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Design and Simulation of Above Knee Prosthetic Limb

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A B S T R A C T

In medicine, Prosthesis is defined as an artificial device designed to replace a missing body part which may be lost through trauma, diseases, or congenital conditions. Therefore, prostheses are introduced to substitutes the functions of the missing body organ usually. The major issues related to prosthetic practices and technologies contained poor prosthetic comfort and durability. This project aims to design prosthesis for people who experience a missing above knee limb. This project includes the design and simulation of above knee prosthetic limb with the help of solid work for designing the component and mat lab soft wares for obtaining the result (output).The project is targeted to help people who need a prosthesis to live everyday life, considering the durability of the materials to avoid a premature failure of prosthetic, the comfort for the beneficiary by considering the prosthetic socket fit and alignment.

Keywords: Prosthesis, Knee Limb, and Simulation.

1. Introduction

A prosthetic limb is a non-natural limb that substitutes the natural biological limb, which may have been gone due to an accident or birth. For example, if an individual lost his limb due to many reasons, he or she would not be able to move naturally. It would require a walking cane to drive or use a wheelchair to move to their places. However, using a wheelchair or a walking cane would not help the individual to move independently. It would require help or aid from another individual. To overcome this situation, prosthetic legs were introduced.

Therefore, our prosthetic limb that we are designed does not require any help from others because it is body powered, he or she may go at his places. With a prosthetic leg, the individual would not need to depend on another person to move independently with freedom. Many designs were introduced of prosthetic legs by numerous companies. Among these designs, various prosthetic legs were designed with different purposes, some configurations are for running or exercising specifically, and some were designed for daily usage and walking.

This paper will discuss the prosthetic lower limbs and calculate the engineering design with constraints and simulation of the prosthetic and find the economics behind this project. Generally, the beneficiaries of this project are the amputee (people with missing limbs). Hence the design should fulfill their demands as much as possible.

1.1 Objectives

Every work is done so as to get some satisfactory outcomes/results; same to this research we are doing this because we believe it will deliver tremendous results. As the main objective is to replace the missing body part, not only to replace it structurally but should also deliver most of the functions of the original limb as much as possible.

1.2 Background

According to a survey in 2012 in the United States of America, a population 1.9 million Americans was using prosthetic limbs to get rid of the aid of other individuals and keep themselves moving with freedom without help. When going back in years and studying the history of prosthetic manufacturing, we come to know that archaeologists exhumed a 3000 year old mummified body. Though, there was somewhat very exceptional about this finding. With that mummy, the archaeologists found a buried prosthetic toe that was made of wooden. This unique form of a prosthetic was prepared with fastenings to attach to the foot of the body and the leg of the body while the toe was fluctuating made to move with the feet, which they found pretty strange when one thinks about the period in which it was made. However, this mummified body was the first ancient object to be revealed, sporting a prosthetic limb of classes. In 1910, the Capua Leg was uncovered in the north of Naples back to 300 BC. This European made prosthetic was shaped from wooden material with an external coating of bronze material. The upper part of the prosthetic was excavated out with filling at the foot to provide housing for the owner. In addition to this antique prosthetic was fortified with tinny rods and strips that protected the limb in a good place. With the evidence that diversities of prosthetics in the years back to the B.C. ages, it is lovely to see the development of prosthetic limbs. Thanks to incredible advancements in engineering, the growth, and design of prosthetics have significantly developed.

1.3 Prosthetic Components

The hydraulic component (Figure 1) is composed of four cylinders, out of which one cylinder is sprigged cylinder but the remaining three cylinders are simple non-sprigged single acting cylinders. The first and second hydraulic cylinder are connected through hydraulic hose, while the second set of cylinders, i.e. the third and fourth cylinders are connected through another hose. Generally, there are two set of cylinders, each containing two cylinders. There is no hydraulic connection between the two set of cylinders but there is mechanical linkage between the two set of cylinders. The two set of cylinders are connected using simple sliding lever.

During the stance phase 70% of the body weight is loaded on the prosthetic. From here the body weight is received from socket, then this weight is transmitted from the socket then to the Four bar knee joint (will be explained later) after the four-bar knee joint the weight reaches the hydraulic component. The first cylinder is the one that receives the weight, this weight causes the piston of the first cylinder to slide downward and generating internal pressure, the same internal pressure is developed in the second cylinder because they are connected by hydraulic hose. But the pressure is not the same with the third and fourth cylinder because there is no any kind of hydraulic connection between them, the second set of cylinders are only connected through mechanical sliding lever.

After the first cylinder descend the second cylinder also descends at the same time, here at this time while the second cylinder descends the spring in the second cylinder is compressed. Hence energy is stored in the spring by the downward descending of the second cylinder. This stored energy in the spring then can be released and be used to bend the prosthetic. This is general idea of the hydraulic components, but all in all it passes through three phases.

