

Comparative Analysis of Natural Fiber Reinforced Hybrid Composite using RSM and ANN Approach.

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Abstract

Natural fibers are progressively being utilized as fortifications in different applications. The present work examines the strength of various natural fibers along with the impact of various testing process parameters. This exploration was completed by strengthening the network (Epoxy) tar with natural fibers and synthetic glass fiber. The natural fibers like jute and flax strengthened with epoxy were delivered utilizing Vacuum Assisted Resin Transfer Molding. After manufacturing of composite material, the mechanical properties like flexural strength was examined. It was discovered that flexural strength of jute and flax fiber composite are having good strength. Two soft computing techniques like response surface method (RSM) and artificial neural network (ANN) were implemented for the effective analysis. Both the method shows the good reliability and commitment towards the fitness.

Keywords: Natural fiber reinforced hybrid composites, glass, jute, flax, coir and hair fibers, and Mechanical properties. RSM, ANN.

1. Introduction :

In the last 30 years, the demand for the composite materials, plastics and ceramics have been increases tremendously. There are various applications of composite material which will help for the steadily, acute and winning new markets persistently. These composite materials include aramid, carbon and glass fiber reinforced plastics which are use in the field of aviation, recreation, car, development and brandishing businesses. Glass fibers are the most generally used to strengthen plastics because of their minimal effort and genuinely great mechanical properties. Natural fibers are intense, flexible and show great mechanical quality. The composite from natural fibers is presented for business reason and turns into a decent option of glass reinforced composites in numerous uses [1,2]. Hybrid composites are materials which are made by joining at least two distinct kinds of fibers in a typical grid. The properties of the natural fiber reinforced composites can be improved by hybridizing with high quality engineered fibers. The idea of hybridization offers adaptability to the structure architect to tailor the material properties as per the prerequisites, which is one of the significant focal points of the composites[3]. Hybridization of natural fibers with manufactured ones offers a fascinating answer for upgrade the mechanical exhibitions just as the dampness obstruction of the hybrid composites.[4] Incorporation of glass in jute fiber composites improves the properties of

coming about hybrid composites. Blending of natural fiber with Glass-Fiber Reinforced Polymers (GFRPs) is finding expanded applications. The joining of sisal jute fiber with GFRP can improve the properties and utilized as a substitute material for glass fiber reinforced polymer composites.[3] The interlaminar shear quality and the interlaminar crack durability of flax/glass fiber reinforced hybrid composites were higher than those of GFRP. Intercalation of basalt with flax layers demonstrated helpful for flexural and interlaminar strength [5]. Composite materials reinforced with natural fibers, for example, flax, hemp, kenaf and jute, are increasing expanding significance in car, aviation, bundling and other mechanical applications. Another and novel hybrid Glass/Flax/Epoxy composite plate with sandwich structure with potential for long bone break plate application has been developed [6]. Hybridization of natural fibers with manufactured ones offers an intriguing answer for improve the mechanical exhibitions just as the dampness opposition of the hybrid composites [4]. Flax, jute and hemp in unadulterated pressure with suitable regard for fiber and gum plan and auxiliary geometry, natural fiber composites may demonstrate a practical option in contrast to conventional structure materials [7]. Due to high fiber volume and low void contents Vacuum Assisted Resin Transfer Moulding process gets beneficial than hand layup process. It also increases strength of composites by 7 to 8 % in total volume fraction [11].

2. Experimental.

2.1 Materials

In this experiment for fabricating the composites specimen Jute, Flax, coir, hair and Glass fabrics are used. The raw jute and flax fabrics are collected from Go Green Products Chennai, Tamil Nadu India. The coir and hair collected from local market. The epoxy resin (Biresin CR-82) and Hardner (CH-80) are provided by Axson Sika pvt.ltd. Germany. The Glass- fabric 7781 available in Nano composite lab BVUCOE Pune.

2.2. Preparation of composite specimen

Following are the steps of preparation of final composite samples which is according to ASTM standards.

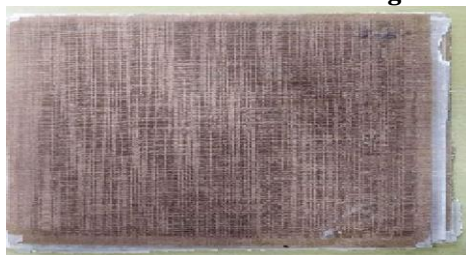
2.2.1 Laminate Preparation

In this work, samples of laminates of jute, Flax, Glass having each six layers of fabrics and for combination of fabric having three layers of each

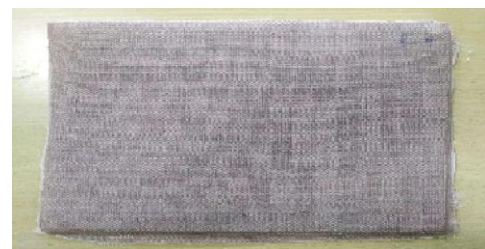
fabric. For coir and hair fibers consider the average weight of six layer flax fabric 100 gm. All laminates were made by using VARTM process as shown in figure.2.2.1 (a) This method used in this study was employed due to its simplicity and availability of the items. Also maintain high fiber volume low void in the composite laminate. First, the vacuum pump is turned on to expel air from the perform assembly. After the system has been equilibrated and all air leaks have been eliminated, the resin is allowed to flow into the preform. A pressure of 1 atm. provides both the driving force for the resin to impregnate the reinforcement and the compression force to compact the preform to the desired fiber volume fraction. The vacuum is left on until the resin has completely gelled. The part may then be cured at room temperature or in an oven. Due to the low injection pressure (1 atm), a resin distribution medium with high permeability is often incorporated into the vacuum bag lay-up to facilitate the resin flow in the preform.



Fig: 1 VARTM setup



Jute Fiber composite



Flax Fiber composite



Glass Fiber composite

Fig. 2 Laminate sheets of Natural and Synthetic fiber composite.

