"Design Of E-Glass Epoxy Prosthetic Leg"

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***Abstract**: The Research work was done to design a prosthetic leg which can fill the gap between the imported and conventional leg. The leg should be such that it will be lighter in weight as compared to the conventional leg and should be much cheaper than imported leg. This is achieved by analyzing the drawbacks in the conventional leg and proposes modifications which result in less weight. Thereafter, applying the properties of different polymer matrix composites materials, the best materials which helps in reducing the weight is found to be E-Glass Epoxy. With help of the material properties of this composite, the shin and socket for the prosthetic leg have been designed in SOLIDWORKS, tested for stress analysis using simulation studies.*

Keywords**: **QFD, Prosthesis, E-Glass epoxy, PMC.

1. INTRODUCTION:

It is an artificial limb that replaces a natural leg. This artificial extension can be used as a replacement as above knee prosthesis and below knee prosthesis. It is part of the field of bio-mechatronics, the science of using mechanical devices with human muscle, skeleton, and nervous to assist or enhance motor control, lost by trauma, disease, or defect. Prostheses are typically used to replace parts, lost by an injury (traumatic), missing from birth (congenital) or to supplement defective body parts. In this present work E-Glass Epoxy was used as a Composite material for designing the Prosthetic Leg, which is further divided into three parts namely, Socket, shaft and foot. In this, Composites are used as a Biomaterials, Biomaterials are materials of natural or man-made origin that are used to direct, supplement, or replace the functions of living tissues of the human body .Now a day hybrid composite materials are also used in making of prosthetic limbs. Hybrid forms by the mixing of two types of fibers in a resin. A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase.

Numerous researches has been done and is still currently underway in the design of smart prosthetics with the focus being on the control system though overlooking the frame or foundation of the prosthetic .Prosthetic legs have found their way into the 21st century, in terms of their design.

Taking our cue from nature, we are able to model and design systems that maximise the functional advantages of nature without completely mimicking nature, resulting in less technological complexity. A study was conducted to find out the amputees's requirement for the prosthetheic leg. Amputees from different age groups were having different requirements and with the help of quality fuction deployment it became easy to separate the amputee's requirements and rate them according to the majority in the category.Every effort was made to make the amputee requirements fulfill with different age groups.The objective was to Design a Prosthetic leg which was lighter in weight and cheaper then imported leg and better than conventional leg used in India. The Present work was focuses on the lower extremity smart prosthetics, studying the Composite material properties, designing and analysis of Prosthetic leg.

MATERIALS AND METHODS

To fabricate, a low in weight prosthetic leg and with high strength, selection among composites material is done. Polymer Matrix Composite is chosen as their weight is less as compared to other composite materials (Metal-Matrix composites and Ceramic-Matrix composites).The use of PMCs has increased considerably over the last decade. The PMCs has been widely used for structural parts because of their superior mechanical and physical properties such as high strength synthetic fibers such as carbon, glass and Kevlar with thermoplastic resins (nylon and polyolefin), thermo set resins (epoxies, polyurethanes) and unsaturated polyesters. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The composite material however, generally possesses characteristic properties, such as stiffness, strength, weight, high-temperature performance, corrosion resistance, hardness, and conductivity that are not possible with the individual components by themselves.

To make prosthetic leg the following three composites are chosen as they are most widely used.

a. **E-Glass Epoxy**
b. **Kevlar Epoxy**
c. **Carbon Epoxy**

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But from above three composites, we use E-Glass Epoxy, because of easy availableness and less expensive than other two composites.

Of the three fibers, the E-glass is the most common reinforcement material used in civil structures. The fiber itself is regarded as an isotropic material and has a lower thermal expansion coefficient than that of steel. These are used when strength and high electrical resistivity are required. For making a composite Araldite AW 106 and Hardener HV 953 IN is used incorporated with E-Glass fiber. Araldite resins belong to epoxy group which have excellent thermal and physical properties.

