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Optimization of tensile and flexural stress of epoxy based walnut reinforced composite using Taguchi method

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ABSTRACT: Increasing environmental concerns and growth in product development had accelerated research in the field of Bio-composites. Extensive research is going on in the area of polymer based composites due to their ease of manufacturing, low weight to volume ratio, high strength to weight ratio and a wide range of application areas. In the present paper, an attempt is made to present and summarize the effect of loading speed on the mechanical behaviour of walnut reinforced epoxy composite processed with six different % of filler content. Experimental design was based on Taguchi L18 orthogonal array while considering two parameters *i.e.* % filler wt. and loading rate. Optimal condition of process parameters for tensile and flexural stress are determined. Taguchi optimization method is used for analysing the experiment and experimental data is statically analysed using (ANOVA) Analysis of Variance. It was found from the analysis that loading speed and % filler content are the main significant factors affecting tensile stress value and flexural stress value at 95 % confidence level. Also, tensile stress and flexural stress value increases at higher loading speed.

Keywords: Bio-composite; Epoxy resin based composite; Walnut Particles; Taguchi Method; ANOVA

I. INTRODUCTION

In the recent years, several attempts and advances are made in understanding the behaviour of polymer based composites due to the fact that these composites are no longer considered as secondary structure materials which were earlier used primarily for weight saving. With so many useful properties like ease of manufacturing, low weight to volume ratio, high stiffness to weight and strength to weight ratios, corrosion resistance and low water absorption, these fibre reinforced polymer composites are finding their way in various engineering applications [Bhowmick *et al.* (2012) and Netravali and Chabba (2003)].

Wood flour and natural fibres are mostly commonly used reinforcements for the production of such polymer composites, and wooden flour is readily available from sawmills and can be further used for composite preparation after proper sieving [Sandberg *et al.* (2013)]. Other than these wooden derivatives other natural organic fillers begun to find their applications as well such as sisal & kneaf [Joseph *et al.* (1996), Joseph *et al.* (1999)], starch [Willett J (1994)], banana fibre [Sapuan *et al.* (2006)], Pissava fibre [Nascimento *et al.* (2012)], Coconut coir [Mylsami & Rajendran (2011)]. Agricultural wastes like Walnut shell which is sometimes used as a fuel for heating can be new a source of raw material for the particle board industry [Ramazan Yildirim (2005)].

With all types of plant and natural fibres and agricultural wastes as reinforcement, these composites are made with matrix materials such as polyethylene, polyester, various epoxy resin, Polypropylene etc. [Ashori (2008)]. Among all the available composite matrices epoxy resins are very versatile and may yield various desirable properties, for example, simpler processing, high tensile strength, fine chemical and thermal stability, dimensional stability etc. due to their cross-linked polymer structure and amorphous nature [Song *et al.* (2000)].

Fibre reinforced polymer composites find a wide range of application such as automotive, aerospace, marine, sports structures etc. due to their easy manufacturing, better mechanical properties and low cost [Ray B C and Rathore D (2014)]. During the service period, these composite materials are exposed to various loading conditions ranging from static to dynamic loading and in many structural cases even to high velocity and high energy dynamic loadings that can produce multi-axial and dynamic states of stress [Sethi S, Rathore D K and Ray B C (2015)]. Fibber reinforced composites are widely researched for investigation of mechanical properties but very few efforts have been done for the investigation of mechanical behaviour under varying loading rates. Also, the correlation between operating characteristics and mechanical properties is an important factor which needs to be optimized for satisfying various functionalities.

In the present work, an attempt is made to study and analyse the effect of varying loading speed on mechanical properties of walnut reinforced epoxy based bio-composite and to find the optimal combination of parameters. Out of various optimizing techniques available Taguchi Method is used as it involves reducing the variation in a process through the robust design of experiments. The overall objective of the method is to produce high-quality output more precisely at low cost and with greater reproducibility. The Taguchi method was developed by Dr. Genichi Taguchi of Japan. The experimental design proposed by Taguchi involves the use of orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied. Taguchi suggested the use of loss function which is a measure of quality and could be transformed into a statistical measure known as signal to noise ratio (S/N ratio) which are log functions of desired output and serves as an objective function for optimization. Taguchi method involves the design of experiments in form of orthogonal arrays to reduce variations in a process [Roy (1990)].

