An Approach to Use Nanocomposite Binders to Recycle Thermoset Plastics

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Abstract

A novel approach of using nanocomposite binders is implemented in recycling the thermosetting scraps. In this work the thermosetting scraps are collected and ground in the form of granules and flakes of size ranging from 0.5 to 3 mm. The thermoset polyester resin is selected as binder and incorporated with varying weight fraction of nanoclay. The thermoset polyester mixture (binder) with various weight fraction (0, 1, 2, 3, 4 & 5 wt.%) of nanoclay were prepared. The thermoset flakes were blended with the clay-thermoset mixture for a period of 15 minutes until attaining homogenous mixture for recycling. Required catalyst (1 wt.% Methyl Ethyl Ketone Peroxide) and accelerator (1 wt.% Cobalt Naphthanate) were added to the mixture and mixed further for 5 minutes to initiate and accelerate the curing process. Finally the mixture is poured in steel dies of different cross section. The mouth of the die was covered with steel plate and squeezed with hand operated clamps and allowed to cure in room temperature. These samples were tested for mechanical properties. The compression strength, hardness and stiffness of the recycled thermosetting plastics fabricated by using nanoclay infused binder are superior when compared with thermosetting samples formed with pristine organic binder. It also found that, the properties are significantly improved with rise in weight fraction of nanoparticle in organic binder.

Key words: Recycling, Thermoset, Nanoclay, Binders.

1. INTRODUCTION

Thermoset polymers have wide range of commodity and engineering applications. How ever the material is having limitation from recycling point of view.

The mechanical properties of Isophthalic polyester thermoset plastic is improved to greater extent by incorporating nanoclay. The recent works carried out by our team has shown considerable improvement in mechanical properties [1-3] and tribological properties [4,5] by infusing nanoclay in polyester matrix. Considering the enhancement in properties by nanoclay incorporation in thermoset resins and also the possibility of using the nanoclay infused thermosetting resin as binder. In this work, we have collected the thermoset polyester scraps and ground them as granules. The nanoclay infused polyester resin was used as binder to bind the thermoset granules to produce recycled thermosetting components.

2. EXPERIMENTAL PROCEDURE

2.1 MATERIALS

The resin used for matrix system is isophthalic polyester resin (PE), procured from Vasavibala resins (P) Ltd, Chennai. The Nanoclay used is Cloisite 30 B Procured from Southern Clay Products, Canada. The thermosetting scraps were collected in house from the wastes left out in our research laboratory. The scraps were ground to fine granules form of size varying from 0.5 mm to 3 mm as shown in Fig. 1.

Fig. 1 Thermoset Polyester Granules.

2.2 COMPOUNDING

The polyester resin is selected as binder for compounding. The nanocomposite binder mixture was prepared by taking 300 ml of isophthalic polyester resin in the container. Nano clay of definite proportion was added to resin and mixed well at 500 rpm for 30 min to obtain desired exfoliation of nanoclay.

The thermoset polyester granules were added to the nanocomposite binder and mixed further for 15 minutes until attaining homogenous mixture for recycling. The accelerator (1 wt.% Cobalt Naphthanate) and catalyst (1 wt.% Methyl Ethyl Ketone Peroxide) were added and mixed further for 5 minutes. The recycling mixture was poured in the steel molds to fabricate samples for studying the hardness and compression strength. The cured samples were shown in Fig. 2.

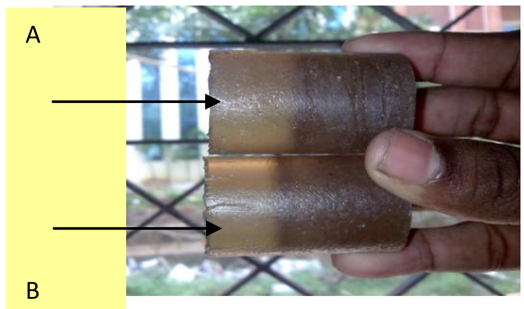

Fig. 2 Recycled Thermoset using (a) Pristine Resin Binder (b) Nanocomposite Binder

2.3 MICROSTRUCTURE ANALYSIS

TEM characterization was carried out to confirm the formation of intercalated and exfoliated structures in the nanocomposite binder used for recycling the thermoset plastics. It gives information about the dispersion of clay layers and so it is a direct evidence for the formation of nanocomposites. Thin films of 60-90 nm thickness were sliced by diamond blade using Philips microtome. The sliced films were taken in copper grids for further characterization using transmission electron microscope (JEOL JEM 1200EX), operated at the operating voltage of 200 KV.

