

## EXPERIMENTAL INVESTIGATION OF OVEN CURED JUTE FIBER/GLASS REINFORCED POLYESTER COMPOSITES

B. Sutharson<sup>1\*</sup>, M. Rajendran<sup>2</sup>, R. Sarala<sup>3</sup> and A. Karapagaraj<sup>3</sup>

<sup>1</sup>Mechanical Engineering Department, Chendhuran College of Engineering & Technology, Pudukkottai, - 622507, India.

<sup>2</sup>Mechanical Engineering Department, Government College of Technology, Coimbatore- 641 013, India.

<sup>3</sup>Alagappa Chettiar College of Engineering and Technology, Karaikudi- 630004, India.

\*Corresponding author's E-mail: bsutharson@gmail.com

Received 24 June 2012, Accepted 19 December 2012

### ABSTRACT

This paper deals with an experimental study on the properties of hot air oven cured jute fiber/glass reinforced hybrid composite laminates. An experimental investigation and analysis has been carried out to optimize the parameters like stacking sequence of jute/glass fiber, percentage of NaOH, fiber treatment hours and duration (minute) of oven curing of composite laminate. During the experiments the aforesaid parameters were varied and Taguchi's optimization approach was applied to obtain an optimal setting of parameters. Changes occurring in jute fiber composites with 5-15% concentration of a NaOH treatment for 24 h were investigated. Flexural strength, impact strength and bearing strength of the hybrid composites testing were performed in order to study the mechanical properties of the composites. It was found that oven curing time in minutes has some considerable influence on both flexural strength and bearing strength. Effectiveness of the oven curing was found by comparing the relative performance.

**Keywords:** Hybrid composites, Jute fiber treatment, Taguchi method, Oven curing.

### Nomenclature

NaOH	- Sodium Hydroxide
SS	- Sum of Squares
DF	- Degrees of Freedom
MS	- Mean Squares
F	- Variance
% C	- Percentage contribution
C1	= Stacking sequence of fiber Glass-Jute-Jute-Jute-Glass
C2	= Stacking sequence of fiber Glass-Jute-Glass-Jute-Glass
C3	= Stacking sequence of fiber Jute-Glass-Jute-Glass-Jute
MEKP	- Methyl Ethyl Ketone Peroxide
PVA	- Polyvinyl acetate.

### 1. INTRODUCTION

Natural fibers have the advantages of low density, low cost, and biodegradability. However, the main disadvantages of natural fibers in composites are the poor compatibility between fiber and matrix and the relative high moisture absorption (Wambua et al., 2003; Sutharson et al., 2012a). Therefore, chemical treatments are considered in modifying the fiber surface properties.

Natural fibers, especially bast fibers, such as flax, hemp, jute, and many others were applied by some researchers as fiber reinforcement for composites in recent years (Ashok et al., 2011; Irawan et al., 2011; Dahlke et al., 1998; Wambua et al., 2003; Sutharson et al., 2012b).

In synthetic fibers, glass fibers are the most widely used to reinforce plastics due to their low cost (compared to aramid and carbon) and fairly good mechanical Properties (Vemu, 2011).

Glass fiber reinforced plastic (GFRP) composites have widely used in engineering application such as automotive, aircraft and manufacture of spaceships and sea vehicles industries due to their significant advantages over other materials. They provide high specific strength/stiffness, superior corrosion resistance, light weight construction, low thermal conductivity. Natural fiber reinforced composite has been widely used in various structural applications (Sutharson et al., 2012a). Natural fibers are used in composites structures and partly replacing currently used glass fiber lead to hybridizations of natural fiber with glass fiber. In addition, glass fiber can cause acute irritation of the skin, eyes, and upper respiratory tract. Other great advantages of the vegetable fiber are their low cost and the positive social impact.

The curing reaction is a very important stage in the processing of unsaturated polyester resins for producing a composite product. In order to achieve good quality product, the curing reaction should occur in a controllable manner (Yang and Lee, 1988).

