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Effect of Stacking Sequence and Orientation on Tensile Response of Natural Fiber Reinforced Hybrid Composites: Fibrous - Glass/Hemp/Jute/ Epoxy Composite Plates

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***Abstract* –This paper is concerned with evaluation of failure mechanisms under tensile loading with different stacking sequence and orientations of fiber-reinforced laminate composites under tensile loads. The fibrous-Glass/Hemp/Jute/Epoxy laminates are fabricated with different stacking sequence and orientations by hand layup technique, and all the parameters of laminated composite materials were measured experimentally. The tensile strength and failure mechanisms were investigated for hybrid composites. Static uni-axial tensile tests were performed on specimens made with single layer of glass, hemp, and jute fibers and epoxy resin combined to give different stacking and orientation hybrid composite materials. The results are analyzed by using Taguchi technique.**

Keywords-Glass fiber, Hemp fiber, Jute fiber, Stacking sequence, Orientation, Tensile response, Taguchi technique.

I. INTRODUCTION

Progressions in the use of laminated composite materials for structure of aircraft and automobile industries were increased significantly over the past decade. This was motivated by the need for improved performance requirements in stipulations of payload, range, stability and simultaneously, a reduction in costs in terms of maintenance, operation and construction. Much experience in the use of hybrid composites in the aerospace industries were achieved from the design of composite airplanes, which were designed using high stiffness requirements and not for all the parts of the current body of airplanes being planned. The stiffness of composites can be determined equitably accurately using the particular tests and material properties from standard material characterization tests. However, with more demanding requirements, this was changed and the minimization of damage is something that is now required in order to satisfy higher-performance demands. This is not as simple as optimizing the elastic stiffness of the structure due to the complex damage modes that can occur in hybrid composites.

Tensile strength is an important topic as it is one of the design drivers for composite structures. [1-2] have studied properties of different type's composites like unidirectional (UD) layered glass/carbon hybrid composites. [3] Also observed consistently higher strains to carbon failure in their UD glass–carbon–glass sandwich laminates than in all carbon specimens. The conventional material such as glass, carbon and boron fibers are quite expensive and the use of fiber like carbon or boron is justified only in aerospace application. Therefore it is meaningful to explore the possibility of using cheaper materials such as natural fiber as reinforcement [4]. The mechanical behavior of unidirectional hemp fiber reinforced epoxy composites is studied [5].The effect of fiber content on the properties of natural fiber reinforced composites is particularly significance. It is often observed that the increase in fiber loading leads to an increase in tensile properties. The layering sequence has larger effect on the flexural and inter-laminar shear properties than tensile properties [6-7].

The tensile strength and Young's modulus of composites reinforced with bleached hemp fibers increased incredibly with increasing fiber loading[8]. The hybridized composite shows greater tensile strength compared to the composites with individual type of natural fibers as reinforcement [9-10]. The effect of stacking sequence on compressive response and energy absorption of glass, carbon and Kevlar fiber reinforced epoxy hybrid composites were studied [11-12].The fiber properties, conventional fibers such as short and long glass fibers and carbon fibers are exhibit significantly higher strength values and the natural fibers also attain the nearest value of conventional fibers[13].

II. EXPERIMENTAL PROCEDURE

A) Material Selection

Traditionally, aerospace composites were composed of high-stiffness carbon fibers to maintain dimensional stability under high-performance application. The stiffness property is often associated with a particular susceptibility to impact damage and a corresponding reduction of mechanical properties. However, such structures were expected to only encounter few unintentional impacts. Composite structures for military ground vehicles were designed to absorb multiple high-energy impacts, but they had much less dimensional restrictions. Since softer materials tend to dissipate more energy during impact, a low modulus/high strength alternative may be suited well for backing panel composites [12]. Figure 1 shows the three types of fibers, including hemp, jute, glass which was used in fabricating the specimens.

Fig 1: left to right hemp, jute and glass fibers

Hemp is an environmental "savior". Hemp can be used in a variety of ways; it can produce everything from clothing to paper to fuel easily, cheaply, and most of all, in an environmentally friendly fashion. Hemp fiber is longer, stronger, more absorbent and more insulative than cotton fiber [5].

