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EXPERIMENTAL INVESTIGATION OF TENSILE AND FATIGUE STRESSES FOR ORTHOTIC/PROSTHETIC COMPOSITE MATERIALS WITH VARYING FIBER (PERLON, E-GLASS AND CARBON)

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ABSTRACT

In this paper an effort is made through experimental study to investigate the tensile demeanor and fatigue properties of Hybrid and compound materials such as perlon, E-glass fibers, and Carbon fibers with epoxy resin, by variation of thickness according to lamination. The outcome shows that changing the sort of reinforcement layers of material give a huge influence upon measured properties. (Epoxy + Carbon reinforcement) compounds yield maximum experimental outcomes, whichever make them the good candidate to become better the tensile and fatigue features of for Orthotic/Prosthetic. When the numbers of perlon layers are increased at 11 stratums, the mechanical properties (modulus of elasticity E) are clearly improved 44% but the tensile strength decreased 22%. Material properties (tensile and fatigue) results when a stratum of material is added. Carbon fiber is strongest than fiberglass matter are improved with fixing layers of perlon for all classes of laminates 15% for (5perlon4carbon fiber5perlon), reinforcement sort has a apparent influence upon their fatigue resistance Carbon reinforcement gave the highest fatigue limit 58% as compared with 11 perlon layers only and with (5perlon4glassfiber5perlon) 29% appropriate to the maximum Young's modulus (E).The endurance limit stresses are decreased to 27% with the increasing of number of perlon laminations.

Keywords: orthotic/prosthetic materials, tensile, fatigue, perlon, E-glass fibers, and carbon fibers, epoxy resin, composite.

1. INTRODUCTION

Numerous looks into were the creation of Orthotic/Prosthetic apparatuses for field testing. The lay-up, sap sort, complete weight and the creator's subjective assessment of each Orthotic/Prosthetic part was recorded over late years. The goal of this article is to introduce the levelheaded for particular uses of composites and pitches prosthetic/orthotic apparatuses in view of field study.

For the situation a level foot, the strengths following up on the foot stay compressive back and are transformed to a compressive power along the foremost viewpoint. At toe off, the back power changes to a pliable anxiety, with the foremost compel stays compressive. Different powers required with an orthopedic machine are torque, shear and effect stress; hence, they should be considered and acknowledged. With all the particular and individual strengths and anxiety required with an orthopedic structure, the required properties of a fortifying composite would be [1]:

- Lightweight.
- Strong under strain.
- Strong under pressure.
- Durable, to resist fracture under impact.
- Capable of resisting stress in all planes.
- Cost effective.
- Easy to apply.

Assembling of prosthetic/orthotic by utilizing distinctive weighted materials, for example, perlon, nylon, carbon fiber and fiber glass which was utilized as a part of outlining and assembling the above knee prosthetic attachment by a cover comprising of a blend of some of these materials inserted with an acrylic pitch. Fiberglass is by a long shot the most widely recognized and efficient composite. Despite the fact that the heaviest material of the three, Fiberglass is anything but difficult to immerse with gum and simple to get in numerous structures and qualities. The main properties of fiberglass are its solidness and adaptability, because of the filaments being twice as solid under pressure when contrasted with the fiber quality under strain [2]. Carbon and Glass strands are better known for their sturdiness, medium modulus, quality and solidness, however are inadmissible for use in weakness safe composites, while carbon filaments are portrayed by high modulus, fragility, low thickness and predominant exhaustion properties. Be that as it may, carbon filaments are thermally less steady and have lower durability when contrasted with glass strands. Consequently, to tailor the properties for adjusted execution necessities, fiber hybridization has as of late turned into an appealing methodology [3], [4].

Larger parts for disappointment of prosthesis segments are weakness connected less than annular strolling capacities. The mechanical properties and Materials of the prosthesis attachment being examined by numerous agents. T.A. and *et al*, [5] evaluated an auxiliary quality for different trans-tibia compound attachments. Five diverse fortification matters with two sap sort utilizing to build this attachments.

