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Fabrication, Evaluation and Optimization of Tensile Characteristics of Banana Pistil Reinforced Polymer Composite

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Abstract

World is now concentrating on alternate material sources that are eco friendly in nature. Because of this, the use of composite materials is increasing in engineering. In the present scenario, the researchers are concentrating on natural fibers composites due to its availability, cost effective, environment friendly, formability and many other features. This paper is based on a natural fiber reinforced composite, in which the fiber (reinforcement) is obtained from the banana flower and percentage of fiber loading, effect of different chemical treatment and the suitable resin (matrix) selection was studied and the values are optimized. The banana flower is collected and the pistil part is separated from it, dried and chemically treated to increase its wettability. Then the fibers are again dried and reinforced into the chosen resins using the Hand Layup (HLU) method and allowed to cure. The banana pistil orientation is randomized throughout the composite. After curing, the composite is subjected to tensile characterization studies [1,4,8]. All the tensile tests were carried out as per the ASTM standards. The parameters were determined by using Taguchi's experimental design method. Taguchi (Orthogonal array) and the analysis of variance (ANOVA) are employed to find the optimal levels. Confirmation tests with the optimal levels of parameters were carried out in order to illustrate the effectiveness of Taguchi's optimization method.

Keywords: *Eco friendly; Hand layup method; banana pistil; wettability; formability.*

1. Introduction

In the modern world, the need for efficient material is significant which leads to the development of new products. The composites play a major role as strong load carrying material is embedded in weaker material. Reinforcement provides strength and rigidity to the material to withstand the load. In polymers the strength is low when compared to the ceramics and metals. Hence this demerit is overcome by reinforcing other materials into polymers. Nowadays many fibers are reinforced in polymer matrix like natural and synthetic. The natural fibers are mostly preferred, since it is environment friendly and easily biodegradable and available in plenty as well as cost effective. There are many natural fibers which are used as reinforcement into polymer matrix such as bamboo, flax, kenaf, hemp, jute, etc. The most abundantly used fiber is obtained from banana pseudo stem and it exhibits excellent mechanical properties [2,3]. Thermosetting resins which are preferred in engineering applications are epoxy, than polyester and vinyl ester. In this present work the banana pistil is made as reinforcement in different types of resins at different composition ratios and by various chemical treatments and their tensile characterization studies were carried out and also the optimized values of different factors was found out and validated.

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2. Materials and Methods

2.1 Matrix material

The matrix material is a resin. Out of many resin types polyester, vinyl ester and epoxy were chosen for the matrix and it is obtained from Coimbatore aiswarya polymers. The resin is mixed with proper proportion of catalyst, hardener and promoters. For unsaturated polyester resin MEKP (Methyl ethyl ketone peroxide) and cobalt is used as catalyst and hardener respectively. For vinyl ester type resin a promoter DMA (Dimethylaniline) is also used. The epoxy resin is mixed with hardener in a ratio of 100:80.

2.2 Reinforcement material

Reinforcement adds strength and greatly decreases crack propagation. Fiber-reinforced composite materials can be divided into short fiber-reinforced materials and long continuous fiber-reinforced materials. The short fibers come in the form of flakes, chips, and random mate. In this work the pistils obtained from the banana flower (Has an average length of 25mm) is used as reinforcement. It is collected, dried to remove the moisture and then chemically treated to increase its wettability and used as reinforcement in proper assigned ranges in chosen matrix [6,7,9].

2.3 Fabrication method

Selection of a method for a particular part will depend on the property materials, the part design and end-use or application. A mold tool is required to give the unformed resin /fiber combination a required shape.

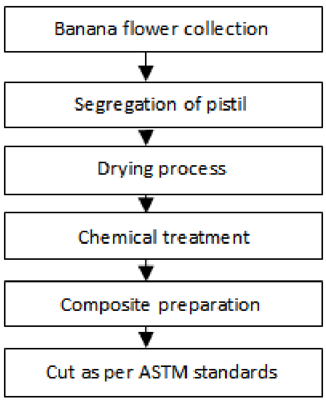

Figure 1: Fabrication process flow chart

The mostly preferred fabrication technique for thermoset composites is Hand layup technique, which is a simple technique for polymer composite processing. First of all, a release gel is sprayed on the mold surface to avoid the sticking of resin to the surface. Matrix is spread over the mould surface and reinforcement is dispersed into it homogeneously. Then thermosetting polymer in liquid form is mixed with hardener then poured onto the surface of the mold. The polymer is uniformly coated over the surface with the help of brush or roller. Second layer of reinforcement is then dispersed on the polymer surface and a roller is moved with a mild pressure to remove any air trapped as well as the excess resin present. The process is repeated for each layer of composite, till the required layers are attained. After that, release gel is sprayed on the inner surface of the top mold plate and the pressure is applied. After curing at room temperature, mold is opened and the finished composite part is taken out and further processed. The schematic layout of hand lay-up is shown in figure 2. Then the fabricated composites are taken out and modified to the required dimension as per ASTM standards and the unwanted projections are removed. Hand lay-up method is used in many areas like aircraft components, automotive parts, boat hulls, dash board, deck etc.