Jute fiber is obtained from two herbaceous annual plants, white Corchoruscapsularis (white jute) originating from Asia and Corchorusolitorius (Tossa jute) originating from Africa. Next to cotton, it is the second most common natural fiber, cultivated in the world and extensively grown in Bangladesh, China, India, Indonesia, and Brazil. The jute plant grows six to ten feet in height and has no branches. The stem of the jute plant is covered with thick bark, which contains the fibers. In two or three months of time, the plants grow up and then are cut, tied up in bundles and kept under water for several days for fermentation. Thus, the stems root and the fibers from the bark become loose. Then the cultivators pull off the fibers from the bark, wash very carefully and dry them in the sun [7].

Glass fibers are made of silicon oxide with addition of small amounts of other oxides. Glass fibers are characteristic for their high strength, good temperature and corrosion resistance and low price. There are two main types of glass fibers: E-glass and S-glass. The first type is the most used, and takes its name from its good electrical properties. The second type is very strong (S-glass), stiff, and temperature resistant. The proposed composites used as reinforcing materials in many sectors, e.g. automotive and naval industries, sports equipments, etc. They are produced by a spinning process, in which they are pulled out through a nozzle from molten glass (thousands of meter/min).

B) Selection of Resin and Hardener

Epoxy or poly-epoxide is a thermosetting polymer formed from reaction of an epoxide "resin" with polyamine "hardener". Epoxy has a wide range of applications, including fiber-reinforced plastic materials and general purpose adhesives.

The choice of a resin system for use in any component depends on various characteristics:

1. Adhesive Properties
2. Mechanical Properties
3. Micro-Cracking resistance
4. Fatigue Resistance

The curing process is a chemical reaction process in which the epoxide groups in epoxy resin reacts with curing agent (hardener) to form a highly crosslinked, three-dimensional network. In order to convert epoxy resins into a hard, infusible, and rigid material, it is necessary to cure the resin with hardener. Epoxy resins cure quickly and easily at practically any temperature from 5-150°C depending on the choice of curing agent [14].

A wide variety of curing agents for epoxy resins are available depending on the process and properties required. The commonly used curing agents for epoxies include amines, polyamides, phenolic resins, anhydrides, isocyanates and polymercaptans. The cure kinetics and the T_g of cured system are dependent on the molecular structure of the hardener. The choice of resin and hardeners depends on the application, the process selected, and the properties desired. The stoichiometry of the epoxy-hardener system also affects the properties of the cured material. Employing different types and amounts of hardener which, tend to control cross-link density vary the structure. In the present work epoxy(lepox-12) resin and hardener-K6 was selected.

C) Preparation of Samples

For making the test specimen, the moulds are prepared for tensile test using glass material of dimensions 250x85x12mm is made by fixing 12mm thick glass plates of width 25mm on four sides of the plate using araldite. The mould is dried at room temperature for a period of time.

Hand lay-up is the simplest and oldest open moulding method of the composite fabrication processes. Glass or other reinforcing mat or woven fabric or roving is positioned manually in the open mould, and resin is poured, brushed, or sprayed over and into the glass plies. Entrapped-air is removed manually with squeegees or rollers until the laminate structure is completed. Room temperature curing epoxies are the most commonly used matrix resins. A catalyst initiates curing in the resin system, which hardens the fiber-reinforced resin composite without external heat, and kept them in-room temperature (19 °C, Humidity 13%)[11].

Fig 2: hand layup technique

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Table 1and 2 displays the orientation and sequence of fibers plies in each hybrid composite materials.

Table 1: sequencing order of composites

Sequence-1	Sequence-2	Sequence-3
Glass	Hemp	Jute
Hemp	Jute	Glass
Jute	Glass	Hemp

Table 2: changing orientation of composites

Hybrid no	Glass	Hemp	Jute
1	1-V	2-V	3-V
2	3-V	1-V	2-V
3	2-V	3-V	1-V
4	1-V	2-V	3-H
5	3-V	1-V	2-H
6	2-V	3-V	1-H
7	1-V	2-H	3-V
8	3-V	1-H	2-V
9	2-V	3-H	1-V
10	1-V	2-H	3-H
11	3-V	1-H	2-H
12	2-V	3-H	1-H

*V-vertical *H-horizontal

III. EXPERIMENTAL TESTING PROCEDURE

The fabrication involves three different compositions of composites where the composite plates are cut down according to the ASTM standards in order to carry out tensile test on each specimen.