In the present work, a bi-composite is developed using the walnut shell as reinforcement and epoxy resin as the matrix material and its mechanical properties are investigated at varying loading rates. Moreover, experimental data regarding tensile Strength and flexural strength is analysed using Taguchi method. L18 orthogonal array is used for the design of experiment and later Analysis of Variance (ANOVA) is carried out to find the significant factors affecting tensile and flexural stress.

II. MATERIAL AND EXPERIMENTAL DETAILS

i) Materials and composite fabrication

In present work low temperature curing epoxy resin (Araldite/CY-230) and corresponding hardener HY-951 along with walnut particles as reinforcement are used to form the bio- composite. Elongation, yield strength, and young modulus value are maximum when 8 % (by wt.) hardener (HY-951) is mixed with resin (CY-230) [V.K. Singh & P.C Gope (2009)]. Walnut shell powder is obtained from Walnut shell (agro-waste) using ball mill and is then sieved in a sieve shaker to get the desired particle size.

For making Composite walnut shell particles having 0.8mm size are dried and then reinforced in epoxy resin CY-230. The solution obtained by mixing walnut particles in the resin is kept in the furnace at a temperature of 100 °C for two hours. The electric furnace having Temperature Range 0-600^{o}C is used for this purpose. At each interval of 30 minutes, the solution is remixed by a mechanical stirrer at low speed. After two hours the whole solution is taken out and allowed to cool to a temperature of 30°C. When a temperature of 30°C has been attained the hardener HY-951 is mixed immediately. Due to the addition of hardener high viscous solution has been obtained which is again mixed mechanically by a high-speed mechanical stirrer and is gradually poured into Plexiglas moulds of dimension 100 mm X 80 mm X 10 mm. The curing of the casting is done at room temperature for 24 - 48 hours and after that, the walnut particle reinforced composite specimen is taken out for investigation of mechanical behaviour.

ii) Experimental Design based on Taguchi method.

The Design of experiment is done using an L18 orthogonal array with eighteen rows and two columns to treat one parameter (Loading rate) at three levels and the second parameter (% wt.) at six levels. Each parameter level setting is based on Taguchi Design of experiments as per L18 orthogonal array. Experimental observations regarding tensile Stress and flexural stress are recorded and are transformed into signal to noise (S/N) ratios using Minitab 17 software [Minitab user manual (2017)].

In the present investigation, one parameter (filler % wt.) is treated at six different levels and another parameter (loading rate) at three different levels as shown below in Table 1. The total degree of freedom of the experiment is 17, so the orthogonal array that is to be selected should have a degree of freedom higher than 17. Therefore one of the most suitable orthogonal arrays that can be used for this experiment is L18. The S/N ratio for maximum tensile and flexural stress values can be expressed as "higher is better" characteristics, which can be calculated as logarithmic transformation of loss function as stated below-

$$\eta = -10 \log \sum_{i=1}^{n} \frac{1}{y_i^2}$$

These signal to noise (S/N) ratios as obtained from experimental observations are statistically analysed by analysis of variance (ANOVA).

Table 1. Levels of control factors used in the experimental design.

	Levels						
Control Factors	1	2	3	4	5	6	Units
Filler Content	5	10	15	20	25	30	% wt.
Speed	0.5 1 2	0.5 1 2	0.5 1 2	0.5 1 2	0.5 1 2	0.5 1 2	mm/min

iii) Tensile and flexural test

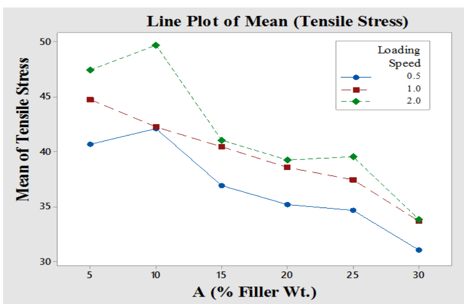
The tensile test was performed as per ASTM D638-03 and the flexural test is performed as per ASTM D790-03 standard using 100 KN servo hydraulic ADMET make Universal testing machine. All experiments are performed at an ambient temperature of 25oc with 55 % relative humidity. Six different samples with 10%, 15%, 20%, 25%, 30% and 35 % filler weight are tested at three different loading rates i.e. 0.5 mm/min, 1 mm/min and 2mm/min.