2.2.2. Cutting of coupons:

After manufacturing sheets of all natural fiber composites cutting according to ASTM: D638 standards by Water Jet Machining (WJM), OMAX 60120 Jet

Machining Center at Kakade Laser, Narhe Pune as shown in Figure 2.2.2. is used to cut the

coupons as per the ASTM standards. In WJM, mechanical energy of water i.e high pressure about 3800 bar is used to achieve material removal or machining. As the process does not produce any heat, there is less damage to the component.



Figure 3 Water Jet Machine

2.2.3 Mechanical Properties of Composites 2.3.2.
Flexural test

Preparation of the flexural test specimens as shown in figure 2.3.2 (a) and 2.3.2 (b) as per the ASTM D790 standards and 3-point flexure test as shown in figure 2.3.2 (c) is used for testing.

The deflection of the specimen is measured and the tests are carried out at an average relative humidity of 50% and the temperature about 35°C. From the testing machine the flexural load as well as the displacements is recorded for all the test samples.

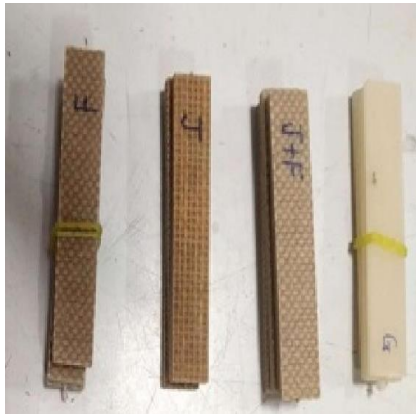


Fig.4(a) Flexural test samples of (jute, flax, Glass and hybrid of Jute +flax) composites.



Fig 4(b) Tensile test samples of (coir, hair, jute + coir and jute +Glass) composites.

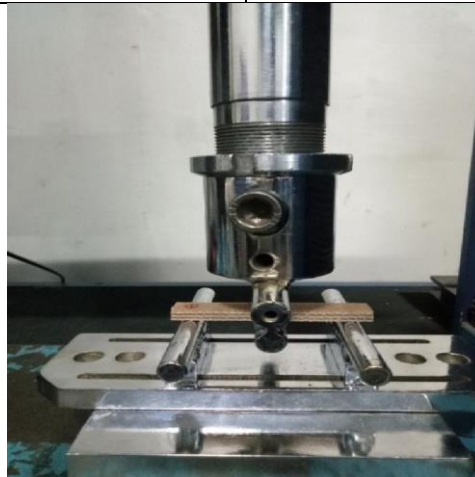


Fig 4 (c) Flexural Machine with test specimen.(PRAJ Metallurgical Laboratory)

Table 1: Input and output process and their levels

Parameter	Level 1	Level 2	Level 3
Composition (CP)	Jute Fiber composite (G+)+G	Glass Fiber composite (G+)+G+)+G	Flax Fiber composite (G+F+G)
Load (N) (LD)	100	150	200
Displacement (mm) (DS)	1	2	3

2.2 Plan for the experimentation

In this current work, three stages of the research work were essential to analyze the listed performance parameters. In the initial stage of the experimentation various process parameters were identified. After fixing the various input process parameters and the target response various experimentation were carried out using Taguchi's L_{27} plan of experimentation.

Finally the experimental was used to carry out the analysis using ANN and RSM techniques. In the present work, all calculation and the various plots have been carried out using MATLAB R2015 version. The lists of parameters considered for the investigation are listed in Table 2. The experimental data is shown in Table 3.

Table 2: Observation table

Exp no	Composition (CP)	Load (LD)	Displacement (DS)	Strength(STG)
1	1	1	1	96.573
2	1	1	1	101.12
3	1	1	1	107.05
4	1	2	2	143.03
5	1	2	2	147.253
6	1	2	2	153.31
7	1	3	3	194.628
8	1	3	3	202.041
9	1	3	3	206.588
10	2	1	2	105.394
11	2	1	2	113.378
12	2	1	2	126.33
13	2	2	3	215.4
14	2	2	3	202.98
15	2	2	3	194.818
16	2	3	1	154.276
17	2	3	1	183.374
18	2	3	1	181.866
19	3	1	3	180.535
20	3	1	3	209.43
21	3	1	3	211.319
22	3	2	1	134.038
23	3	2	1	140.613
24	3	2	1	147.09
25	3	3	2	142.476
26	3	3	2	148.775
27	3	3	2	154.542

2.3. Response Surface Method (RSM):

Response surface method (RSM) is the statistical technique use to correlate the two input process parameters (keeping others constant at selected level) with the response output. The seconds order mathematical equation is created in this method. Minitab software is used for the analysis. The generalized second degree RSM based equation as given by the equation (1).

$$Y = A_0 + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + A_5X_5 + A_6X_6 + A_7X_7 + A_8X_8 + A_9X_9 + A_{10}X_{10} + A_{11}X_{11} + A_{12}X_{12} + A_{13}X_{13} + A_{14}X_{14} + A_{15}X_{15} + A_{16}X_{16} + A_{17}X_{17} + A_{18}X_{18} + A_{19}X_{19} + A_{20}X_{20} + A_{21}X_{21} + A_{22}X_{22} + A_{23}X_{23} + A_{24}X_{24} + A_{25}X_{25} + A_{26}X_{26} + A_{27}X_{27} + A_{28}X_{28} + A_{29}X_{29} + A_{30}X_{30} + A_{31}X_{31} + A_{32}X_{32} + A_{33}X_{33} + A_{34}X_{34} + A_{35}X_{35} + A_{36}X_{36} + A_{37}X_{37} + A_{38}X_{38} + A_{39}X_{39} + A_{40}X_{40} + A_{41}X_{41} + A_{42}X_{42} + A_{43}X_{43} + A_{44}X_{44} + A_{45}X_{45} + A_{46}X_{46} + A_{47}X_{47} + A_{48}X_{48} + A_{49}X_{49} + A_{50}X_{50} + A_{51}X_{51} + A_{52}X_{52} + A_{53}X_{53} + A_{54}X_{54} + A_{55}X_{55} + A_{56}X_{56} + A_{57}X_{57} + A_{58}X_{58} + A_{59}X_{59} + A_{60}X_{60} + A_{61}X_{61} + A_{62}X_{62} + A_{63}X_{63} + A_{64}X_{64} + A_{65}X_{65} + A_{66}X_{66} + A_{67}X_{67} + A_{68}X_{68} + A_{69}X_{69} + A_{70}X_{70} + A_{71}X_{71} + A_{72}X_{72} + A_{73}X_{73} + A_{74}X_{74} + A_{75}X_{75} + A_{76}X_{76} + A_{77}X_{77} + A_{78}X_{78} + A_{79}X_{79} + A_{80}X_{80} + A_{81}X_{81} + A_{82}X_{82} + A_{83}X_{83} + A_{84}X_{84} + A_{85}X_{85} + A_{86}X_{86} + A_{87}X_{87} + A_{88}X_{88} + A_{89}X_{89} + A_{90}X_{90} + A_{91}X_{91} + A_{92}X_{92} + A_{93}X_{93} + A_{94}X_{94} + A_{95}X_{95} + A_{96}X_{96} + A_{97}X_{97} + A_{98}X_{98} + A_{99}X_{99} + A_{100}X_{100}$$