Mechanically fastened joints are frequent and critical elements in composite structures. Marshall et al. (1989) studied the effects of clamping ratio, stacking sequence and clamping type of bolted connections in composite structures. Net-tension and shear-out failure modes are catastrophic and can be avoided by increasing the end distance from the hole center (E) and width of the plate (W) of the structural part for a given thickness (Buketokutan, 2002). These modes result from excessive tensile and shear stresses. Bearing mode is a local failure. This kind of failure cannot be avoided by any modification of the geometry. This mode is progressive and associated with compressive failure (Icten and

Sayman, 2003; Wang et al., 1996; Sutharson et al., 2012c).

The effect of selected Process parameters and their optimal settings have been analyzed mostly using Taguchi methodology (Zaharudin et al., 2012; Jagannatha et al., 2012). It is necessary to understand the relationship among the various controllable parameters and to identify the important parameters that influence the quality of composites.

For the present work, Taguchi design of experiments was employed to study and analyse the effects of the process parameter on the strength of the composite laminate and report on studies of the oven curing composites behaviour.

## 2. MATERIALS AND METHODS

Jute is a bast fiber obtained from inner bast tissues of the plant stem. The jute fiber was purchased from jute service center, Madurai. Glass fibers in the form of woven are supplied by GVR Enterprises, Madurai. The resin system consists of General purpose polyester resin, MEKP catalyst and Cobalt naphthenate accelerator. Jute fabrics were dipped in 5%, 10%, 15% NaOH solution for 24 hours at room temperature for alkali treatment.

Table 1 Parameters and their levels.

Sl.No	Parameters	label	Levels		
			L1	L2	L3
1	Stacking sequence	A	C1	C2	C3
2	NaOH %	B	5	10	15
3	Oven curing time (mins)	C	30	60	90

The fabrics were further washed with distilled water and then the jute fabrics were washed with fresh distilled water again until NaOH was removed.

Table 2 Input parameters and response.

S.No.	Sequence	%NaOH	Oven curing time (min)	Flexural strength (N/mm <sup>2</sup> )	Bearing strength (N/mm <sup>2</sup> )	Impact strength (KJ/m <sup>2</sup> )
1	C1	5	30	66.6656	38.94	31.67
2	C1	10	60	66.6656	35.81	41.67
3	C1	15	90	66.6656	31.55	28.33
4	C2	5	60	83.332	95.69	25.00
5	C2	10	90	16.6664	49.07	50.00
6	C2	15	30	33.3328	78.75	33.33
7	C3	5	90	83.332	49.29	16.67
8	C3	10	30	33.3328	31.19	33.33
9	C3	15	60	33.3328	50.79	33.33

Hybrid laminates were manufactured by simple hand lay-up technique in a mould at laboratory temperature. PVA release agent was applied to the surfaces of the mould.

Jute and glass fabrics were pre-impregnated with the matrix material consisting of polyester, accelerator and catalyst in the ratio of 1:0.015:0.015. After 24 hours, the laminate was removed from the mould and cured in hot air oven at various minutes (30,60 and 90 min). All the laminates were made with total 5 plies by varying the number and position of glass layers to obtain various stacking sequences for 5.2 mm thickness.

## 3. TAGUCHI'S TECHNIQUE

Taguchi techniques have been used widely in engineering design. The main trust of the Taguchi techniques is the use of parameter design, which is an engineering method for product or process design that focuses on determining the parameter (factor) settings producing the best levels of a quality characteristic (performance measure) with minimum variation.

The experimental parameters are shown in table-1. Taguchi designs provide a powerful and efficient method for designing processes that operate consistently and optimally over a variety of conditions (Kathirvel et al., 2011). To determine the best design requires the use of a strategically designed experiment which exposes the process to various levels of design parameters. There have been plenty of recent applications of Taguchi techniques to materials processing for process optimization; some of the previous works are listed Yang and Tarn (1988) and Lin (2002).

## 4. ANALYSIS OF VARIANCE (ANOVA)

The orthogonal array for three factors at three levels was used for the elaboration of the plan of experiments the array L9 was selected (Kishore et al., 2010)

The first row was assigned to the stacking sequence (A), the second row consists of NaOH % (B) and the third one consists of oven curing time in minutes (C).