III. RESULT AND DISCUSIION

i) Tensile & flexural test results

Tensile and flexural test are carried out at three different loading speed with six different filler content samples. Three samples for each experiment is tested for achieving repeatability in result. The variation in different tensile and flexural test values with varying % filler wt. is shown in Fig.1 a), b) and c) respectively. From the results, it is observed that flexural stress and tensile stress values first increases up to 10 % wt. and then decreases with the increase of walnut content from 10 % to 30% wt. the maximum and minimum value of tensile stress at 2 mm/min is 49.732 MPa and 33.812 MPa. The maximum and minimum value of flexural stress at 2 mm/min is 82.325 MPa and 60.030 MPa.

a)



b)

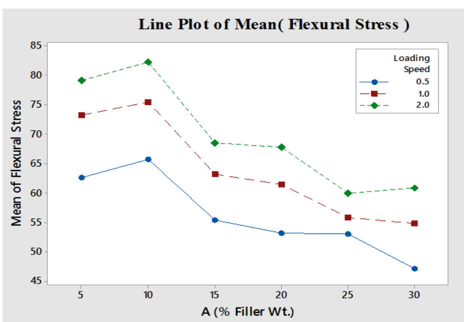


Fig.1. (a) Flexural stress vs % filler wt.

ii) Taguchi analysis for tensile stress and flexural stress

Analysis for tensile stress value and flexural stress value along with their S/N ratios are compiled in Table 2 and 3 respectively. Analysis of control parameters i.e. loading speed and % filler weight on responses (tensile stress values and flexural stress values) are obtained response table of mean S/N ratio and their results are presented in Table 4 and 5 respectively. The main effect plots of S/N ratios are presented in Fig.2 a) and b) for tensile stress and flexural stress. S/N ratios reflecting higher values corresponds to better quality, thus the optimal condition of design parameters is A2B3 for tensile stress and flexural stress.

Table 2: Results of tensile stress along with S/N ratios.

A (Filler Weight %)	B Speed (mm/min)	Tensile stress	SNRA
5	0.5	40.692	32.190
5	1	44.761	33.018
5	2	47.447	33.524
10	0.5	42.1	32.486
10	1	42.238	33.345
10	2	49.732	33.933
15	0.5	36.954	31.353
15	1	40.465	32.142
15	2	41.095	32.689
20	0.5	35.203	30.932
20	1	38.582	31.728
20	2	39.283	32.315
25	0.5	34.647	30.793
25	1	37.419	31.462
25	2	39.589	31.952
30	0.5	31.021	29.833
30	1	33.658	30.542
30	2	33.812	31.081

Table 3: Results of flexural stress along with S/N ratios.

A (Filler Weight %)	B (Speed (mm/min)	Flexural stress	SNRA
5	0.5	62.666	35.941
5	1	73.319	37.304
5	2	79.184	37.973
10	0.5	65.676	36.348
10	1	75.527	37.562
10	2	82.325	38.311
15	0.5	55.431	34.875
15	1	63.191	36.013
15	2	68.563	36.722
20	0.5	53.157	34.511
20	1	61.396	35.763
20	2	67.842	36.630
25	0.5	53.010	34.487
25	1	55.842	34.939
25	2	60.030	35.567
30	0.5	47.152	33.470
30	1	54.791	34.774
30	2	60.817	35.681

Table 4: Response table of S/N ratio for tensile stress.

Level	A (% filler wt.)	B (Loading Speed (mm/min))
1	32.91	31.26
2	32.98	31.9
3	31.92	32.36
4	31.51	
5	31.4	
6	30.32	
Delta	2.66	1.09
Rank	1	2

Table 5: Response table of S/N ratio for flexural stress.