(1)
Where, 'Y' is the output variable and 'X' is the value of input variables and $A_0, A_1, A_2, \dots, A_{23}$ are the regression coefficient. Response surface

method (RSM) two degree model with three process parameters is given by the Equation 1.

2.4. Artificial Neural network (ANN)

Artificial neural network (ANN) is an effectual soft computing technique consists of a network of nodes distributed in the layers. The methodology of ANN is identical to the brain. The primary structure of ANN is as shown in the following figure 2. The network is divided into three basic layers i.e. input layer – received the data through nodes and send it to the next level where the weights are assigned to the data and normalized the data. The number of nodes and the layers are depends on the type of data, its nature, processing time and the accuracy accepted from the data. In the present work, feed forward back propagation neural network was used for the generation of neural response.

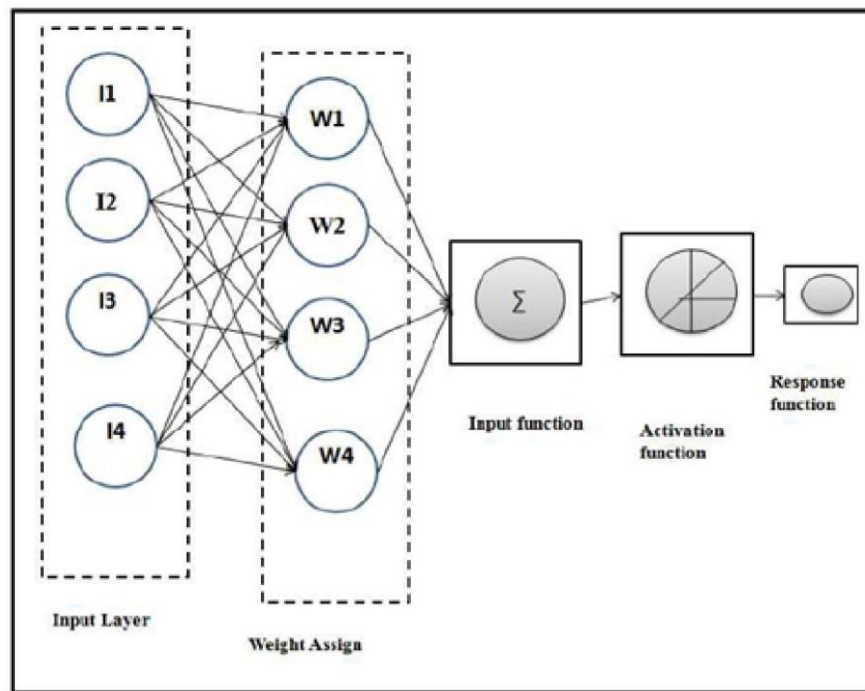


Figure 5: ANN basic simulation approach

3. Results and discussion

In this study natural fiber and Glass fiber composite are made and their effect on tensile and flexural properties are evaluated and compared. The results for the tensile and flexural testing of the hybrid composite samples are given in Table 1.

3.2 Flexural properties

The flexural properties of the composite samples tested in the UTM and the typical load deformation curve generated for all synthetic and natural fiber hybrid composite (Jute + Flax) sample some of which is presented in Fig 6.