Table 2 shows the L9 orthogonal array for this experiment and their results.

Table 3 ANOVA for flexural strength.

Factor	SS	DF	MS	F	% C
A	802.4	2	401.2	0.81	16.45
B	2654.2	2	1327.1	2.68	54.43
C	432.0	2	216.0	0.43	8.86
Error	987.6	2	493.8	1	20.25
Total	4876.3	8	-	-	-

Table 4 ANOVA for bearing strength.

Factor	SS	DF	MS	F	% C
A	2541.1	2	1270.5	21.9*	64.81
B	794.6	2	397.3	6.8@	20.26
C	468.8	2	234.4	4.0@	11.95
Error	115.8	2	57.9	1	2.95
Total	3920.3	8	-	-	-

Table 5 ANOVA for impact strength.

Factor	SS	DF	MS	F	% C
A	111.7	2	55.87	0.73	15.57
B	448.6	2	224.33	2.94	62.55
C	4.31	2	2.15	0.02	0.60
Error	152.5	2	76.25	1	21.26
Total	717.2	8	-	-	-

The observed values of flexural strength, bearing strength and impact strength were used for determining the significant factors influencing the hybrid composites strength. The significant parameters influencing the responses were found using the ANOVA procedure.

From f table  $F_{0.25,2,2} = 3.00$ ,  $F_{0.10,2,2} = 9.00$ ,  $F_{0.05,2,2} = 19.00$ .

\*Factor is significant at both 5%, 10% and 25% significance levels

@ Factor is significant at 25% significance levels.

## 5. RESULT AND DISCUSSION

The purpose of the analysis of variance (ANOVA) is to determine the control factor that significantly affects the quality characteristics. Tables 3, 4 and 5 show the ANOVA for flexural strength, bearing strength and impact strength, respectively.

From the ANOVA Table 3 for flexural strength, it was found that percentage of NaOH (54.43%) is the most significant parameter, which affects the hybrid composites strength. From the calculations it is being inferred that percentage of NaOH (B) has more influence on flexural strength & impact strength, and stacking sequence (A) has more influence on bearing strength. The effect of oven curing of composite laminate is very

less (0.6%) in the case of impact strength and for others is has considerable level contribution (8.86-11.95%).

The F -ratio value can be found using the ratio of mean square of a factor to variance of error. It can be seen from the F -ratio value result that the significant factors are the control factors in the order of stacking sequence (A), % NaOH (B), and oven curing time in minutes (C). It is clear from Figure 1 the flexural strength of composites are maximum at first level of stacking sequence (A<sub>1</sub>), first level (5% NaOH) of percentage of NaOH (B<sub>1</sub>), and second level (60 minutes) of oven curing time in minutes (C<sub>2</sub>). It was found that percentage of NaOH (54.43%) is the most significant parameter, which affects the flexural strength of composite material. From the Figure 2 It is being inferred that 5% alkaline treatments produce the peak strength, when compare to 10% and 15 % concentration. The oven curing time 60 minutes and stacking sequence C2 shows good result.

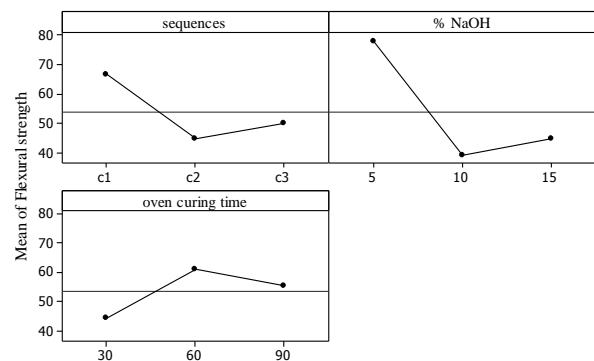


Figure 1 Main effects plot for flexural strength.