E-Glass Epoxy composite laminates were produced in a hand lay-up process (fiber to matrix ratio 40:60 by weight) in room temperatures (25-30^{0}C). The prosthesis prototype produced with two layers of glass fiber, a symmetrical fiber orientation, thickness (t): 1.5 mm. The Epoxy and hardener were then mixed in the ratio 1:1. The prosthesis prototype produced with two layers of glass fiber with symmetrical fiber orientation. The Prosthetic leg was designed by using solid works.

MODELING:

Modeling of the leg is inspired from natural as well as conventional leg. Model of the prosthetic leg is made by using solid works as a platform.Various tool bars were used to model the prosthetic leg.First step in modelling of the prosthetic leg was to make the 2-d sketch of the Socket as can be easily seen that Socket is axis-symmetric about the central axis and then by using the 3-D toolbar and selecting the revolving feature, the model of the Socket is made in 3-D.

Modelling of the Shin is quiet complicated as the cross section of the Shin varies along its length.Three circles were made in 2-d sketch at prescribed distance and then by applying the loft feature in 3-D feature toolbar and guiding the various curves while applying the loft feature to make the Shin was done. Figure 8 shown below is an assembly of the leg.The two views of the prosthetic leg are shown below.

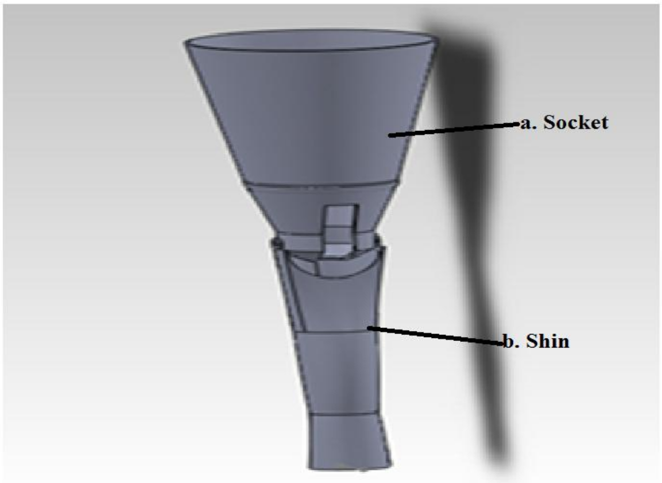


Figure 1: Assembly of prosthetic leg

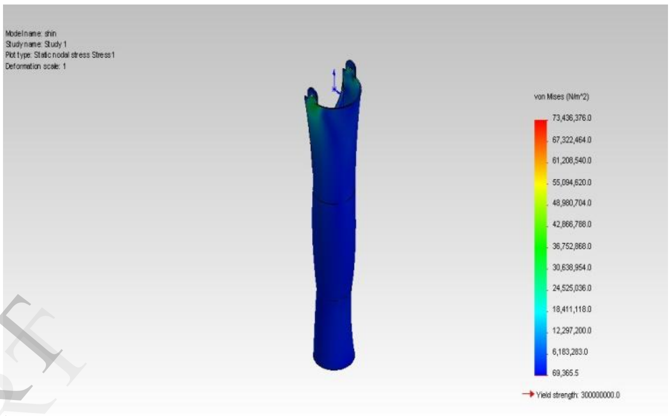
RESULTS:

Loads and Fixtures details for the Shin:

The lower part of the Shin is fixed and the upper part (holes) where it is to be pinned with Socket is applied with the pressure.

Stress plot of Shin
Composite Used: E-Glass Epoxy

Figure below shows the stress distribution in Shin. Maximum stress induced in the Shin is 73.4 MPa and thickness of Shin is 1.5 mm. Minimum factor of safety induced in the Shin is 4.Composite taken for analysis is E-



Glass Epoxy.

Figure 2: Stress plot of shin

Displacement plot of Shin

Composite Used: E-Glass Epoxy

Shows the displacement plot of the Shin using E-Glass Epoxy Composite. The max displacement in Shin is .63 mm with Shin thickness of 1.5 mm.

