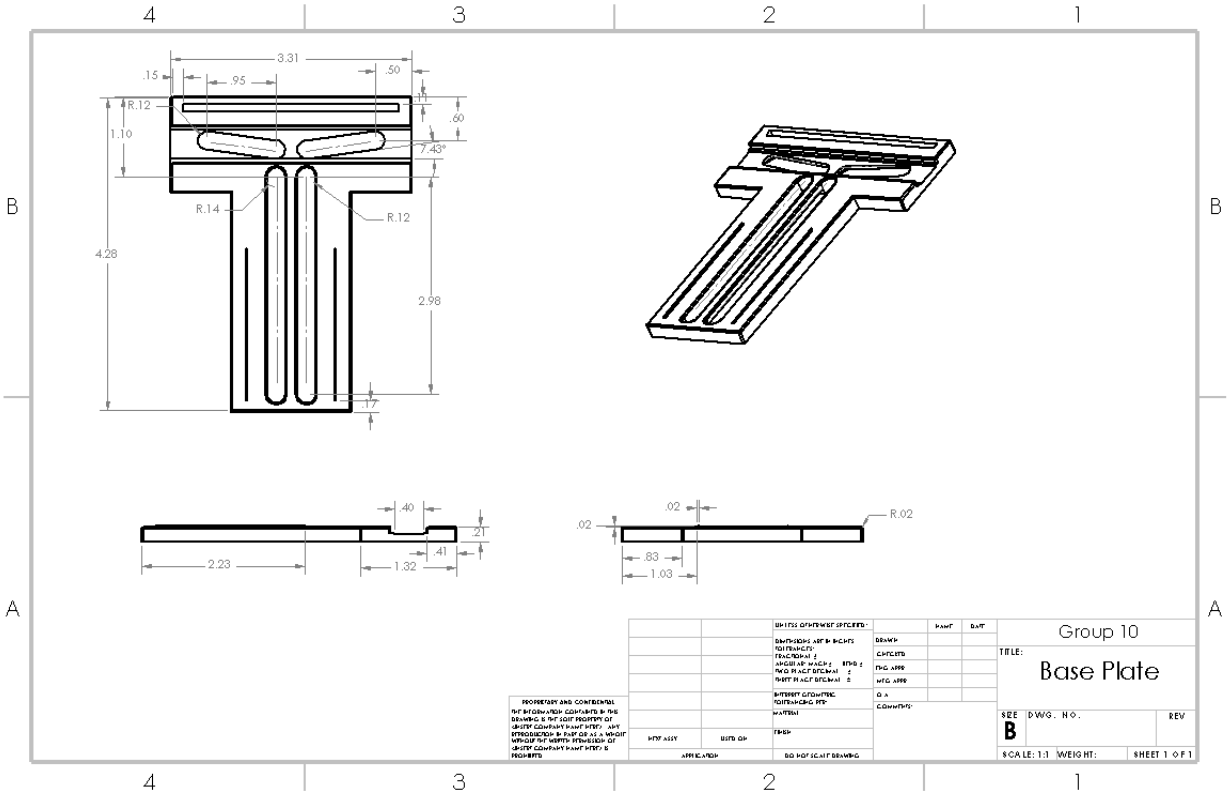

Figure 12. Engineering drawing for base plate

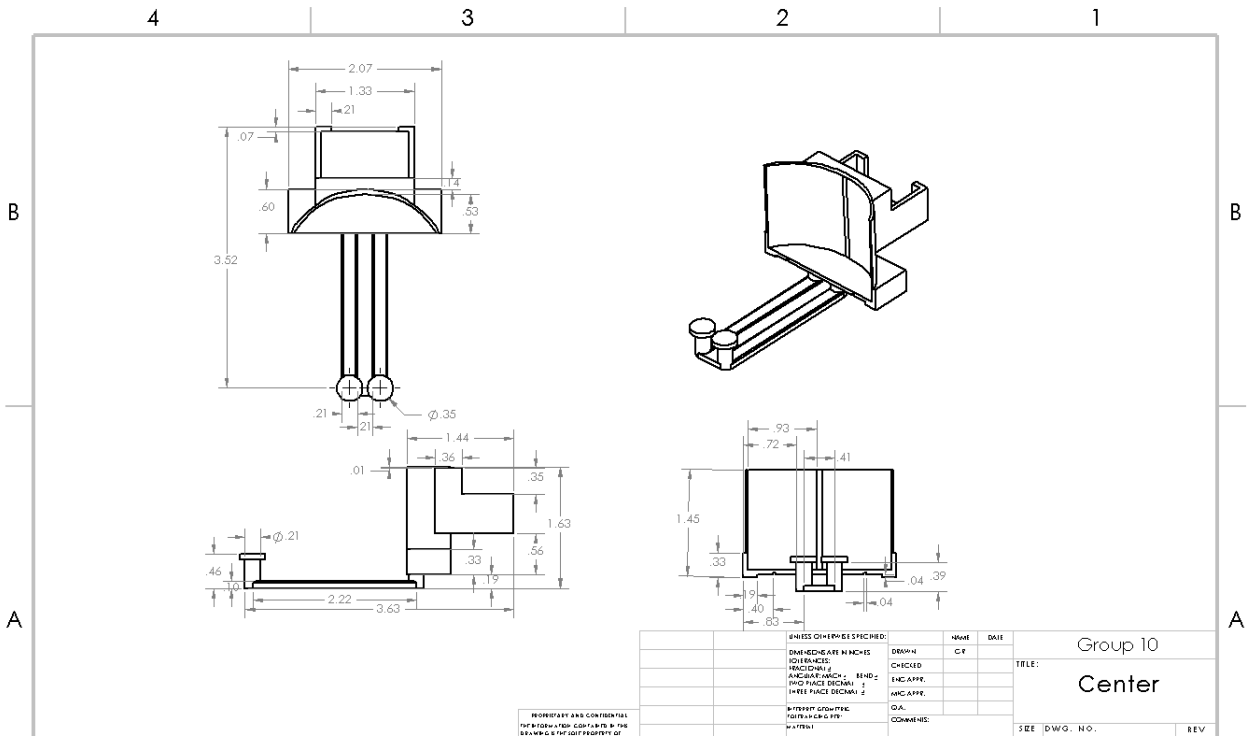

Figure 13. Engineering drawing for center

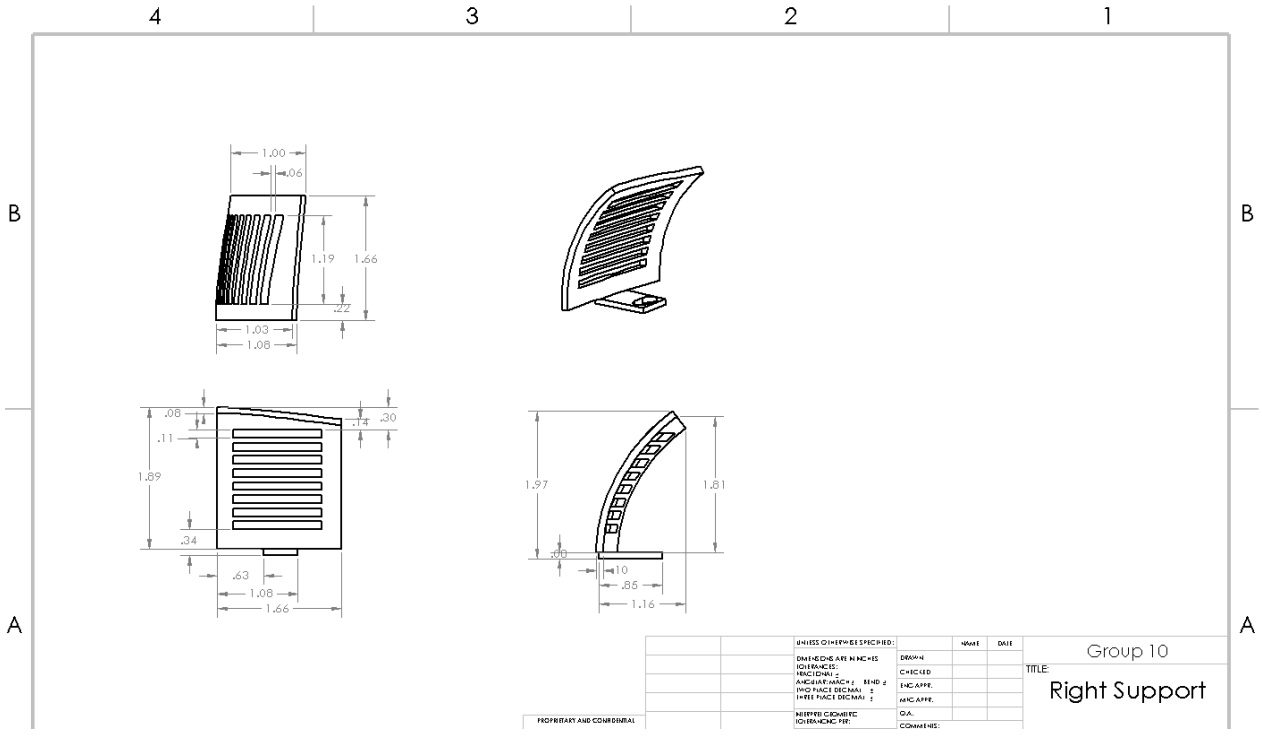

Figure 14. Engineering drawing for right support

Simulation

We carried out static structural analysis on the main mechanism that we designed for gripping the foot. Therefore, to reduce the complexity of the analysis, we had to exclude a few parts of the assembly from the analysis. Only integral parts for the mechanism to work were analyzed. The parts were assigned the default material properties for ABS plastic in SolidWorks.

Using local contact options in connections, we applied virtual walls to both the green pins present in the slot. The base plate was applied with fixed geometry.

For the load, a force of 1 N or 0.2248 lbf was applied on the back of the heel of our shoe, under the housing for the IMU.

Given below are the meshing details and parameters for our mechanism which is supplied with 1 Newton or 0.2248 lbf force on the back of the heel.

