International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 10 | Oct 2022 www.irjet.net p-ISSN: 2395-0072

ANALYSIS OF COMPOSITE MATERIALS FOR PROSTHETIC ANKLE OR MEDICAL USE

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Abstract

In general we can say that prosthetic ankle are the artificial devices which are used as a body part on the place of missing body parts is there any person who faces the difficulty of losing a body part due to diseases or by major accident then the body part which is artificial manufactured is transplanted on that place which provide some comfort and freedom to work but they are not work as a natural body part they fulfill some primary needs of work which are essential .the selection of these types of devices is very difficult because it requires meet the characteristics which are present in natural path the material should have high quality and lightweight with high tensile strength it requires to bear the force acting on it some other properties which are considered as flexibility in durability fracture resistance and chemical resistance and it should be cost efficient this property is playing a major role in designing the artificial ankle for the prosthetics.

Key Words- Composite fiber, Light Weight, Strength, Material properties, Durability

Introduction

Prosthetic limb are artificial devices which are used in the place of missing body parts the limb or ankle which are designed to meet the performance level of natural human limb and also provide comfort so that the weight of prosthetic it has been always a problem , the approximate weight is start from 2.5 kg - 4 kg or more as per the efficiency class and work of prosthetic the weight of prosthetic main cause excessive muscle work that will result in high energy loss which is feel like tired and less comfortable for humans so that there are some material which are less density and sustain the load of the body parts. The foot is made with different types of structure which is biomechanical structure and it is work with the combination of some parts like muscles, veins and bones etc. The human ankle is made as like a c -channel shape which is good for structural loading and high load bearing capacity, when load applied the middle bones of ankle work as a linear spring which supports the force and increase load bearing capacity.

Literature review

In prosthetics there are many types of material present and currently in use which are fulfill the needs of prosthetics but those material are not available at low cost .there are study is continue on the materials like different composites fibers(Kevlar ,glass fiber etc.).

1 K. M. Walke and P. S. Pandure [2]observes that the properties of the carbon fiber and glass fiber good strength and durability which is required and the density of these fibers is low as camper to metals.

2. In Evaluation of High Strength Materials for Prostheses,[1] The weight of prosthesis has always been a problem for prosthetic researchers. The weight of a prosthesis may cause excessive muscle work that will result in high energy consumption for amputees Prostheses are normally excessively heavy, which tends to increase residual limb trauma and energy expenditure with the likelihood of less successful prosthetic function.

3. G. VERES analyses [4] that the foot with its active and passive structures (muscles, bones, Apo neuroses and ligaments) represents a complex three dimensional system. In addition it is not only purely a mechanical system, as an engineer would prefer, For the purpose of the analyses the foot is considered to be a segmented solid coplanar body, placed in the sagittal plane of the foot and articulating with the crus in the talocrural joint. The force acting on one or both leg is analyzed. On concluding this in my study there are different types of material laminates with fibers and develop a hybrid which is use as a prosthetic material which is light in weight and cost effective for humans and effects on design of ankle with this materials.

To find which metal has similar properties to use as a prosthetic material with cost efficient and easy to manufacturing. To find the laminated material and the base material, which is suitable for light weight high strength for static in future?

Methodology

1. Material used

1.1 Base materials

These base materials are sandwiching b/w the laminating fibers in a length with specific thickness which is required.

Stainless steel- These types of Steel used for making high strength structure with the toughness and without losing its ductility ,they are made by the heat treatment process which increase its strength, this type of steels are having ultimate high tensile strength and they are classified as a low carbon Steel in special class they are having less amount of carbon percentage to the high strength of this type of steel is not generate from the carbon compound present in metal composition but the other compound or material composition in the metal they provide good load bearing capacity is for these types of Steel.

Its strength is increased by cold rolled as much as 90% without cracking.

Steel provide good resistance over chemical compounds, free from corrosion, it shows good ductility.

Aluminum -It has less density and less modulus of elasticity its elongation up to break is 12 to 25%. Medium tensile stress and fracture toughness is low as compare to other is 22 to 35 MPa.