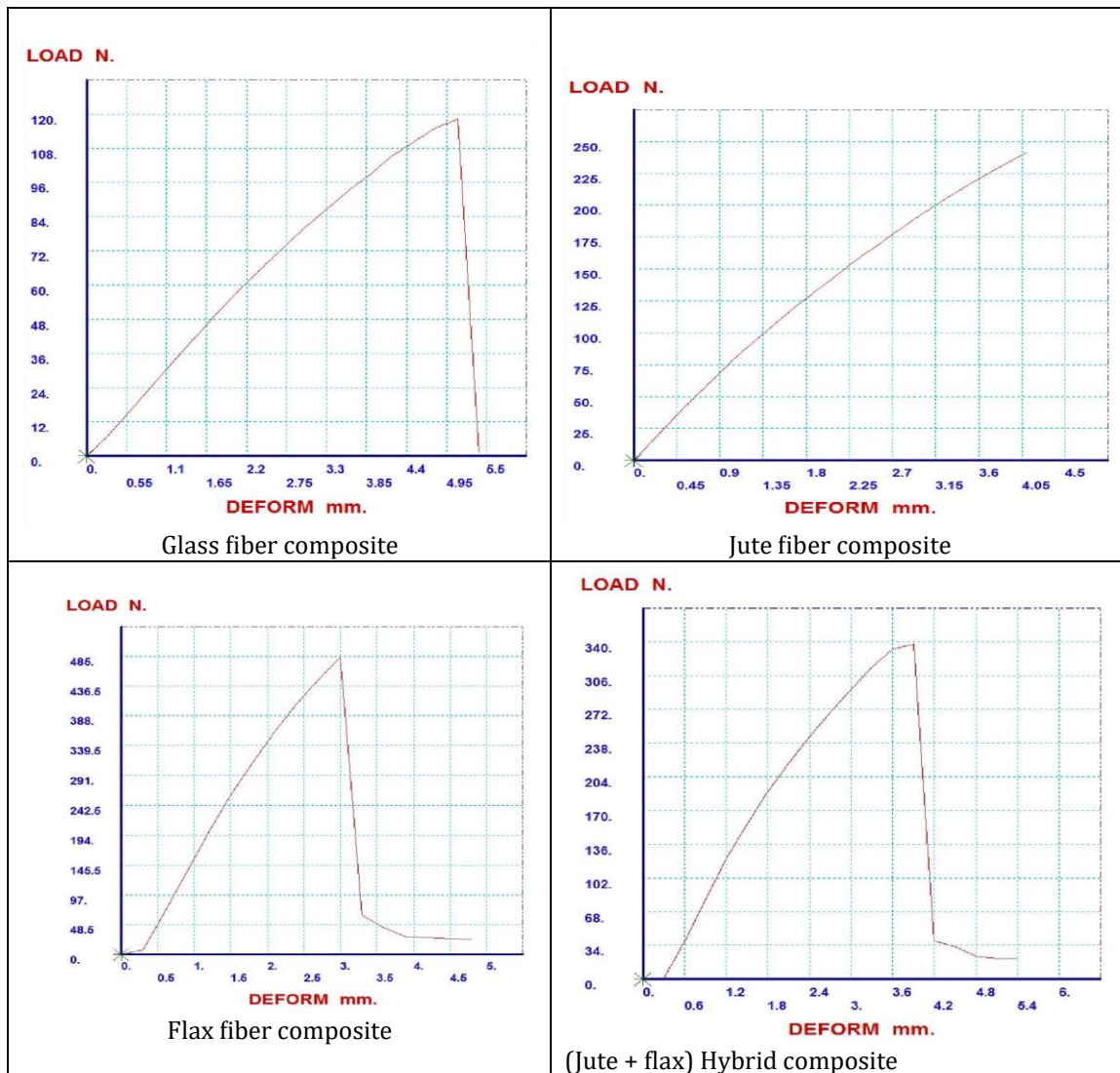


Figure 6 Load-deformation curve for synthetic and natural fiber composite.

The flexural strength for different composite samples are observed and presented in Fig 3 From the figure, it is asserted that the flexural load carrying capacity of jute and flax composites is better than GFRP composites tested by 0.8 % and 10.59 % respectively. But it is also observed that

hybrid composite of jute + flax composite is less than Glass fiber composite by 1.5 % only. It is also observed that when jute fiber added to glass fiber composite its flexural strength is less than Glass fiber composite for the same fiber volume fraction.

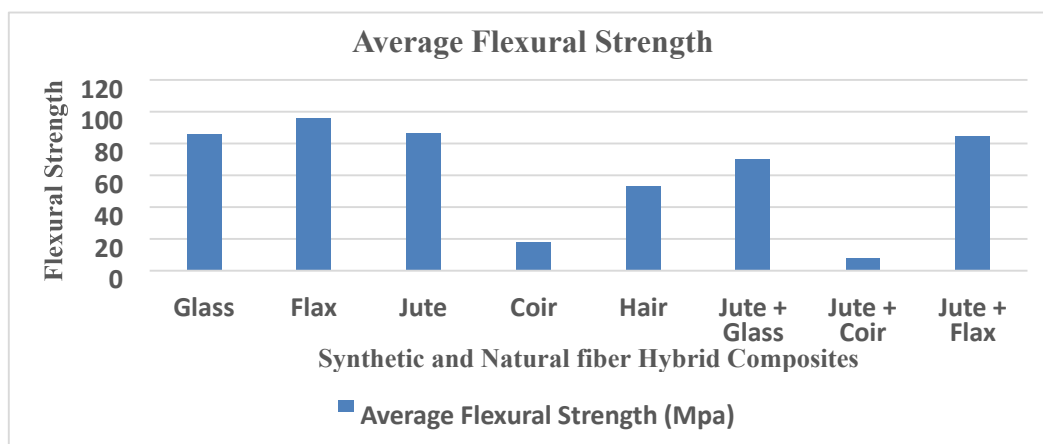


Fig. 7 Synthetic and natural fiber hybrid composite.

Four graphs such as Pareto chart obtained during the data analysis through RSM are as shown in figure 9. Pareto chart use to find out the magnitude and the impact of the various process parameters and their interactions. The normal probability plot and the residual plot is as shown in figure 8 and 10 respectively. These plots are used to know the accuracy of the model. In the Pareto chart, the horizontal bar that crosses the reference line is known as a significant. The bars B(LD), A(CP) are

showing significant impact on the response trength.

Analysis of variance (ANOVA) is carried out to know the impact of various process parameters and their interaction on the response process parameter. ANOVA results are tabulated in the table 3. It is observed that all four process parameter has a significant impact on the surface roughness. But current and pulse on time has a dominant impact on response as compare to the remaining process parameters.

Table 3 Analysis of Variance (ANOVA) for response 'STG'

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-
Model	8	34651.6	94.78%	34651.6	4331.5	40.83	
Linear	3	24521.9	67.07%	7540.4	2513.5	23.69	0.000
CP	1	1763.4	2.09%	399.4	399.4	3.76	0.068
LD	1	5598.1	15.31%	3522.7	3522.7	33.20	0.000
Square	3	7238.9	19.80%	4543.1	1514.4	14.27	0.000
CP*CP	1	338.6	0.93%	338.6	338.6	3.19	0.091
LD*LD	1	349.4	0.96%	1527.8	1527.8	14.40	0.001
2-Way Interaction	2	2890.9	7.91%	2890.9	1445.5	13.62	0.000
CP*LD	1	793.7	2.17%	2236.9	2236.9	21.08	0.000
CP*DS	1	2097.2	5.74%	2097.2	2097.2	19.77	0.000
Error	18	1909.7	5.22%	1909.7	106.1		
Total	26	36561.3	100.00%				

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
10.3003	94.78%	92.46%	4296.87	88.25%

