A Brief Review on Effect of Nano fillers on Performance of Composites

Reshmi Olayil, V. Arumugaprabu, Oisik Das and W A Lenin Anselm

Shinas College of Technology, Oman
Kalasalingam Academy of Research and Education, Krishnankoil-626126, Tamilnadu, India
Lulea University of Technology, SE-97187 Lulea, Sweden
Lecturer, Engineering Department, University of Technology and Applied Sciences-Shinas, Oman
v.arumugaprabu@klu.ac.in

Abstract. The utilization of nano materials creates a huge impact on today’s scenario in development of various products. One such type of nano material developing concept is the usage of nano fillers for making composite product. This review briefs about the development of various nano fillers and its types followed by the fabrication of various composite combinations along with various nano fillers also discussed in detail. The addition of these nano fillers as a reinforcement or matrix for the composite making creates a significant impact in the mechanical properties of the composites. Special focus is given in such a way that the nano filler dispersion in which way enhances the mechanical properties. Better bonding between the matrix and reinforcement only improves the property how the nano fillers behave in that aspect also discussed in this review. The dispersion of nano fillers in various polymer matrix composites also presented in the review. Tensile, Flexural and Impact property of the composites decides its usage in various structural applications and this review presents briefly how these properties varying with respect to various nano fillers. Further the nano filler performance on the thermal properties as well as its impact in various sectors such as automobile, biomedical, sports, and aerospace applications etc., also presented in this review paper.

1 Introduction

The development of technology in modern era focuses on making materials by means of nanotechnology which attracts many researchers for finding innovative materials for various applications. One such technique derived from the nanotechnology is the usage of nano fillers. Nano fillers are dispersed into the various polymer matrixes to identify the improvement in various mechanical, thermal, electrical and moisture resistance properties. The concept of fillers in making composites evolved around the 20th century itself which acts as a binder to hold the matrix and reinforcement strongly together. The nano filler is the ones which find its place when the nano concept evolves since the main advantage offered by the nano fillers or particles is the high surface to volume ratio which in terms increases the filler and matrix bonding. The uniformly dispersed nano fillers play a vital role in deciding the mechanical properties [1]. By means of adding nano fillers the adhesion between fillers and matrixes increases which avoids the failure of the composites in early stages. This review paper addresses the fabrication of composites using nano fillers and its influence on the mechanical properties briefly based on early researches. Also to overcome the issues of dispersion proper methodology for making the nano fillers composites also discussed in this review.

2 Fabrication of Nano filler based Composites

The earlier stages use nano fillers in two common forms as nanoclays and carbon nano tubes. Nano fillers used in such a way that either the matrix or reinforcement anyone has the dimension in the range of 1-100nm.Based on the shapes nano fillers used in various forms as nanoplates in1D, nanofibers
in 2D and nanoparticles in 3D [2]. In the beginning stages CaCO$_3$, Silica and carbon are used as the familiar types of nano fillers and researches on this is established, on the other hand few emerging materials used as nano fillers are Alumina, Magnesium, Silicon carbide, Titania and zinc oxide. All these are widely used nano filler materials for making composites. Each material has some special property in terms of increasing the mechanical properties, wear properties, thermal properties and electrical properties and depending on the applications they have chosen. The most commonly available methods used for the manufacturing of nanofiller based composites are: Insitu method, wet process-solgel method, dry process-ball milling, gas impinging etc., evaporation process-CVD, GVD and the sedimentation process [1,2].

3 Various Performance Studies on Nano filler based Composites

3.1 Mechanical and Electrical Performance

The Usage of carbon as nano fillers as reinforcement in various polymer matrixes and its effect on the mechanical, electrical, thermal, magnetic and wear properties has been analyzed in the research by Al Sheheri et al[3]. The fabrication of CNT, graphite, graphene and fullerene all are carbon based nano fillers and its influence on the polymer matrixes shows that the improvement in performance of all the properties has been evident. Also conclude that the nano fillers based composites finds a suitable place in alternating the existing ones with some excellent features. With this emphasis further research has been carried out using carbon fillers along with polyazomethine [4] as hybrid ones. The prepared composites were subjected to thermal studies and the degree of polymer crystallinity in order to know the better dispersion of nano fillers with the polymer matrixes. Also they concluded that this hybrid combination nano filler produces a better dispersion in polymer matrix that produces an enhancement in the thermal conductivity as well as low cost involved.

Further studies carried out on using polyethylene terephthalate (PET) composites reinforced on four different types of carbon fillers such a CNT, Graphite and hybrid combinations[5]. All the nano filler composites were prepared by using the high energy ball milling (HEBM) method. Mechanical, Thermal and electrical properties of the composites were compared with the pure PET in such a way that the impact of nano fillers be identified and conclude that both properties increases in all the four types of nano fillers addition. Nilagiri Balasubramanian [6] et al carried out a complete review on the usage of nano fillers and micro fillers for the electronics applications. The thermal and electrical conductivity of the prepared composites were analyzed using the filler arrangement as a key factor. The improvement in the thermal conductivity of the composites happens by the addition of nano fillers along with the mechanical properties. Also they concluded that the addition of nano fillers increased the compatibility with the matrix is the reason for the increase in all properties.