A) Tensile Test:

The tensile strength was determined by using Universal Test Machine with precision cage arrangement. The tensile test generally performed on flat specimen. Tensile test of composite sample is carried out in ASTM D3039-76 test standard, which is used to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point. Tensile tests produce a stress-strain diagram, which is used to determine tensile modulus. The data is often used to specify a material, to design parts to withstand the applied force.

Fig 3: tensile test specimens as per ASTM D3039-76 standards

Fig 4: sample specimens

B) Test Procedure:

In tensile test, an uni axial load was applied through both the end. Tensile test was performed to evaluate the ultimate tensile strength. A specimen of standard specification was cut from the composite plate readymade. Specimens are placed in the grips of a Universal Test Machine at a specified grip separation and pulled until failure. As the load increase, fracture occurred in the gauge length portion of the test specimen. The load at break was noted from the scale at the time of failure. The same procedure was repeated for remaining specimens cut from the same composite plate. Later, the average load at the break was noted and tensile strength was calculated on the basis of the following formula.

Fig 5: UTM with digital out put

Fig 6: After test specimens

C) Tensile Properties:

The tensile stress and tensile strain of the composites were determined by substituting the load and elongation values in below formulae

$$\text{Tensile stress } \sigma_t = P/bd \text{ MPa}$$

$$\text{Tensile strain } \varepsilon_t = \frac{L}{l}$$

$$\text{Tensile modulus} = \sigma_t / \varepsilon_t \text{ MPa}$$

Following are the notations used in above formulae
P=Load, (N)
L=Support span, (mm)
b=Width of test beam, (mm)
d=Depth of test beam, (mm)
l=change in the length

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D) Optimization technique (Taguchi):
Minitab software is used for optimization to select the best alternatives from number possible alternatives. The main aim of this technique is to selecting the top ranked alternative and comparing it with all ranks in this set of simulations.

IV. RESULTS AND DISCUSSIONS

Hybrid-1(all fibers are arranged in unidirectional orientation):
The fibers in this case are arranged in unidirectional manner. Among the different stacking arrangements, the stacking laminate having order of Jute, Glass and Hemp (Type-3) is showing good load carrying capacity.

Table: 3: Sample Hybrid-1

Type1	Glass	Hemp	Jute
Type2	Glass	Jute	Hemp
Type3	Jute	Glass	Hemp

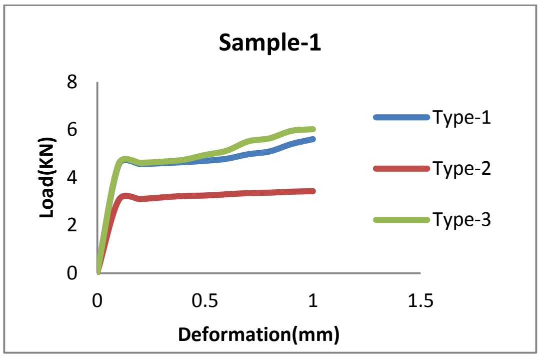

Fig 7: comparison of sample hybrid-1 with loads and elongations

Hybrid -2(jute fiber is in horizontal orientation):
In this sample hybrid, the Jute fiber is arranged in Horizontal direction and other fibers are in unidirectional manner. From the different stacking arrangement, the stacking laminate having order of Glass, Jute and Hemp (Type-5) is showing good load carrying capacity.

