

Flexural analysis of palm fiber reinforced hybrid polymer matrix composite

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Abstract. Uncertainty in availability of fossil fuels in the future and global warming increased the need for more environment friendly materials. In this work, an attempt is made to fabricate a hybrid polymer matrix composite. The blend is a mixture of General Purpose Resin and Cashew Nut Shell Liquid, a natural resin extracted from cashew plant. Palm fiber, which has high strength, is used as reinforcement material. The fiber is treated with alkali (NaOH) solution to increase its strength and adhesiveness. Parametric study of flexure strength is carried out by varying alkali concentration, duration of alkali treatment and fiber volume. Taguchi L9 Orthogonal array is followed in the design of experiments procedure for simplification. With the help of ANOVA technique, regression equations are obtained which gives the level of influence of each parameter on the flexure strength of the composite.

1. Introduction

Environmental Pollution, which is mostly caused by non-biodegradable plastics, is driving researchers all over the world to produce a bio-degradable substitute. Bio composite is one of the most promising solutions to environmental pollution. There has been an increase in the production of materials made from natural resins worldwide [1]. Practical applications of Bio composites include interior automotive components and housings for notebook computers [2]. The growth in the use of natural fibers has led to a decrease in the carbon dioxide in the atmosphere [3]. Bio degradability and disposability are the most important aspects of hybrid composites. But, Renewable Polymers being more sensitive to moisture provide poor gas barrier properties which leads to reduction in the mechanical properties of the composite [4].

Synthetic fibers are costly and the production of these fibers is generally associated with large carbon footprint. Natural fillers are more economic and eco-friendly alternative. The main disadvantages of using natural fibers as reinforcement are the moisture absorption and poor adhesion between the fiber which is hydrophilic and the matrix which is hydrophobic. Poor adhesion between the fibers and the matrix leads to reduction of mechanical properties [5]. Various treatments that have

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been employed to improve the fiber matrix adhesion are bleaching, peroxide treatment, de-waxing, vinyl grafting, alkali treatment, isocyanate treatment, acetylation and treatment with coupling agents [6].

Low concentration alkali treatment has led to the increase in mechanical, physical and thermal properties of jute fibers. Alkali treatment also increased the hydrophobicity of the fibers which lead to better fiber matrix adhesion [7]. Alkali treatment has also led to an increase in the tensile and flexural strengths of Kenaf fibre reinforced polypropylene composites [8].

Goulart et al. studied the mechanical behaviour of palm fiber reinforced polypropylene composites and concluded that the reinforcement of palm fibers to the matrix increased the flexural strength and modulus when compared to pure polypropylene [9].

The tensile, flexural, thermal stability and biodegradation properties increased up to 50% of the fiber weight and then started to drop [10]. Venkatachalam et al. studied the effect of reinforcement of natural fibers such as jute and aloe Vera on the mechanical properties of the composite and concluded that the reinforcement of natural fibers increases the tensile and flexural strength of the polymer hybrid matrix composite [11-13]. They have used Taguchi L9 array in the design of experiments procedure for simplification. Also Venkatachalam et al investigated the influence of various factors on flexural strength of coir fibre reinforced hybrid polymer matrix composite [11].

In this work, hybrid polymer is used as matrix. The primary constituent of the hybrid polymer is General purpose resin and the secondary constituent is Cashew Nut Shell Liquid. Palm fiber which is known for its high strength is used as the reinforcement material. The fiber is treated with NaOH solution. The parameters which have been varied are alkali concentration, alkali treatment duration and fiber volume. The flexural test is carried out with the help of INSTRON Testing machine. Analysis of variance (ANOVA) is a statistical technique which is employed to find the influence of parameters such as soak time, alkali treatment and fiber volume on the flexural strength of the composite. The main advantages of ANOVA are random variability and robust design. ANOVA analysis is performed using MINITAB software.

2. Experimental procedure

In this work, naturally occurring fibers on the branches of palm tree are used as reinforcement. The fibers are treated with Sodium Hydroxide solution (shown in figure 1). The NaOH concentrations used are 5%, 15% and 25%. The duration of treatment considered are 6, 12 and 24 hours. 3 sets of hybrid polymers are prepared with CNSL concentration being 5%, 15% and 25%. The prepared samples are shown in figure 2.



Figure 1. Treated fibers.



Figure 2. Prepared samples.

Table 1 shows the Taguchi L9 array for design of experiments procedure. 9 samples are prepared for each concentration of CNSL (5%, 15%, and 25%). Flexural test is performed on all 27 specimens

using INSTRON TESTING MACHINE. Figure 3 illustrates the sample undergoing flexural test and figure 4 presents the tested samples.

Table 1. Taguchi L9 array for design of experiments.

