

Tensile properties of Polyester/Vinylester Blended Hybrid Nanocomposites Reinforced with Carbon Fibre

P. Hari Sankar¹, Y. V. Mohana Reddy², K. Hemachandra Reddy³

¹Research Scholar, JNTUA, Ananthapuramu-515002, Andhra Pradesh, India

²Department of Mechanical Engineering, G. Pulla Reddy Engineering College, Nandyal Road, Kurnool-518007, Andhra Pradesh, India

³Department of Mechanical Engineering, Jawaharlal Nehru Technological College of Engineering Anantapur, Ananthapuramu-515002, Andhra Pradesh, India
pallahharisankar1@gmail.com.

Abstract: In the present research a polymer blended hybrid nanocomposites are prepared by mixing of two polymers i.e. polyester and vinylester reinforced with carbon fibre and filled with nanoclay. Hybrid nanocomposites was loaded with different clay weight ratios such as 0, 2, 2.5, 3, 3.5, 4, 5, 6 wt.% using principle of hybrid mixtures. By using hand layup technique two different systems such as blend plus clay as the first system and blend plus carbon fibre plus nanoclay is the second system. Tensile strength and tensile modulus were studied on effect of clay loading and miscibility. It was observed that dispersion of clay was uniform and also interactions between fibre and blend were also significantly improved for the second system. Nanoclay wt.% was varied with respect to the blend. It was also observed that tensile strength was increased linearly from 0 wt.% to 3.5 wt.% and then decreases for the first system whereas for the second system linearly increases from the 0 wt.% to 4 wt.% and then decreases. Tensile modulus was optimised at 3.5 wt.% for first system and at 5 wt.% for second system and the reason were attributed that addition of clay increases the modulus but excess clay produces high viscosity that makes difficult to flow the modified mixture.

Keywords: Nanocomposites, Montmorillonite Nanoclay, polyester/ vinylester blend, Tensile Properties..

I. Introduction

The term *nanocomposite* is widely employed to describe an extremely broad range of materials, where one of the components has a dimension on the submicron scale. A better and far more restrictive definition would require that a true nanocomposite be a *fundamentally new material* (hybrid) in which the nanometerscale component or structure gives rise to *intrinsically new properties*, which are not present in the respective macroscopic composites or the pure components [1-5]. The latter definition necessitates that the nanostructure has dimensions smaller than a characteristic scale that underlies a physical property of the material. As for polymer blends, the thermodynamics of mixing for polymers and nanofillers can be described through a balance of entropic and enthalpic factors, which determines whether a pristine or organically modified filler will be dispersed in a polymer. Especially for nanoparticles, favourable thermodynamics of mixing are essential since these ultra small particles are held together with very high apparent attractive forces when immersed in liquid or polymeric media, and purely mechanical methods of mixing are not expected to be effective. Moreover, given the extensive amount of surface area that imposes entropic penalties for adsorbed, physisorbed, or

intercalated macromolecules, the dispersion of nanofillers necessitates sufficiently favourable enthalpic contributions to overcome the entropic penalties. In general, the degree of dispersion of the clay platelets into the polymer matrix determines the structure of nanocomposites [6]. Depending on the interaction between the clay and the polymer matrix, two main idealized types of polymer-clay morphologies can be obtained: namely, intercalated and exfoliated. The intercalated structure results from penetration of a single polymer chain into the galleries between the silicate layers, resulting in formation of alternate layers of polymer and inorganic layers. An exfoliated structure results when the individual silicate layers are completely separated and dispersed randomly in a polymer matrix. Usually exfoliated nanocomposites are preferred because they provide the best property improvements. Carbon fibers are usually combined with other materials to form a composite [7-10]. When combined with a plastic resin and wound or molded it forms carbon-fiber-reinforced polymer (often referred to as carbon fiber) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. However, carbon fibers are also composited with other materials, such as with graphite to form carbon-carbon composites, which have a very high heat tolerance. Most polyester resins are viscous, pale coloured liquids consisting of a solution of polyester in a monomer which is usually styrene. The addition of styrene in amounts of up to 50% helps to make the resin easier to handle by reducing its viscosity. The styrene also performs the vital function of enabling the resin to cure from a liquid to a solid by 'cross-linking' the molecular chains of the polyester, without the evolution of any by-products. These resins can therefore be moulded without the use of pressure and are called 'contact' or 'low pressure' resins. Polyester resins have a limited storage life as they will set or 'gel' on their own over a long period of time. Often small quantities of inhibitor are added during the resin manufacture to slow this gelling action. According to the literature there are several articles were published regarding nanocomposites with different polymers with new fillers and all were discussed the reasons for optimization of performance of the composites. Recently mixing two different polymers (i.e. Blends) brought lot of attention on the researchers. Thus in the present research work focus is made on the blended nanocomposites in which polyester and vinylester were blended in addition to that clay was dispersed into the modified blended system. Thus couple of systems were made in which system(1) Blend+ NC and (2) Blend + Carbon fibre + NC. Tensile properties were studied.

