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Evaluation of tensile strength of hybrid fiber (jute/gongura) reinforced hybrid polymer matrix composites

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Abstract. The polymer matrix composites attract many industrial applications due to its light weight, less cost and easy for manufacturing. In this paper, an attempt is made to prepare and study of the tensile strength of hybrid (two natural) fibers reinforced hybrid (Natural + Synthetic) polymer matrix composites. The samples were prepared with hybrid reinforcement consists of two different fibers such as jute and Gongura and hybrid polymer consists of polyester and cashew nut shell resins. The hybrid composites tensile strength is evaluated to study the influence of various fiber parameters on mechanical strength. The parameters considered here are the duration of fiber treatment, the concentration of alkali in fiber treatment and nature of fiber content in the composites.

1. Introduction

Polymer Composites are materials having two or more chemically distinct constituents. The discontinuous phases are embedded in the continuous phase to form a material composite. The discontinuous phase is called as reinforcement, and the continuous phase are called as the matrix. If the matrix material is polymeric, then the composites are called as polymer composites (PMC) [1, 2]. The reinforcing phase can either be fibrous or non-fibrous, and if the fibers are derived from plants or natural resources, they are called natural-fibers. The fiber reinforced polymers (FRPs) consist of fibers of high strength and modulus embedded in or bonded to a matrix with a distinct interface between them [3]. In this form, both fibers and matrix retain their physical and chemical identities. In general, fibers are the principal load-carrying members, while the matrix keeps them at the desired location and orientation. The matrix also acts as a load transfer medium between the fibers, and protects them from environmental damage [4, 5].

Hybrid composites are materials that are made by combining two or more different types of fibers or different types of matrix. Viswanath et al. investigated the tensile behavior of coir fiber reinforced hybrid polymer matrix composites. The authors used CNSL and general purpose resin for getting hybrid polymer. Vimalanand et al. explored the tensile, and flexural strength of aloe vera fiber

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reinforced hybrid polymer matrix composites. Venkatachalam et al. studied the flexural behavior of coir fiber reinforced hybrid polymer matrix composites. Authors [6-8] used CNSL and general purpose resin for getting hybrid polymers. An attempt is made in this work to have hybrid (two) fibers as reinforcement and hybrid polymer as the matrix. Taguchi's L9 orthogonal array was used for determining different combination of specimens. This material composition will attract engineering markets for the good environmental friendly feature and improved mechanical properties.

2. Experimental

Natural fibers are eco-friendly, available in abundant on earth and are cheaper. The jute fiber and the gongura fibers were chosen as reinforcement material. Jute is the cheapest and most abundantly available natural fibers. Gongura are cultivated for its fiber in south India. Polyester resin was used to bind fiber as a matrix in polymer composite. To improve the biodegradation of the polymer composite, about 25% of the natural resin extracted from cashew nut shell (cashew nut shell resin-CNSL) is mixed with polyester resin. Hand layup technique was followed for the preparation of composites. The fibers are knitted as shown in the figure 1. After the knitting of fiber in the mold, the resin mixture is poured into the mold cavity.

The molds were kept at room temperature for curing. Different composite specimens are prepared according to the composition specified in the table 1 and is presented in figure 2.

Figure 1. Fiber knitted mold.

Figure 2. Composite specimens.

Table 1. Specimen composition.

Sample No	Fiber Parameter		
	Duration of Fiber treatment (Hrs)	**Fiber treatment % of NaOH concentration**	**Fiber Hybridization-proportion of fibers**
1	6	5	3 Jute-1 Gongura
2	6	10	2 Jute-2 Gongura
3	6	15	1 Jute-3 Gongura
4	12	5	2 Jute-2 Gongura
5	12	10	1 Jute-3 Gongura
6	12	15	3 Jute-1 Gongura
7	24	5	1 Jute-3 Gongura
8	24	10	3 Jute-1 Gongura
9	24	15	2 Jute-2 Gongura

Figure 3. Tensile Testing and fractured specimens.

2.1. Tensile tests
After the curing process, the specimen is tested for its tensile strength that is shown in figure 3. Tensile testing is carried out using Instron machine according to ASTM D 638–76. The load vs displacement curves were obtained, and the modulus were calculated.

3. Results and discussions

3.1. Analysis of tensile strength
The results obtained from tensile testing of composites with hybrid fibers as reinforcement and hybrid polymers as matrix are given in table 2.