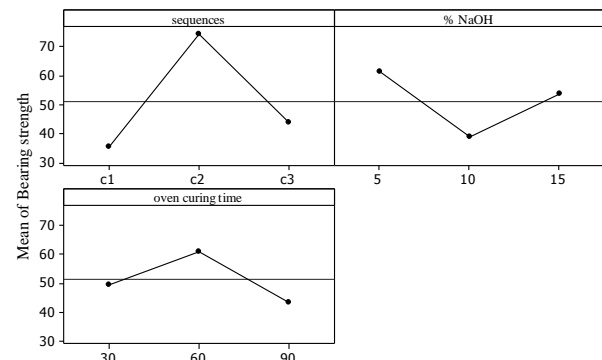


Figure 2 Main effects plot for bearing strength.

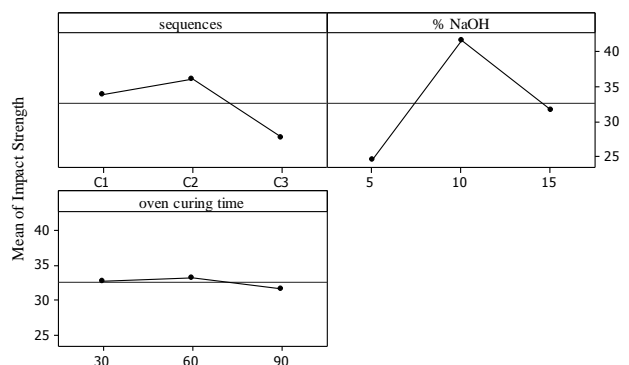


Figure 3 Main effects plot for impact strength.

Figure 3 indicate the variation of impact strength of the hybrid composite. The impact strength is increased with decreasing the weight percentage of natural fiber from 60% to 40% i.e. the sequence C2 produced high strength. Better outcome achieved for 10% NaOH concentration. The effect of oven curing have gradually increased from 30 minutes to 60 minutes and then decreased to minimum at 90 minutes. Impact strength of composites are maximum at second level of stacking sequence (A2), second level (10%) of percentage of NaOH (B2), and second level (60 minutes) of oven curing time in minutes (C2). Figure 4 illustrates the surface plot between three factors. It is clear from the graph (Figure 4-a) that there exists a interaction between the factors. The variability in strength is minimum when sequence and % NaOH is kept at medium level. The variability in strength is maximum when sequence is kept at medium level and %NaOH is kept at low level. From the recorded values Figure 4a-d were plotted for percentage of NaOH, oven curing time in minutes and stacking sequence. From the graphs it is being inferred that for any combination of oven curing time in minutes and stacking sequence, 5% NaOH always outperform the other two percentage (10% and 15%). From the Figure 4d it is noticed that the impact strength values almost remained to be equal for NaOH percentage parameter with a given oven curing time of 30 minutes. From the Figure 4e it is observed that

the impact strength is maximum for fiber processed with 10 % NaOH. In Figure 4f oven curing time of 90 minutes influences the laminate to have high impact strength of about 50 N/mm<sup>2</sup>. Fiber exposed to 30 minutes oven curing time has nearly the same strengthening value for all the three sequences.

## 6. CONCLUSION

Experimental study on the properties of hot air oven cured jute fiber/glass reinforced hybrid polyester composite laminates were performed. Oven curing of composite laminate were considered as important parameters in the manufacturing process along with percentage of NaOH used for treatment of natural fiber and fiber treatment hours. An analysis of variance (ANOVA) was made and it was found that percentage of NaOH has greater influence on flexural strength & impact strength. Stacking sequence has greater influence on bearing strength (64.81% contribution). Further it was found that of oven curing time in minutes has some considerable influence on both flexural strength and bearing strength. Effectiveness of the oven curing in improving the composite laminate strength was found by comparing the relative performance. Since oven cured natural fiber hybrid composite laminate having very good bearing strength by optimizing the stacking sequence, it can be used for modular composite tank.