Coded Coefficients

Term	Coef	SE Coef	95% CI	T-Value	P-Value	VIF	Constant	31.8	32.8	(-37.0, 100.6)	0.97	0.345
CP	38.0	19.6	(-3.1, 79.1)	1.94	0.068	65.00	LD	146.7	25.5	(93.2, 200.2)	5.76	0.000
DS	-110.1	19.1	(-150.3, -70.0)	-5.76	0.000	62.00	CP*CP	-7.51	4.21	(-16.35, 1.32)	-1.79	0.091
LD*LD	-18.43	4.86	(-28.63, -8.22)	-3.79	0.001	65.33	DS*DS	21.89	4.86	(11.69, 32.10)	4.51	0.000
CP*LD	-22.30	4.86	(-32.50, -12.09)	-4.59	0.000	34.67	CP*DS	21.59	4.86	(11.39, 31.79)	4.45	0.000

Table 4 Fits and Diagnostics for Unusual Observations

Obs	Strength	Fit	SE Fit	95% CI	Resid	Std Resid	Del Resid	HI	16	154.28	173.17
19	180.54	200.43	5.95	(187.93, 212.92)	-19.89	-2.25	-2.57	0.333333	2.37	2.77	0.333333

Obs Cook's D DFITS
16 0.28 -1.82016 R
19 0.31 -1.95797 R

R Large residual

Effects Plot for Strength

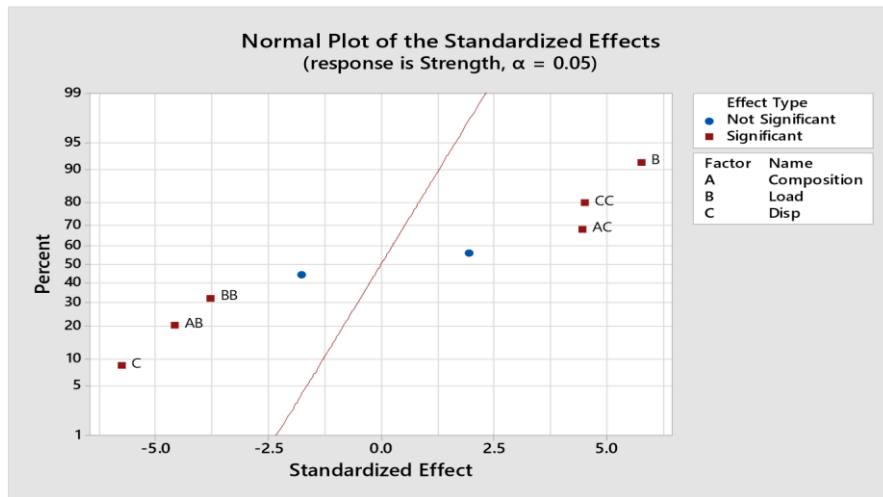


Fig 8 : Normal plot for response 'STG'

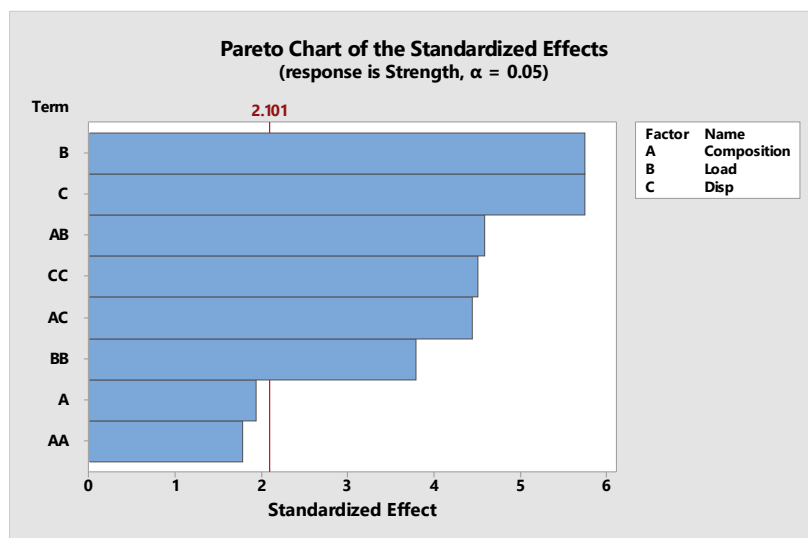


Fig 9: Pareto chart of the standardized effect for response 'STG'

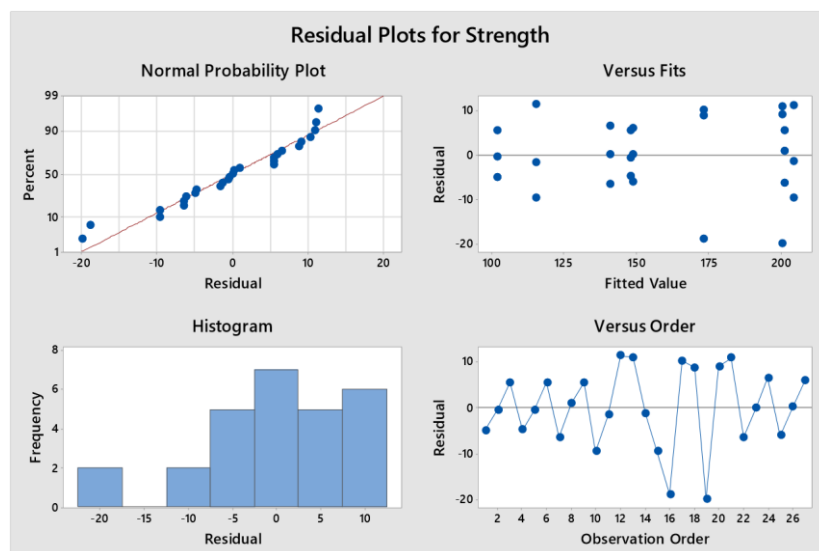


Fig 10: Residuals plots for response 'STG'

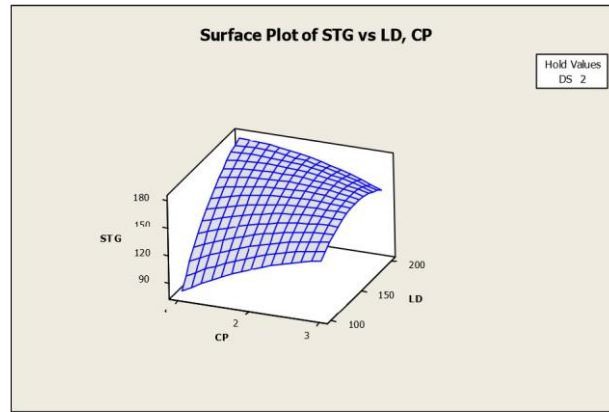


Fig 11(a): Response surface plot for the response 'STG' vs 'LD' & "CP'

