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Post-stress Induced Tensile Property Modification of Jute Polymer Composite

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Abstract. Jute fiber reinforced composites is an emerging area in composite science because of their low cost, low density and high specific properties. These composites are biodegradable and non-abrasive. In this research work, 10 and 15 wt% raw jute fiber reinforced polyester composite were made in hand lay-up method. Then each type of composite was again fabricated but this time, different levels of post-stress of 2.5, 5 and 10 kPa were applied to observe their effect. Later on, the developed composites were subjected to the tensile test. All composites had higher tensile properties (tensile strength and tensile modulus) than pure polyester. Tensile properties were observed to increase with increasing post-stress for same weight percentage of jute fiber.

Keywords: Jute fiber composite, Polyester, Post-stress, Tensile strength

1. Introduction

Over the past few decades, polymers have replaced many of the conventional materials in various applications. This is due to the advantages polymers offer over conventional materials. The most important advantages of using polymers are the ease of processing, productivity, lightweight and cost reduction. Property of polymers can be modified and enhanced by reinforcing fillers. Today synthetic polymers are combined with various reinforcing fillers in order to improve the mechanical properties and obtain the characteristics demanded in actual applications [1-3]. Fibers are most commonly used as fillers. Natural fibers have recently attracted the attention of scientists and technologists because of the advantages that these fibers provide over conventional reinforcement materials, and the development of natural fiber composites has been a subject of interest for the past few years [4].

Growing attention nowadays is being paid to jute fiber. Jute fiber is one of the most common natural fiber since it is produced on a large scale in the Indian sub-continent, especially Bangladesh, and has a minimal effect on the environment because of its biodegradable properties [5,6]. Jute is the cheapest lignocellulosic long vegetable bast fiber and abundantly available in South Asia. But Jute has an affinity towards moisture. Due to its hygroscopic nature, dimensions of the filament, as well as its mechanical and electrical properties, are changed [7]. So proper wetting of the two phases is naturally poor which does not conduct the desired properties in composite materials.

Various types of polymers are used to make composites that are normally used in engineering applications. Normally they are classified as Thermoplastic and Thermoset polymers. Thermoset polymers outperform thermoplastics in a number of areas, including mechanical properties, chemical resistance, thermal stability, and low raw material cost.

In this research work thermoset composites were made under different amount of pressure. This was done by applying certain amount of weight when the resin started to coagulate during the composite fabrication process which is called post-stress. Mechanical properties, including the tensile strength, flexural strength, tensile modulus and flexural modulus of the composites, also declined with the increase of the void content which is created by air bubbles. Applying post-stress ensures the removal of air bubbles and optimizes the fiber to resin ratio [8]. At the same time, better interaction between resin and fiber is also occurred. A highly compact product can be obtained by applying molding pressure. Because of this, mechanical properties are reported to improve [9].

Mechanical properties were observed to increase for coir fiber-polyester composite under various post-stress or molding pressure [10]. On the other hand secondary effect of molding pressure was observed for piassava–polyester [11] and chopped bagasse–polyester composites [12]. The aim of this project is to find the effect of post-stress on tensile properties of jute fiber reinforced polyester composites.

2 Experimental

2.1 Materials and methods

At first, washed and sun-dried jute fiber was collected from the local market. Jute fiber used in this research was untreated.

As matrix material unsaturated polyester resin and Methyl Ethyl Ketone Peroxide hardener were used. Various amount (10 wt% and 15 wt%) of continuous jute fiber aligned in the lower mold. Then the upper mold was placed on it. Polyester resin was mixed with 2 wt% hardener. This mixture was placed in the vacuum chamber for removing primary air bubbles. This vacuumed mixture was poured into the mold. After 10 minutes, when the mixture started to coagulated, a post-stress (2.5, 5 & 10 kPa for individual sample) was applied. Each post-stress (2.5, 5 & 10 kPa) was applied for both 10 wt% and 15 wt% jute fiber reinforced composites. Composites without any post-stress (0 kg load) were also prepared for 10 wt% and 15 wt% jute fiber. For 10 wt% fiber content, 3 test specimens were prepared for each post-stress. The same approach was carried out for 15 wt% jute fiber composites. Pure polyester sample was also made.

Figure 1. Post-stress applied during fabrication of composite.

2.2 Tensile test
Universal testing machine was calibrated. Tensile properties in the longitudinal direction of jute fiber reinforced polymer matrix composites were determined according to ASTM D638 at a cross speed of 3 mm/min. Tensile properties of pure polyester sample were also measured with same standard.