Titanium- Titanium and aluminum which has less density and fine tensile strength which is greater is used as a base material for the laminating materials.

Table1. Comparative study of some materials

Material	Ultimate tensile strength(MPa)	Modulas of elasticity (GPa)	Density (g/cm^3)
Stainless steel	586	193	7.75
Titanium	1070	96	4.62
Aluminum	310	71	2.77

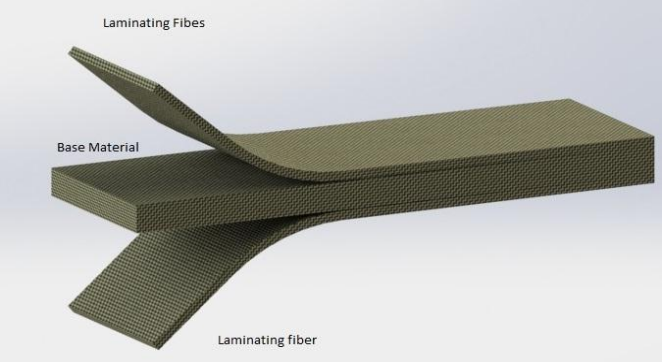

Fig-1: Laminating Pattern

Material properties of base materials-

1.2 Laminating fiber materials –

Carbon fiber- Carbon fiber is a lightest material used as a prosthetics which have low density and the modulus of elasticity as compared to other materials used to make prosthetics they are laminated on the both side of base material with varying thickness as per the loading conditions or use in prosthetics. the mixture of carbon and glass fiber exhibit great combination which provide the great strength and they have less tensile strength and having high strength to weight ratio and the property of carbon fiber is increased when the laminated carbon fiber is in continuous and straight fiber form and then the stiffness is increased up to 3 times of the glass fiber so that if the each layer of carbon fiber is in forward and right orientation scheme then the each layer improve the mechanical property of material.

Kevlar - It has very low density which shows that it is very light in weight than the other material like glass fiber or carbon fiber it used as a laminating material because it is weak when alone used to make a structure under high loading compression but it can bear 5 times more tension than compression loading but it also shows another property which is very important that is fracture resistance when high fracture loading is occur it can resist corrosion or other chemical reaction the hybrid of Kevlar and carbon fiber is developed because when the Kevlar is mixed with resins it resist and difficult to manufacture so that the hybrid form made which provide to overcome this problem and it also improve the limitations of Kevlar fiber and improve some properties like stiffness talk and the impact of any load.

Glass fiber- It has average compressive and tensile strength as compared to other material like Kevlar where it can be found in different quality as per the requirement of user and different forms of glass fiber is also available can highly absorb the tension but it is twice weaker in comparison loading it is very flexible in nature and more durable than other fiber it cannot regain its shape and size

so it cannot provide momentum in structure. The hybrid of glass fiber and carbon fiber improve the quality as like in carbon fiber and hybrid, does the hybrid of glass fiber and carbon fiber gives good ratio of strength to wright where strength is very high as compared to weight .the other properties are also enhances which are important on the basis of prosthetics like weight ,durability, flexibility and the cost of composite material which plays a major role in making prosthetics choosing the material for prosthetics.

Table2. Comparative study of above laminating fibers-

Material	Ultimate tensile strength (MPa)	Modulas of elasticity (GPa)	Density g/cm^3	Elongation upto break
Carbon fiber	3790	300	2.25	1.5%
Kevlar	3600	86.9	1.44	2.4%
Glass fiber	4500	88.9	2.48	5.7%

Analyzation criteria on materials -

The design simple prosthetic ankle which used as a sample or prototype for my analysis it has different layers for different materials and force acting on the structure is 2500 Newton. Which is the approximate weight of the human body applied on one ankle when the whole body weight is depending on one leg and the step time is 2 sec?

