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Technical Report

Effect of nanomodified polyester resin on hybrid sandwich laminates

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ABSTRACT

Effect of nanoclay modified polyester resin on flexural, impact, hardness and water absorption properties of untreated woven jute and glass fabric hybrid sandwich laminates have been investigated experimentally. The hybrid sandwich laminates are prepared by hand lay-up manufacturing technique (HL) for investigation. All hybrid sandwich laminates are fabricated with a total of 10 layers, by varying the extreme layers and wt% of nanoclay in polyester resin so as to obtain four different combinations of hybrid sandwich laminates. For comparison of the composite with hybrid composite, jute fiber reinforced composite laminate also fabricated. X-ray diffraction (XRD) results obtained from samples with nanoclay indicated that intergallery spacing of the layered clay increases with matrix. Scanning electron microscopy (SEM) gave a morphological picture of the cross-sections and energy dispersive X-ray spectroscopy (EDS) allowed investigating the elemental composition of matrix in composites. The testing results indicated that the flexural properties are greatly increased at 4% of nanoclay loading while impact, hardness and water absorption properties are increased at 6% of nanoclay loading. A plausible explanation for high increase of properties has also been discussed.

1. Introduction

In recent years, there has been a renewed interest in hybridization of natural fibers with synthetic fibers as reinforcement in composite materials. In hybrid composites, two different fibers are combined in a single matrix in order to compensate the drawback of one fiber by the other. These hybrid composite materials provide high specific stiffness, strength and lightweight which makes them attractive materials for secondary load bearing applications [1–3]. The properties of composites are significantly related to the properties of composite constituents, i.e., fiber, matrix and the interphase between them [4].

The utilization of nanoclay as fillers in polymer composites has attracted considerable attention due to the improved mechanical, thermal, flame retardant and gas barrier properties of the resulting composites. Because of the extremely high surface to volume ratios and the nanometer size dispersion of nanoclays in polymers, they exhibit improved properties as compared to the pure polymers.

Clays used in preparing polymer–clay nanocomposites is a montmorillonite (MMT) layered aluminoclay in the family of smectite clays. Each layer consists of two sheets of silica tetrahedral with an edge shared octahedral sheet of either aluminoclays or magnesium clays [5]. These layers are hold together with a layer of charge-compensating cations such as Li^+, Na^+, K^+, and Ca^+. Generally the surface of the clay needs to be modified to improve the wettability and dispersibility of hydrophilic clay. The charge compensating cations can be easily exchanged with surfactants including alkyl ammonium cations.

Since natural fibers offer significant cost advantages and benefits associated with processing as compared to synthetic fibers such as glass, nylon and carbon, during the last few years, a series of works have been done to replace the conventional synthetic fiber with natural fiber composites [6–8]. However, mechanical properties of natural fiber composites are much lower than those of synthetic fiber composites. Hence, use of natural fiber alone in polymer matrix is inadequate in satisfactorily tackling all the technical needs of a fiber reinforced composite. In an effort to develop a superior but economical composite, a natural fiber can be combined with a synthetic fiber in the same matrix material so as to take the best advantage of the properties of both the fibers [9–12]. Incorporation of nanoparticles (clays, carbon nanotubes, etc.) in the matrix system for fiber reinforced composites has been recently studied by several groups [13–15]. Kornmann et al. [16] developed glass fiber reinforced laminates with a matrix of layered clay/epoxy system and their results revealed that flexural strength of the composites is increased due to the presence of the nanoparticles in the matrix. Fraga et al. [17] studied the immersion of isophthalic polyester/glass composites in water at 80 °C. They

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observed that a degradation of the fiber/matrix interphase due to oligomer extraction and hydrolysis of silane coupling agent of the fibers. Huang and Netravali reported that the flax fibers/soy-protein nanoclay green composites produces better tensile and flexural properties compared to conventional composites [18].