2.4 MECHANICAL TESTING

Shore D hardness was determined for pristine polyester, thermoset polyester recycled by nanocomposite binders according to ASTM D2240 standard using Bluesteel SHR.D D-361 hardness tester. The specimen was first placed on a hard flat surface. The indenter for the instrument was then pressed into the specimen. The hardness was read within one second of firm contact with the specimen. The Compression testing was done by using an universal testing machine (Enkay Enterprises, India).

3.0 RESULTS AND DISCUSSION

Transmission electron micrographs of polyester filled with OMC were analyzed to study the structure. Fig. 3. shows the TEM micrograph of polyester filled with 1 wt.% OMC. The clay platelets are well exfoliated and spacing between the clay platelets is more than 70 Å. This confirms the formation of well-exfoliated nanocomposites for 1 wt.% OMC addition. Similarly exfoliated clay platelets are found for nanocomposites with 5 wt.% OMC (Fig. 4). From TEM pictures, it is understood that, the silicate platelets are closely packed for composites with 5 wt.% OMC (Figs) than the nanocomposites with 1 wt.% OMC. The d-spacing between the silicate layers is less than 70 Å and also the parallel arrangements of the clay platelets confirms the formation of intercalated nanocomposites. TEM studies reveal the formation of exfoliated nanocomposites for the organoclay contents of 1 wt.% and intercalated nanocomposites for the clay contents of 5 wt.%.

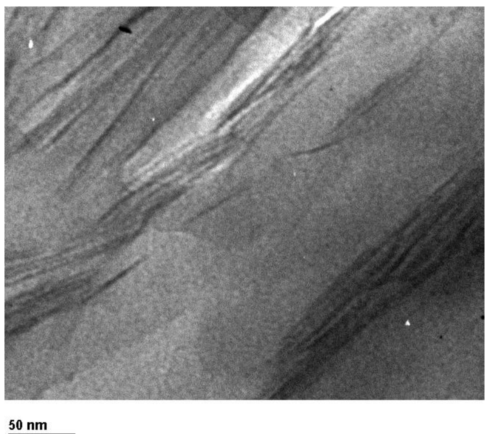

Fig. 3. Transmission electron micrograph of polyester with 1 wt.% OMC

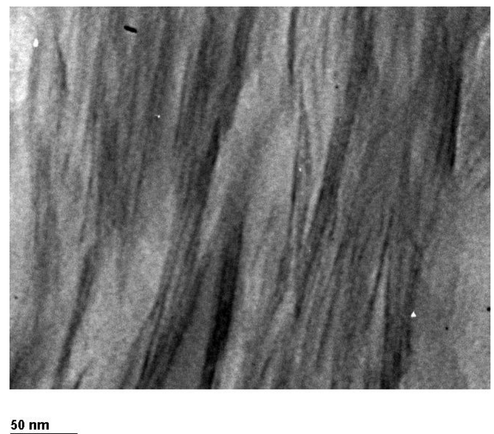

Fig. 4. Transmission electron micrograph of polyester with 5 wt.% OMC

The shore D hardness values of recycled thermoset plastic are shown in Fig. 5. The plastic recycled by pristine binder has the hardness value of 70. The hardness value increases when the binder is reinforced by nanoclay. The Hardness value of recycled plastic is 74 when 1 wt.% nanoclay is infused in the binder. The hardness value increases significantly as the clay content increases. The hardness value is maximum for the clay content of 3 & 4 wt.% and there after, it remains almost constant. The presence of exfoliated and intercalated nanosize clay platelets in nanocomposite binders is the reason for the increase in hardness. The nanosize clay platelets can effectively restrict indentation. The polyester binder without nanoclay being soft does not restrict the indentation much compared to the binders with nanoclay.

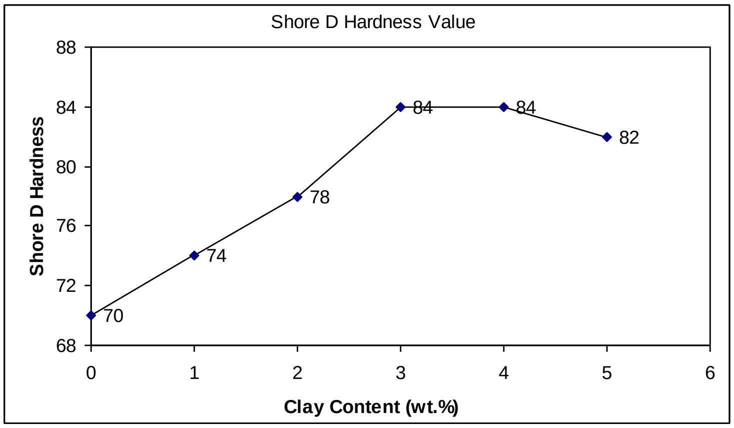

Fig. 5 Hardness value of Recycled Thermoset Plastic

Similarly the Compression breaking strength and compression modulus for the Recycled thermosetting plastic material is studied by conducting a quasi static compression test on samples (Fig. 6).

