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# Study on the effect of aluminium addition on the physical properties of unsaturated polyester/ jute composites

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## Abstract

Jute fibre along with Al particle reinforced unsaturated polyester composites having different filler (both Jute and Al were in equal wt.%) loading *viz*. 2, 5, 10 and 15 wt.% were fabricated by compression molding technique. Structural investigation is done through SEM. The physical testing like density measurement, void % measurement and gel point calculation has been done and optimum result obtain for UP/Jute/Al composites at the filler content of 10 wt.%. At 10 wt.% of filler content the UP/Jute/Al composites contain lower void content and cure at a controllable manner. Due to this feature of the UP/Jute/Al composites, these composites may be shown good mechanical property.

**Keywords:** Aluminium, jute, natural Fibre, physical property.

## Introduction

Thermosetting polymers, such as polyesters and epoxies, exhibit several useful characteristics viz., high glass transition temperature, high specific modulus and specific strength, creep resistance and good solvent resistance coupled with ease of processing due to the high degree of cross-linking between individual polymer chains which make them the most important matrix materials for fiber-reinforced composites (FRCs). Unfortunately, this cross-linking also makes these materials inherently brittle with poor resistance to crack initiation and propagation, in comparison to other engineering plastics. So it is important to make a composite in a way that makes a composite in a controllable manner with optimum cross link. However, highly cross linked thermosetting polymers are incapable of extensive shear yielding. This improvement of physical and mechanical property can be done by rubber additions. Thus, significant improvements in the physical and mechanical properties of thermosetting polymers are required to improve the damage tolerance and long-term durability of structures and materials based on these polymers, especially FRCs (Pearson and Yee, 1989 ; Hwang et al., 1989). Initially, these approaches have involved the addition of micron-sized soft (elastomeric or thermoplastic) or rigid (glass or ceramic)

particles into the polymer matrix (Zhang and Singh, 2004 ; Singh et al., 2002). In the first approach, micron-sized rubber particles are dispersed in the polymer matrix to enhance the overall mechanical properties of the polymer (Zhang and Singh, 2004 ; Singh et al., 2002 ; Lebaron et al., 1999). Many investigations has been done by reinforcing nano and micron size metal, metal oxide and ceramic particle which improves many physical, mechanical, thermal and electrical property of thermosetting polymer composites. It was investigated that micron- and nanometer-sized Al particles could enhance the physical and mechanical properties of unsaturated polyester (UP) resin with maintaining the deagglomeration (Lebaron et al., 1999). The mechanical properties of commercial thermosetting (epoxy) resin have been enhanced by incorporation of Cu particle were studied (Mohammed, 2011). Mohammed, (2014) reported the effect of sun flow and water-melon seed shells powder on the mechanical and physical properties of UP matrix. Another approach of improvement of mechanical and physical behaviour of the composites by incorporation of particle and natural fibre within polymer matrix was reported (Singh et al., 1995).

The objective of the present investigation is to fabricate polymer composites by incorporation of natural fibre (jute) as reinforcement along with metal powder (Al) within thermosetting (UP) matrix which can be used as an ideal candidate for structural applications. Moreover, the investigation extends a scope to develop an economical and natural fibre reinforced polymer based composite with a balance between strength and toughness and to correlate its property with the microstructure of the composites.

**Materials and Methods**

Procured Jute fibre was cut into shorter length ranging from 4-5 mm. The UP resin of GP grade, methyl ethyl ketone peroxide, MEKP (catalyst) and cobalt naphthenate (accelerator) were bought from M/s A K B Agencies, Kolkata. The 98% pure Al powder (size ~ 74 µm) was procured from Loba chemie. The fabrication of the UP matrix composites were done by compression molding technique. A metal mold of dimensions (140 × 120 × 5) mm was used for casting the UP matrix composites. A release agent (WAXPOL) was applied at the inner surfaces of the mold for quick and easy release of the fabricated composites. A measured amount of filler (*viz.*, Jute fibre, Al powder) was uniformly blended with the UP resin by mechanical stirring. The mix was then degassed under vacuum and then mixed with the accelerator and catalyst (2% each). It was then poured in the mold and allowed to cure at room temperature for 24 hours followed by 4 hours post curing in an oven at 100°C. A pressure of 1 kgf is applied during the cold curing process. The microstructural features of the composites were examined by using Scanning electron microscope (Hitachi S-3400N) with the operating voltage of 15 kV.

The theoretical density of composite material can be calculated using the formula given by Agarwal and Broutman (Agarwal and Broutman, 1990).

$$\rho_{ct} = \frac{1}{\frac{W_f}{\rho_f} + \frac{W_m}{\rho_m}} \quad (1)$$

where, W and ρ represent the weight fraction and density respectively. The suffix f, m and ct stands for fibre, matrix and composite material, respectively. The actual density ($\rho_{ce}$) can be calculated experimentally by simple water immersion technique. The volume fraction of the voids ($V_v$) in the composite is calculated by following equation:

$$V_v = (\rho_{ct} - \rho_{ce}) / \rho_{ct} \quad (2)$$

**Fig. 1. Image of the fabricated composite.**

The curing characteristics of the resin-catalyst-accelerator with different fillers, determined by the gel time test. In this test, a measured amount (100gm) of the resin thoroughly mixed with catalyst accelerator and filler combination is poured into a standard test tube. First accelerator and different filler (fibrous and particulate) mixed by stirring with resin then mixed with catalyst. The time count starts from the time of the catalyst addition. The resin viscosity increases very rapidly owing to the increasing number of cross links by curing reaction. The time at which rapid increases in cross link ensures is called the gel point. The time is measured by probing the surface of the reacting mass with a clean wooden applicator. Stick in every 15 seconds until the reacting material no longer adheres to the end of the clean stick.