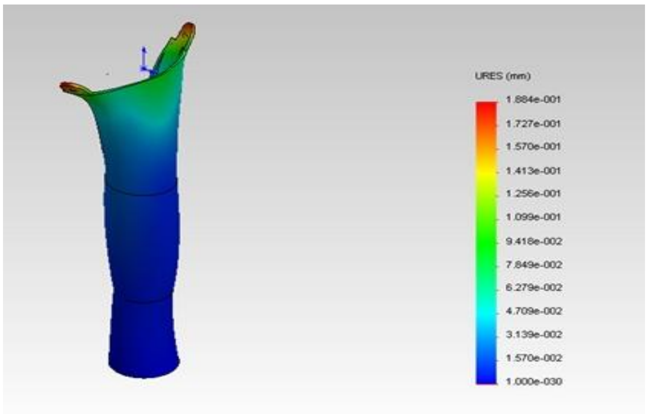


Figure 3: Displacement plot of shin

Table 1: Results of Shin using E-Glass Epoxy with different thickness:

Thickness (mm)	Max stress (MPa)	FOS	Deflection (mm)	Mass (Kg)
3	39.41	7	0.18	.500
3.5	30.9	9	.13	.535

Stress Analysis of Socket

Composite Used: E-Glass Epoxy

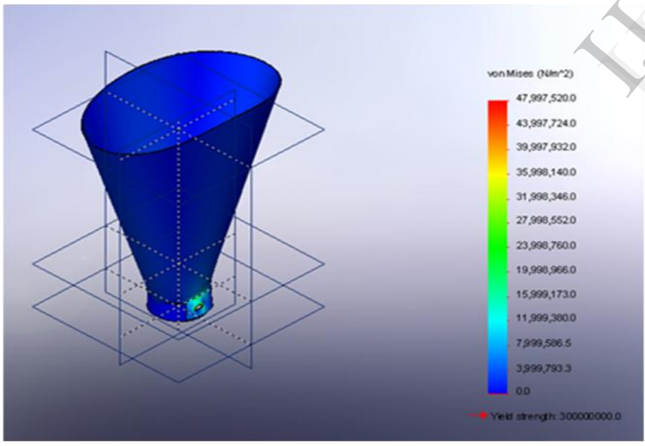
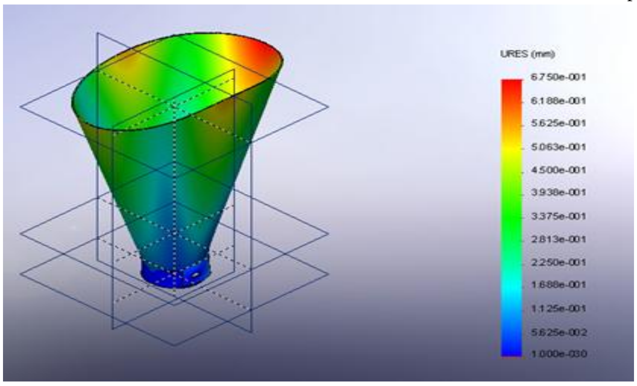


Figure 4: Stress Analysis of Socket

Displacement plot of Socket

Composite Used: E-Glass Epoxy

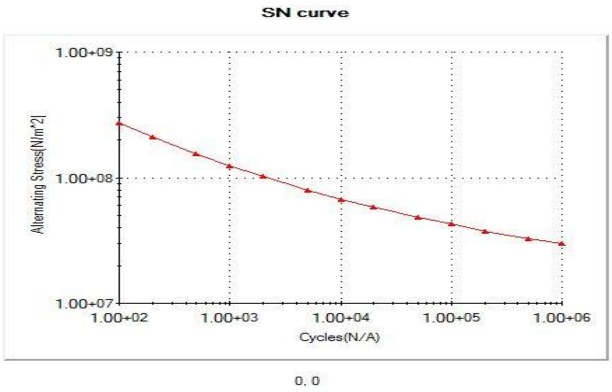


Figures 5: Above shows the stress plot and displacement plot of the Socket using E-glass Epoxy as a composite. Maximum stress induced in the Socket is lower than the yield value which shows that composite can easily bear the weight of the amputee. Displacement plot of the Shin shows that applying a load of 100kg will cause a displacement of .006 mm which is negligible in this case. So it can be said that E-glass Epoxy can be used as a composite to make the prosthetic leg.