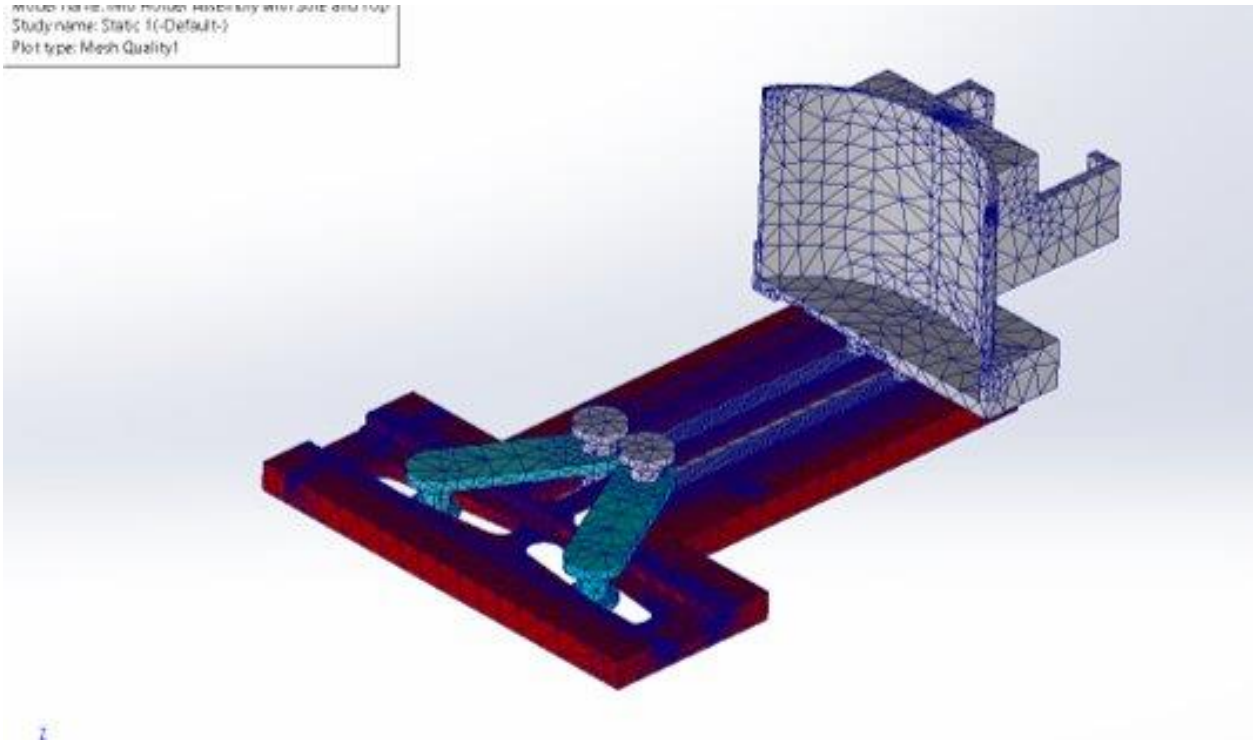

Figure 15. Mesh plot for main mechanism

Mesh Details

Study name	Static 1* (-Default-)
DetailsMesh type	Solid Mesh
Mesher Used	Standard mesh
Automatic Transition	On
Include Mesh Auto Loops	On
Jacobian points for High quality mesh	16 points
Element size	0.176407 in
Tolerance	0.00882035 in
Mesh quality	High
Total nodes	94135
Total elements	53659
Maximum Aspect Ratio	77.002
Percentage of elements with Aspect Ratio < 3	86.5
Percentage of elements with Aspect Ratio > 10	0.212
Percentage of distorted elements	0
Number of distorted elements	0
Remesh failed parts independently	On
Time to complete mesh(hh:mm:ss)	00:00:03
Computer name	

Figure 16. Mesh parameters

The following two plots are the plots for von-Mises stress and displacement respectively.

We can observe that the maximum stress that is generated is 1.295e+02 psi.