Figure 2. Tensile test specimen.

3. Results and Discussion
3.1 Tensile strength
The average tensile strength of pure polyester was found to be 30.45 MPa. According to the composition of their main chain, polyesters can be of different types and their tensile strengths also vary according to their compositions [13].

Normally, tensile strength of jute fiber reinforced polymer matrix composite increases with increasing pressure during fabrication. Pressure plays a significant role to obtain high tensile strength because of the good interface bonding between fiber and resin. This is due to the fact that the increase in pressure makes the fiber and resin very well compressed and resin was forced into various passages of the jute fibers [14].

Here is the tensile strength of 10 wt% jute fiber reinforced composite for various post-stresses. Standard deviation of 3 test sample of each post-stress are also given in table 1.

Table 1. Tensile strength of 10 wt% jute polyester composites for different post-stresses.

Jute fiber content (wt%)	Post-stress (kPa)	Tensile strength (MPa)	Standard Deviation
10	0	61.23 63.3 64.85	1.48
	2.5	80.4 82.69 84.63	1.73
	5	88.56 90.94 92.25	1.52
	10	99.25 102.42 103.65	1.85

To draw the stress-strain diagrams, we took only median value from the tensile strength of 3 specimens of each post-stress. Tensile strength of 10 wt% jute fiber reinforced polymer matrix composites increase with increasing post-stress. Here tensile strength increased from 60.53 MPa (at no post-stress) to 102.42 MPa (at 10 kPa post-stress). For other post stress conditions like 2.5 kPa and 5 kPa, average tensile strengths were 82.69 MPa and 90.94 MPa respectively.

Tensile stress vs. tensile strain curves for 10 wt% jute fiber reinforced polyester prepared under various post-stresses are plotted along with the tensile stress vs. tensile strain curve of pure polyester in figure 3.

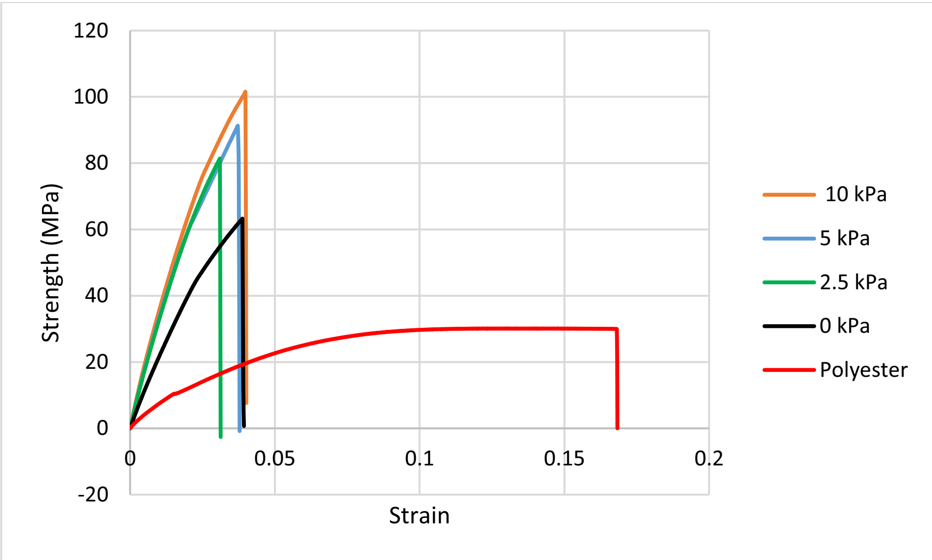

Figure 3. Tensile stress vs. strain curves for 10 wt% jute fiber reinforced PMC under different post stresses.

Again tensile strength of 15 wt% jute fiber reinforced composites are given below with standard deviation.

Table 2. Tensile strength of 15 wt% jute polyester composite for different post-stress.

Jute Fiber Content (wt%)	Post-stress (kPa)	Tensile Strength (MPa)	Standard Deviation
		71.8	
	0	73.77	1.1
		74.39	
		78.96	
	2.5	79.20	1.13
		81.47	
15			
		90.59	
	5	91.13	1.62

		94.27	
		108.1	
	10	110.47	2.28
		113.66	

To draw sress-strain curves, only median value was taken for each set of specimens. Result of tensile test of 15 wt% jute fiber reinforced polyester composites under 0 kPa, 2.5 kPa, 5 kPa & 10 kPa post-stress are pronounced. Under 0, 2.5, 5 & 10 kPa post-stress tensile strength of the samples were 73.77, 79.20, 91.13 and 110.47 MPa respectively. For 15 wt%, jute fiber reinforcement effect of post-stress on tensile strength can easily be visualized.

