Bent Knee Adapter for Experimental Testing

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Background

Novel prosthetic devices must be undergo testing as part of their development. Testing with amputees is problematic at the development stage due to safety and administrative burdens. A bent-knee adapter allows able-bodied individuals to perform preliminary testing. A bent knee adapter made by the Cleveland Clinic to conduct experiments was available for modifications. Although it was very well made, it did not provide an accurate depiction of a walking motion. This was due to the prosthetic leg being mounted laterally instead of inferior to the knee. Because it was mounted laterally, the experimental prosthetic would encounter unnatural forces that do not occur in a normal walking motion. A more natural bent knee adapter had to be engineered to account for these issues.

Goal

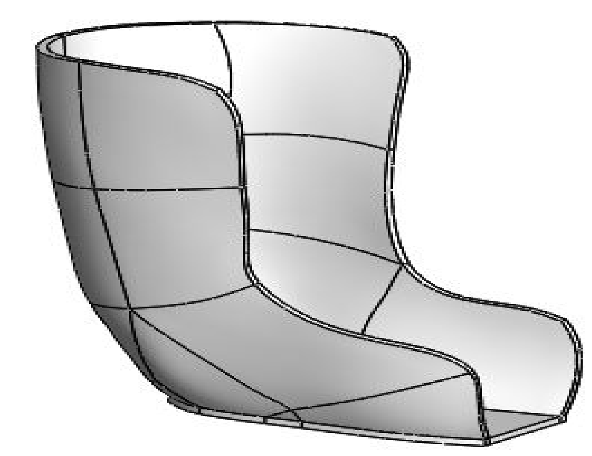
In order to obtain accurate results during testing, it was determined that the axis of rotation of the prosthetic knee joint and the human knee joint must be as close to each other as possible. Previously, it was stated that the prosthetic was attached to the side of the adapter. Attaching it to the side would allow the axes to be aligned but produced unnatural forces on the prosthetic leg. With that being said, the goal of this research was to re-engineer the previous bent knee adapter to be able to have a prosthetic leg mounted to the underside of the adapter while keeping both knee axes as close to each other as possible.

Methodology

1. 3D scan the inside surface of the Cleveland Clinic adapter at CWRU.
2. Thicken the surface outward to obtain a modifiable solid body.
3. Bring a flat plane upward from the bottom surface of the adapter to make a flat surface for mounting.
4. Trim away the unwanted surfaces under the flat plane.
5. Thicken the flat plane downward to the same thickness value as the rest of the adapter.
6. Sketch and extrude cut two channels into the thickened flat plane.
7. Use Solidworks Simulation to show that the adapter will not deform under the applied walking load.
8. 3D print the bent knee adapter in the CSU 3D printing lab.
9. Walk with powered prosthesis attached.

Prototyping

Shown below is a Solidworks model of the bent knee adapter.

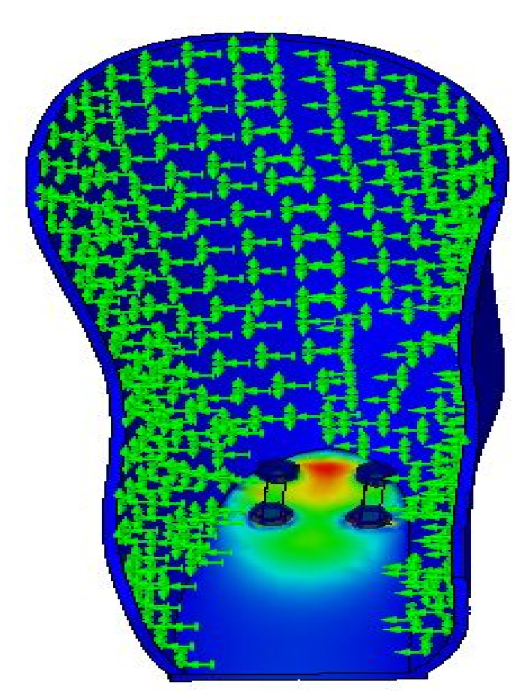


In order to generate the mesh and subsequent surfaces from that mesh, a point cloud of 3D scan data was used from the scanning of the interior surface of the Cleveland Clinic adapter. In order to create a solid body from the surfaces, a smooth mesh needed to be obtained before hand or the surfaces would not thicken. During the mesh simplification process in Solidworks, the mesh must be smoothed several times to eliminate any overlapping faces in the geometry of the part. Only then will the surface thicken into a solid body.