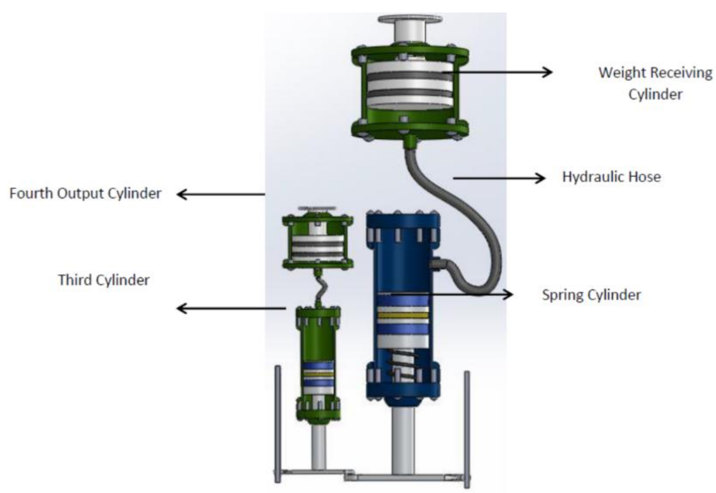

Figure 1 Prosthetic Limb

1.4 Prosthetic Foot

The prosthetic foot (Figure 2) is an integral component of any lower-limb prosthesis after major lower-limb amputation (i.e. ankle disarticulation level or proximal). In attempting to best restore the functionality previously provided by the anatomical foot and ankle. There is number of prosthetic feet is available in market. However, prosthetic feet are generally classified into several key categories reflecting basic difference in technologies, functional performance limitations and costs.

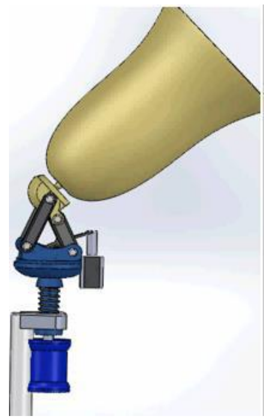

Figure 2 Prosthetic Foot

2. Analysis

All the designed parts were analyzed for loads with at least a factor of 2.5 to prevent failure. The sample that more stressed results was as follows. Figure 3 shows the stresses on the feet with forces due to the body weight. The figure shows only a few red areas near the joint hole. It shows the stresses on the shank with forces due to the body weight.

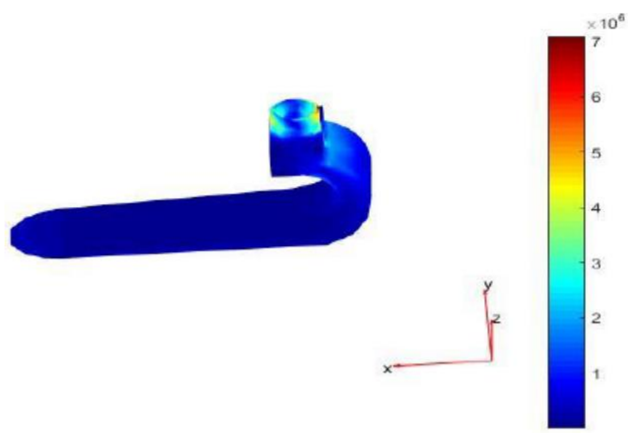

Figure 3 FEA of Prosthetic Foot

```
% matlab code for FEA

model = createpde('structural','static-solid');

importGeometry(model,'Feet.stl');

pdegplot(model,'FaceLabels','on')

pdegplot(model,'FaceLabels','on','FaceAlpha',0.5);

msh=generateMesh(model,'Hmax',10);

pdeplot3D(model);

E=885E10;

nu=0.34;

structuralProperties(model,'YoungsModulus',E,'PoissonsRatio',nu);

structuralBC(model,'Face',17,'constraint','fixed');
```

```
p1=250000;

p2=250000;

structuralBoundaryLoad(model,'face',15,'Pressure',p1);

structuralBoundaryLoad(model,'face',18,'Pressure',p2);

Rs=solve(model);

pdeplot3D(model,'ColorMapData',Rs.VonMisesStress,'Deformation',Rs.Displacement,'DeformationScaleFactor',100);
```

3. Conclusion

While brainstorming the project, we wanted to work on a project that might impact our community positively. Due to the scarcity of efficiently working prosthetics limb in Eritrea even though the conventional prosthetic that we have in our country are do not bend at the knee, while the ones that bend require more energy from the amputee. The idea of producing a lower limb prosthetic intrigued us. In this project, we applied what we learned from previous courses. The project involved numerous engineering disciplines such as statics, dynamics, material science, engineering economy and soft wears. Revisiting these subjects helped us to strengthen our problem-solving skills. Our teamwork skills were improved significantly due to the difficulty of working individually on such a project. This skill was utilized by organizing tasks between members and helping each other with much harder duties. Moreover, designing a prosthetic leg challenged us in many ways. One of these challenges is envisioning the design of the prosthetic leg.

Future Recommendations

Any design can be improved. Further, our design is not an exception. One of the ways to improve our design is to use carbon fiber instead of aluminum. In this instance, carbon fiber provides excellent strength to weight ratio. Another way to improve our design is to use an advanced hydraulic system. Moreover, the software can be developed to mitigate the inconvenience of adjusting the height of the prosthetic limb or aiding in changing the process of the foot attachments. Furthermore, a customizable casing can be added to the prosthetic for aesthetic use.

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