Table 2. Yield strength, ultimate tensile strength and young's modulus for the various compositions of specimens.

Sample No	Yield strength (MPa)	Ultimate Strength (MPa)	Young Modulus (MPa)
1	1.35	3.24	152.53
2	0.6	2.86	178.306
3	0.54	2.18	150.235
4	0.909	2.647	176.214
5	0.89	2.243	154.563
6	0.649	3.323	156.902
7	0.769	2.113	145.578
8	0.89	3.561	168.431
9	0.802	2.345	142.854

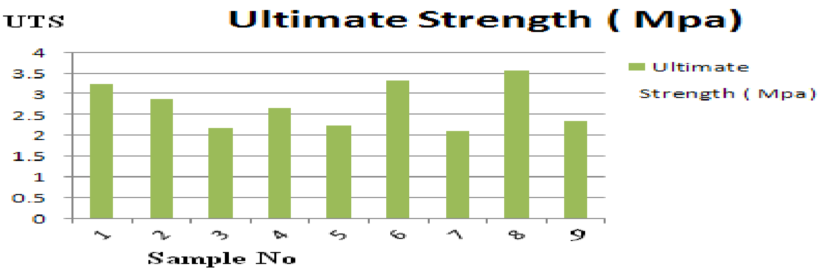


Figure 4. Comparative analysis of ultimate strength of composite specimens tested.

A comparison analysis of the ultimate strength of various specimens is plotted and shown in the figure 4. The study on ultimate strength of specimens showed that composites with the following composition exhibited good ultimate strength

- 3:1 proportion of Jute and Gongura fiber, treated for 6 Hours with 5% NaOH solution
- 3:1 proportion of Jute and Gongura fiber treated for 12 Hours with 15% NaOH solution

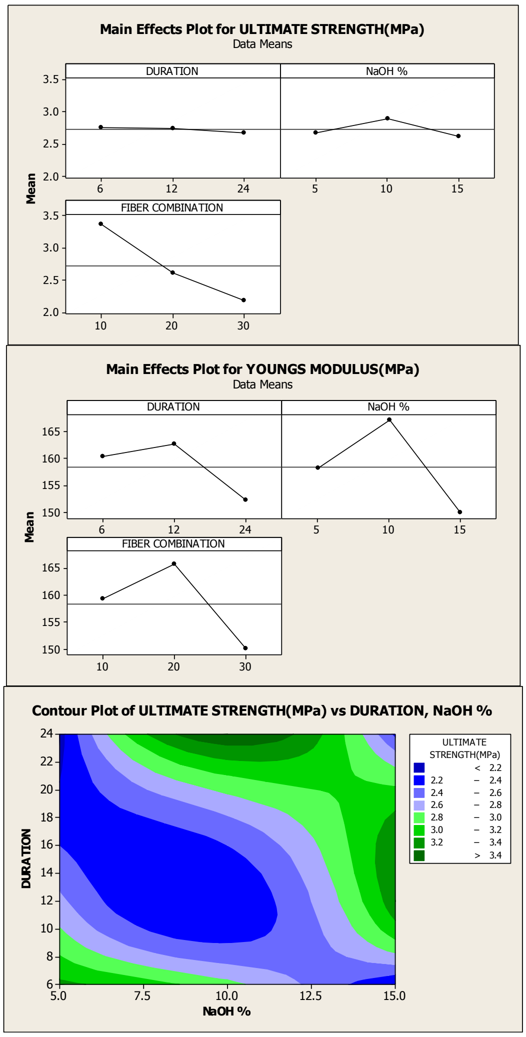
- 3:1 proportion of Jute and Gongura fiber treated for 24 Hours with 10% NaOH solution

Hence, it is decided to study the influence of each fiber parameters on tensile strength by ANOVA techniques to find the optimal material composition.

3.2. Optimization of Composite proportion using ANOVA Techniques

The ANOVA technique is used to evaluate the influence of fiber parameters on tensile strength. The Minitab software is used to carry out ANOVA.

3.2.1. Study on influence of various fiber parameters on ultimate strength, yield strength, and Young's modulus. The main effects plots, presented in figure 5, for ultimate strength shows that the duration of fiber treatment has little influence on ultimate strength and fiber treatment with 10% concentration exhibits higher ultimate strength. But the increase in fiber combination reduced the ultimate strength. The same is conferred in yield strength study also. In case of modulus of elasticity, the strength is good for the specimen with the fiber treatment for 12 hours, 10% concentration NaOH solution and medium fiber combinations.



