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INFLUENCE OF NANOPARTICLES ON IMPACT PROPERTIES OF SANDWICH GFRP COMPOSITES

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ABSTRACT

The effect of nanoclay content on the impact properties of glass fibre reinforced, polyester sandwich composite laminates is investigated. Nine different combinations of jute and polystyrene foam core sandwich composites with nanoclay (montmorillonite) are developed by hand lay-up manufacturing techniques (HL).The samples were tested for charpy impact strength and measurement showed that the impact strength is greatly increased, over the range of nanoclay loading. A plausible explanation for high increase of properties has also been discussed.

Keywords: Nanocomposites, Sandwich Composite, Montmorillonite and Hand-Layup

1. Introduction

Sandwich structures are commonly used in aerospace and automobile structures, since they offer efficient energy absorption systems without significant weight penalties. By varying the core, the thickness and the material of the outer face sheet of the sandwich structures, it is possible to attain various properties and desired performance [1–3]. The widely used skin materials are glass reinforced plastic (GRP) and carbon reinforced plastics (CRP). There are many varieties of core materials being in use. Among them, honeycomb, foam, balsa and jute fibre cores are the most widely used [4-7]. For the bonding of skin and core materials, normally two types of adhesive bonding are commonly employed in sandwich construction, i.e., co-curing and secondary bonding. The determination of the sandwich material behavior under suddenly applied loads is normally done with the help of impact tests.

We are entering into the gateway of next generation "nanotechage", where smaller and shorter things will play a big role. Nanotechnology will find its application in energy, medicine, electronics, computing, security and material sciences, etc. Nano clay is the most commonly used tool for the preparation of nanocomposites. Montmorillonite, hectorite, and saponite are the most commonly used layered silicates. Layered silicates have two types of structure: tetrahedral-substituted and octahedral substituted. The main attraction of polymer (Polyester resin) is its high performance-to cost ratio. Polymers can also be easily modified to achieve greatly enhanced properties [8]. With regard to reinforcement effects, considerable research can be found in recent literature on improving impact properties of polymer using various kinds of nano fillers. Polymer nano composites (PNC) are now prepared by different methods, namely, mechanical mixing, shear mixing, Brabender mixing and Hand mixing. It is now well recognized that the use of inorganic fillers is a useful tool for improving mechanical properties of polymer. The Preparation of Organic Montmorillonite and Mechanical Properties of Montmorillonite/Unsaturated Polyester Composites based on fabrication methods have been reported by XU Fang et al. [9]. The formation mechanism of unsaturated polyester – layered silicate nanocomposites based on fabrication methods has been reported by Lepoittevin et al. [10]. Tribological property of the nanocomposite system is studied to assess the influence of nanoclay by Jawahar et al. [11]. The effect of clay intercalation on mechanical properties of polyester nanocomposites was studied by Bharadwaj et al. [12]. The incorporation of nanosize particles with medium-density Polyethylene [13], seed oil based polyester resin [14] and polyester-based polyurethane [15] matrix has lead to better enhancement in mechanical properties. In addition to nanoclay polymers, synthetic fibre is also used in fabrication of fiber reinforced nano composites [16-18]. It is expected that incorporation of nanoclay in polyester resin will also improve the impact properties of sandwich nanocomposites.

The present work describes the application of nanoparticle reinforced polyester resin as matrix for conventional sandwich structure. The very first time an example of sandwich structure in dimension of structural element is presented, consisting of glass fibre

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fabric as a skin, polystyrene foam as a core with a nano clay particle modified matrix containing different amount of unmodified clay (0 wt. %, 2 wt. % 4 wt. % and 6 wt.%). The manufacturing via hand lay-up method and the investigation of impact properties are described.

2. Materials and Methods

2.1 Materials

The plain weave glass fabric 600 g/m^2 are supplied by Binani industries limited, Mumbai, India. Polyester was used as a resin. Methyl ethyl ketone peroxide and cobalt naphthanate were used as catalyst and accelerator respectively. Woven jute fabric 22X12 (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/m2 and average thickness of 0.8mm and GEN-M-01-03002R04 Medium density polystyrene foam sheet in squares 10 mm were used as a core material for sandwich structure. Cloisite Na^+ is a natural, untreated montmorillonite type of clay, supplied by Southern Clay Products Inc. (Gonzales, TX). The specific gravity and mean particle size of Cloisite Na^+ is reported as 2.86 and 6 μm, respectively, by the supplier. According to the x-ray diffraction results provided by the supplier, the gallery spacing of Cloisite1 Na^+ is 11.7A°and having CEC 2.6meq/100 g clay.