A.A. Ibrahim [6] explored this basic quality of the syme prosthetics besides suggesting two overlays toward various support matters. William Crelius and Sam L. Philips [7] started with this database on properties of the material of regular overlays utilized as a part of prosthetic appendage attachments, the creator's subjected tests of normal prosthetic covers to tractable and bowing experiments. For the eight assortments of sock away matters (filaments) where each covered independently by one for three basic tars (network), bringing about 24 miles of fiber/sap covers. H. F. Neama, [8] displayed investigations for beneath knee prosthetic attachment. Attachment stress dissemination was accomplished above three sorts for this attachments, polypropylene for different dimensions (5mm), (3mm) and normal overlay (8 stratum of nyl-glass) size (3mm) attachments unto decide this anxiety way between the prosthesis attachment amid walk annular. Mohammed S. H. [9] explored numerically lowering leg foot orthoses and tentatively utilizing perlon-carbon-filaments-acrylic matters rather than run the mill utilization of polypropylene materials.

Jumaa S. C. *et al* [10] considered the prosthesis subjected to malleable or weariness stress with fluctuating temperatures, a mechanical and warm properties of composite materials prosthetic attachment made of various overlay for perlon/fiber glass/perlon, are figured by utilizing tractable test gadget under shifting temperatures (from 20ºC to 60ºC.Kahtan A. *et al* [11] five overlaid composite materials utilized for assembling lower-appendage prosthetic attachments. The network matter for these compounds was Epoxy, Five sorts from fortified woven filaments with particles: (carbon, glass, perlon, crossover (glass and carbon) half and half (glassandcarbon) having Nano Silica particles and smaller scale.

This paper demonstrate mechanical properties of (tensile and fatigue) have been investigated using seven laminated composite materials reinforced by carbon and glass fibers with epoxy resin.

2. EXPERIMENTAL WORKS

The work steps of this paper are summarized as:

Manufacturing of specimens

Materials part which describing the method of manufacturing socket from perlon only, perlon/carbon and glass/perlon at different seven laminations lay- up as explain in schedule-1.

Table-1. Covers lay-up.

Covers layup procedures	Entire No of layers	Thickness (mm)
5Perlon	5	1.8
8Perlon	8	2.7
11Perlon	11	3
5perlon+2fiberglass+5perlon	12	3.1
5perlon+4fiberglass+5perlon	14	3.21
5perlon+2carbon fiber+5perlon	12	3.14
5perlon+4carbon fiber +5perlon	14	3.28

a. Materials

The materials that used in the manufacturing of different types of specimens in this paper are as follows and shown in Figure-1:

a) Perlon stockinet white (ottobock health care 623T3).
b) Fiber glass stockinet (Ottobock health care 616 G3).
c) Carbon fiber (ottobock health care 616G15).
d) Lamination resins 80:20 polyurethane and c-orthocryl lamination resin for use with carbon fiber (proter hand icap technology).
e) Hardening powder (ottobock health care 617P37).
f) Polyvinyalcohol PVA bag (ottobock health care 99B71).
g) Materials for Jepson.
h) Polypropylene.

Figure-1. Materials used for specimens manufacturing.

b. Procedure of laminations

All laminations were performed under vacuum with the following procedures:

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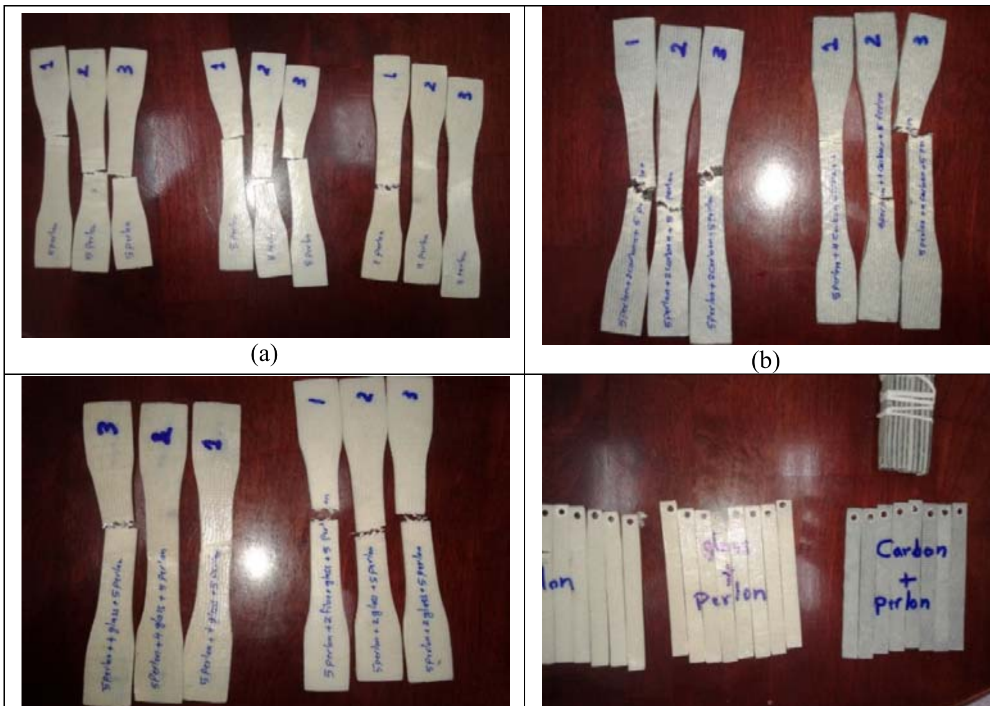
a) Mount the positive mold at the laminating stand.
b) Put the Perlon stockinet, Perlon and fiber glass stockinet and Perlon and carbon fiber stockinet as indicated by the overlaying lay-up given in Table 1.
c) Blend the overlay resin 80:20 polyurethane with the hardener.
d) Maintain constant vacuum until the composite materials becomes cold and then lift the resulting lamination.

Tensile and fatigue tests

The tensile specimens for each lamination were machined according to ASTM D638 [12] with50mm original length and 13mm width while the fatigue specimens have the geometry as described in Figure-3. The dimensions of samples are 100mm length and 10mmwidth according to the fatigue device test shown in Figure-2 while the thickness of each tensile and fatigue specimen varies with the type of layup.

Figure-2. Tensile and fatigue test device.



(a) (b)

(c) (d)

Figure-3. Tensile and fatigue specimens (a): perlon only, (b): perlon/carbon, (c): perlon/glass (d): Fatigue specimen for all laminations).

3. RESULTS ANALYSIS AND DISCUSSIONS

The mechanical properties results of each sample are shown in Table-2, Figure-(4) and Figure-5. Those results can be calculated by taking the average value of these properties (modulus of elasticity (E), yield stress (σ_y), ultimate stress (σ_{ult})).These results were found for all laminations according to the arrangement shown in Table-1:

a) For Perlon lamination only the mechanical properties (E) are increasing about 44% with the increasing

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Perlon layers, especially at 11perlon layers, but the mechanical (yield strength σ_y 38% and ultimate tensile strength σ_{ult} 23%) are decreasing with the increasing Perlon layers, especially for high number of Perlon layers because the matrix epoxy stronger than Perlon fiber these result agreement with [10].

b) For lamination (Perlon+fiberglass+Perlon) these properties results for increasing fiber glass with constant Perlon layer in the lamination, the mechanical properties (E) are increasing about 22% with the increasing fiber glass layers about as compared with 11 layers of perlon only also the properties (yield strength σ_y52%and ultimate tensile strength σ_{ult} 42%) are increasing with the increasing fiber glass layers these result agreement with [10].

c) For lamination (Perlon+carbonfiber+Perlon) as compared with 11 layers of perlon only the mechanical properties (yield strengthσ_y60% and ultimate tensile strength σ_{ult} 50%) were increased with presence of the carbon layers with constant Perlon layers. This was due to increasing the absorbing ability which led to increase in the lamination thickness of samples the different in plastic behavior for both materials. This addition of thickness consisted of fiber and matrix materials but the greater part of this addition thickness come from the matrix material which was certainly weaker than the fiber materials [13] This resulted in an optimum absorbing ability to the epoxy matrix which gave a strong binding to the sandwich layup lamination which led to the high mechanical properties.