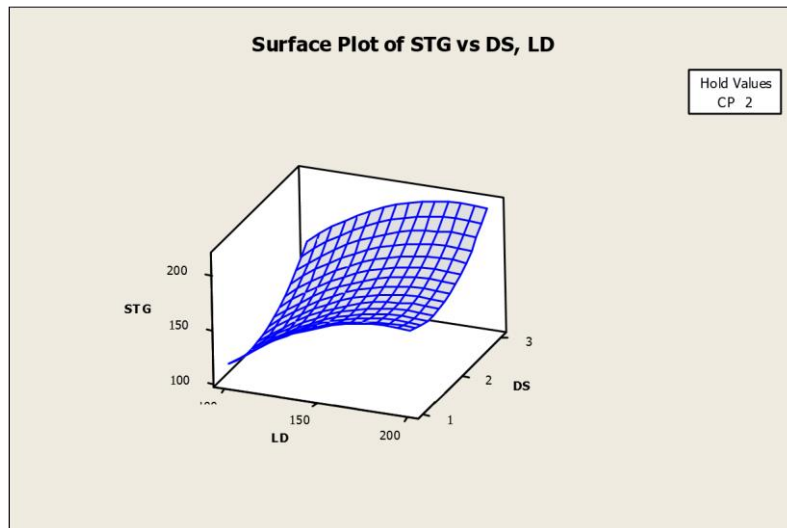


Fig 11(b): Response surface plot for the response 'STG' vs 'LD' & "DS'

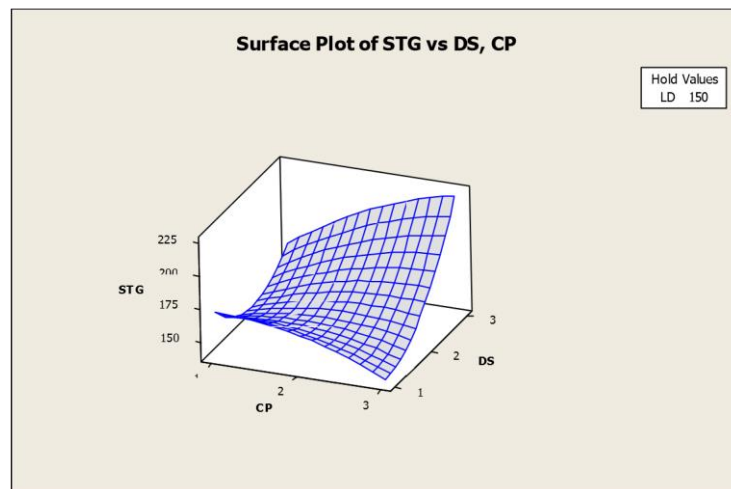


Fig 11(c): Response surface plot for the response 'STG' vs 'DS' & "CP'

Surface plots for the response (STG) are as shown in Fig Fig 11 (a)-11(c). Surface plots are the three dimensional representation of variables in which the response variables is plotted on Z axis while the two variables are on the X and Y axis respectively. The remaining variables are kept constant at their mean value

during the analysis. From fig. 11, it can seen that the strength increases with increase in composition (CP) and displacement (DS). Hence both are directly affects the STG. The other variable load (LD) has insignificant impact on the STG.

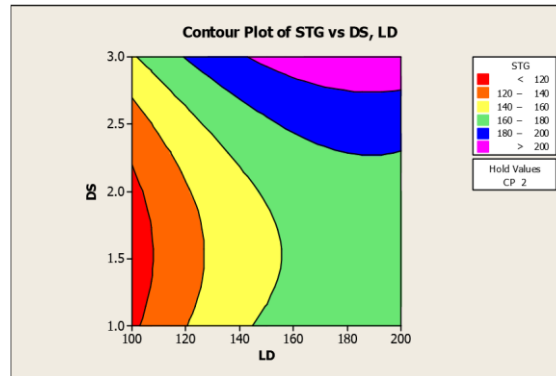


Fig 12(a): Contour plot for the response 'STG' vs 'LD' & "DS'

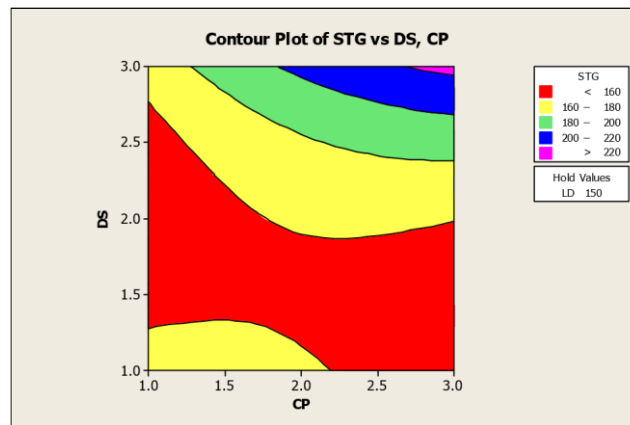


Fig 12(b): Contour plot for the response 'STG' vs 'CP' & "DS'

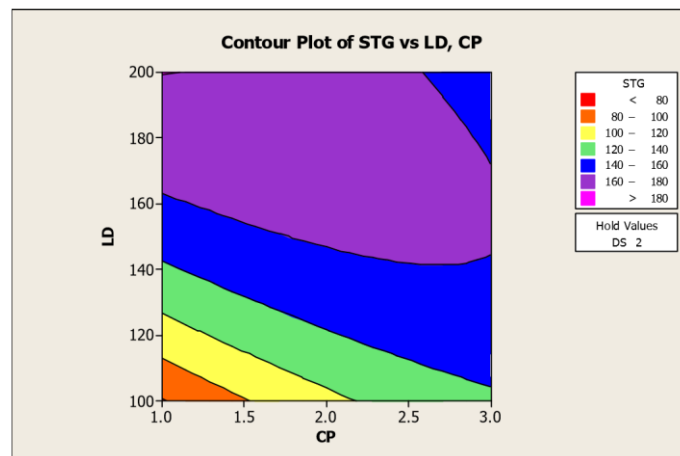


Fig 12(c): Contour plot for the response 'STG' vs 'LD' & "CP'

The impact of the various process parameters on response surface is also express by surface contours as shown in the figures 12(a) to 12 (c). The contour is a slice of the response surface. The elliptical slices showed the most influencing process parameters.

