ISSN 2229-5518

Fabrication and Mechanical Characterisation of Jute-Glass-Silk Fiber Polymer Composites

Madhusmita Pathal, Biswajit Parida and Sasmita Kar

Abstract— In this paper hybrid polymer composites are manufactured using jute (0-20%), glass (0-16%) and silk (0-8%). Experiments have been planned as per Taguchi's L16 orthogonal array. After preparing the composite material by hand layup technique mechanical characterizations are performed. The effect of filler in modifying the physical and mechanical properties of hybrid composites are analyzed. Only single response optimization has been carried out. In single objective optimization, Taguchi's method has been utilized. Optimal results have been verified through confirmatory experiments. Based on the experimental observations, tests like 3-point bending, UTS, impact strength, it is concluded that the materials having maximum UTS, when fiber content is maximum in material. Flexural strength is also found to be maximum in fiber matrix compared to the neat polyester resin The UTS of glass fiber having greatest effect on S/N ratio compared to jute fiber and silk due to a good mechanical behavior it can be used in different field of application.

Index Terms Polyester Resin, Hand Layup Technique, Hybrid Polymer Nano Composite, Tensile Test, Flexural Test, Taguchi Method

1 Introduction

In general monolithic materials do not provide sufficient mechanical characterizations in every field of use. To overcome such difficulties composite materials came into picture. The composite materials have advantage over other conventional materials due to their higher specific properties such as tensile, impact and flexural strengths, stiffness and fatigue characteristics, which enable structural design to be more versatile.

Ramesh et.al. has done a comparative evaluation on hybrid Glass Fiber-Sisal/Jute Reinforced Epoxy Composite and have found that the sisal/GFRP composite samples possess good tensile strength and can withstand the strength up to 68.55 MPa. The jute/GFRP composite specimen is holding the maximum flexural load of 1.03KN slightly higher than the sisal/GFRP composite sample. [1]

Paul Wambua has done a relative study on the mechanical properties of sisal, hemp, coir, and jute reinforced polypropylene composites have been investigated. The tensile strength and modulus increases with increasing fiber volume fraction. Among all the fiber composites tested, coir reinforced polypropylene composites registered the lowest mechanical properties whereas hemp composites showed the highest. However, coir composites displayed higher impact strength than jute composites. [2]

A.C.B. Naidu has done a study on elastic properties of woven jute and jute–glass fabric hybrid composites and found out that jute composites undergo more transverse strain and less longitudinal strain than jute–glass hybrid composites. [3]

C. Santulli a, F. Sarasini studied that hybridization with jute fibres can significantly enhance both the tensile and flexural properties of wool fiber reinforced epoxy composites. [4]

- *Madhusmita Pathal, CAPGS, Biju Patnaik University of Technology, Odisha, India, E-mail: madhusmita.lipa@gmail.com*
- *Biswajit Parida, CAPGS, Biju Patnaik University of Technology, Odisha, India, E-mail: biswajitparida321@gmail.com*
- *Sasmita Kar, CAPGS, Biju Patnaik University of Technology, Odisha, India, E-mail: sasmitakarom@gmail.com*

Different researchers have studied the mechanical properties fiber polymer composites i.e. palm fiber, date fiber, bamboo fiber, jute, hemp, coir fiber, glass silk. Almost all the fiber shows good mechanical properties in polymer composites.

2 Material Used and Experimental Setup

Unsaturated polyester resin Ecmalon 4413, methyl ethyl ketone peroxide (MEKP), cobalt octoate was purchased from Ecmas Resins (P) Ltd., woven jute, silk and glass fiber were purchased fromlocal store. Composites were prepared using mold of dimension 20cm x 10 cm.Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Then gel/silicon spray is sprayed on the mold surface. The low temperature curing polyester resin is uniformly spread with the help of brush. Layer of mat is then placed on the Polyester surface and a roller is moved with a mild pressure on the mat-resin layer to remove any air trapped as well as the excess resin present. The process is repeated for each layer of resin/polymer and mat. Different percentage of reinforcement were taken as shown in Table 1. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. Normal curing time at room temperature is 24-48 hours. Prepared composites are tested by using a capacity of 600 KN universal testing machine (UTM BSUT 60JD) and with a cross head speed of 10mm/min. Ultimate tensile strength (MPa) was found out using the expression:

$$\sigma_u = F/A \quad (1)$$

TABLE 1
Factors and levels

Factor	Level 1	Level 2	Level 3	Level 4
Jute	0%	10%	15%	20%
Glass	0%	8%	12%	16%
Silk	0%	4%	6%	8%

Where σu the ultimate tensile strength (MPa), F is the maximum load (KN) applied and A is the cross-sectional area (meter^2) of the composite. The flexural stress in a three-point bending test is found out by using formula

$$\sigma_f = 3FL/2bd^2 \quad (2)$$

Where σf is the flexural strength, F is the maximum load applied, L is the distance between the supports, and b and d are breadth and thickness of the specimen respectively.