Notable features include:

1. Same shape as the shape of a human's bent knee.
2. A flat surface to ensure a smooth, snug fit between the adapter and the prosthetic.
3. Two channels matched to the size of the holes in the prosthetic knee with a .010 in. tolerance.

Stress Analysis with Expected Loading



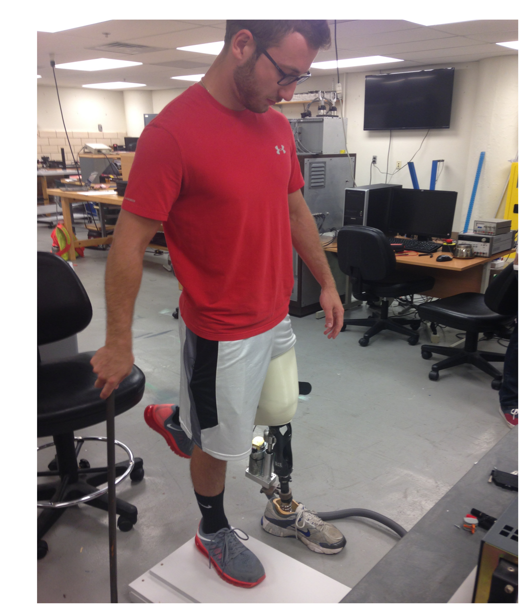
Shown above is a finite element analysis of the deflection of the adapter in Solidworks. For a normal force of 300 lbf acting upward onto the bottom of the flat face of the adapter, the largest defection that resulted was 0.00298 in.. This minuscule deflection is due to the elasticity of the ABS Plus material that was chosen for the adapter. The results show that the adapter will not deform under 1.5 times the average person's weight. The average persons weight was chosen to be 200 lbf. This analysis shows that the experimental bent knee adapter will hold up to the walking forces that wil be applied on it.

3D Printing

The adapter was printed using ABS Plus material. It was printed at the Cleveland State 3D printing lab on the 4th floor of Fenn Hall. It took approximately 42 hours to print the 40 cubic inches of material needed to form the part. There were no complications during printing.

First Walking Test

After the adapter was 3D printed, it was attached to the powered prosthetic and a walking test was preformed using it. The test consisted of a test subject strapping into the bent knee adapter and taking two steps. During the motion of those two steps, the knee force and knee angle were recorded. The absolute maximum knee angle was found to be 44.63 degrees. The absolute maximum force was found to be 116.44 lbf. The observed force and knee deflection are not representative of the capabilities of the powered prosthesis, since its control system has not yet been properly tuned. But this preliminary test indicates that the bent knee adapter will perform as expected.



Future Work

This experimental bent knee adapter is the first of its kind at Cleveland State University. With that being said, some changes need to be made in order to ensure optimal comfort and durability during testing. Improvements to this design will be made in the coming fall semester.

It was determined that the wall thickness of the bent knee adapter needs to be increased. There are also fitment issues with the top strap of the adapter. The top portion of the adapter has a larger radius than the legs of most test subjects. A new Solidworks model will have to be made to decrease the radius of the top portion of the adapter. Making these future changes will ensure a quality product for the testing of advanced prosthetics at CSU for years to come.

A systematic procedure will be followed to tune the prosthesis control system. For this, the subject will wear a safety harness and walk over a treadmill. Control gains will be adjusted as walking takes place, while monitoring ground reaction forces and gait kinematics. The user will also undergo a natural learning process to improve walking.

Acknowledgements

I would like to thank Dr. Hanz Richter, Dr. Tushar Borkar, Poya Khalaf, and Prashanth Reddy Yennam for their guidance and assistance through the duration of my project. I would also like to thank the Cleveland State Undergraduate Research Program for the funding to make my project possible.