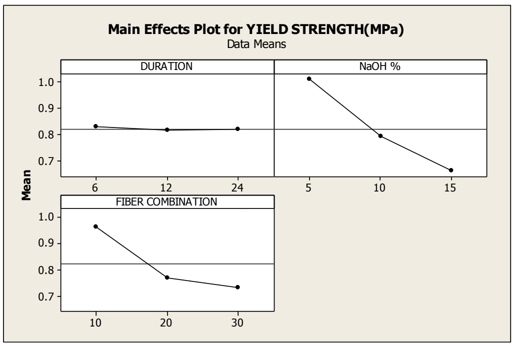
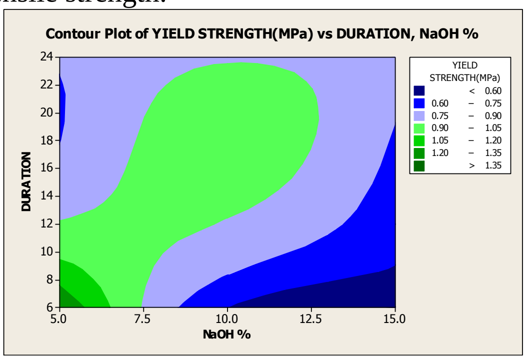


Figure 5. Influence of fiber parameters on tensile strength.



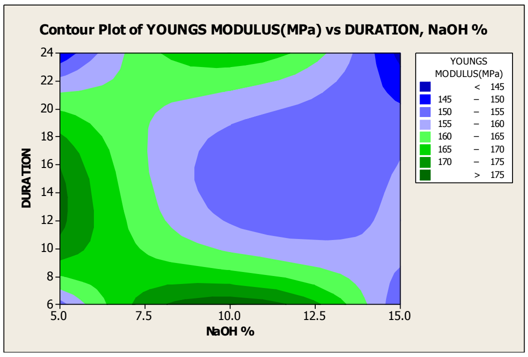


Figure 6. Contour plots of influences of and NaOH solution concentration on tensile strength.

3.2.2. Influence of treatment duration and NaOH solution concentration on tensile strength. The contour plots, shown in figure 6, are extracted to study the influences of various fiber treatment solution concentrations and duration of treatment on tensile strength. It was found from the plot that the tensile strength decreases with increase in treatment duration and alkali solution concentration.