3 Results and Discussion

Samples are prepared by using L-16 orthogoonal array which is shown in fig 1. The samples are cut into desired size by using electric cutter which is shown in fig 2. The experimental results are then analysed using MINITAB 17 software.

Fig. 1. Prepared Sample

Fig. 2. Sample Before and After Test

3.1 Tensile test

From Table 4 it is found that under some parametric conditions of the composite, ultimate tensile strength is remarkably good. For sample numbers 1-16 it is within the range of 103 MPa – 318 MPa. For the sample number 7, ultimate tensile strength is maximum and for the sample number13, ultimate tensile strength is minimum.

TABLE 2
ANOVA FOR TENSILE STRENGTH

Source	DF	Seq SS	Adj SS	Adj MS	F	P	P%
Jute	3	30.42	30.42	10.141	1.09	0.424	4.05
Glass	3	16.90	16.90	5.633	0.60	0.637	7.294
Silk	3	19.91	19.91	6.635	0.71	0.580	6.191
Residual Error	6	56.05	56.05	9.342	-	-	-
Total	15	123.28	-	-	-	-	-

From Table 2 it can be concluded that the p-value for the interaction term (0.637) is greater than 0.05. Thus, the interaction of the glass is not significant, and we can consider the effects of the individual factors separately. The p-value for silk (0.580) is also greater than 0.05, indicating that the Ultimate Tensile Strength factor is not associated with a significant amount of variation in the strength of the fibers. The p-value for the jute is (0.424). Since this is greater than the chosen -level of 0.05, the effect of jute is significant. In other words, a not significant amount of variation in the strength of the fibers is associated with the variation in the ultimate Tensile Strength. For the fiber strength data, S is 3.057, R-Sq is 54.5%, and adjusted R-Sq equals 0.00%. The large drop in the adjusted R, compared to R, suggests that unnecessary terms are in the model. From table 3 it can be concluded that jute affects the strength to a higher rate followed by silk then glass. From fig. 3 it can be concluded that 0% of silk, 0% of jute and 12% of glass gives the higher results.

TABLE 3
Response table for UTS

Level	Jute	Glass	Silk
1	46.91	45.10	46.78
2	45.90	44.52	44.62
3	44.42	46.81	43.74
4	43.31	44.11	45.39
Delta	3.61	2.70	3.04
Rank	1	3	2

Fig. 3. Main Effect plot for UTS

TABLE 4
ANOVA FOR TENSILE STRENGTH

Sl. No	Jute	Glass	Silk	UTS (MPa)	Flexural strength (MPa)	S/N ratio of Tensile Strength	S/N ratio of Flexural Strength
1	0	0	0	294.00	8580.00	49.36	78.66
2	0	8	4	158.75	5053.12	44.02	74.07
3	0	12	6	191.75	5218.12	45.66	74.35
4	0	16	8	269.333	3154.80	48.59	69.97
5	10	0	4	178.50	3154.80	45.34	69.97
6	10	8	0	247.333	3135.00	47.85	69.92
7	10	12	8	317.66	8763.33	50.04	78.85
8	10	16	6	104.2857	9460.00	40.34	79.91
9	15	0	6	187.25	9130.00	45.43	79.20
10	15	8	8	135.83	9056.66	42.67	79.13
11	15	12	0	199.25	8726.66	45.97	78.81
12	15	16	4	151.40	8928.33	43.57	79.01
13	20	0	8	102.71	9038.33	40.25	79.12
14	20	8	6	150.28	9276.66	43.52	79.34
15	20	12	4	189.20	9423.33	45.52	79.48
16	20	16	0	156.80	9698.33	43.91	79.73
1	0	0	0	294.00	8580.00	49.36	78.66

3.2 Flexural strength

From Table 4 it is found that under some parametric conditions of the composite, ultimate tensile strength is remarkably good. For sample numbers 1-16 it is within the range of 3135 MPa –9698.33 MPa. For the sample number 16, three-point bending is maximum and for the sample number 06, three-point bending Stress is minimum.

From table 5 it can be concluded that the fiber three-point bending strength analysis, the effects jute, glass silk on the strength of the fibers were assessed. Assuming the common -level of 0.05 was chosen for the test, the results indicate the following- the p-value for the interaction term is (0.864) which greater than 0.05. Thus, the interaction of the silk is not significant, and you are free to consider the effects of the individual factors separately. The p-value for glass (0.888) is also greater than 0.05, indicating that the factor is three-point bending strength associated with a significant amount of variation in the strength of the fibers. The p-value for the jute is (0.239). Since this is greater than the chosen --level of 0.05, the effect of jute is significant. In other words, a significant amount of variation in the strength of the fibers is associated with the variation in the density. For the fiber strength data, S is 4.100, R-Sq is 53.5%. The large drop in the adjusted R, compared to R, suggests that unnecessary terms are in the model. From table 6 it can be concluded that jute affects the strength to a higher rate followed by glass then silk. From fig. 4 it can be concluded that 6% of silk, 20% of jute and 12% of glass gives the higher results.