2.2 Preparation of nanocomposites

Prepare molding box with the required size and use wax polish and polyvinyl alcohol which acts as a releasing agent. A mixing of clay with polyester resin has been performed by mechanical mixing. Apply the mixture of nanopowder and polyester resin (2, 4, and 6 % wt of clay) over the fiber mat of 300 cm square for a setting period of 12–24 hours. The specimens were carefully cut from the panels using a diamond saw with sufficient allowance for finishing. Final dimensions were obtained by finishing the samples using medium grade emery paper. Table1 shows various combinations of polyester resin, fiber, foam and nanopowder (montmorillonite) in wt. %. Specimen GF0 was prepared in the combination of polyester resin (PR) and glass fibre (FR) only. Specimens SJ0 and SP0 are sandwich structures were prepared by changing the core materials jute and PS foam respectively. Specimen SJ2, SJ4, SJ6, SP2, SP4 and SP6 were prepared by changing the wt. % of nanopowder

Table 1: Combination of Polyester Resin, Fibre, Foam and Nanopowder

Specimen	Combinations	%	Weight (g)
GF0	PR/FR	66.6/33.3	400/200
SJ0	PR/FR/J	66.6/33.3	500/200/50
SJ2	PR/FR/J/NP	66.6/33.3/2	400/200/8
SJ4	PR/FR/J/NP	66.6/33.3/4	400/200/16
SJ6	PR/FR/J/NP	66.6/33.3/6	400/200/24
SP0	PR/FR/F	64/32/4	400/200/20
SP2	PR/FR/F/NP	64/32/4/2	400/200/20/8
SP4	PR/FR/F/NP	64/32/4/4	400/200/20/16
SP6	PR/FR/F/NP	64/32/4/6	400/200/20/24

PR-Polyester resin, FR-Fibre, PS-Foam, J-Jute, NP-Nanopowder

Table 2: Dimensions of the Samples Tested for the Impact Properties

Type of samples	Skin thickness for each side (mm)	Sandwich Width (mm)	Core Thickness (mm)	Span length (mm)
Impact sample	1.75	10	10	127

2.3 Characterization

2.3.1 Impact testing

The Charpy impact strength was determined from the various specimens in accordance with ASTM D6110. The sample dimensions for all types of samples are given in Table 2. Five replicate specimens were used for each test and the data reported are the average of five tests.

2.3.2 Scanning electron microscopy

Scanning electron microscopy is utilized to analyze the impact fractured surfaces of sandwich FRP nanocomposites. Through-the-thickness surfaces of the samples are polished using a series of aluminum oxide lapping films down to 1 μm grit size. The samples were then coated with gold-palladium to render the surface conductive and prevent charging. All specimens were examined with EO MA15 high resolution microscope in secondary electron imaging mode at magnifications of 1000x.In addition to the polished surfaces, the fracture surfaces of the mechanically tested samples are also studied under SEM to identify any change in adhesion between polyester matrix and glass fibers because of nanoclay.

3. Results and Discussion

3.1 Impact properties

The impact properties of PS foam and jute core sandwich nanocomposites are summarized in Table 3. Fig.1 shows the variation of impact strength with respect the specimens used for various combinations of clays. The results indicated that the specimen GF0 is yielding up to 20.35 kJ/m.^{2} In this case the fibre content is 33%. Specimen SJ0 shows better result which yielded at 48.71 kJ/m^2. Impact strength of the specimen contains 2% nanopowder is 50.35 kJ/m.$^{2.}$ Specimen SJ4 shows further increase in impact strength which yielded 52.72 kJ/m^2. This specimen contains 4% nanopowder. The increase in nanopowder addition increases the better bonding between fibre and polyester resin. Further increase in impact strength for a nanoclay loading at 6 wt. % is 59.63 kJ/m^2.

Table 3: Impact Properties of Sandwich FRP Nanocomposites

S. No.	Specimen	Impact strength (kJ/m^2)
1	GF0	20.35
2	SJ0	48.71
3	SJ2	50.35
4	SJ4	52.72
5	SJ6	59.63
6	SP0	24.32
7	SP2	25.68
8	SP4	25.83
9	SP6	36.59

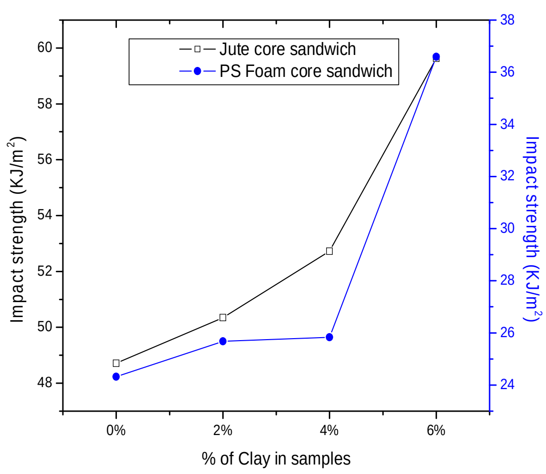

Fig.1 Impact Strength Vs Jute Core and PS Core Sandwich Specimens

The impact strength for PS foam core sandwich composite increased considerably over the range of nanoclay. The impact strength measured for the PS foam core sandwich composite without adding nanoclay is 24.32 kJ/m^2. By addition of 2 wt% of nanoclay, the impact strength increased to 25.68 kJ/m^2. Further the increase of 4 wt% of nanoclay increase the impact strength 25.83 kJ/m^2. Further adding of nanoclay sharply increases the impact strength. The graph indicates that the adding of 6% nanoclay to the specimen increases the impact strength to and 36.21 kJ/m^2.

