Predicting the best hardness of Banana-Bamboo-Glass fiber reinforced Natural fiber composites using Taguchi method

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***Abstract* - Over the past twenty to thirty years, composite materials is being used extensively in many applications. This is due to proven fact that composite materials possess high stiffness, high strength to weight ratio and low thermal expansion. Now-a-days, natural fibers are being used in the field of composites as reinforcement. The reason behind this fact is that natural fibers are environmental friendly, non-abrasiveness, low cost of raw material. In this present experiment, the best hardness of the Bamboo-Banana-Glass fiber reinforced composite is to be predicted using Taguchi method.**

***Keywords:* Natural fiber, Hardness, Taguchi method**

Nomenclature used:

1. BM – Bamboo fiber
2. BN – Banana fiber
3. G – Glass fiber
4. OA – Orthogonal Array
5. S/N ratio – Signal to Noise ratio

I. INTRODUCTION

Engineers and researchers have started to focus on the natural fiber composites which are also known as biocomposites. The natural fiber composites are composed of natural fibers reinforced in a polymer matrix and this polymer matrix is nothing but the resin. Natural fibers possess more superior environmental properties when compared to other conventional fibers. A keen interest is shown towards natural fiber reinforced polymer composites both in terms of industrial applications and fundamental research. Natural fibers such as jute, sisal, abaca, pineapple and coir are now-a-days used as reinforcements in composites. The most commonly used natural fiber is the banana fiber, sisal fiber, bamboo fiber and coir fiber.

The reinforcement of banana fiber into a rubber matrix increases the hardness of the composite and this can be related to strength and toughness [1]. On the basis of earlier reports, bamboo has 60% cellulose with high content of lignin and its microfibrillar angle is 2-10 degrees which is relatively small. This characteristic property has made bamboo fiber as one of the most popular fiber for reinforcement in variety of matrices. It has been proved that tensile strength showed an increasing trend with the increase in the length of the fiber but the elongation at the break point of the composite is not affected significantly by the length of the fiber [4].

It has been reported that the hybrid composite produced by using bamboo fibers and glass fibers possess good tensile properties and good resistance to chemical treatment [3]. Also bamboo fiber bundles have a potential ability to work as reinforcement with the polymer matrix. The tensile strength of the bamboo fiber bundle is as high as that of jute fiber [2]. Banana fiber with high specific strength can be utilized to produce light weight composites which can be used to manufacture light weight automobile interior parts [6].

Laly.A.Pothan has reported that the tensile strength of banana-glass fiber hybrid composites show a linear increase as the volume fraction of glass fiber is increased [5]. Hoyur and Cetinkaya investigated and have reported that banana-glass fiber biocomposites can be used for indoor and outdoor applications where high strength is not required [7]. It is found that banana fiber reinforced polymer matrix natural is the best natural composites among the various combination, also banana fiber reinforced polymer biocomposites can be used to manufacture automobile seat shells [8].

D.Dash and S.Samanta has reported that bamboo composite laminates are having higher tensile strength and stiffness than jute composites laminates, but not at par the glass fiber reinforced composite, also the compressive strength of bamboo fiber composites is less than the jute fiber composites and glass fiber reinforced composites [9].

It has been reported that as the banana fiber concentration increases the tensile strength of the corresponding composite increases and when the fiber concentration is less, then the matrix and fiber interface shows a weak bonding [1].

Since, the combination of Banana-Bamboo-Glass fiber reinforced epoxy composites is not been used, the present experiment deals with the production and prediction of the best hardness of the Banana-Bamboo-Glass fiber reinforced epoxy composites.

II. EXPERIMENTAL DETAILS

A. *Materials used*

The bamboo fibers, banana fibers, glass Fiber in the form of Chopped Strand Mat (CSM) are used as a reinforcing material. Epoxy resin with a suitable hardener is used as a matrix material.

B. *Method of fabrication*

Hand layup technique is used to manufacture the composite material. Since hand layup technique is economical and simple, this method of composite manufacture is used widely in small and medium scale industries.

C. *Preparation of samples*

A total of four samples, each of 127x13x5mm are prepared as per the Taguchi DOE. The orientation of the first two samples is [0_G, 90_{BM}, 0_{BN}, 0_G] and the orientation of the next two samples is [0_G, 0_{BM}, +45_{BN}, 0_G].

D. *Taguchi DOE*

In the present experimental work, three factors which influence the output to be measured (hardness) are considered. These three factors are set at two levels. These factors are called as control factors. The control factors and levels for this present experiment are given in Table 1. Based on the number of control factors and levels L_4 OA is chosen. The generalized L_4 OA is shown in Table 2. Based on the L_4 OA, a substituted matrix is formed as shown in Table 3. From the Substituted matrix (table 3) it is clear that the first sample is to be prepared by having an orientation of [0_G, 90_{BM}, 0_{BN}, 0_G] with a mixing ratio of 5:1and a curing time of 30min.