Table-2. Mechanical properties results for all laminations.

Lamination layup procedures	Total No of layers	Thickness (mm)	σ_y MPa	σ_{ult} MPa	E GPa
5Perlon	5	1.8	39	40	1.65
8Perlon	8	2.7	31	35	2.3
11Perlon	11	3.2	24	31	2.95
5perlon+2fiberglass+5perlon	12	3.4	47	49	3.3
5perlon+4fiberglass+5perlon	14	3.6	50	54	3.8
5perlon+2carbon fiber+5perlon	12	3.41	55	59	5.1
5perlon+4carbon fiber +5perlon	14	3.62	60.67	63.767	9.2

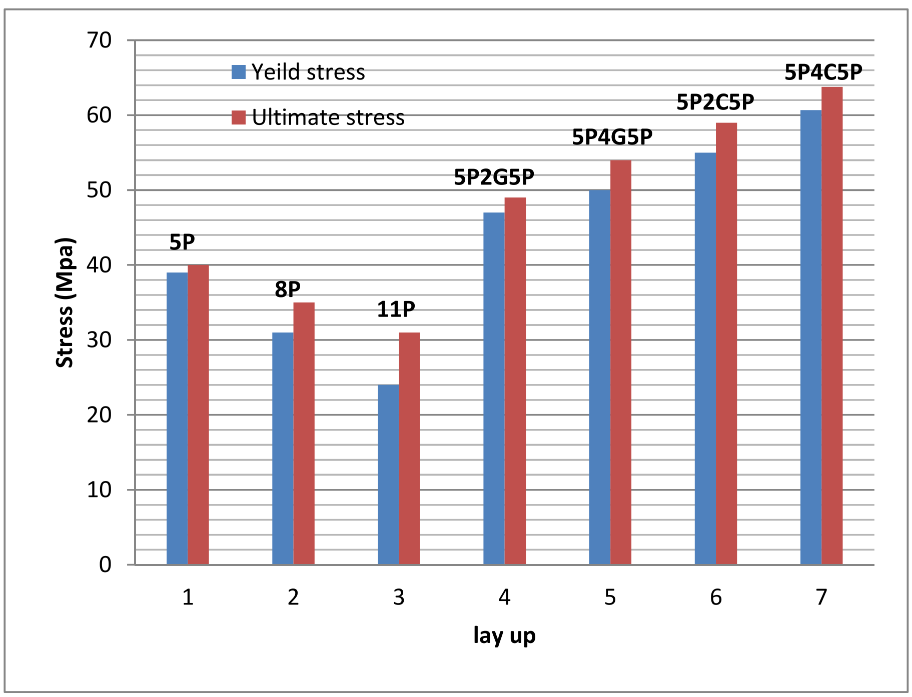

Figure-4. Tensile properties (yield strength, ultimate strength) with various laminations.