Table 4: Sample Hybrid-2

Type4	Glass	Hemp	Jute(H)
Type5	Glass	Jute(H)	Hemp
Type6	Jute(H)	Glass	Hemp

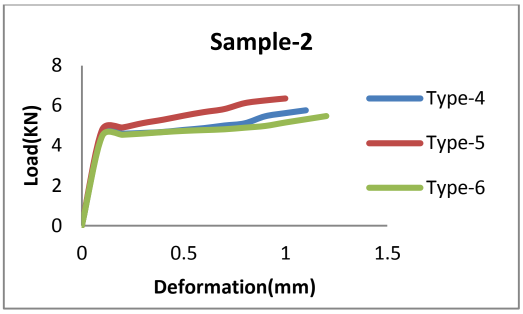

Fig 8: comparison of sample hybrid-2 with loads and elongations

Hybrid -3(hemp fiber is arranged in horizontal orientation):
In this sample hybrid, the Hemp fiber is arranged in Horizontal direction and other fibers are in unidirectional manner. Among the different stacking arrangement, the stacking laminate having order of Glass, Jute and Hemp (Type-8) is showing good load carrying capacity.

Table 5: Sample Hybrid-3

Type7	Glass	hemp(H)	Jute
Type8	Glass	Jute	Hemp(H)
Type9	Jute	Glass	hemp(H)

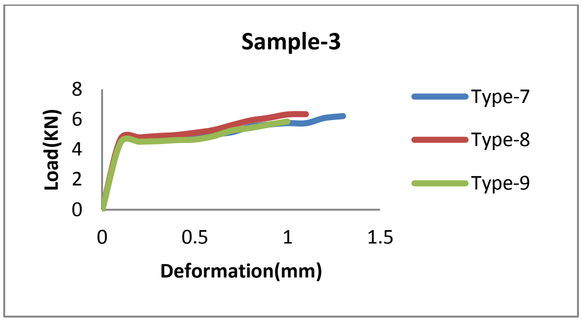

Fig 9: comparison of sample hybrid-3 with loads and elongations

Sample Hybrid -4(jute and hemp are arranged in horizontal orientation):
The Jute and Hemp fibers are arranged in Horizontal direction of this sample hybrid. Among the different stacking arrangement, the stacking laminate having order of Glass, Hemp and Jute (Type-10) is showing good load carrying capacity.

Table 6: Sample Hybrid-4

Type10	Glass	hemp(H)	jute(H)
Type11	Glass	Jute(H)	Hemp(H)
Type12	Jute (H)	Glass	hemp(H)

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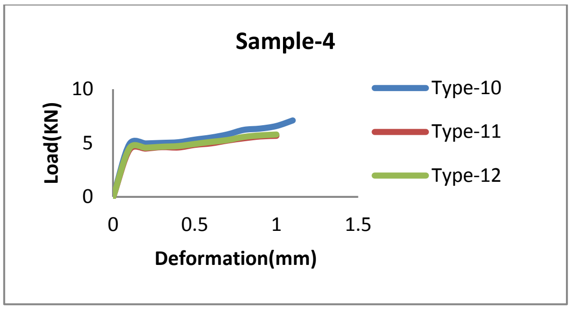

Fig 10: comparison of sample hybrid-4 with loads and elongations

Hybrid -5(all fibers are arranged in random orientation):

In this case, all the fibers are arranged in randomly. Among the different stacking arrangement, the stacking laminate having order of Glass, Jute and Hemp (Type-14) is showing good load carrying capacity.

Table 7: Sample Hybrid-5

Type13	Glass	Hemp	jute
Type14	Jute	Glass	Hemp
Type15	Glass	Jute	hemp

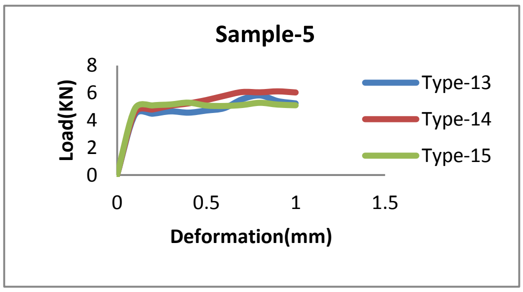

Fig 11: comparison of sample hybrid-5 with loads and elongations

The following are the results and graphs drawn between loads Vs deformation on all the hybrid composites having the same stacking sequence laminates.