Another interesting study has been carried out using the epoxy matrix along with nano fillers cubic boron nitride and hexagonal boron nitride [7]. Hand layup method is used for the fabrication of composites and subjected to wear resistance studies. The addition of fillers increases the wear rate drastically when compared to the unfilled ones which is due to the increase in hardness. Also due to agglomeration of the filler particles varying weight percentage also leads to poor wear rate in few cases. Nano fillers based composites used in making strain sensors especially using carbon fillers. During the electrical resistance test it was noted that this hybrid nano fillers composites poses more resistance also additional few more special features such as high durability and high repeatability observed from the strain gauge sensors [8].

Polymer because of its excellent properties along with nano fillers used as a electromagnetic interference shield material since they have high electrical resistance properties. Among all the composites combinations prepared and studied using the polymer and filler the multi walled carbon nano tube based polymers and nano carbon black produces much improved electrical conductance. In addition the combination of Ag/MWCNT composites has the capability to produce a very high shielding efficiency that caters the industry needs [9].

The influence of nano fillers extended towards the biomedical sector also in such way research reported using silica nano fillers and silver nano fillers to improve the banding adhesives both in terms of physical level as well as microbial level. Among the two the experimental composites adhesives with the silver nanoparticles possess better results in terms of both physical as well as biological aspects[10]. Further studies performed using nano fillers effect in hybrid composite mechanical properties. The hybrid composites were prepared using injection molding method in which short carbon fiber used as the reinforcement and polypropylene used as the matrix. Along with this various natural fibers such as alumina, silica and CNT were added as nano fillers and the hybrid composite effect on the tensile and flexural properties has been analyzed in detail by using theoretical models. It has been noted that the adhesion properties of the composites improved by means of nano filler addition. Among all the fillers used the alumina, silica and CNT improve the inter shear strength of the composites. Based on the
theoretical model inference alumina particles reflect as a best one in terms of improvement [11]. The studies using the polypropylene matrix along with nano fillers now focus towards on flame retardant capability. The fillers used are organo clay, layered double hydroxides, polyhedral oligomeric silsesquioxane (POSS), and carbon nanotubes (CNTs). All these fillers were dispersed in the polypropylene medium and studied for its flame retardancy and thermal stability. When compared to all CNTs posses better dispersion with the polypropylene, matrix in such a way there is no agglomeration observed during the TEM studies but interestingly organo clay composites possess better thermal stability and flame retardance among all the combinations [12]. The research on nano fillers using epoxy matrix and zinc oxide particles for the electrical resistance applications has been reported. It was noted that even an addition of small amount of the filler zinc oxide improves the electrical resistance drastically leads to the treep growth which extend the breakdown time and inferred that the high surface is the main reason for this behavior as well as the reduction of voids[13].

Zhifang Gao et al [14] carried out research on various nano fillers produced such as Nano-AIN particles, AIN/graphene nano-hybrids (AIN/GE) and AIN/carbon nanotubes nano-hybrids (AIN/CNTs). All the prepared fillers were subjected to the thermal conductivity studies along with the epoxy matrix. From the results it was revealed that the combination of epoxy composite with 5 wt% AIN/GE nano-hybrids and 45 wt% micro-Al2O3 particles hybrids possess enhanced thermal conductivity when compare to the pure epoxy. Edison et al [15] performed studies on the hybrid composites prepared using woven Kevlar fabric and aluminium sheets along with the epoxy matrix, in addition fillers of micro and nano size added to the combination to know its improvement in the ballistic performance. The fillers used are gamma alumina, silicon carbide, aluminium, colloidal silica and potato flour. They concluded that the addition of all fillers improves the fiber and metal bonding strength. Also it was noted that the addition of aluminium, silicon carbide and colloidal silica improves the ballistic effect when compared to the unfilled ones. The various types of nano fillers used and its classification is presented in Figure.1

Takahiro Imai et al [16] also carried out studies on the effect of nano filler based composites for electrical resistance applications. They focused on preparing a new type composite for insulation purposes. The composites were made using LS, SiO2 or TiO2 as nano fillers and epoxy as the matrix. The epoxy based nano/micro filler composites of different weight percentages possess the better insulation capability when compared to the pure epoxy. Another type of composites developed using in situ method for the combination of epoxy, spherical silica and organo-modified montmorillonite. Mechanical and tribological studies has been carried out on the made composites showed that the addition of different shapes montmorillonite nano filler improves the toughness properties which leads to good mechanical strength and also the wear resistance gets improved a lot[17].