## Results and Discussions

### SEM Analysis

Fig. 2(a) and Fig. 2(b-c) shows the micrograph of UP and UP reinforced composites respectively. The SEM micrographs clearly show the uniform dispersion of the fillers (marked with white circles) within the UP matrix. A uniform distribution of both Al (5 wt.%) and Jute fibers (5 wt.%) as a filler was observed in Figure 2.(c). The microstructure reveals a clear signature of dispersion of Al particles with Jute fibre within UP matrix.

### Physical testing

### Density and void content measurement

In Figure 3. the void % is shown with variation of filler content irrespective of fillers. The density value and void content is tabulated in table 1. Here it is observed that at 10 wt.% of filler content the increment of void percentage is less as compared to the increment of filler. These trend reflects better deposition of the filler at 10 wt.% of filler content that will help to obtain a good property of the composites. For 15 wt.% of filler loading, the detected void percentage is significant that refers to irregular deposition of the filler at 15 wt.% of filler content, that may affect the property of the composites. It is also observed that for UP/Jute composites the trend of increment of void content is maximum.

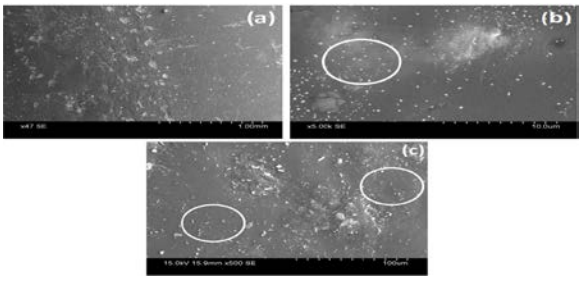


**Fig. 2. (a), (b), (c) shows the SEM image of UP, UP/Al and UP/Jute/Al composite.**

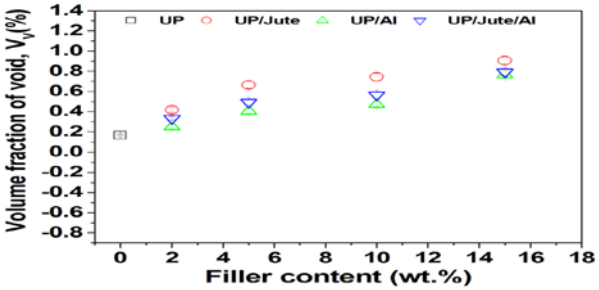


**Fig. 3. Variation of void content along with filler addition for Al filled jute fibre reinforced UP based composites.**

As, the fibers are discontinuous the dispersion will not be better leading to the void contents. Another reason of void is that the fibers are untreated resulting inferior adhesion which leads to the void creation between fibre and matrix interface. The same reason is applicable for particulate filler also. Bulk density and void content for different UP based composites are tabulated in table 1.

**Table 1. Bulk density and void content of the composites for different Al filled Jute fibre reinforced UP based composites.**

| Composites | Theoretical density (gm/cc) | Experimental density (gm/cc) | VFV (%) |
|---|---|---|---|
| UP | 1.20 | 1.198 | 0.167 |
| 2% UP/Al | 1.214 | 1.211 | 0.248 |
| 5% UP/Al | 1.235 | 1.230 | 0.404 |
| 10% UP/Al | 1.271 | 1.265 | 0.472 |
| 15% UP/Al | 1.309 | 1.299 | 0.763 |
| 2% UP/Jute | 1.202 | 1.196 | 0.416 |
| 5% UP/Jute | 1.205 | 1.197 | 0.664 |
| 10% UP/Jute | 1.210 | 1.201 | 0.744 |
| 15% UP/Jute | 1.214 | 1.203 | 0.906 |

| | | | |
|---|---|---|---|
| 2% UP/Jute/Al | 1.208 | 1.204 | 0.332 |
| 5% UP/Jute/Al | 1.220 | 1.214 | 0.492 |
| 10% UP/Jute/Al | 1.240 | 1.233 | 0.565 |
| 15% UP/Jute/Al | 1.261 | 1.251 | 0.793 |
| **VFV: Volume fraction of voids** | | | |

**Gel time calculation**

Figure 4. shows the variation of gel time of different composites with their different composition. It is observed that, the gel time decreases significantly with increase in the filler loading. This is attributed to the more retardation of chain movement along with filler addition, that affect in the cross linking. Another reason may be with increase in the filler loading, the liquid obtains more surfaces for secondary nucleation which results in its faster gelation. For UP/Jute composites the decrease in gel time is more significant. It may be due to the more surface area of fibre than particulate filler. That is followed by UP/Jute/Al composites and lesser decrease is observed for UP/Al composites. For UP the gel time is 361 seconds. The gel time variation with different filler loading and filler content is tabulated in Table 2.

**Conclusions**

The void % increases with filler addition. Metal powder and jute are reinforced so first and foremost reason of void generation is interfacial interaction between matrix and fillers. The gap contents as a hole between the matrix and filler interface which increases with increase in the filler content. This may be responsible for microcrack, pull out and deboning occurrence during mechanical testing failure. The sequences in a decreasing manner for void content as UP/Jute, UP/Jute/Al and UP/Al. This result is attributed in the other properties. Gel time result shows that along with filler addition the gel time decreases. Due to filler addition filler accrues more surfaces for secondary nucleation and the molecule are become stable very fast with cross linking. The UP/Jute/Al composite of 10 wt.% filler content shows an optimum result for void content and gel time. This may be responsible for making these composites good candidate both from properties and financial point of view.

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