Sequence order-1:

In this case, all the fibers are arranged in same sequentional order of Glass, Hemp and Jute but the orientation of fibers has been changed. Among the different orientation arrangement, the stacking sequence having an order of Type-10 is showing good load carrying capacity.

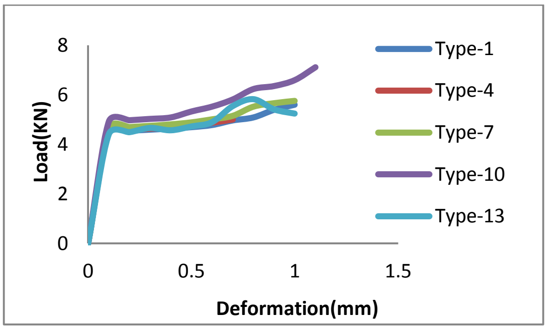

Fig 12: comparison of sequencing order-1 with loads and elongations

Sequence order -2:

In this case, all the fibers are arranged in same sequentional order of Glass, Jute and Hemp but the orientation of fibers has been changed. Among the different orientation arrangement, the stacking sequence having an order of Type-5 is showing good load carrying capacity.

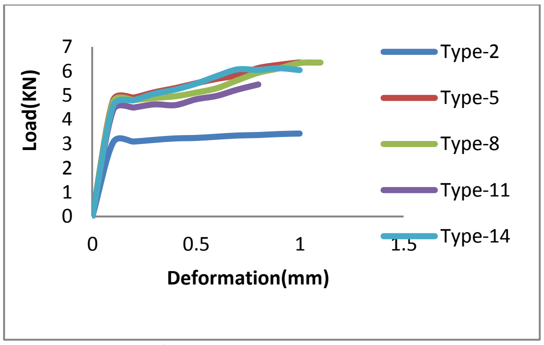

Fig 13: comparison of sequencing order-2 with loads and elongations

Sequence order -3:

In this case, all the fibers are arranged in same sequentional order of jute, glass, hemp but the orientation of fibers has been changed. Among the different orientation arrangement, the stacking sequence having an order of Type-15 is showing good load carrying capacity

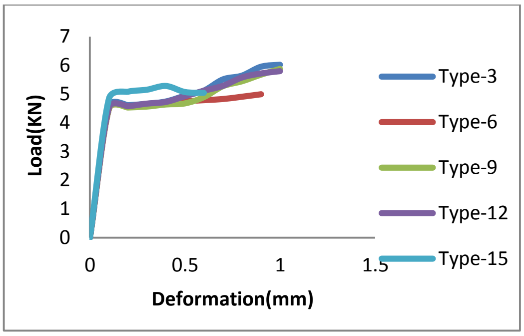

Fig 14: comparison of sequencing order-3 with loads and elongations

Effect of tensile response on composites:

It is evident from the Figure 15 the tensile modulus of composites is changed with change in fiber stacking sequence and orientation. During the tensile test the average tensile strength of all the fiber samples with different stacking sequence and different orientations are calculated.

The following table indicates the average tensile modulus of each stacking sequence hybrid sample.

Table 8: Tensile modulus of all samples with sequencing order

	Tensile modulus (MPa)		
	sequence-1	sequence-2	sequence-3
sample-1	1650.23	569.308	1299.2429
sample-2	4394.7368	4216.666	1620.5131
sample-3	725.3055	3297.8	2363.6363
sample-4	3603.7216	1635.9842	508.3939
sample-5	583.548	710.4576	618.1286

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Note: Sequence-1: Type-1, Type-4, Type-7, Type-10, Type-13
Sequence-2: Type-2, Type-5, Type-8, Type-11, Type-14
Sequence-3: Type-3, Type-6, Type-9, Type-12, Type-15