Ermias G Koricho et al [18] analyzed the impact resistance of the composite made using nano clay and glass bubbles along with the glass fiber reinforcement. They concluded that the composites which are tailor made using these combination posses a good impact resistance under drop weight test by means of addition of nano/micro fillers. Carbon fiber reinforced polymer composites subjected to modifications in such a way to improve its performance on toughness aspect nano fillers are incorporated. GNP's and MWCNTs were used as the fillers, the improvement in inter laminar fractures takes place due to the increase in toughness by the addition of fillers [19].

![Figure 1. Classification of nano fibers](image_url)
Tao Li et al [20] have done research on the preparation of composite membranes using the nano fillers. The filler used is nano-sized zeolitic imidazole framework ZIF-7. The addition of this improves both the selectivity and permeability of the prepared composite membranes. Nano composites were developed using the combination of silver nanoparticles and carboxylated cellulose nano crystals in such a improvement in mechanical properties and biological properties obtained when used with waterborne polyurethane. Bio nano composites obtained by means of these combinations which can be used as potential filler in waterborne polyurethane applications [21]. Further new composite combination prepared by using nano scopic silica fillers along with polyamide matrix. The specimens were fabricated by means of in situ polymerization. The mechanical properties gets influenced by the size of the nano fillers was reported where reduction in the filler size provides less dispersion rate which in term leads to poor bonding [22].

3.2 Thermal performance

More commonly used nano fillers now a days are clays and nano tubes. The impact of usage of nano fillers and nano particulates create a significant impact in the markets already in which the influence of polymer matrixes gets increasing day by day. With the focus towards innovation research the usage of nano crystals as fillers attracts many even though the costs involved in making this is high. The future trend will shift towards making and usage of nano fillers in order to make a green composite [23]. Sanada et al [24] used two fillers such as carbon nano tubes, alumina particles in micro filler form used in polymer matrixes for making polymer composites. The prediction of nano filler impact on the thermal conductivity of the composites has been done using the finite element analysis. From both the experimental results and the theoretical experiments it has been noticed that the addition of these micro fillers drastically improve the thermal conductivity of the prepared composites. The different types of matrixes which are used for preparing nano composites along with its applications are shown in Table. 1

| Matrix       | Properties studied | Applications   |
|--------------|--------------------|----------------|
| Polyester    | Tensile Strength   | Automobile     |
| Epoxy        | Flexural Strength  | Biomedical     |
| Polypropylene| Impact Strength    | Packaging      |
| Polyurethane | Thermal Conductivity| Sports goods  |
| Polyethylene | DMA and TGA studies| Electronics   |

The studies on grapheme nano fillers along with the titanium composites has been carried out by song et al[25] and inferred that an improved mechanical properties such as hardness and yield strength happens. Also the nano fillers added composites has the capability to resist the various failure mechanism such as micro cutting, ploughing etc., Further Suresha et al[26] analyses the effect of micro/nano fillers on the composites made using the combination of polyamide 66 and polypropylene. The prepared composites were subjected to mechanical and tribological performance studies and observed that the filler effect creates an impact in the hardness, tensile and flexural strength in such a way all gets increased. On the other hand the wear rate also very low in the case of filler based composites. Graphene possess some excellent property that makes it as a suitable candidate for preparing the nano filler based composites in such a way that the graphene along with polymer matrixes widely used for various industrial applications. Also advanced composites were developed for electrical applications using grapheme as nano filler in polymer matrixes [27].

Another interesting study on the nano filler in such a way using the boron nitride tubes and boron nitride nano sheets combined together along with the epoxy matrix form hybrid composites. The thermal conductivity increases drastically by means of 95% and young’s modulus by 57% respectively by the addition of the fillers were reported [28, 29]. Shaoxin Zhou et al [30] carried out studies on the impact on carbon based nano fillers along with the flake graphite and polymer matrix composites. A special emphasis was given to know the thermal conductivity of the prepared composites. Also by means of forming a new model the experimental results were compared theoretically in such a way that...
they were well fit and the addition of nano fillers size creates an improvement in the thermal conductivity behavior of the composites.

4 Summary and Conclusions
From the brief review on the importance of nano fillers following conclusions were drawn:
- The nano fillers based composites fabricated successfully by various techniques such as hand lay up, insitu method, sol gel method etc.,
- The prepared nano fillers enhance the mechanical, thermal and electrical, wear properties of the composites when compared to unfilled ones or other existing conventional materials.
- The excellent improvement in properties is due to the high surface volume ratio as possess by the nano fillers and also it increases the hardness of the material. In addition material cost also low.
- From the vast research done it has been noted that the influence of nano fillers will be high in modern days because of its interesting characteristic behavior also offering special features with low space and cost. Also the research scope will be high in the near future on this aspect.
- The nano filler based composites extend its application in major sectors such as automotive, aerospace, electronic parts and sports good.

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