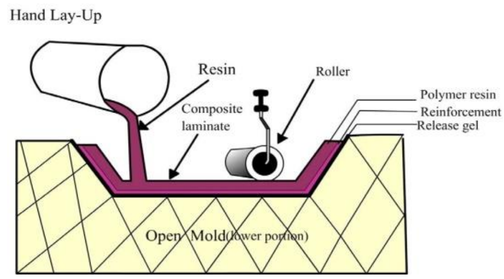

Figure 2: Hand layup process

3. Experiments

3.1 Tensile test

The most commonly used specimen geometries for tensile test are of dog bone type. The specimen used for this experiment is shown in figure 3. The tensile tests were conducted according to the ASTM D 3039-76 standard on universal testing machine (UTM, H10KS, Tinius Olsen, UK) at 23°c. The cross head speed of 5mm/min and a constant strain rate of 5 mm/min are given [5].

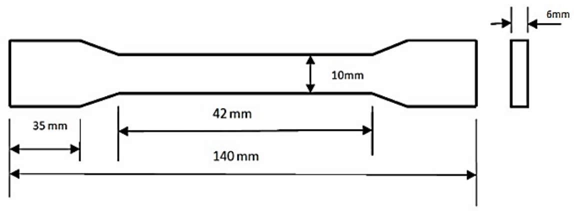

Figure 3: Specimen for tensile test

Figure 4: UTM, H10KS, Tinius Olsen, UK

3.2 Taguchi method

Traditional experimental design methods are very complicated and difficult to use. Also, these methods require a large number of experiments when the number of process parameters increases. To minimize the number of tests required and to make the task easier, Taguchi experimental design method is a powerful tool for designing high-quality system. In this a design of orthogonal arrays to study the entire parameter space with small number of experiments is used [13].

3.3 Design of Experiments

The objective of this research was to evaluate and optimize the tensile properties of the banana pistil composite. Variables such as percentage of fiber loading, different chemical treatments and suitable resin type were identified as the most influencing process parameters.

All these parameters were varied at three levels. The process parameters and their levels in this study are given in Table 1. The three level orthogonal array L_9 with nine experimental runs was selected for the present work. The tests values for nine trial condition were tabulated and given in Table 2.

Table 1: Process parameters and their levels

Sl. No	Parameters	Unit	Levels		
			1	2	3
1	% of fiber loading(A)	%	10	20	30
2	Chemical treatment(B)	-	No treatment	NaoH treatment	Stearic acid
3	Type of resin(C)	-	Unsaturated polyester	Vinyl ester	Epoxy

Table 2: Nine trial conditions for Taguchi analysis

Trial No	Designation	% of fiber loading (A)	Chemical treatment (B)	Type of resin (C)
1	A1B1C1	1	1	1
2	A1B2C2	1	2	2
3	A1B3C3	1	3	3
4	A2B1C2	2	1	2
5	A2B2C3	2	2	3
6	A2B3C1	2	3	1
7	A3B1C3	3	1	3
8	A3B2C1	3	2	1
9	A3B3C2	3	3	2

Table 3: ANOVA for S/N ratio of Tensile strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P
% of Fiber	2	1.34783	1.34783	0.67392	49.23	0.02
Chemical treatment	2	0.02097	0.02097	0.01049	0.77	0.566
Type of resin	2	0.04787	0.04787	0.02394	1.75	0.364
Residual Error	2	0.02738	0.02738	0.01369		
Total	8	1.44406				
S = 0.1170	**R-Sq = 98.1%**		**R-Sq(adj)=92.4%**			

4. Results and Discussion

4.1 Regression analysis

To predict the tensile strength within the specific level values of parameters, using regression analysis, a first order polynomial regression equation for tensile strength with significant parameters is derived with R-Sq value of 98.1% and given as Equation.

Tensile strength = 53.2 + 3.20 % of Fiber + 0.277 Chemical treatment- 0.617 Type of resin (1)

4.2 ANOVA

A statistical technique used to identify and screen the significant parameters that influence the tensile strength. From the analysis of variance for S/N ratios of the tensile strength shown in Table 3 with computed R-Sq value of **98.1**%, percentage of fiber is identified as the significant parameters with **95%** contribution. The consequence of type of resin and chemical treatment is found to be insignificant on the tensile strength with very low percentage contributions.

The contribution chart (Fig. 5.) is plotted from the ANOVA and shows the contribution of the individual and interaction factor on the tensile strength. The Percentage of fiber shows the maximum contribution followed by interaction of resin type and chemical treatment.