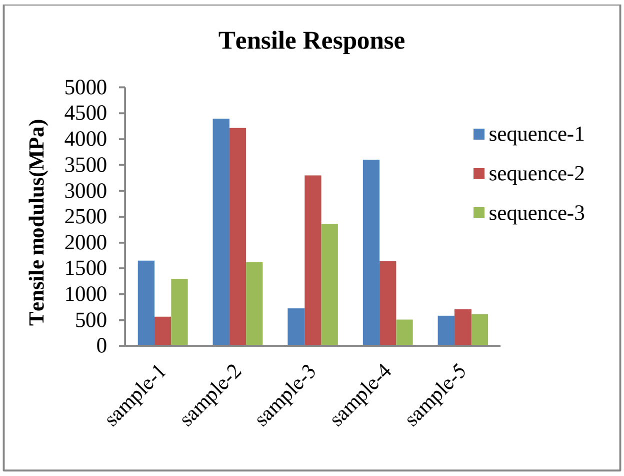

Fig 15: comparison of all the sample hybrids with tensile modulus

Analysis of materials using Taguchi:

Taguchi is an optimization technique for selecting the best alternatives from number possible alternatives. The main aim of this technique is to selecting the top ranked alternative and comparing it with all ranks in this set of simulations. All the composite materials are compared based on stacking sequence and orientation, and ranking has been done.

Table 9: Tensile modulus of all samples with sequencing and orientations

S. No	Glass	Hemp	Jute	Tensile modulus(MPa)
1	1-V	2-V	3-V	1650.23
2	3-V	1-V	2-V	569.308
3	2-V	3-V	1-V	1299.2429
4	1-V	2-V	3-H	4394.7368
5	3-V	1-V	2-H	4216.666
6	2-V	3-V	1-H	1620.5131
7	1-V	2-H	3-V	725.3055
8	3-V	1-H	2-V	3297.8
9	2-V	3-H	1-V	2363.6363
10	1-V	2-H	3-H	3603.7216
11	3-V	1-H	2-H	1635.9842
12	2-V	3-H	1-H	508.3939

Taguchi

Taguchi method is being widely used in all the applications as a powerful tool to analyze and optimize complex problems. Taguchi was used in this work to investigate the effects of the base materials through the small number of experiments and it takes less time for the experimental investigations.

Signal-to-noise ratio characteristics

Researchers have used the Taguchi method for optimization of orientation and stacking sequence of base materials. The Taguchi method uses S/N ratio to measure the variations of experimental design. The word signal says the desirable value and the word noise says the undesirable value. The formulae for signal-to-noise ratio are designed such that the experimentalist can always select the larger factor level settings to optimize the quality characteristics of an experiment. Then, the selection of calculating the signal-to-noise ratio depends on the characteristics such as smaller-the better, larger-the-better or normal-the-better.

S/N ratios for different categories are given as follows:
Normal is the best
$S/N = -10 \log (\hat{y}/S^2 y)$
Smaller is the best
$S/N = -10 \log ((I/n) (\sum y^2))$
Larger is the best
$S/N = -10 \log ((I/n)(\sum I/y^2))$

Where $\hat{y}$ is average of observed data y, $s^2 y$ is variance of y, and n is number of observations. S/N ratios were calculated for tensile strength using larger is the best characteristic.
In this method, measured values of tensile strength for all the trials are taken in the Table 8 and signal-to-noise ratios were measured with 'larger is better' characteristic for all the trials. Taguchi results show that the jute has more influence on the tensile strength and shown with 1st rank in Table 8.

Table 8: Response table for signal to noise ratios

Level	Glass	Hemp	Jute
1	66.39	67.32	59.16
2	62.02	63.80	64.87
3	65.56	64.17	68.39
4		68.60	62.74
5		60.80	72.00
6		63.23	60.78
Delta	4.37	7.81	12.84
Rank	3	2	1

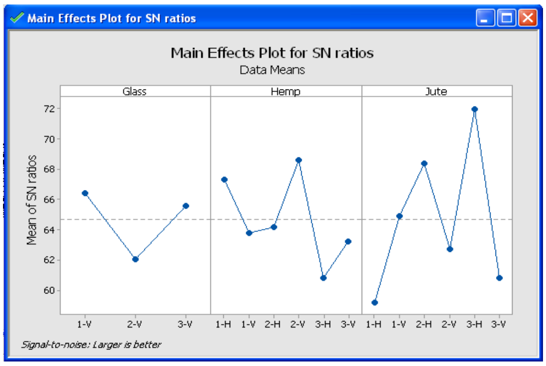

Fig 16: main effects plot for SN ratios

V. CONCLUSION

The fabrications of a new class of epoxy based hybrid composites reinforced with jute, glass and hemp fiber have been successful done. The present investigation revealed that the fiber stacking sequence and orientation significantly influences the tensile properties of composites. The tensile modulus of hybrid composites is

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varied with change in stacking sequence of lamina and orientations of lamina. The maximum tensile modulus is obtained for the stacking sequence of Glass, Hemp and Jute composites reinforced composite where the orientation of jute is horizontal.

