THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Preparation of Nanocomposites Based on Thermosetting Resins: A Review

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Abstract:
It is reviewed from the various studies that the dispersion is the main step in the preparation of nanocomposites with the thermosetting materials such as Epoxy, Unsaturated polyester resins.For Epoxy nanocomposite, In situ and inclusion polymerization method is preferred for better test results of nanocomposites. Mostly, hand lay up technique is used for unsaturated polyester resin.
From the results of X- ray diffraction, DSC, SEM, TEM and mechanical properties testings, it is found that upto 5 wt% of nanofillers, the better properties were obtained.

Keywords: *Thermosetting resins, nanoclay, nano calcium carbonate, mixing of nanofillers, nanocomposites.*

1. Introduction

Polymeric materials are widely utilized in every field for economic purpose and also due to their properties, the trend is rapidly growing. The specific requirements for each purpose are varied which cannot be satisfied by only the polymer materials. Hence, the new group is developed which is welknown as "Polymer composites", to meet the designed expected properties. Glass fibres, minerals fillers, metallic fillers, etc. are some of the examples of fillers reinforced presently for composites. These fillers size ranges from several microns to a few millimeters. [1]

While the matrix used in composites play a very significant role, performing various functions. Due to the matrix, the shape of the product is maintained as well as it helps in binding reinforcements together and also transfers the applied load to the reinforcing fibres. Reinforcements are protected from abrasion and environmental attacks with the help of a matrix. Mainly, the thermosetting plastics such as polyester resins, epoxy resin, phenolic and vinyl ester resins are used as the matrices for the structural composites.[2]

A new class is developed in composites, namely "Nanocomposites", which specifies the materials with atleast one dimension less than 10 nm. Due to an ultralarge interfacial area between the organic and inorganic phases per unit volume, nanocomposite has a great value created in the various fields.[3] It is stated in the large number of researches that the addition of rigid nanoparticles could improve the toughness as well as the strength of the obtained nanocomposites.[4] The strength of particulate composites depend on the particle size and particle/matrix interfacial adhesion as well as the particle loading. The effect of particle loading on the composite strength have observed due to the correlation between these three factors.[5]

2. Components Used in Nanocomposites

1. Thermosetting Materials / Matrices-: Epoxy resin is the crosslinked polymer in which an epoxy group is responsible for crosslinking reactions. To get better mechanical strength, chemical resistance and electrical insulating properties, epoxy resin can also be used in both laminating and molding techniques.[6]
2. Unsaturated polyester resin is widely used thermoset resin for composite applications. There are so many studies reported on nanocomposites of unsaturated polyester and organically modified clay (OMC).[3]
3. Reinforcement:-One of the important reinforcing materials is a glass fibres, which is the single filaments of glass ranging in diameter from 3 to 19 micrometres. The strength of fibres in fibrous composites increase the strength of the matrix considerably.[6]
4. Fillers:-Nanofillers are the additives which are in solid form and atleast one dimension of them is in nanoscale. They differ from the polymer matrix in terms of their composition and structure.[7] The physical and mechanical properties of composites are improved by hybridization of fibres with fillers.[8]

The size of nano- calcium carbonate used mostly is 30-50 nm, but due to agglomeration of the closer particles, they form a size of 100-500 nm, as observed by the zeta potential and laser dispersion particle size analyzer.[9,15]

Due to the potentially high aspect ratio and unique intercalation / exfoliation characteristics, clays have received great importance as a reinforcing materials for polymers. They are having high aspect ration from 100 to 1500 as well as a layered silicate structure about 1 nm in thickness. [6,1,14]

Montmorillonite or MMT is the one of the common silicates, having a crystalline, 2:1 layered clay minerals in which a central alumina octahedral layer is sandwiched between two silica tetrahedral layers.[1]
Various studies state that introduction of nanofillers into epoxy resin can greatly improve its toughness. The molecular weight of epoxy / nanocalcium carbonate, nanocomposite was even little less than that of pure epoxy resin, although their molecular distribution were almost the same.The reason for this is the ultra-small size of nano- calcium carbonate particles, large amount of C=O bonds which can interplay with the polymer chains through hydrogen bond were exposed to the surface of the particles.[9]
The addition of nanoclay into epoxy has been proved to be an alternative for the improvement of the mechanical and thermal properties of the resultant nanocomposites. This is due to the nanomer size and hogh aspect ratio of OMMT silicate layers.[8]
When the loading percentage of fillers increased, the tendency of clay to agglomerate was increased, which reduce the interfacial interactions and lowered strengthening effect of clay in the composites. The clay agglomeration can act as crack initiation sites and the premature failure of nanocomposites occur.[8]
Nearly, 3-5 wt% OMC content in unsaturated polyester resin will give the maximum degree of exfoliation. The clay particles consume free radicals needed for thr curing reactions, and is result in the lower crosslink density and lower Tg at high clay contents.[3] OMC content also control the shrinkage behavior in low-profile unsaturated polyester resin systems.[3]

3. Dispersion of Nanoparticles in Polymer and Processing

In the processing of nanocomposites, well dispersion of nano-particles is the most important step. Exfoliation of clay platelets is also an essential factor. These factors are responsible for optimal and more uniform material properties. But, practically, it is very difficult to form uniform and stable dispersion of nanoparticles in polymers[13]
Preparation of epoxy /calcium carbonate (clay) nanocomposites are made through different methods which are solution blending, in situ and inclusion polymerization, or extruding.[4,9] For more efficient dispersion of nanoparticles, in situ and inclusion polymerization results better.[9] Well dispersion of nanoparticles in the polymer matrix is a decisive factor in improving properties of the corresponding nanocomposites.[4]
The parameters on which the dispersion process affects are mixing temperature and time, speed and time of stirring, power of ultrasonic tooling, shear forces, etc. Epoxy and organoclay mixing is generally done by direct mixing with mechanical stirring and sonication, but however it can't reach upto well dispersion.[11]
Preparation of unsaturated polyester / nanoclay nanocomposite is made widely by direct mixing. Nanofillers in the powdered form are taken and unsaturated polyester resin is added slowly in that. Mechanical stirring is done upto visible dispersed fillers in resin.[3]
In open literature, the mainly used techniques for polymer hybrid composites are hot melt lay up, autoclave process, vacuum assisted resin transfer molding process and hand lay up technique.[8]

4. Conclusion

The main most challenging work for the good thermo-mechanical properties of nanocomposites, is the synthesis of well dispersed and exfoliated nanocomposites.The morphology and development of clay dispersions and level of intercalation and exfoliated is observed with the help of the rheological study.
From the above studies, it is demonstrated that better results are achieved with the addition of upto 5 wt% nanofillers. This results observed from the XRD, DSC, SEM, TEM and the mechanical testings.

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