Artificial neural network (ANN) is a soft computing technique use for the analysis of various systems. It is the network of various nodes distributed in the various layers. The function of ANN is synonymous to the working of human brain and the functioning of the sense organs. The human brains sense the data from

the sense organs and process it and send the signal in terms of response. The basic structure of ANN is as shown in the following figure 2. The network is divided into three basic layers i.e. input layer – received the data through nodes and send it to the nest level where the weights are assigned to the data and normalized the data. The number of nodes and the layers are depends on the type of data, its nature, processing time and the accuracy accepted from the data. In the present work, feed forward back propagation neural network was employed to analyze the data.

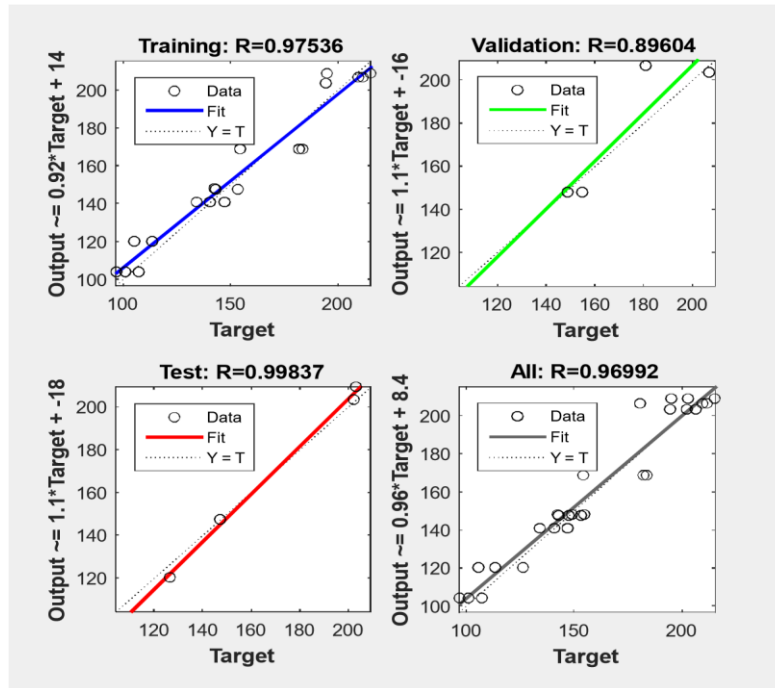


Fig 13: ANN based regression analysis for training, testing and validation phase.

The feed forward back propagation neural network (BPNN) is employed with three layers. The number of layer depends on the number of inputs and the response parameters. In the present work there were four inputs and one response variable. Hence three layers ANN is preferred. Levenberg-Marquardt (LM) i.e. TRAINLM was used as a training function. The learning function 'LEARNGDM' was used for learning process. The transfer function 'TANSIG' was used for the

analysis. The ANN network works in the three layers, Training, testing and the validation of the network. The performance of the train network is as shown in the figure 14-17. The accuracy of the train network is measured in terms of the correlation coefficient obtain for the data. The regression curve, correlation and the correlation coefficient is as shown in figure 13.