Material	**E-Glass Epoxy**	**Kevlar Epoxy**	**Carbon Epoxy**
Yield Strength (MPa)	300	1300	2280
Thickness	**1.8 mm**		
Max. Stress(MPa)	121	127	126
FOS	2.47	10.23	18
Deflection (mm)	2.26	2.35	.886
Mass (Kg)	.470	.300	.350
Thickness	**2.5mm**		
Max Stress (MPa)	47.9	52.8	52.4
FOS	6.3	24.6	43.5
Deflection (mm)	0.67	0.71	.26
Mass (Kg)	0.700	.450	.500

Fatigue analysis of Socket with Constant Amplitude:

S N Curves: Data is presented as a plot of stress (S) against the number of cycles to failure (N), which is known as an S-N curve. A log scale is almost always used for N. Since the amplitude of the cyclic loading has a major effect on the fatigue performance, the S-N relationship is determined for specific loading amplitude.



Life cycle of Socket:

Composite Used: E-Glass Epoxy:

Table 3: Life cycle of Socket using E-Glass Epoxy composite

Name	Type	Min	Max
Result 2	Life plot	3495.55 cycles Node: 37842	1e+006 cycle Node: 1

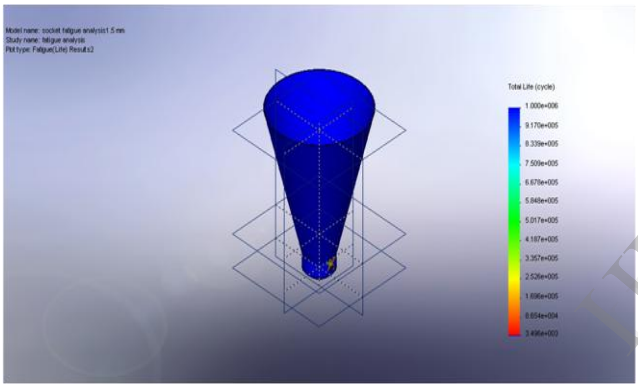


Figure 6: Life cycle plot of Socket

Life cycle plot of Shin:

Composite Used: E-Glass Epoxy:

Table 4: Life cycle of Shin using E-Glass Epoxy composite

Name	Type	Min	Max
Result 2	Life plot	7685.19 cycles Node: 699	1e+006 cycle Node:1

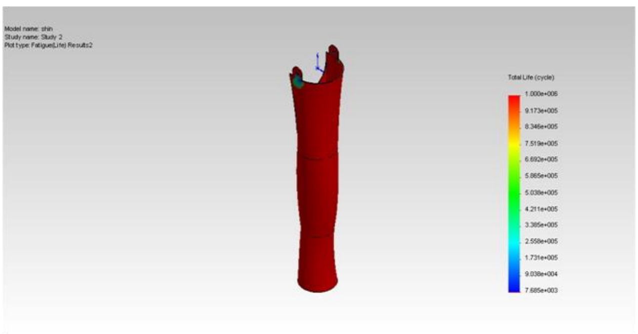


Figure 7: Life cycle plot of shin

Conclusions:

Use of E-Glass Epoxy material reduces the weight of Shin and Socket which overall will reduces the weight of the prosthetic leg as compared to the conventional leg. Above results shows that Shin and Socket can easily bear the load acting on it without failure. The conventional leg is made of Polyethylene whose density is more than E-Glass Epoxy which results in more weight of the conventional leg. There are further chances of improvement in reducing the weight of the Shin and Socket, if factor of safety is reduced.

Using the mentioned analysis, the components are designed and the prosthetic leg is ready to be assembled. The composite developed for the prosthetic leg are found to serve the purpose of desired properties at reduced weight and also has been able to maintain a low cost portfolio. The design analysis has also been targeted to fulfill the requirements of strength and comfort of use. The design of the shin and the socket been crucial for producing the components have also yielded desired outcome when combined with the composite used. The designed model has provided us with the design parameters for desired strength which is comparable or better than the present products. The analysis was done in SOLIDWORKS and boundary conditions were applied by considering conditions of use.

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