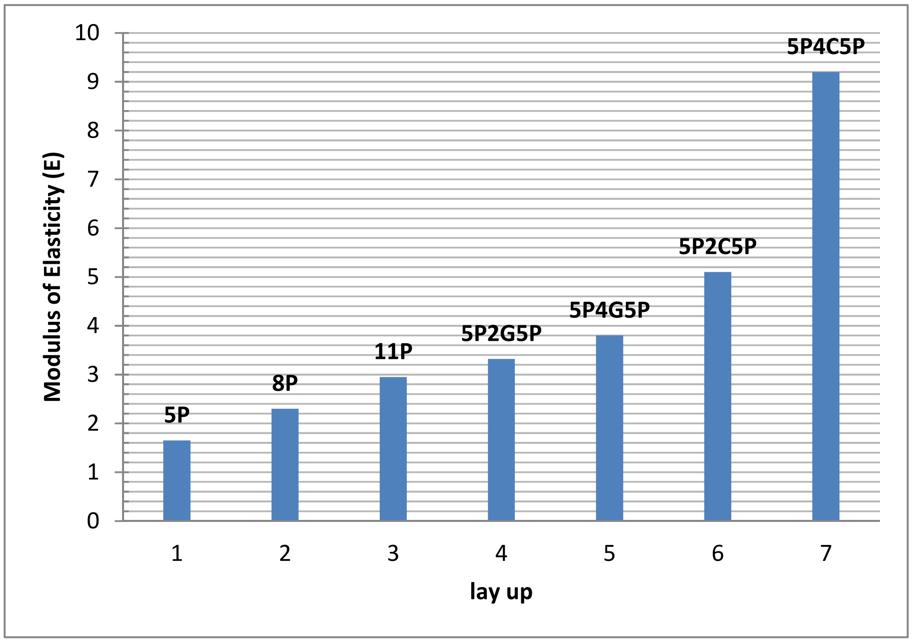

Figure-5. Tensile properties (modulus of elasticity) with various laminations.

For that reason, the higher quality originates from the expanding of the fiber material confronting the shortcoming originates from the lattice material. Also, it can be noticed that lamination which consisted of five layers of Perlon plus two layers of carbon fiber plus five layers of Perlon bound by the acrylic resin matrix, had the optimum mechanical properties.

According fracture shape of laminations type we can noted that the interfacial interaction between the fiber and polymer matrix phase, for the carbon composite, it is shown that fiber was sacking on polymer matrix which means a poor adhesion between fiber and polymer matrix. For the glass composite, it is shown that there is a small gap between the fiber and the matrix, which means fairly good adhesion.

Fatigue failure occurs when the specimen fractures under alternative loading. The readings were recorded by the fatigue tester represent the number of cycles until the specimens fractured. The S - N curves results of each sample as shown in Figures from 6 to 9 can be calculated and by taking the average value of the failure stress with number of cycles, these S - N results for all Perlon laminations the disappointment stress results are diminishing with the expanding Perlon layers around 27%, while the quantity of cycles to achieve the disappointment focuses are expanding with the expanding Perlon layers. Likewise for all covers, from these outcomes the endurance limit stresses (σ_e) are decreased with the increasing of number of Perlon.

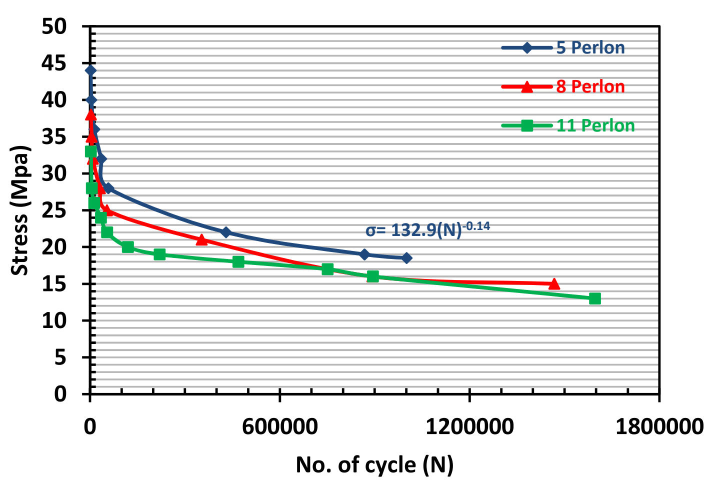

Figure-6. S-N curves for perlon laminations.