Force distribution on ankle-

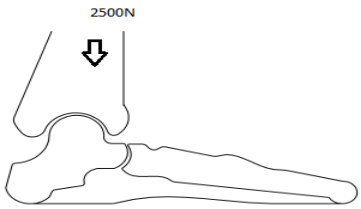

Fig-2: Force Distribution

Software use

Software is used ansys 18.2 version which used to analyze the behavior of mechanical structures when forces acting on that structure. It is majorly used software for analysis in industries or research labs.

Design

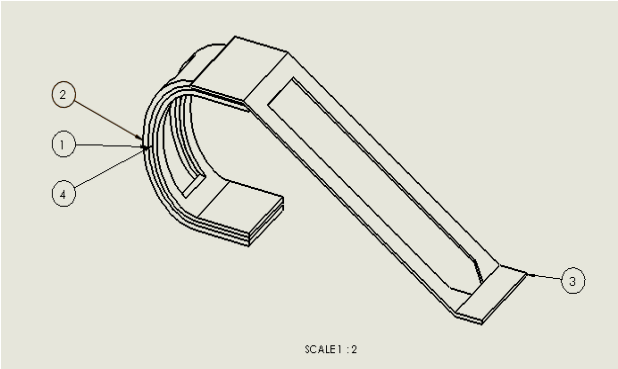

Fig-3: Design and Distribution of fiber layers

This is a simple design of an ankle which is use as a prototype for testing.in which continuous laminating fiber is used thickness of 1 and 3 layer is .3 cm , the 2 layer is .5cm thick and 4 layer is .4cm thick. They are simple added on both side of first layer. 2 and 4 layer is of laminating material (fiber) like carbon fiber, glass fiber and Kevlar. The 1 and 3 layer is a base material like aluminum, titanium and stainless steel. The other accessories used which are necessary for make an ankle.

Analyization factors

First we check the deformation on -2500 load in y axis with bottom side is fixed or act as ground. Then we check equivalent stress generated in the body which is based on von misses theory Equivalent stress (also called von Misses stress) is often used in design work because it allows any arbitrary three-dimensional stress state to represent as a single stress value. Equivalent stress is part of the maximum equivalent stress failure theory used to predict yielding in a design.

Equivalent elastic strain is calculated by the addition of components of elastic, plastic, thermal, and creep strains and then equivalent total strain is calculated from total strain components. Weight is based on the density of materials. Strain energy is checked which is generated in the body. In ansys stress tool calculate different quantities like: Equivalent stress (σ e), Maximum tensile stress (σ 1), Maximum shear stress (τ MAX) This uses Mohr's circle: where- σ 1 and σ 3 = principal stresses., Mohr-Coulomb stress This theory uses a stress limit based on different values and equations.

Design optimization

In design optimization we can reduce the material with our requirement which is of any type like Mass Reduction, Force variable and volume etc.it increases the life, durability and fulfill our requirements, by this we can reduce more weight and make better design for

professional use. If the orientation of sheet 3 is reversed in opposite direction then all properties are enhanced due to support of curve base.

Test and Result- The result is based on the mean value of different values from different material in which the Titanium having high value result in all laminating material so the comparison in B/W the carbon fiber with titanium , Kevlar with Titanium and glass fiber with Titanium.

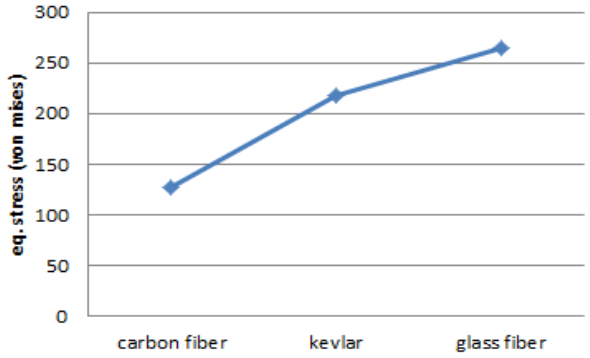

Chart- 1: Eq. Stress (Won Misses)