The compression breaking strength, modulus for the recycled thermoset is 40 MPa and 3 GPa respectively for system with pristine binder. By incorporating nanoclay in binder, The strength increases to 44, 45, 48, 45 & 44 MPa for the clay content of 1, 2, 3, 4 and 5 wt.% respectively. Similarly by incorporating the nanoclay in binder, the compression modulus increases to 3.5, 4.2, 4, 4.1 and 4 GPa respectively.

The increase in strength of recycled thermoset with nanocomposite binder suggests that, the nanoclay platelets can induce some strengthening mechanism in the material. It has been reported by researchers that crack pinning, and crack bifurcation are some of the strengthening mechanisms observed in nano particle filled composites [6].

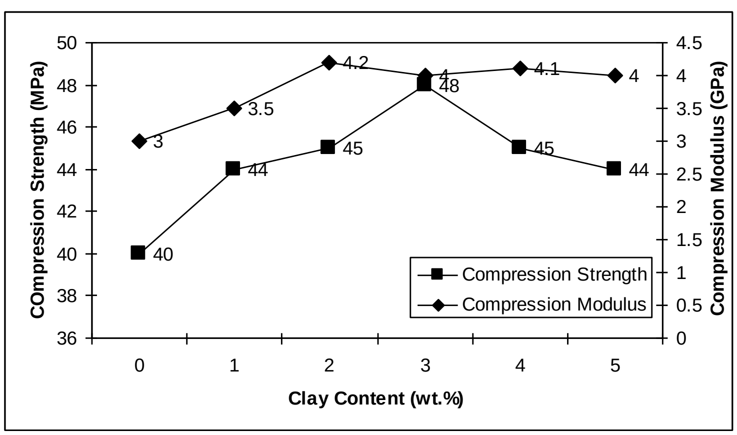

Fig. 6 Compression Strength and Modulus of Recycled Thermoset Plastic

The improvement of modulus for nanocomposites may be due to the exfoliation/intercalation of nanoclay particles in the matrix, which restricts the mobility of polymer chains under loading [7].

4. CONCLUSION

- The Thermoset is prepared using nanocomposite binder
- The TEM Micrograph confirms the dispersion of nanoclay in nanolevel and confirms the formation of nanocomposite binder.
- The properties like hardness, strength and modulus are significantly increased and maximum value is obtained for 3& 4 wt.%.

5. REFERENCES

1. P. Jawahar and M. Balasubramanian (2006) Influence of Nanosize Clay Platelets on The Mechanical Properties of Glass Fiber Reinforced Polyester Composites. Journal of Nanoscience and Nanotechnology, 6, 3973-3976.

2. P. Jawahar and M. Balasubramanian (2006) Preparation and Properties of Polyester Based Nanocomposite Gel Coat System. Journal of Nanomaterials, 2006, 21656, 1-7.

3. P. Jawahar and M. Balasubramanian (2005) Thermal, Mechanical and Water Barrier Properties of Clay – Polyester Nanocomposites. International Journal of Plastics Technology, 9, 472-481.

4. P. Jawahar, R. Gnanamoorthy and M. Balasubramanian (2006) Tribological Behaviour of Clay – thermoset Polyester Nanocomposites. Wear, 261, 835-840.

5. P. Jawahar, R. Gnanamoorthy and M. Balasubramanian (2005) Flexural and Tribological Properties of Polyester – Clay Nanocomposites. Journal of Material Science, 40, 4391 – 4393.

6. J.H. Park and S.C. Jana (2003) The relationship between nano- and micro- structures and mechanical properties of PMMA-epoxy-nanoclay composites. *Polymer*, 44, 2091-2100.

7. A. Yasmin, J.L. Abot and I.M. Daniel (2001) Processing of clay/epoxy nanocomposites by shear mixing, Scripta Materialia, 49, 81-86.