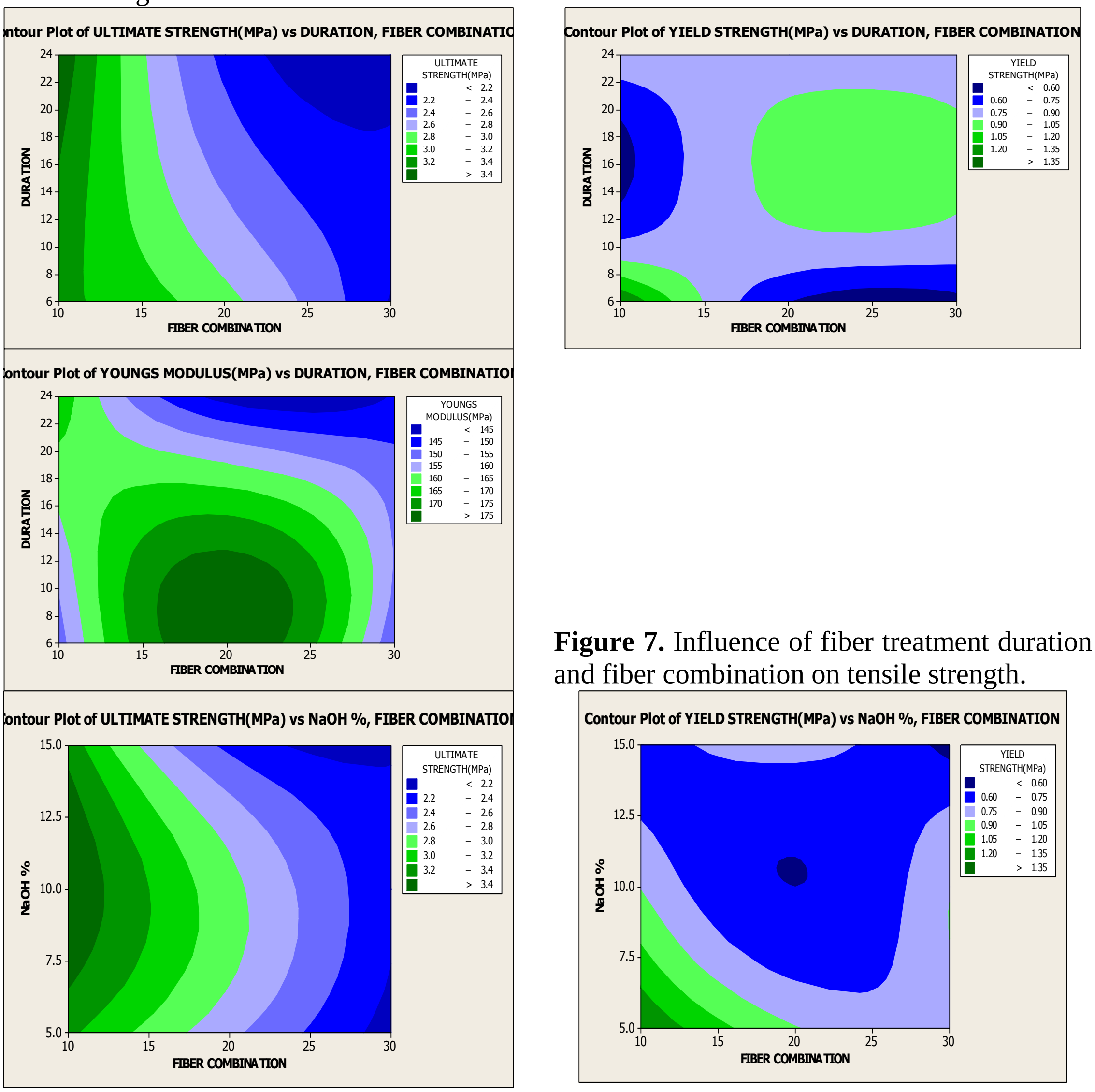


Figure 7. Influence of fiber treatment duration and fiber combination on tensile strength.

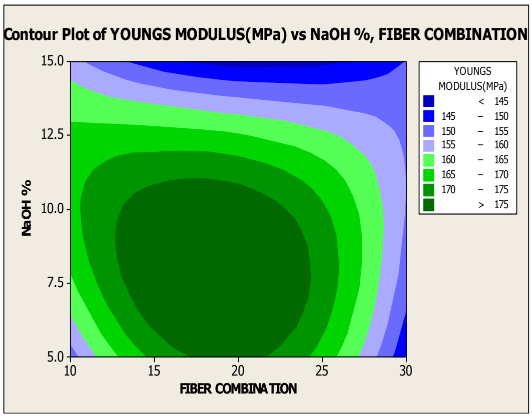


Figure 8. Influence of NaOH concentration and fiber combination on tensile strength.

3.2.3. Influence of fiber treatment duration and fiber combination on tensile strength. The contour plot, presented in figure 7, between fiber treatment duration and fiber combination, reveals that the increase in duration of treatment will increase the tensile strength whereas an increase in fiber combination proportions will decrease the tensile strength.

3.2.4. Influence of NaOH concentration and fiber combination on tensile strength. During the study on influence of NaOH concentration and fiber combination on tensile strength, it is found that increase in NaOH concentration will increase the tensile strength. An increase fiber concentration will reduce the tensile strength of the material that is shown in figure 8.

3.2.5. Regression equations. Regression equations were obtained via ANOVA analysis in MINITAB software with which we can find the approximate tensile strength of the composite with other fiber combination, alkali concentration and duration of treatment.

The regression equation is

- YIELD STRENGTH(mpa) = 1.40 - 0.00041 DURATION - 0.0346 naoh % - 0.0115 FIBER COMBINATION
- ULTIMATE STRENGTH(mpa) = 4.04 - 0.00491 DURATION - 0.0051 naoh % - 0.0598FIBER COMBINATION
- YOUNGS MODULUS(mpa) = 183 - 0.507 DURATION - 0.81 naoh %- 0.458 FIBER COMBINATION

4. Conclusion

As the present industry requirement is environment friendly materials, a new composite material with hybrid polymer and hybrid fiber is developed, and its properties are evaluated. It was concluded from the analysis that fiber treatment duration and concentration of alkali solution had to be chosen as 12 hours and 10% respectively, and hybridization of fiber should be low for the better tensile strength

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