TABLE 5
ANOVA FOR FLEXURAL STRENGTH

Source	DF	Seq SS	Adj SS	Adj MS	F	P	P%
jute	3	93.22	93.22	31.072	1.85	0.239	2.325
Glass	3	10.47	10.47	3.490	0.21	0.888	20.705
Silk	3	12.22	12.22	4.075	0.24	0.864	17.740
Residual error	6	100.88	100.88	16.814			
total	15	216.79					

TABLE 6
RESPONSE TABLE FOR FLEXURAL STRENGTH

Level	Jute	Glass	Silk
1	74.27	76.75	76.79
2	74.57	75.62	75.64
3	79.05	77.88	78.11
4	79.42	77.06	76.77
Delta	5.15	2.26	2.47
Rank	1	3	2

4 CONCLUSIONS

The present work deals with the preparation of jute, glass silk fiber reinforced polyester composite. The mechanical behavior of the hybrid composite lead to the following conclusions.

1. Successful fabrication of multi-component hybrid jute –glass–silk-polyester composites is prepared by hand layup technique.
2. After Successful preparing the composite material the physical and mechanical properties of the jute, glass and silk fiber reinforced polyester composites of different compositions prepared for this work. The following test impact strength, ultimate tensile strength and three-point bending strength are the response parameters.

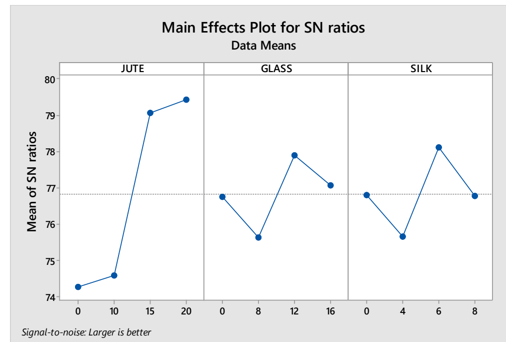

Fig. 4. Main Effect plot for Flexural strength

3. Analyzed by several approaches including Taguchi methodology using Minitab 17, it had been observed from this work that the Ultimate Tensile strength is maximum for 318 MPa which is greater than neat resin. However, there the S/N ratio of the maximum value is high. This increase in strength of the only resin is may be due to present of fiber-matrix.
4. However, Three Point Bending strength is found to be more than neat polyester for all layers of fiber reinforced composites. And it is found to be maximum for sample 9698.33 MPa which is greater than neat polyester resin i.e., 8580MPa. The high value of Three Point Bending strength is observed for high percentage of fiber matrix.

5 FUTURE SCOPE

The present work leaves a wide scope for future investigators to explore many other aspects of particulate filled FRP composites. Some recommendations for future research include:

1. The response of these composites to other wear modes such as sliding and abrasion. Possible use of other ceramic/metallic fillers, epoxy resins other than polyester resin and natural fibers other than jute and silk in the development of new hybrid composites.
2. Cost analysis of these composites to assess their economic viability in domestic/industrial applications.
3. Exploring the possibility of using manmade fibers other than glass fibers along with ceramic particulates to fabricate hybrid composites with improved functional properties.
4. Possible use of these composites such as in building and construction industry (partition boards, panels for partition and false ceiling, floor, wall, window and door frames etc.), Storage devices (grain storage silos, post-boxes, bio-gas containers etc.) is recommended.

REFERENCES

[1] M.Ramesh, K. Palanikumar, K. Hemachandra Reddy, “Comparative

Evaluation on Properties of Hybrid Glass Fiber- Sisal/Jute Reinforced Epoxy Composites", Proceedings of Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference(NUiCONE 2012), Procedia Engineering, vol 51,pp 745 – 750, 2013.

[2] Paul Wambua, Jan Ivens, Ignaas Verpoest, "Natural fibers: can they replace glass in fiber reinforced plastics?", Composites Science and Technology, vol 63, pp 1259–1264, 2003.

[3] K. Sabeel Ahmed, S. Vijayarangan, A.C.B. Naidu, "Elastic properties, notched strength and fracture criterion in untreated woven jute–glass fabric reinforced polyester hybrid composites", Materials and Design, vol 28, pp 2287–2294, 2007.

[4] C. Santulli, F. Sarasini, J. Tirillò, T. Valente, M. Valente, A.P. Caruso, M. Infantino, E. Nisini, G. Minak, "Mechanical behaviour of jute cloth/wool felts hybrid laminates", Materials and Design, vol 50, pp 309–321, 2013.