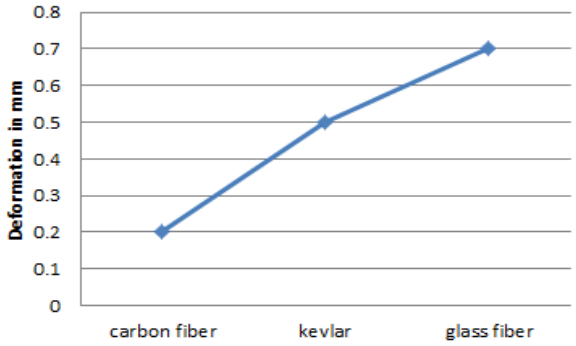

Chart -2: Max. Deformation

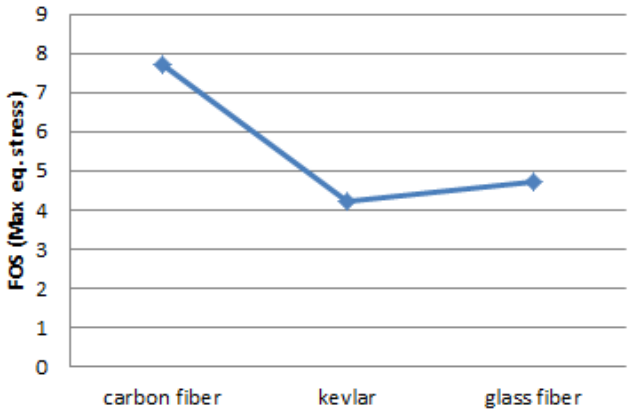

Chart -3: FOS Max. eq. Stress

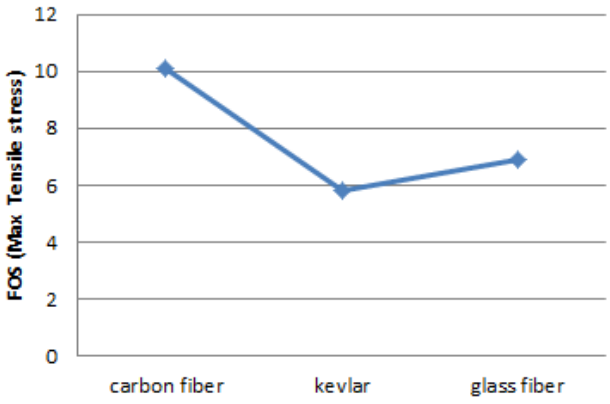

Chart- 4: FOS (Max. Tensile Stress)

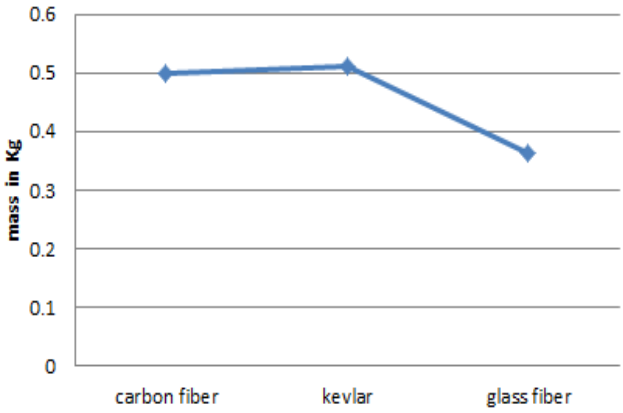

Chart -5: Mass in kg

On comparison in above charts deformation of carbon fiber with Titanium is less than the other material and all the factor of safety which comes under stress Tool factor is high.

Conclusion

In this study we observe that Carbon fiber shows high performance than the other materials laminating with different types of base material in which titanium shows high values , which are necessary for prosthetic ankle like tensile strength , density, and cost. It also improve the durability of composites and the weight of overall design is .45kg with other accessories it becomes .7kg and we can reduce the weight as per the requirement force is about 1500 max then the weight is overall body is .5 kg which is more comfortable for humans. The cost of carbon fiber is normal as compare to Kevlar which is high and availability is low. This is the simple analysis of continuous laminating material with fiber.

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