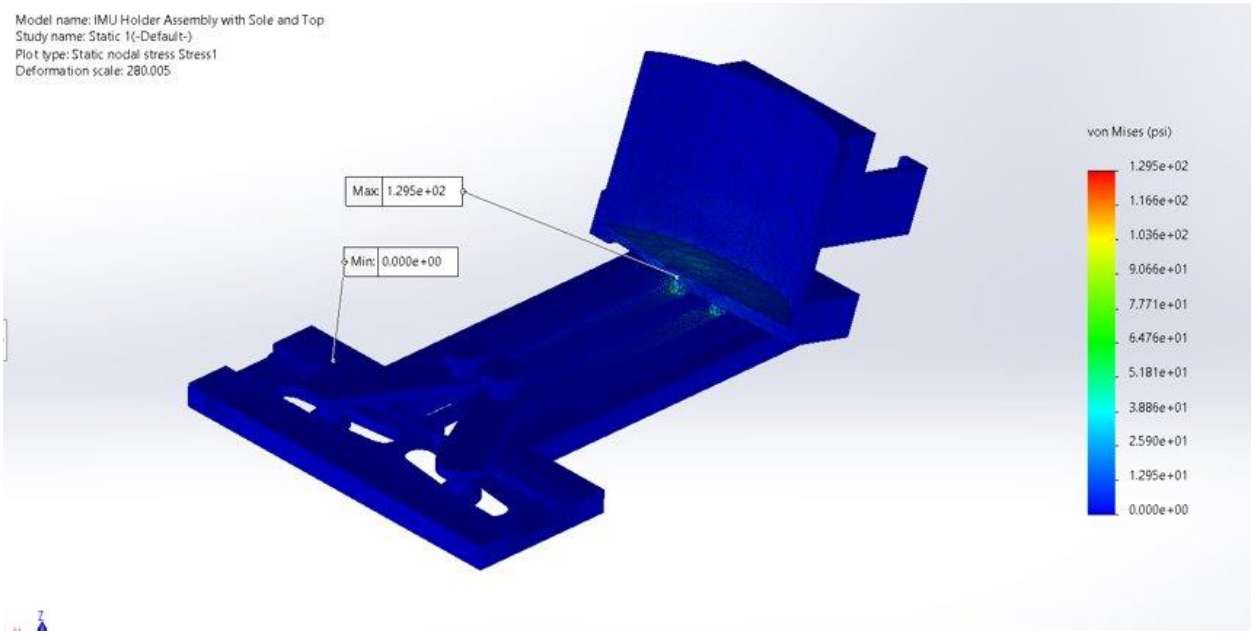

Figure 17. Von Mises stress (in psi)

The maximum displacement that occurs is that of 1.998e-03 inches.

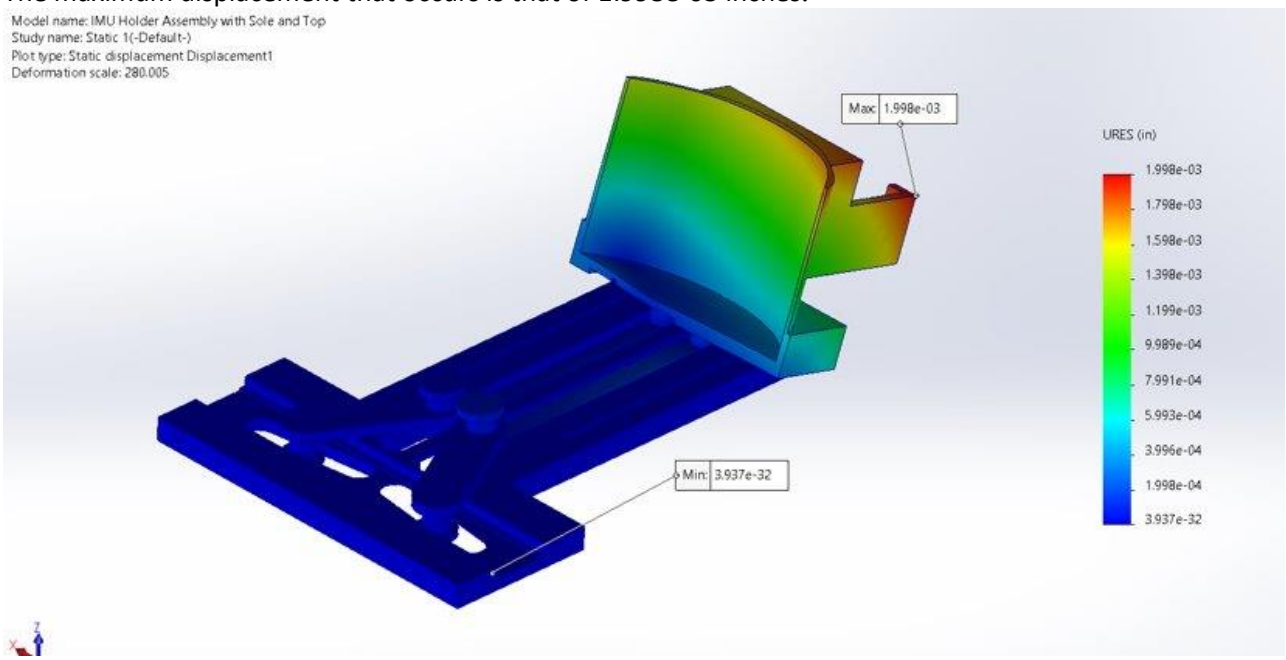

Figure 18. Resultant displacement (in inches)

References

1.https://www.researchgate.net/figure/Shoe-type-IMU-system-and-detection-of-gait-events-HS-represents-heel-strike-and-TO_fig1_339955724

2. https://robinhsieh.com/gait_analysis_system/