Sample No.	NaOH Concentration (%)	Fibre volume (%)	Soak Time (hrs.)
1	5	0.444	6
2	5	0.89	12
3	5	1.34	24
4	10	0.89	6
5	10	1.34	12
6	10	0.444	24
7	15	1.34	6
8	15	0.444	12
9	15	0.89	24

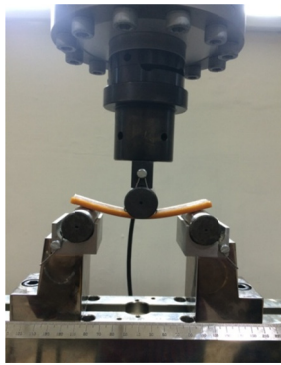


Figure 3. Sample undergoing flexural test.



Figure 4. Samples after completion of test.

3. Results and discussions

Table 2 elucidates the Ultimate Flexural Strength of the 27 specimens.

Table 2. Ultimate flexural stress (MPa).

Sample No	Ultimate Flexural Stress (MPa)		
	5% CNSL	15% CNSL	25% CNSL
1	24.73	19.53	3.42
2	25.59	20.47	4.4
3	26.47	21.47	3.74
4	25.45	19.37	2.98
5	26.03	21.19	3.52
6	24.6	19.38	3.39
7	26.26	21.33	3.66
8	24.34	19.09	3.38
9	25.69	20.35	3.41

3.1. Main effects plot

The main effects plots are shown in figures 5-7 which illustrate the level of influence of different parameters on the Ultimate Flexural Stress of the composite. The fiber volume is directly proportional to the Ultimate flexural stress and also has the highest influence over other parameters. The optimum fiber volume for Ultimate Flexural stress is 1.34%.

For Composites with 5% CNSL Concentration, there is a reduction in the Ultimate Flexural Stress when the alkali concentration is increased from 5% to 15%. The increase in the Flexural Stress when the alkali concentration is further increased to 25% is negligible. The optimum alkali concentration is

5%. There is a reduction in the Ultimate Flexural Stress when the alkali treatment duration is increased from 6 to 12 hours. However, there is a considerable increase in the Ultimate Flexural Stress when the alkali treatment duration is further increased to 24 hours, hence the optimum alkali duration is 24 hours.

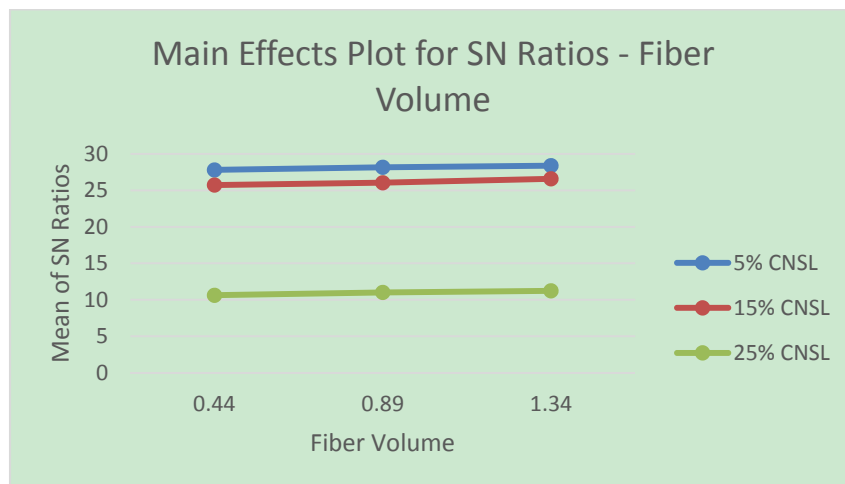


Figure 5. Main effect plot for signal to noise ratio - fiber volume.

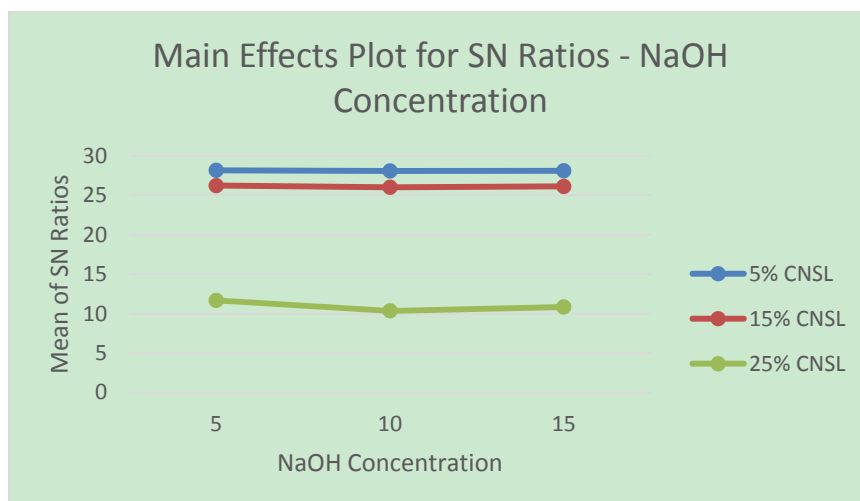


Figure 6. Main effect plot for signal to noise ratio - NaOH concentration.