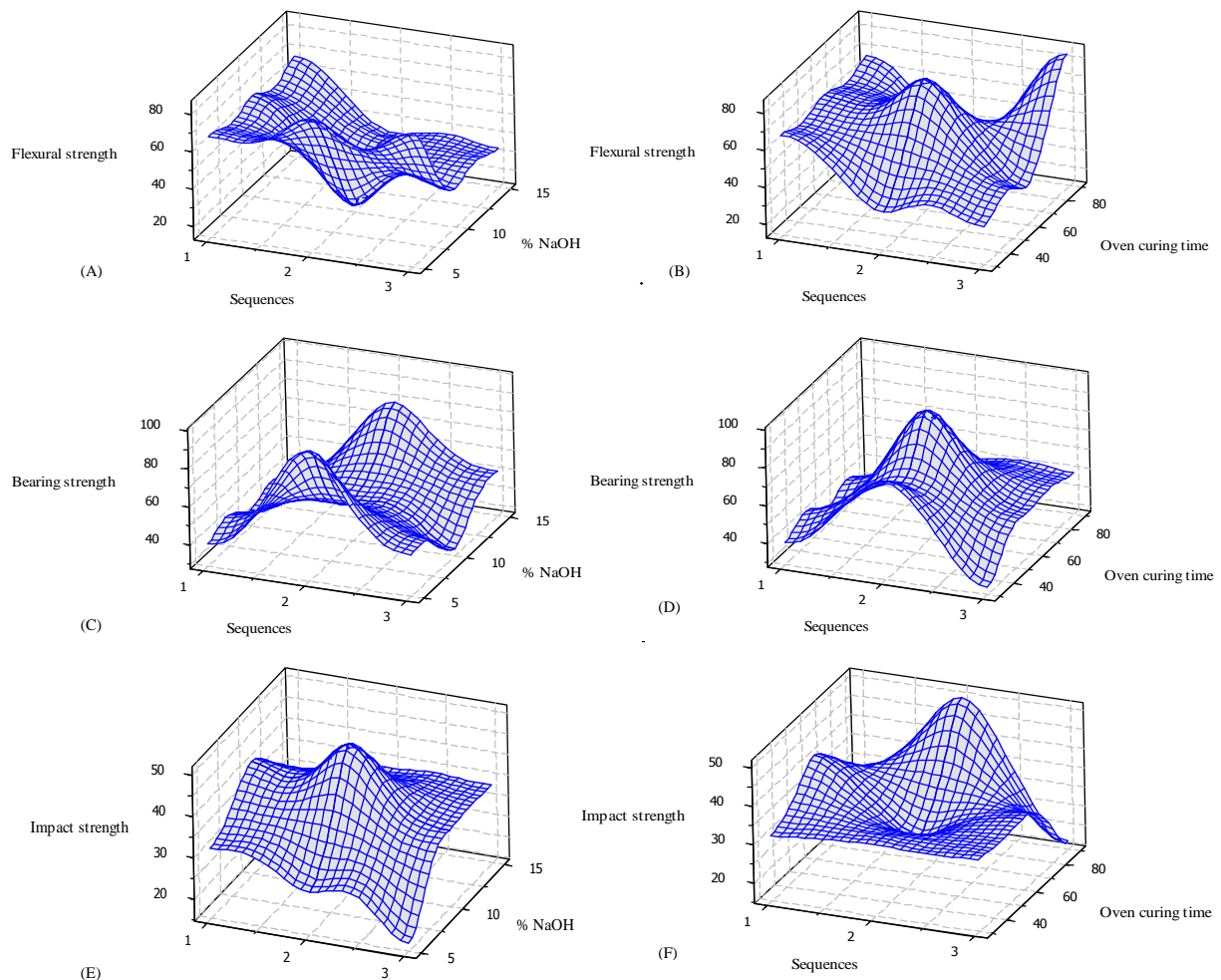


Figure 4 Surface plot- (A,B): Flexural strength, (C,D): Bearing strength and (E,F): Impact strength.