Table 1: Control Factors and Levels

ITEM	CONTROL FACTOR	LEVEL 1	LEVEL 2
A	Orientation	[0_G, 90_{BM}, 0_{BN}, 0_G]	[0_G, 0_{BM}, +45_{BN}, 0_G]
B	Mixing Ratio	5:1	10:1
C	Curing Time	30	40

Note: Mixing Ratio is nothing but the Epoxy resin-Hardener mixing ratio.

Table 2: L_4 Orthogonal Array

Expt.No.	A	B	C
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

Table 3: Substituted Matrix

Expt.No	Orientation	Mixing Ratio	Curing Time (minutes)
1	[0_G, 90_{BM}, 0_{BN}, 0_G]	5:1	30`
2	[0_G, 90_{BM}, 0_{BN}, 0_G]	10:1	40
3	[0_G, 0_{BM}, +45_{BN}, 0_G]	5:1	40
4	[0_G, 0_{BM}, +45_{BN}, 0_G]	10:1	30

Fig.1 First sample with [0_G, 90_{BM}, 0_{BN}, 0_G] orientation

Fig.2 Second sample with [0_G, 90_{BM}, 0_{BN}, 0_G] orientation

Fig.3 Third sample with [0_G, 0_{BM}, $+45_{BN}$, 0_G] orientation

Fig.4 Fourth sample with [0_G, 0_{BM}, $+45_{BN}$, 0_G] orientation

I. RESULTS AND DISCUSSION

The prepared composite materials are tested for its hardness. Rockwell Hardness is determined by using HRL scale and the ball size is 6.35mm or 1/4 inch. The hardness recorded for the corresponding sample is tabulated as shown in Table 4.

Table 4: Experimental values of hardness

Expt.No.	Orientation	Mixing Ratio	Curing Time	Hardness value (HR_L)		
				1	2	Mean
1	[0_G, 90_{BM}, 0_{BN}, 0_G]	5:1	30	67.52	63.00	65.25
2	[0_G, 90_{BM}, 0_{BN}, 0_G]	10:1	40	75.00	71.80	73.40
3	[0_G, 0_{BM}, $+45_{BN}$,0G]	5:1	40	70.00	85.00	77.50
4	[0_G, 0_{BM}, $+45_{BN}$, 0_G]	10:1	30	90.00	87.50	88.75

Now, we have to find the Signal to Noise ratio for each of the combination as shown in table 3. Taguchi has postulated three types of objective function. They are:

1. Larger the better
2. Nominal the best
3. Smaller the better

In this experimental, since the aim is to predict the best hardness and naturally hardness should be larger or higher and hence choosing the larger the better type of objective function. The formula to calculate the S/N ratio for this case is as follows:

$$\eta = -10log_{10}\left(\frac{1}{y^2}\right)$$

The S/N ratio for each experiment can be computed by using the MINITAB version 16.0 software. The computed S/N ratio from MINITAB software is shown in Table 5.

Table 5: S/N ratios values

Orientation	Mixing ratio	Curing time	Hardness	SNRA1
[0_G, 90_{BM}, 0_{BN}, 0_G]	5:1	30	65.25	36.2916
[0_G, 90_{BM}, 0_{BN}, 0_G]	10:1	40	73.40	37.3139
[0_G, 0_{BM}, $+45_{BN}$, 0_G]	5:1	40	77.50	37.7860
[0_G, 0_{BM}, $+45_{BN}$, 0_G]	10:1	30	88.75	38.9634

Table 6 shows the Response values of the control factors at each level.

Table 6: Response Table

Factor	Level 1	Level 2	Max – Min	Rank
Orientation	36.80	38.37	1.57	1
Mixing ratio	37.04	38.14	1.10	2
Curing time	37.63	37.55	0.08	3

The main effects plot for S/N ratios is given in Figure 5.

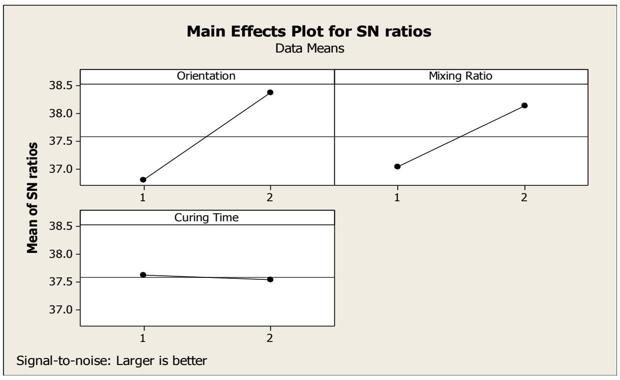

Figure 5: Main effects plot for S/N ratios

From the main effects plot for S/N ratios, it is clear and obvious that the combination A_2 (orientation of [0_G, 0_{BM}, $+45_{BN}$, 0_G]), B_2 (mixing ratio of 10:1) and C_1 (curing time of 30 minutes) would give the best hardness.

II. CONCLUSION

- The hardness of the banana-bamboo-glass fiber reinforced epoxy hybrid composite is superior to the hardness of composites made from banana, bamboo individually.
- The combination A_2, B_2, C_1 would give the best hardness.
- It is to be noted that orientation of fibers and the mixing ratio play a vital role in predicting the hardness of the composite material.

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