II. Material and Methodology

Materials

Unsaturated polyester (Ecmalon 9911, Ecmas Hyderabad) with cobalt naphthanate as accelerator, 2% Methyl ethyl ketone peroxide (MEKP) as catalyst in 10% DMA solution, ratio of resin/accelerator/catalyst/promoter is 100:2:2:2. The vinyl ester resin used was HPR 8711 grade, a Bakelite Hylam product. Methyl ethyl ketone peroxide (MEKP), Co-naphthanate and N, N dimethylamline were used as the catalyst, accelerator and promoter respectively. Montmorillonite clay (1.28E) surface modified with 25-30% trimethylstearyl ammonium (supplied by Nanocar Inc., Aldrich, nanomer, USA) was used as a nanofiller. Carbon fiber is defined as a fiber containing at least 92 wt % Carbon, while the fiber containing at least 99 wt % carbon is usually called a graphite fiber. Carbon fibers generally have excellent tensile properties, low densities, high thermal and chemical stabilities in the absence of oxidizing agents, good thermal and electrical conductivities, and excellent creep resistance. Carbon fiber was obtained from the Sree composites, Miyapur, Kukatpalli, Hyd and it has the following properties.

Methods

Tensile strength was measured using Instron Universal Testing Machine-3369 and the specimen size was 100 x 20 x 3mm³ and these are maintained on par with ASTM standards.

Composite Preparation

A mould was prepared with ASTM standards, and it was coated with a mould releasing agent to facilitate the easy removal of the casting after curing. Nanoclay was kept in the oven for 1 hr at 50° C to remove the moisture out of it. Predetermined amounts of clay was weighed and kept aside and followed by 80 wt.% and 20 wt.% of polyester and vinyl ester respectively were mixed together with spatula for about 30 min under the presence of room temperature. Clay was added into the modified mixture (i.e. blend) with the help of mechanical stirrer for about 45 min, then followed by probe type ultra-sonication for about 45 min to get uniform distribution of the clay particle. Artificial cooling system was employed to control rise in temperature during the sonication process. Then the accelerator/catalyst/promoter (100:2/2/2) parts by weight was added to the modified polyester/vinylester mixture. The mixture was poured into the mould. The carbon fibers were wetted by a thin layer of blend (i.e. polyester/vinylester filled with clay) suspension in a mould. A stack of carbon fibers were carefully arranged in a unidirectional manner after pouring some amount of resin against the mould to keep poor impregnation at bay. The remaining blend was poured over the carbon fiber. Brush and roller were used to impregnate the fiber. The closed mould was kept under pressure for 24 h at room temperature. To ensure complete curing, the composite samples were post-cured at 70°C for 1 h and test specimens of required size were cut out from the sheet.

III. Results and Tables

Tensile strength (TS) for system-1 are calculated as a function of clay loadings shown in the **Fig. 1** and their performance was assessed based on their magnitudes. TS for 2 wt.% clay dispersion was 26.01 MPa, and also FS was linearly increasing right from the 2 wt.% clay to 3.5 wt.% clay loading. At 3.5 wt.% clay loading TS was observed as 35.45 MPa and TS was increased up to 36.29 % for 3.5 wt.% when compared with 2 wt.% clay loading. However after 3.5 wt.% TS was decreasing. Tensile strength (TS) for system-2 are calculated as a function of clay loadings shown in the **Fig.1**. wt.% clay dispersion was 45.25 MPa, and also TS was linearly increasing right from the 2 wt.% clay to 4 wt.% clay loading. At 4 wt.% clay loading TS was observed as 65.23 MPa and TS was increased up to 44.15 % for 4 wt.% when compared with 2 wt.% clay loading. However after 4 wt.% TS was decreasing. The reason for decrease in strength was due to poor interface between the fiber and matrix, and increased viscosity of modified matrix is difficult to flow as a result of that possibility of air entrapment, consequently voids will form.

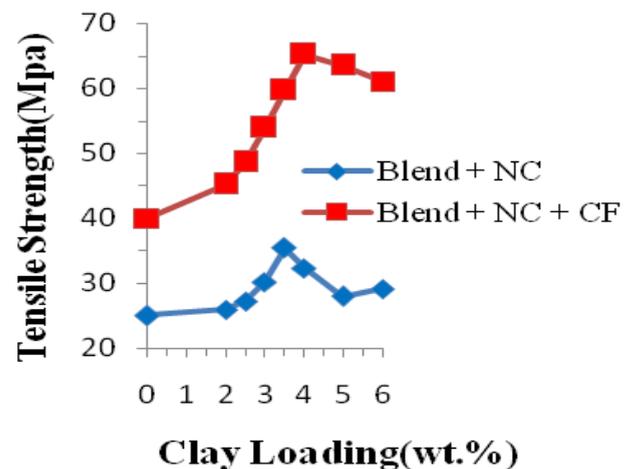


Figure 1: Evaluation of Tensile Strength of Blended Nanocomposites and Blended nanocomposites Reinforced with Carbon fiber as a Function of clay percentage weight