Tensile stress vs. tensile strain curves was also plotted from above data and it's shown in figure 4.

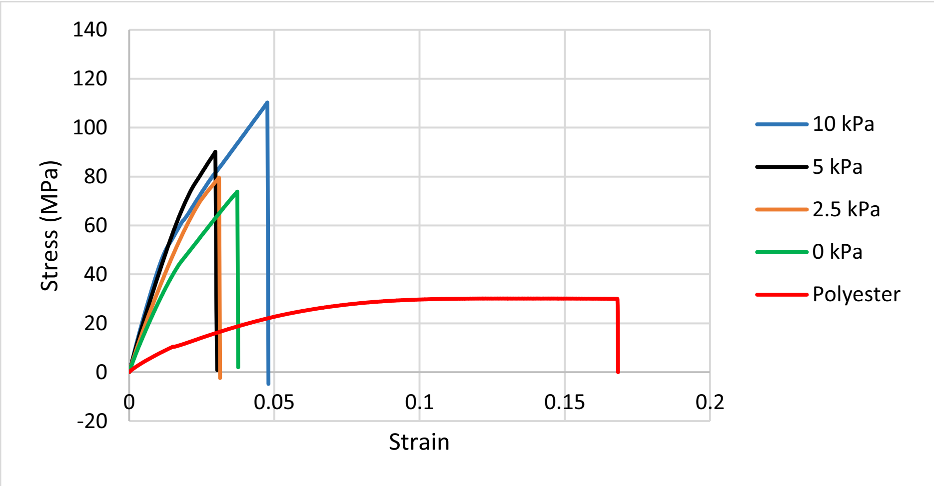

Figure 4. Tensile stress vs. strain curves for 15 wt% jute fiber reinforced PMC under different post-stresses.

Similar effect was found by E. Shakouri et al. carried a research for wood-plastic composite with changing die pressure [15].

3.2 Tensile modulus

The effect of post-stress is shown in figure 6 (for 10 wt% jute fiber) and figure 7 (for 15 wt% jute fiber). Tensile modulus increased with increasing post-stress. Normally, post-stress ensures sufficient wetting of fiber. Voids can also be reduced by using high external pressure[16,17]. At the same time, post-stress gives better fiber to resin ratio which enhances the tensile modulus of composite. E. Shakouri at el. also found that tensile modulus also increases with die pressure [15].

For 10 wt% jute fiber reinforced composite, tensile modulus was calculated by averaging the value from 3 test specimen of each post-sress. A table of average tensile modulus of 3 test specimen of each post-stress and their standard deviation given below.

Table 3. Average tensile modulus of 10 wt% jute polyester composite for different post-stress.

Jute Fiber Content (wt%)	Post-stress (kPa)	Tensile Modulus (MPa)	Average Tensile Modulus (MPa)	Standard Deviation
10	0	2468 2465 2480	2471	3.56
	2.5	5385 5396 5387	5392	3.74
	5	6122 6133 6126	6127	4.54
	10	7405 7415 7413	7411	4.32

For pure polyester, average tensile modulus is 746 MPa. Average tensile modulus of 10 wt% jute fiber reinforced composite (without post-stress) increases to 2471 MPa. Tensile modulus also improves with increasing post-stress. For 2.5 kPa, 5 kPa and 10 kPa post-stress, average tensile modulus values are 5392 MPa, 6127 MPa and 7411 MPa, respectively.