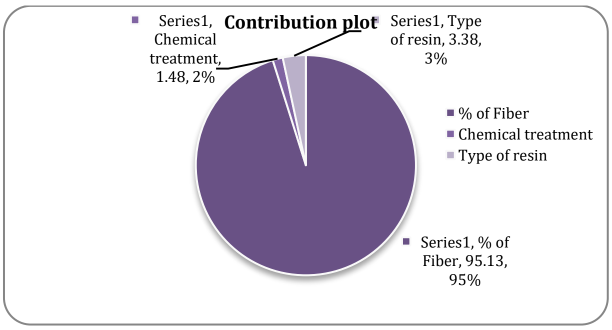

Figure 5: Contribution plot for parameter on Tensile strength

The contour plot bands indicate the ranges of tensile strength against the percentage of fiber and type of resin are shown in Fig. 6. from the contour plot it was observed that the maximum tensile strength can be obtained in the fiber percentage ranging from 27.5% to 30% and type of resin is unsaturated polyester**.** The tensile strength found to increase with the addition of fiber and by using polyester resin. The tensile strength decreases with the usage of other resins such as vinylester and epoxy.

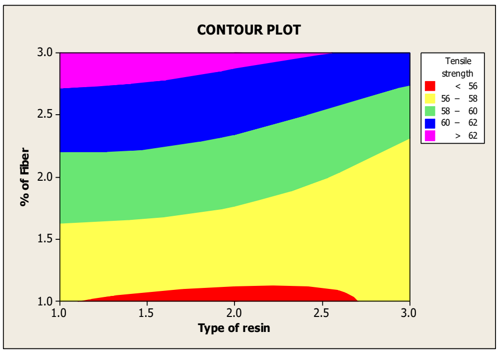

Figure 6: Contour Plot for tensile strength

The main effect plot as shown in fig.7 gives the optimal process parameters to obtain a maximum tensile strength, with a fiber percentage of 30% and treating chemically with stearic acid and polyester type resin. Also further it was observed that percentage of fiber has major influence on tensile strength. The percentage of fiber as decreased is found to have a negative effect on the tensile strength which decreases from 62Mpa to 56Mpa.

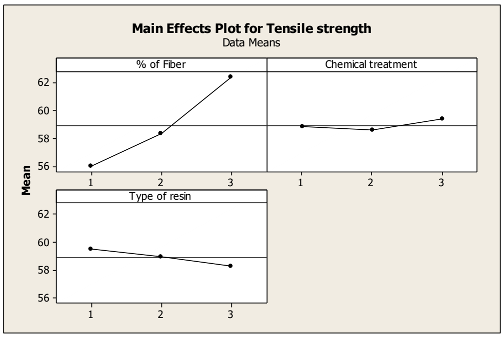

Figure 7: Main Effect Plot for tensile strength

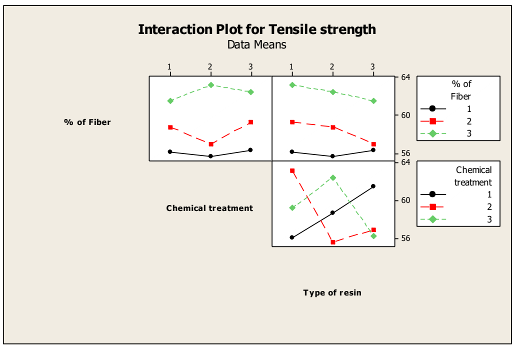

Figure 8: Interaction Plot for tensile strength

The interaction plot for tensile strength between percentage of fiber, chemical treatment and type of resin is shown in Fig. 8. In Interaction graph, the parallel lines specify the absence and non-parallel lines point out the presence of interaction effect of the factors on a response. The interaction plot suggests that chemical treatment and type of resin interacts each other. The percentage of fiber and chemical treatment, percentage of fiber and type of resin is found to have no interaction effect in-between.

Validation Test

A validation test was performed based on the permutation of optimal level of each parameter (i.e. A3B3C1) established from the main effect plot of tensile strength. A minimal error of 1.98% is obtained involving the predicted and experimental value presenting a good correlation as observed in Table 4.

Table 4: Validation of Predicted with Experimental result

	Optimal control parameters		**Error (%)**
	Predicted	**Experimental**	
Level	**A3B3C1**	**A3B3C1**	
Tensile strength in Mpa	62.5	61.26	1.98

Conclusion

Taguchi method has been used to perform analysis of the tensile strength with respect to various combinations of process parameters. The best level of the parameters on the tensile strength is determined using ANOVA. The results of ANOVA reveal that percentage of fibre is the influential parameter, which has greater effect on tensile strength. The optimal levels for the controllable factors are 30% of fibre addition, stearic acid chemical treatment and matrix of unsaturated polyester resin.

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