Miyagawa et al. [19] studied the effect of biobased clay/epoxy nanocomposites as a matrix for carbon fiber composites. They reported that the addition of nanoclay has no effect on the flexural strength and modulus. Sundaram et al. [20] studied the mechanical properties of FRP with nanocomposites in the combination of polyester resin, E-glass fiber and nano-montmorillonite (nanoclay). It results in increase of tensile strength, percent of elongation and yield strength, moderate increase in Poisson ratio and reduced area. Chandradass et al. [21] have studied the hybridization effect of nanoclay dispersion in vinyl ester–fiber composites and they have observed that mechanical, thermal and vibration properties were improved in nanoclay dispersed composites over vinyl ester–glass fiber composites. Jeena Jose Karippal et al. [22] have studied the mechanical properties of epoxy/glass/nanoclay hybrid composites. They concluded that the mechanical properties such as ultimate tensile strength, Youngs modulus, flexural strength, flexural modulus, and interlaminar shear strength of the hybrid composites increased with increase in nanoclay loading up to 5 wt%. Levent Aktas and Cengiz Altan [23] have presented a novel method to prepare prepregs from aqueous dispersion of nanoclay, and used this method to investigate the utility of natural nanoclay with E-glass/waterborne epoxy composites. They concluded that 13.5% decrease in interlaminar shear strength and the flexural stiffness was observed to increase by more than 26% over the range of nanoclay loading. Faguaga et al. [24] studied the effect of water absorption on the dynamic mechanical properties of composites used for windmill blades. They found that nanoclay incorporated unsaturated polyester matrix system showing a detrimental effect in degradation resistance, probably because of the degree of hydrophilicity of the selected clay which produces a weak interphase with the polymeric matrix. Meguid and Sun [25] investigated the tensile debonding and shear properties of composite interfaces reinforced by two different homogeneously dispersed nanofillers, carbon nanotubes and alumina nanopowder. The results revealed that varying the weight percentage of the nanofillers into the epoxy matrix adhesive favorably influences the debonding and shear characteristics of the interface. Arun et al. [26] investigated the Morphology of nanoclay dispersed in resin and suspended in acetone thro scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Further, they used vacuum assisted wet lay-up (VAWL) process for the inclusion of nanoclay in conventional fiber reinforced composites and this specimen has shown improvement in compressive strength for nanoclay enhanced fiber composites and also they developed an elastic–plastic model to predict the compressive strength of fiber reinforced composites based on the matrix properties and the predicted values are close to the experimental results. Hossain et al. [27] performed Flexure tests on the GRPC, 0.1–0.4 wt% CNF-filled GRPC showed up to 49% and 31% increase in the flexural strength and modulus, respectively, compared to the conventional one with increasing loading of CNFs up to 0.2 wt% and the quasi-static compression properties. SEM evaluation revealed relatively less damage in the tested fracture surfaces of the nanophased composites in terms of matrix failure, fiber breakage, matrix–fiber debonding, and delamination, compared to the conventional one. Further, the effects of carbon nanofibers on tensile and compressive properties of hollow particle filled composites were studied by Momchil Dimchev et al. [28]. Their results revealed that that addition of 0.25 wt% carbon nanofibers results in improvement in tensile modulus and strength compared to similar syntactic foam compositions (without nanofibers).

The mechanical and thermal properties of non-crimp glass fiber reinforced clay/epoxy nanocomposites were investigated by Emrah Bozkurt et al. [29]. They reported that that clay loading has minor effect on the tensile properties and the Flexural properties were improved by clay addition due to the improved interface between glass fibers and epoxy and Incorporation of surface treated clay particles increased the dynamic mechanical properties of nanocomposite laminates. Hassan Mahfuz et al. [30] stated that in a sandwich structure, the core plays an important role in enhancing the flexural rigidity and by controlling the failure mechanisms. They made attempt to investigate performance of the sandwich by strengthening the core by infusing nanoparticles into the parent polymer of the core material (polyurethane foam made from polymeric isocyanate (Part A) and reacting with polyol (Part B)). They observed that the flexural strength of nanophased (core) sandwich composites has been found to be significantly higher than with core materials. Although, the application of glass fabrics is being increased in composite fabrication, there is limited study reporting the properties of glass–jute fiber reinforced sandwich composites. Moreover, up to date there is no study carried out on the characterization of glass–jute fiber reinforced sandwich composites laminates with nanoclay matrix.

In this study, clay/polyester nanocomposite systems were prepared to use as matrix material for fabrication of glass–jute fiber reinforced sandwich composite laminates. The structure of clay and clay containing laminates were investigated by X-ray diffraction (XRD) and scanning electron microscopy (SEM). Flexural, impact, hardness and water absorption behavior of sandwich laminates manufactured with modified clay (OMMT) containing polyester resin were investigated.

2. Materials and methods

2.1. Materials

The plain weave glass fabric 600 g/m^2 supplied by Binani industries limited, Mumbai, India is used as reinforcing materials for preparation of hybrid composites. Isothalic polyester was used as resin. Methyl ethyl ketone peroxide and cobalt naphthanate were used as catalyst and accelerator respectively. Woven jute fabric 22×12 (22 yarns of Tex 310 in warp direction and 12 yarns of Tex 280 in weft direction, per inch) having an average weight of 367 g/m^2 and an average thickness of 0.8 mm is directly procured from Kolkata, West Bengal, India. The commercial nanoclay used in this study is provided by Southern Clay Products, Na^+ Montmorillonite (unmodified having CEC 92.6 meq/100 g clay).

2.2. Preparation of organic montmorillonite (OMMT)

Na^+–MMT was dispersed in distilled water with some concentration and octadecyl trimethyl ammonium chloride was vigorously stirred for a few times at a given temperature. The white precipitates were washed with hot distilled water (above 80 °C) until no bromide ion was detected with a 0–1 mol/l $AgNO_3$ solution. The product obtained was then vacuum-dried at 70 °C to a constant weight and then ground and screened with a 300-mesh sieve to get the modified clay (OMMT).

2.3. Preparation of nanocomposites

Molding box was prepared with the required size and use wax polish and polyvinyl alcohol which acts as a releasing agent. Mixture of OMMT nanoclay and polyester resin (2, 4, and 6 wt% of clay) is applied over the fiber mat of 300 cm square for a setting period of 1 h. After curing the laminate was removed from the