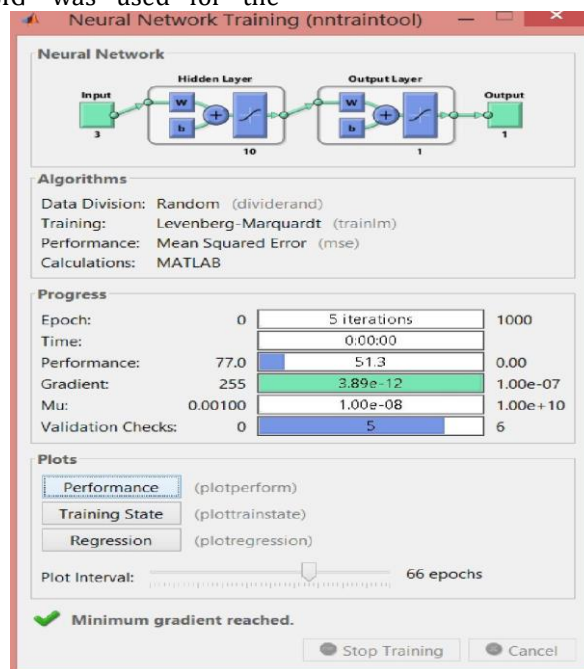


Fig 14: Details of various functions used for the ANN simulation

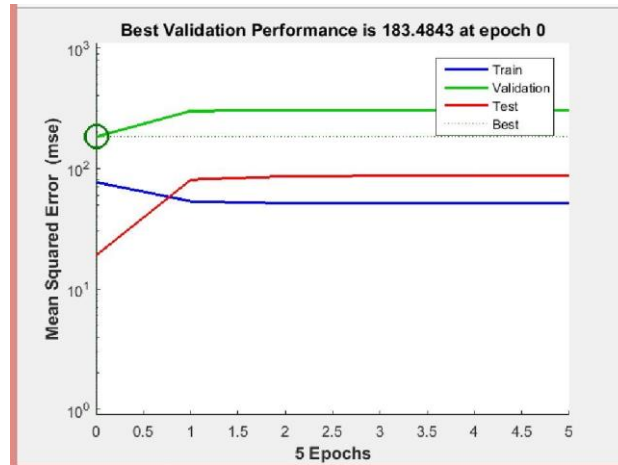


Fig 15: Details of best performance during ANN simulation

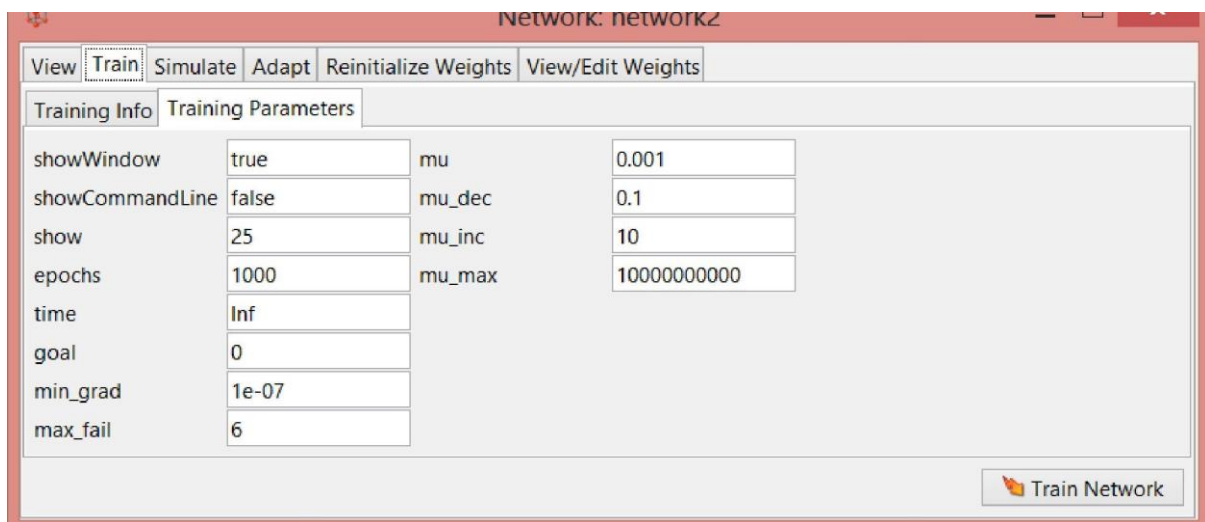


Fig 16: Details of various training parameters used for the ANN simulation

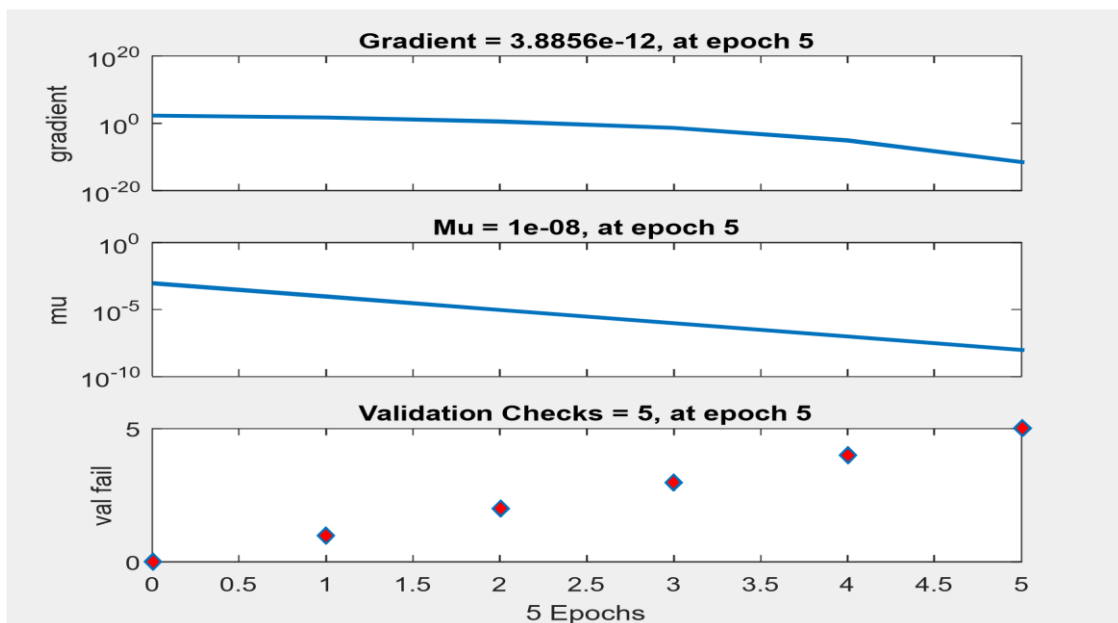


Fig 17: Details of ANN performance vs Epochs.

4. Conclusion

The experimental investigation on mechanical properties of synthetic and natural fiber hybrid composites for the same fiber volume fraction leads to the accompanying ends:

- The natural fibers like jute and flax strengthened with epoxy were delivered utilizing Vacuum Assisted Resin Transfer Molding. The all natural fiber composite samples possess good tensile strength and can withstand the strength up to 56.70 MPa of Flax fiber composite which is greater than Glass fiber composite by 7.2 %
- The all natural fiber composite samples possess good bending strength and can withstand the strength up to 95.96 MPa for flax fiber composite and 86.59 for jute fiber composite which is greater than Glass fiber composite by 10.59 % and 0.8 % respectively. Also (jute + Flax) fiber hybrid composite is nearer to Glass fiber composite and greater than (jute + Glass) fiber hybrid composite by 17.50 %
- The synthetic and natural fiber hybrid composite produced by VARTM process gives a chance of supplanting existing materials with a higher strength, minimal effort elective that is earth benevolent.
- The well known advance and effective modeling techniques i.e. response surface method (RSM) and the artificial neural network (ANN) has been implemented for the analysis. From the experimental findings, it has been observed that the RSM is a very efficient method. Analysis of variance showed the impact of or the contribution of various process parameters along with their interaction effect. The 'P' value shows the variable impact either significant ($p \leq 0.005$) and the insignificant parameters where ($p > 0.005$).
- A good acceptable value of correlation coefficient was observed between the RSM predicted response and the experimental response. The artificial neural network (ANN) based models also showed the effectiveness to represent the process. A good acceptable value of correlation coefficient was observed between the ANN predicted response and the experimental response. From the analysis, it has been concluded that the RSM and ANN both the techniques are efficient and effectively model and analyze the system. But the soft computing techniques i.e. ANN is more superior to the RSM.

Hence recommended for the analysis of similar kind of problem analysis.

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