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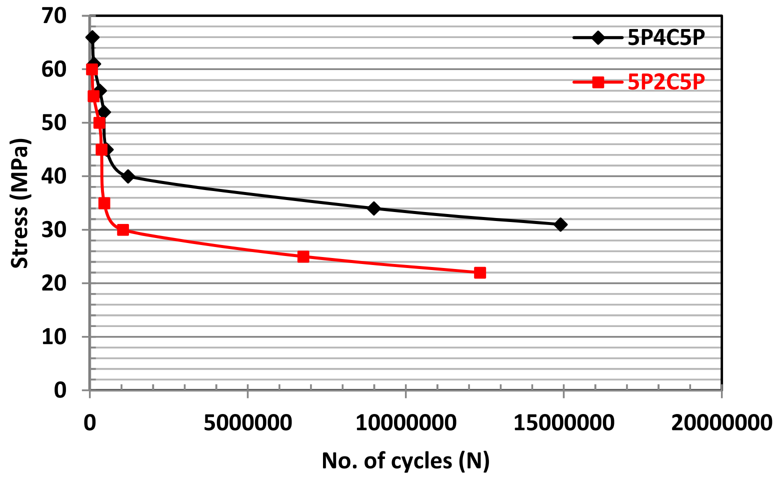

Figure-7. S-N curves for Perlon/Carbon laminations.

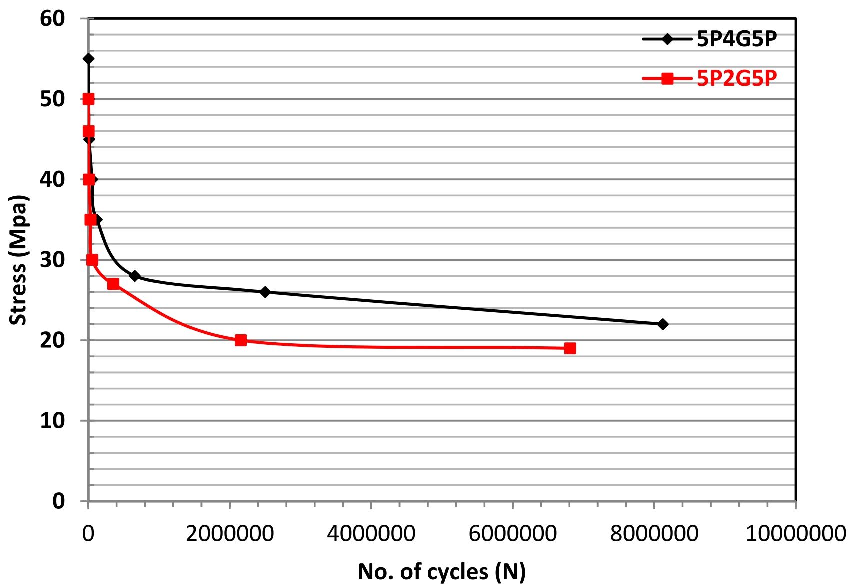

Figure-8. S-N curves for Perlon/Glass laminations.

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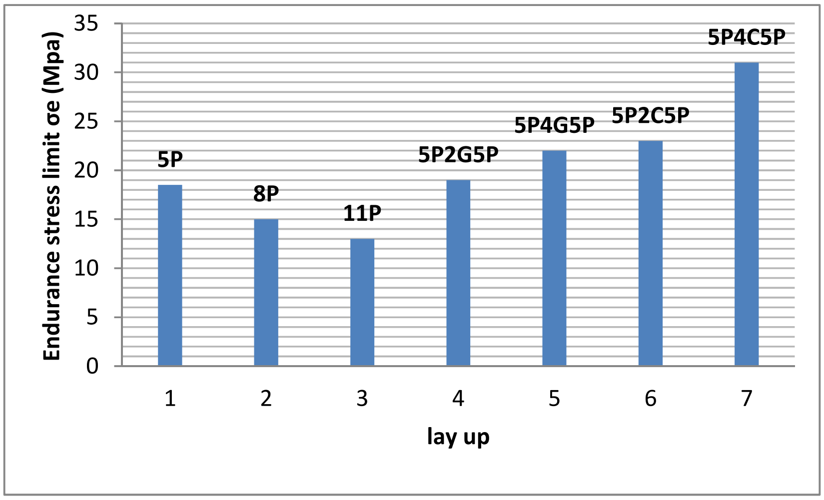

Figure-9. Fatigue endurance stress limit of Epoxy matrix composite with various laminations.