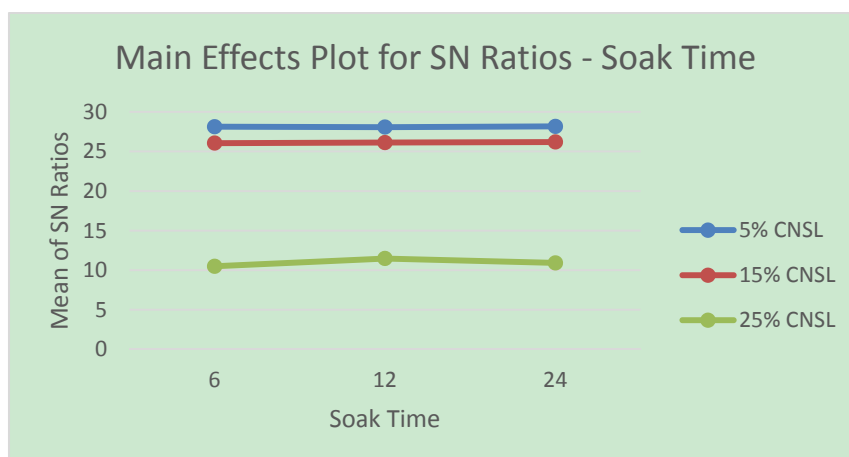


Figure 7. Main effect plot for signal to noise ratio – soak time.

On the other hand for hybrid matrix composites with 15% and 25% CNSL concentration, it has been observed that fiber volume is directly proportional to the Ultimate Flexural stress and the optimal fiber volume is 1.34%. When the NaOH concentration is increased from 5% to 10% there is a decrease in the Ultimate Flexural Stress. However, there is an increase in the Flexural Stress when alkali concentration is increased to 15%. Therefore, the optimum alkali concentration is 5%.

In the case of composites with 15% CNSL concentration the Ultimate Flexural Stress is directly proportional to soak time. Thus, the optimum soak time is 24 hours. On the contrary for 25% CNSL concentration composites, there is an increase in the Ultimate Flexural Stress when the soak time is increased from 6 hours to 12 hours. There is a substantial decrease in the Ultimate Flexural Stress when the alkali treatment duration is increased to 24 hours. Therefore the optimum soak time in this case is 12 hours.

3.2. Regression equation

Regression equations are obtained which enable us to find the Ultimate Flexural Stress values for different values of parameters such as alkali concentration, fiber volume and treatment duration. Equations (1)-(3) present the regression equations for 5%, 15% and 25% CNSL concentration composite respectively.

$$\text{Flexural Stress (MPa)} = 23.8 - 0.0167 \text{ NaOH \%} + 1.89 \text{ Fiber Volume} + 0.00825 \text{ Soak time} \quad (1)$$

$$\text{Flexural Stress (MPa)} = 18.2 - 0.0233 \text{ NaOH \%} + 2.23 \text{ Fiber Volume} + 0.0172 \text{ Soak time} \quad (2)$$

$$\text{Flexural Stress (MPa)} = 3.61 - 0.0370 \text{ NaOH \%} + 0.271 \text{ Fiber Volume} + 0.0046 \text{ Soak time} \quad (3)$$

NaOH-Concentration of alkali solution; Fiber Volume-Volume percentage of palm fibers; Soak time-Duration of alkali treatment in hours

4. Conclusion

In a series of studies on mechanical behaviour of palm fibre reinforced hybrid polymer matrix composite, authors made an attempt to study the flexural strength of the composites. ANOVA technique is employed to study the level of influence of fibre parameters on flexural strength. The three regression equations obtained from ANOVA analysis gives the level of influence of these fibre parameters on flexural strength.

On an average there is an 8.5% increase in the overall Ultimate Flexural Strength, when the fibre volume is increased from 0.44% to 1.34%. Likewise, when the duration of alkali treatment is varied, a small increment of 0.5664% in the Ultimate Flexural Stress is observed. On the other hand when the alkali concentration is varied, there was a negligible decrease of 0.633% in the Ultimate flexural stress is perceived. It is concluded that Fiber volume has the highest influence on the Ultimate Flexural Stress whereas the duration of alkali treatment and alkali concentration have a lesser impact on the Ultimate Flexural Stress.

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