Level	A (% filler wt.)	B (Loading Speed (mm/min))
1	37.07	34.94
2	37.41	36.06
3	35.87	36.81
4	35.63	
5	35	
6	34.64	
Delta	2.77	1.88
Rank	1	2

a)

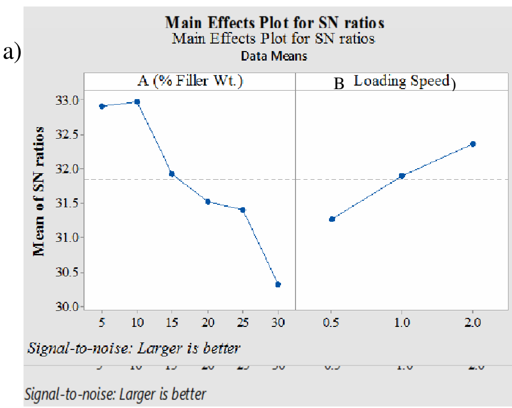


Fig. 2 a) Main effect plot for S/N ratios of Tensile stress value.

b)

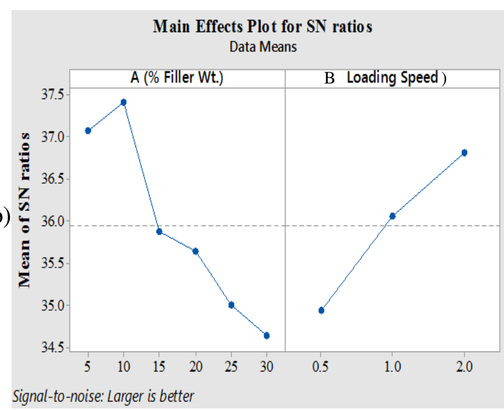


Fig. 2. b) Main effect plot for S/N ratios of Flexural stress value.

iii) Analysis of Variance (ANOVA)

To find out the significance of process parameters i.e. filler content wt. % and particle size on the mechanical properties of walnut reinforced composite Analysis of Variance (ANOVA) is carried out. ANOVA also helps in finding out the percentage contributions of the factors. General linear model is used to model the relationship between factors and responses. The percentage calculations are done from total mean S/N ratio by the total sum of squared deviations. ANOVA table for tensile stress and flexural stress values are shown in Table 6 and 7 respectively. It is seen that filler content and loading speed both are significant factors for tensile stress and flexural stress at 95 % confidence level.

Table 6: ANOVA table for tensile stress.

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
A (% Filler Wt.)	5	308.5	75.90%	308.5	61.71	29.34	0
Loading Speed	2	76.91	18.92%	76.91	38.46	18.28	0
Error	10	21.03	5.17%	21.03	2.103		
Total	17	406.5	100.00%				

Table 7: ANOVA table for flexural stress.

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
A (% Filler Wt.)	5	1004	62.80%	1004	200.8	57.91	0
Loading Speed	2	560	35.04%	560	280	80.77	0
Error	10	34.67	2.17%	34.67	3.467		
Total	17	1598	100.00%				

Responses i.e. tensile stress value and flexural stress value are optimized and predicted values of one or more factors that jointly optimizes the responses are identifies and are shown in fig. 3 (a) and (b).

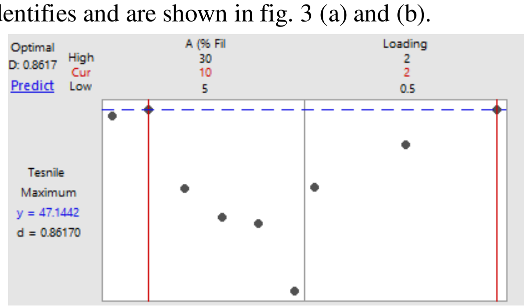


Fig. 3. a) Optimization plot for tensile stress value.

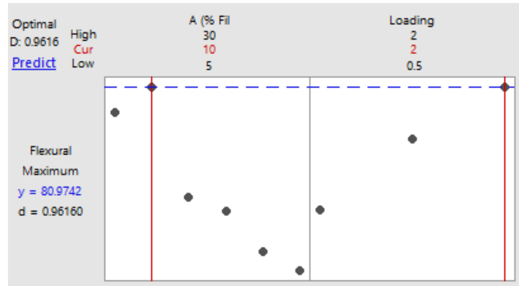


Fig. 3. b) Optimization plot for flexural stress value.