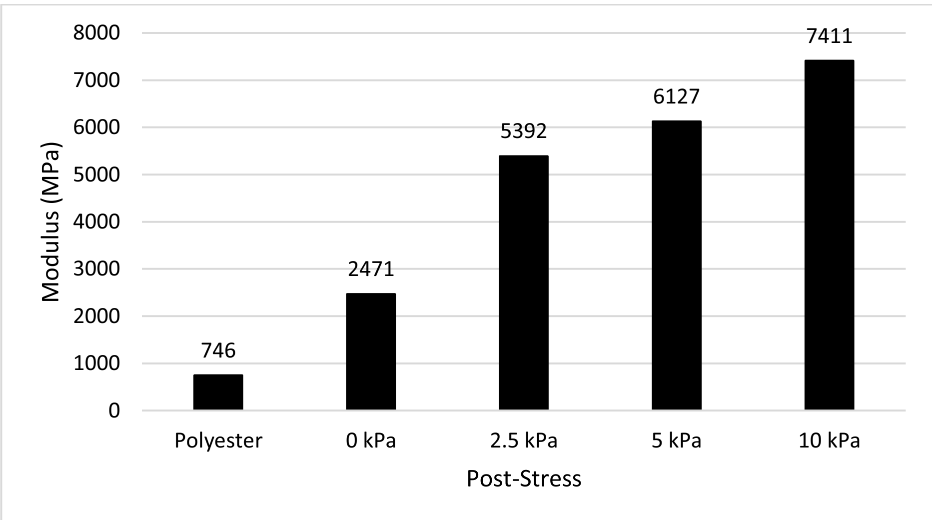

Figure 5. Tensile modulus vs. post stress bar chart for 10 wt% jute fiber reinforced composite.

Average tensile modulus and standard deviation were calculated for each post-stress of 15 wt% jute fiber composite. The results are given in table 4.

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Table 4. Average tensile modulus of 15 wt% jute polyester composite for different post-stress.

Jute Fiber Content (wt%)	Post-stress (kPa)	Tensile Modulus (MPa)	Average Tensile Modulus (MPa)	Standard Deviation
15	0	4710 4716 4713	4713	2.45
	2.5	5055 5060 5062	5059	2.87
	5	6480 6476 6469	6475	4.55
	10	7902 7898 7909	7903	4.56

With increasing fiber content, tensile modulus also increases. For 15 wt% jute fiber reinforced composite, average tensile modulus is 4713 MPa. Here tensile modulus also increases with increasing post-stress. For 10 kPa post-stress, maximum average tensile modulus (7903 MPa) is observed.

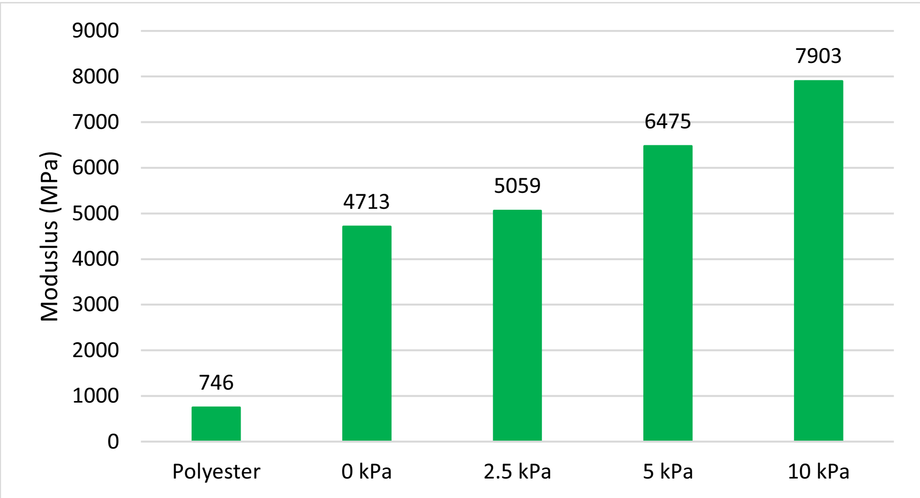

Figure 6. Tensile modulus vs. post stress bar chart for 15 wt% jute fiber reinforced composite.

4. Conclusion

In this research work, different levels of post-stresses (0, 2.5, 5 & 10 kPa) were applied to various percentages (10%, 15%) of fiber reinforcement during the fabrication of composites. The effect of post-stress on tensile strength and modulus of raw jute fiber reinforced polyester has been investigated.

- Tensile properties of composites with 10 wt% and 15 wt% of jute fiber are higher than the pure polyester sample. Tensile properties of composite increases with increasing fiber content. So it may be concluded that with increasing jute fiber content up to a certain amount causes improved tensile properties.
- Tensile properties (tensile strength and tensile modulus) of composite sample without any post-stress are lower than composite samples fabricated by applying post-stress. Tensile strength and modulus increased with increasing post-stress. Higher tensile properties for increasing post-stress were due to better impregnation of the fibers by the resin, which certainly occurred as a higher pressure is applied during the fabrication of composite.

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