Taguchi was used to select a best alternative from a set of alternatives of composite materials. It has been observed that the composites, Glass is in first layer with vertical condition, Hemp is in second layer with vertical condition and Jute is in third layer with horizontal condition shows the best results.

REFERENCES

[1] Hayashi T. Development of new material properties by hybrid composition. 1st report. Fukugo Zairyo (Composite Materials) 1972;1:18–20.
[2] Hayashi T, Koyama K, Yamazaki A, Kihira M. Development of new material properties by hybrid composition. 2nd report. Fukugo Zairyo (Composite Materials) 1972;1:21–25.
[3] P.W. Manders, M.G. Bader.The strength of hybrid glass/carbon fiber composites. J Mater Sci, 16 (1981), pp. 2233–2245
[4] Kalaprasad G. & Thomas S. (1995). Hybrid Fiber Reinforced Polymer Composites,
[5] International Plastics Engineering and Technology,Vol.1,pp. 87-98
[6] Hepworth, D. G., Hobson, R. N., Bruce, D. M. & Farrent, J. W. (2000). The use of unretted hemp fiber in composite manufacture, Composites Part A: Applied Science and
[7] Manufacturing, Vol.31(11), pp. 1279-1283.
[8] Ahmad I, Baharum A, Abdullah I. Effect of extrusion rate and fiber loading on mechanical properties of Twaron fiber-thermoplastic natural rubber (TPNR) composites. J Reinf Plast Compos 2006;25:957–65.
[9] Ahmed, K. S. & Vijayarangan, S. (2008). Tensile, flexural and inter-laminar shear properties of woven jute and jute-glass fabric reinforced polyester composites. Journal of materials processing technology, Vol.207(1), pp.330-335.
[10] Khoathane MC, Vorster OC, Sadiku ER. Hemp fiber-reinforced 1-pentene/polypropylene copolymer: the effect of fiber loading on the mechanical and thermal characteristics of the composites. J Reinf Plast Compos 2008;27:1533–44.
[11] Ku, H., Wang, H., Pattarachaiyakoop, N., Trada, M: A review on the tensile properties of natural fiber reinforced polymer composites, Composites: Part B (2011).
[12] Girisha.C., Sanjeevamurthy. & Gunti Rangasrinivas.(2012).Tensile Properties Of Natural Fibre-Reinforced Epoxy-Hybrid Composites. International Journal of Modern Engineering Research, Vol.2(2), pp-471-474
[13] Elias Randjbaran, Rizal Zahari, Dayang Laila Majid, Nawal Aswan Abdul Jalil, Ramin Vaghei. Effects of Stacking Sequence On Compression Response Testing Of Carbon Fiber And Hybrids: Fibrous-Glass/Carbon/Kevlar/ Epoxy Composite Plates. Matrix Academic International Online Journal Of Engineering And Technology © MAIOJET ISSN: 2348 – 3326
[14] Randjbaran, E., Zahari R., Majid, D.L., Jalil N.A.A., Vaghei R., Ahmadi R. (2013). The Effects of Stacking Sequence Layers of Six Layers Composite Materials in Ballistic Energy Absorption, International Journal of Material Science Innovations, 1 (6): 293-305.
[15] D. NABI SAHEB and J. P. JOG "Natural Fiber Polymer Composites: A Review". Polymer Engineering Group, Chemical Engineering Division, National Chemical Laboratory, Pune, India.
[16] M.Muthuvel, G. Ranganath, K. Janarthanan K. Srinivasan Characterization Study Of Jute And Glass Fiber Reinforced Hybrid Composite Material. International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 4, April - 2013 ISSN: 2278-0181