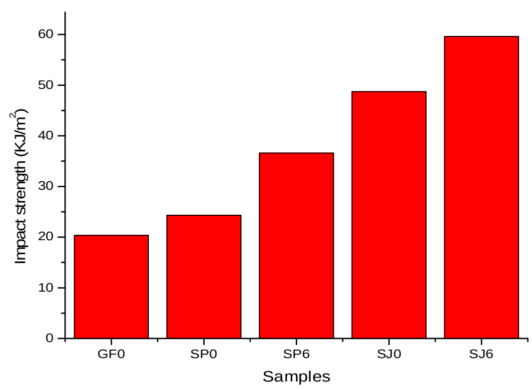

Fig.2 Impact Strength Vs Specimens

3.2 Scanning electron microscopy (SEM) analysis

The scanning electron micrographs of the polished surfaces of the specimens with 0 and 6 wt% nanoclay are shown in Fig. 3. It is often not possible to see individual nanoclay platelets embedded in a polymer matrix using scanning electron microscopy. However, the surface properties observed in polished nanocomposite specimens is an indication of the uniformity of the nanoclay dispersion. In addition, the surface roughness is observed to increase with increasing nanoclay content. These differences in surface topologies are most likely due to the presence of nanoclay clusters. Matrix residues that are observed on the fiber surfaces and between fibers are unequivocal signs of good fiber-matrix adhesion. It is interesting to note that the fiber matrix interface contains more matrix material compared to the specimen without nanoclay. Especially the buildup of matrix material around the fibers is notable. Existence of matrix material around the fibers after fracture indicates that effective fiber-matrix adhesion is maintained after the addition of nanoclay.

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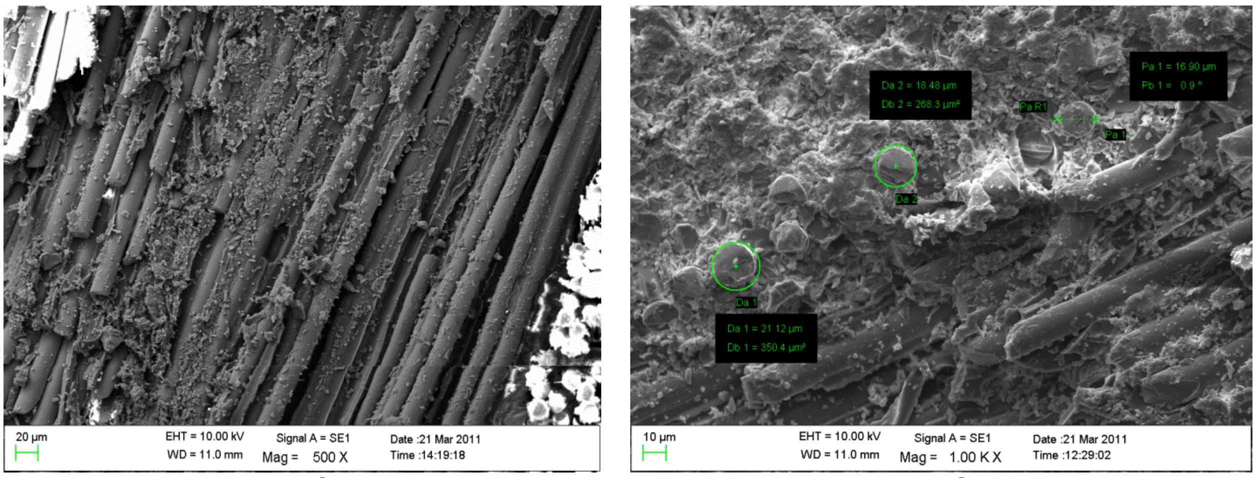

0 % Clay   6 % Clay

Fig.3 Scanning Electron Micrographs of Sandwich Composite Samples with 0, and 6 wt% Nanoclay

4. Conclusion

In this study, the impact strength of jute and PS foam core sandwich nanocomposite in various combinations of nanopowder were investigated at room temperature. The results are summarized as follows.

i. The jute core and PS foam core sandwich nanocomposite has sufficiently high impact strength 23% and 50% improvement of impact strength at 6 wt% increment of nanopowder respectively.
ii. The study of above parameters which can predict the influence of nanoparticle in jute and PS foam sandwich FRP greatly increases impact strength.
iii. Scanning micrographs also revealed improved adhesion of fibers to the matrix material with increasing nanoclay content.

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