## REFERENCES

- Ashok, K.M., Ramachandra, R.G. and Vishnu, M.K.R. 2011. Fabrication and performance of natural fibers reinforced with rubber/polyester composites, *International Journal of Fiber and Textile Research* 1: 15-21.
- Buketokutan. 2002. The effects of geometric parameters on the failure strength for pin-loaded multi-directional fiber-glass reinforced epoxy laminate, *Composite engineering part b* 33: 567-578.
- Dahlke, B., Larbig, H., Scherzer, H.B., and Poltrock, R. 1998. Natural fiber reinforced foams based on renewable resources for automotive interior applications, *Journal of Cellular Plastics* 34: 361-379.
- Icten, B.M. and Sayman, O. 2003. Failure Analysis of Pin-loaded Aluminum-Glass-Epoxy Sandwich Composite Plates, *Composites Science and Technology* 63: 727-737.
- Irawan, A.P., Soemardi, T.P., Widjajalaksmi, K. and Reksoprodjo, A.H.S. 2011. Tensile and flexural strength of ramie fiber reinforced epoxy composites for socket prosthesis application, *International Journal of Mechanical and Materials Engineering* 6 (1): 46-50
- Jagannatha, N., Hiremath, S.S. and Sadashivappa, K. 2012. Analysis and parametric optimization of abrasive hot air jet machining for glass using taguchi method and utility concept, *International Journal of Mechanical and Materials Engineering* 7 (1): 9-15.
- Kathirvel, M.S., Purushothaman, S. and Bose, R.S.C. 2011. Applications of ANOVA in validating hybrid MMC Machinability data, *ARNP Journal of Engineering and Applied* 6 (10): 8-18.
- Kishore, K., Krishna, P.V.G, Veladri, K. and Ali, S.Q. 2010. Analysis of defects in gas shielded arc welding of AISI1040 steel using Taguchi method, *ARNP Journal of Engineering and Applied Sciences* 5: 37-41.
- Lin, T.R. 2002. Experimental design and performance analysis of Ti-N coated carbide tool in face milling stainless steel, *Journal of Material Processing Technology* 127: 1-7.
- Marshall, I.H., Arnold, W.S., Wood, A.J. and Mously, R.F. 1989. Observations on bolted connections in composite structures, *Composite Structures* 13: 133-151.
- Sutharson, B., Rajendran, M., Devadasan, S.R. and Selvam, B. 2012a. Effect of chemical treatments on mechanical properties of jute fiber hybrid composite laminates, *ARNP Journal of Engineering and Applied Sciences* 7 (6): 760-765.
- Sutharson, B., Rajendran, M. and Karapagaraj, A. 2012b. Optimization of natural fiber / glass reinforced polyester hybrid composites laminate using Taguchi methodology, *International Journal of Materials and Biomaterials Applications* 2 (1): 1- 4.
- Sutharson, B., Rajendran, M. and Sarala, R. 2012c. Bearing strength predictions of bolted joints in composite laminates using artificial neural network, *International Journal of Fiber and Textile Research* 2 (2): 21-25.
- Vemu, V.P. 2011. Tensile and Flexural Properties of Glass fiber-reinforced Polyester hybrid composites, *International Journal of Materials and Biomaterials Applications* 1 (1): 14-16.
- Wambua, P., Ivens, J. and Verpoest, I. 2003. Natural fibers, can they replace glass in fiber reinforced plastics?, *Composites Science and Technology* 63: 1259-1264.
- Wang, H.S., Hung, C.L. and Chang, F.K. 1996. Bearing Failure of Bolted Composite Joints. Part I: Experimental Characterization, *Journal of Composite Materials* 30: 1284-1313.
- Yang, W.H. and Tarng, Y.S. 1988. Design optimization of cutting parameters for turning operations based on the Taguchi method, *Journal of Material Processing Technology* 84: 122-129.
- Yang, Y.S. and Lee, L.J. 1988. Microstructure formation in the cure of unsaturated polyester resins, *Polymer* 29: 1793-1800.
- Zaharudin, A.M., Talib, R.J., Berhan, M.N. and Budin, S. 2012. Taguchi method for optimizing the manufacturing parameters of friction materials, *International Journal of Mechanical and Materials Engineering* 7 (1): 83-88.