Tensile Modulus (TM) for system-1 were calculated as a function of clay loadings shown in the **Fig.2**. TM for 2 wt.% clay dispersion was 1206.78 MPa, and also TM was linearly increasing right from the 2 wt.% clay to 3.5 wt.% clay loadings. At 3.5 wt.% clay loading TM was observed as 2008.90 MPa and TM was increased up to 66.46 % for 3.5 wt.% when compared with 2 wt.% clay loading. However after 3.5 wt.% TM was decreasing. Tensile Modulus (TM) for system-2 are calculated as a function of clay loadings shown in the **Fig.2**. TM for 2 wt.% clay dispersion was 3125.65 MPa, and also TM was linearly increasing right from the 2 wt.% clay to 5 wt.% clay loading. At 5 wt.% clay loading TM was observed as 4896.36 MPa and TM was increased up to 56.65 % for 5 wt.% when compared with 2 wt.% clay loading. However after 5 wt.% TM was decreasing.

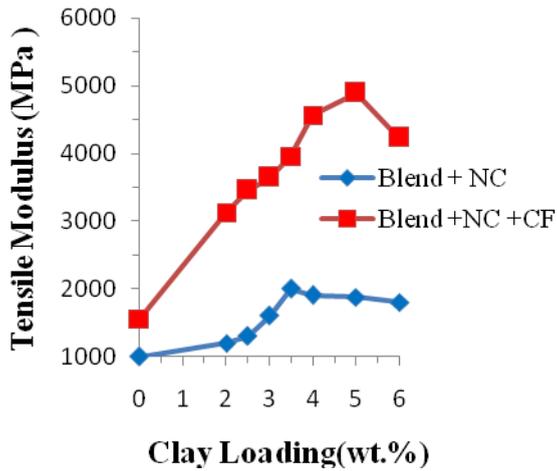


Figure 2: Evaluation of Tensile Modulus of Blended Nanocomposites and Blended nanocomposites Reinforced with Carbon fiber as a Function of clay percentage weight

IV. Conclusion

Development of polymer/polymer blended hybrid composites were evaluated successfully for the system-1 (blend+ Clay) and system-2 (blend+ CF + Clay). Tensile strength were optimized for system-1 at 3.5 wt.% and for system-2 at 4 wt.% clay loading. Tensile modulus were optimized at 3.5 wt.% clay for system-1 and 5 wt.% clay loading for system-2. Overall performance was optimised for the system-1 and system-2 at 3.5 wt.% and 5 wt.% clay loadings.

Acknowledgement

Authors would like to appreciate the Department of Mechanical Engineering, G.Pulla Reddy Engineering College, Kurnool and RV College of Engineering for providing laboratories.

References

- i. Kojima Y, Usuki A, Kawasumi M, Okada A, Fukushima Y, Kurauchi T, Kamigaito O, Mechanical properties of nylon 6–clay hybrid. *J. Mater. Res.*, 1993, 8, 1185–9.
- ii. Kamigaito O, Synthesis of nylon-6-clay hybrid by montmorillonite intercalated with epsilon caprolactam, *J. Polym. Sci. A Polym. Chem*, 1993, 31, 983–986.
- iii. Kawasumi M., Okada Kurauchi, Kamigaito T, One-pot synthesis of nylon 6-clay hybrid, *J. Polym. Sci. Part A: Polym. Chem.*, 1993, 31, 1755–1758.
- iv. Liu L, Qi Z, Zhu X, Studies on nylon 6/clay nanocomposites by melt- intercalation process, *J. Appl. Polym. Sci.*, 1999, 71, 1133–1138.
- v. Lan T, Kaviratna D, Pinnavaia J, On the Nature of Polyimide-Clay Hybrid Composites, *Chem. Mater.*, 1994, 6, 573.
- vi. Usuki A, Kawasumi M, Kojima Y, Okada A, Kurauchi, Kamigaito O, Swelling behaviour of montmorillonite cation exchanged for α -amino acids by ϵ -caprolactam, *J. Mater. Res.*, 1993, 8, 1174.
- vii. Biswas M, Sinha S, Recent progress in synthesis and evaluation of polymer montmorillonite nanocomposites, *Adv. Polym. Sci.*, 2001, 155, 167.
- viii. Gilman J W, Flammability and thermal stability studies of polymer layered-silicate (clay) nanocomposites, *Appl. Clay Sci.*, 1999, 15, 31.
- ix. Lan T, Kaviratna P D, Pinnavaia T, On the nature of polyimide-clay hybrid composites, *J. Chem. Mater.*, 1994, 6, 573.
- x. Hari Sankar P, Venkata Mohan Reddy Y, Hemachandra Reddy K, Polyester/vinylester polymer hybrid blended nanocomposites: Effect of nano on mechanical and thermal properties, *Fibers and Polymers*, 2015, 16, 2, 443.