

## Effect of nano-clay mineral addition on tribological properties on jute/epoxy composite by using design of experiments approach

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Polymer nano-composites have received immense attention in the recent years, as many of these materials present promising properties like high flexural strength, improved pressure barrier properties and depleting flammability. Polycarbonate is one of the most interesting ones, due to characteristic properties like high toughness and strength, excellent ballistic strength and good visual clarity. It could be expected that the addition of relatively low percentages of nano-reinforcements will result into remarkable improvements in mechanical and thermal properties. In this work, (Cloisite 25A) nano clay, Araldite LY 556 epoxy, HY 951 hardener were used to prepare the matrix at various blends 0%, 4%, 8%, and 10% by using hand layup method. And further detailed analysis was performed to study the tribological property of various percentage nano-clay (Cloisite 25A) loaded epoxies, with inclusion of jute fiber using Taguchi's technique. For this purpose, the test samples were prepared according to the ASTM: G99 standard, and the test was carried out with the assistance of Pin-on- Disc machine. For this experimentation L16 orthogonal array was used to evaluate the tribological property with four control variables such as % of nano-clay content, normal load, sliding velocity and sliding distance at each level on friction co-efficient along with wear rate. From the obtained results the combination of factors greatly influenced the process to achieve the minimum wear and co-efficient of friction for jute fiber reinforced laminates were analyzed. The microstructure behavior of the fabricated samples were investigated with assistance of Scanning Electron Microscope (SEM), particle distribution was analyzed throughout the matrix by Transmission Electron Microscopy (TEM) analysis before and after the wear test. ANOVA analysis revealed the nano clay contribution on coefficient of friction and wear of the jute fiber laminate composites.

### Introduction

The present day scenario is attracting the polymer nanocomposites with greater interest both in industry and academics because of significant improvement in the properties when compared to base matrix or traditional composites [1]. The important structural characteristics which give unique properties to nanocomposites are the nanosize and a huge interfacial sur-

face area of the nanofillers.

Since 1980s, advantageous properties of polymer nanocomposites were realized at the Toyota research laboratories where they studied nylon-6 based composite system with nanoclay as the reinforcement material to improve the toughness and heat resistance of nylon-6 [2]. Since then, a large quantity of research work has been carried out on polymer composites system using nanoclays and nanoparticle fillers of metallic or nonmetallic type and remarkable enhancements and benefits in several properties have been reported. The intriguing fact is that the properties which were observed in nanocomposites were never anticipated. Although, the broad group of nanocomposite polymer materials have been widely investigated and fairly understood, the development of thermoset polymer based nanocomposites which also belong to this group, still remains a challenge. This is mainly because of the difficulty in uniform dispersion of nanofiller particles in the thermoset polymer matrix.

### Methods

Poly(vinylidene fluoride) (PVDF) nanocomposites with different content of nanoclay were prepared by melt-intercalation method. The tribological behaviors of the PVDF/clay nanocomposites against 45# carbon steel ring were evaluated on a block-on-ring type (M-2000) wear tester. Transmission electron microscopy (TEM) observation showed the dispersion of nanoclay in PVDF matrix. X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) analysis found that nanoclay incorporation induced the PVDF crystal form to transform from  $\alpha$ - to  $\beta$ -phase, and hence increased the materials polarity. Differential scanning calorimetry (DSC) analysis verified that the crystallinity of the nanocomposites decreased with the increasing nanoclay content. Nanoclay at 1–2 wt.% was effective for improving the tribological properties of neat PVDF, because the nanoclay at the low content may act as the reinforcing element to bore load and thus decrease the plastic deformation. The nanocomposite containing 5 wt.% nanoclay exhibited relatively high wear, weak compatibility between nanoclay and PVDF and also the decreased crystallinity may be responsible for the result.

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## Result & Discussion

### Density of the nanocomposites

Density is an important property in several weight sensitive applications. In many applications, polymer composites are replacing traditional or conventional metals and metal based composites mainly for their low densities. Density of a composite depends on the relative proportion of matrix and the reinforcing filler. There is always a difference between the measured and the theoretical density values of a composite due to the presence of empty space and hole. These empty spaces or voids majorly affect the performance of the nanocomposites. A larger void content indicates lower value of fatigue resistance, greater susceptibility to water penetration and weathering

### Variation of density as a function of filler content for epoxy and vinyl ester nanocomposites.

It is evident from Figure 1 that the density values for Epoxy-oMMT nanocomposite increases with the nanofiller loading content. However, the increase in the density was small in Epoxy-oMMT nanocomposites. With the addition of 7 wt.% oMMT, the density of Epoxy increases by 1% but the density of Epoxy-TiO<sub>2</sub> increases by 10%. This is due to higher density of TiO<sub>2</sub> as compared to oMMT. The density of Vinyl ester is higher than that of Epoxy due to the presence of bromine. Bromine is a heavy atom and there are four bromine atoms bonded in one molecule, and this result in density being higher for brominated Vinyl ester. Similar trends are noticed for Vinyl ester-oMMT nanocomposites.

### Micro-hardness of the nanocomposites

Hardness is one of the significant factors that control the wear property of the composite samples. In this work, the data obtained for micro-hardness of the Epoxy and Vinyl ester composites with different types of weight percentage of fillers loading have been obtained. Figure 2 shows the experimental results of measurements of micro-hardness of pure Epoxy and Epoxy-oMMT, Epoxy-TiO<sub>2</sub>, pure Vinyl ester and Vinyl ester-oMMT nanocomposite samples with different weight percentage of nanofiller content.

### Micro-hardness of epoxy and vinyl ester nanocomposites.

MMT nanofiller into Epoxy, Vinyl ester and TiO<sub>2</sub> to Epoxy results in significant improvement in hardness of nanocomposites. In general, mechanical properties of nanocomposite depend primarily on following things namely filler content, filler size and shape, the degree of interfacial interaction or between the filler particles and polymer matrix and degree of dispersion of nanofiller within the polymer matrix. The improvement in the hardness property of the nanocomposites may be attributed to the intercalated and exfoliated clay platelets structure .

### Mechanical properties

The measured tensile properties of Epoxy-oMMT, Epoxy-TiO<sub>2</sub> and Vinyl ester- oMMT nanocomposites are shown in Table 2. It is noticed from the Table 2 that, lower values of tensile strength and tensile elongation are obtained for nanocomposites than those of pure Epoxy and Vinyl ester. However, the Young's moduli are evidently enhanced by the addition of fillers.

### Mechanical properties of polymer nanocomposites.

The tensile strength and fracture toughness of a nanocomposite samples depend upon the filler shape, size and amount which is mixed with the polymer matrix, the strong bond between the nanofiller and the polymer matrix, the robustness of the polymer matrix and the filler. Nanofillers affect the mechanical properties in accordance with their packing characteristics, size and interfacial interaction. The highest three dimensional packing of filler reflects the size distribution and shapes of the particles. The space between the particles is implicit to be packed with polymer matrix and no empty spaces or air bubbles are expected. With this condition, for a given nanocomposite, the matrix amount is fewer and it acts as separate segment or compartment to hold up tensile load. Properties of nanocomposites are manipulated by the individual properties of the filler and the matrix and also the filler-matrix interface.