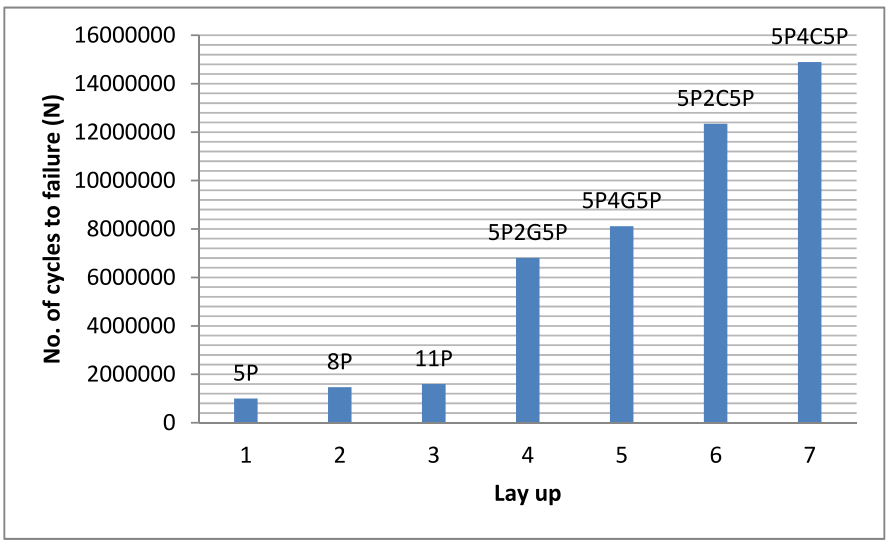

Figure-10. No. of cycles to failure of Epoxy lattice composite with different laminations.

4. CONCLUSIONS

The outcomes demonstrate that the changing in the sort of fortification gives an incredible impact on the measuring results:

a) When the comparison was carried out between the perlon lamination of the different thicknesses, the difference between the tensile strengths of 11 layers is less when compared to the difference of strengths of 8 layers and 5 layers, which shows the weak bond of 11perlon lamina, this may be because of starvation of resin or improper molding of lamina, properties did not enhance with perlon for network matter into any degree and then elastic properties for framework are prevailed in the general conduct of the compounds. When the numbers of perlon layers are increased, the mechanical properties (E) are clearly improved.

b) When the fiber glass and carbon fiber are increased, the mechanical properties (σ_y, σ_{ult}, and E) are improved with fixing layers of perlon that is consistent since their anxiety qualities are high which implies that this composite material can store a lot of vitality before harm and disappointment happen.

c) Material properties result when a layer of material is added. Carbon fiber is stronger than fiberglass matte, but because of the difference in thickness, a layer of carbon and a layer of fiberglass matte take about the same amount of force to break, thus materials with higher extreme elasticity have higher exhaustion edge. from Figure-10 it is apparent all classes of overlays, support sort impacts their weakness impedance appeared in Figures (6-9) Carbon fortification produce most astounding weariness edge because of the high Young's modulus (E).

d) For a constant number of perlon layers, the mechanical properties are clearly improved with increasing the number of the fiber glass and carbon fiber layers due to the capacity of Epoxy sequester superbly to a broad assortment for strands [15].

e) Endurance limit stresses (σ_e) are decreased with the increasing of number of perlon.

f) Likewise we noticed that Perlon produce supported most reduced ductile properties, implying that properties of the perlon did not enhance grid matter to any degree and the pliable properties of lattice are prevailed in the general conduct of the compounds.

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