For tensile stress and flexural stress optimum combination of filler content Wt. % and particle size is 10 % filler Wt. and 2 mm/min loading speed.

IV. CONCLUSION

In this experiment mechanical behavior of walnut particle reinforced epoxy composite was studied under varying filler weight (walnut particles) percentage and varying loading speed. This study utilized an efficient method for determining the optimum composition i.e. filler content wt. % and loading speed for maximum tensile stress and flexural stress values, through the use of the Taguchi Parameter design.

Optimization of tensile stress and flexural stress test parameters were done using Taguchi's analysis. The use of a standard L18 orthogonal array, with 2 control parameters at different levels i.e. filler content at six Wt. % levels and loading speed at three levels, require the casting of 18 composite samples to conduct the experiment. The conclusion can be summed up with the following:

i) Conclusion for Tensile stress

It can be concluded from ANOVA that tensile stress is significantly affected by the filler content Wt. % and loading speed at 95 % confidence level. Also, with an increase in loading speed tensile stress increases and optimum value for tensile stress is obtained at 10 % filler content at increased loading speed.

ii) Conclusion for Flexural stress

In the case of flexural test both filler Wt. % and loading speed affect flexural stress value significantly at 95% confidence interval and the optimum value of flexural strength is obtained at 10 % filler content after which it begins to decrease up to 25 % filler content. Also, flexural strength increases as loading speed increases.

REFERENCES

[1] Dale H. Besterfield, Carol Besterfield, Glen H. Besterfield, Mary Besterfield. Total Quality Management, Pearson Education India 2011.

[2] Ronald F. Gibson, Principle of Composite Material Mechanics, CRC press 21 September 2011.

[3] Bhowmick, M., Mukhopadhyay, S., Alagirusamy, R., 2012. Mechanical properties of natural fiber reinforced composites, *Textile progress,* 44/2, 85-140
[4] Ashori, A., 2008, wood –plastic composites as promising green-composites for the automotive industry, bioresource technology, 98, 46614667.
[5] S.B. Hassan & V.S. Aigbodion, 2010, The study of the microstructure and interfacial reaction of Al–Cu– Mg/bagasse ash particulate composite. *Journal of Alloys and Compounds,* Volume **491**, Issues 1-2, Pages 571-574.
[6] Ramazan Yildirim (2005), Production of the polymer of Composite Board from Walnut Shell and improvements of its features, Ilerui Teknolojiler, 2005 M. Sc.Thesis.
[7] Shokrieh MM, Omidi MJ. Tension behavior of unidirectional glass/epoxy composites under different strain rates. *Composite Structure 2009*; **88**(4): 595-601.
[8] S. Nitin, V. K. Singh: Mechanical behavior of Walnut reinforced composite, volume **4** (2) (2013) pp.233-238.
[9] Gilat A, Goldberg RK, Roberts GD. Experimental study of the strain-rate-dependent behavior of carbon/epoxy composite. *Composite Science Technology* 2002; **62** 1469–76.
[10] Rahul Kumar, Kaushik Kumar, Sumit Bhaumik, Optimization of mechanical properties of epoxy based wood dust reinforced green composite using Taguchi method, *International conference on advances in manufacturing and materials engineering AMME 2014.*
[11] K. Bilba & M.-A. Arsene, 2008, Silane treatment of bagasse fiber for reinforcement of cementitious composites. Composites Part A: *Applied Science and Manufacturing*, Volume **39**, Issue 9, Pages 1488-1495.
[12] Okoli, O. I; Smith, G. F. In Proceedings of Society of Plastics Engineers Annual Technical Conference (ANTEC), *Advanced Polymer Composites Division*, 1995, Vol. **2**, p. 2998–3002.
[13] M.Guru, M. Atar & R. Yıldırım,2008, Production of polymer matrix composite particleboard from walnut shell and improvement of its requirements, *Materials & Design*, Volume **29**, Issue 1, Pages 284–287.
[14] Ray BC. Effects of Changing Environment and Loading Speed on Mechanical Behavior of FRP Composites. *J Reinf Plast Comp*. 2006; **25**(12): 1227–1240.