

# Analysis of Composite Materials Properties in Dispersion of the Particles

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## ABSTRACT

This paper summarizes the recent work in field of {differentof various} types of micro and Nanoparticle particles dispersion take a look at ends up in different polymer matrix composites and news its wonderful performance in mechanical, electrical and thermal applications. The discussion concentrates on differing kinds of dispersion technique used for small and Nano fillers as a result of the dispersion of particles is vital drawback in composites industrialisation. This review has been targeted on the result of natural phenomenon of dispersion, relation between dispersion and physical properties of small and nano-particle on mechanical and different properties of composites. many approaches that will be applied to beat the dispersion of particles ar delineate during this review.

**Keywords: Composites, dispersion, micro particles, nano particles, polymer.**

## 1. INTRODUCTION

In last twenty years there are such a big amount of developments in field of material by victimization completely different nano-filler, micro-filler, and macro- filler. Now-a-days, there square measure several rising application wherever it's necessary to spread nanoparticles into completely different compound matrix. The form directly enhance or improve the properties of material, like strength, hardness, thermal properties, conductivity, wear properties, optical properties etc. thanks to massive surface to volume quantitative relation of nanoparticles that will increase the interactions between particles and compound matrix. The interaction between particles and matrix rely on Dispersion technique. A well spread technique typically yields a lot of fascinating composite properties. Particle agglomerates decrease material performance by the inclusion of voids that act as advantageous sites for crack initiation and failure. Particles, especially within the nano vary (less than a hundred nm) tend to agglomerate, or cluster, thanks to the dominant unit vander Waals interactions between them.

This review paper describes the natural phenomenon of dispersion, relation between dispersion and physical properties, and discusses the preparation of nanocomposites based mostly upon the 3 classes of reinforcement materials, particles (silica, hydroxyapatite, metal, metal oxides and different inorganic particle), and fibrous materials (collagen nanofibers, carbon nanotubes and nanofibers) with smart nanofiller dispersion. whereas massive surface-to-volume quantitative relation of nanoparticle makes them higher reinforcements over standard fillers, it conjointly brings difficulties in dispersing the nanoparticles thanks to their sturdy interactions among themselves. thanks to this internanoparticle interaction, it's extraordinarily troublesome to disperse nanoparticles uniformly, particularly at higher particle loadings.

### 1.1 Dispersion and its Mechanism

There has been so many research works discussed in the papers about how the dispersion and the mechanism of dispersion directly affect the physical properties. Mechanical, thermal and rheological properties depend on degree of dispersion. Several processing methods including shear mixing [1], mechanical mixing [2], in-situ polymerization [3] and sonication [4] have been used for dispersing nanoparticles in polymers. Formation of chemical bonding between polymer and the particle depends on different dispersion techniques used. Dispersion can influence the mechanical properties of composite due to strong interfacial bonding in between polymer and particle, which easily transfer load from matrix to fiber in composite. Poor dispersion of nanoparticles is often blamed for these anomalous results. Thus, a few issues regarding dispersion of nanoparticles need to be addressed: 1) techniques for uniform dispersion, 2) dispersion varies with different particle size.

### 1.2 Technique for Dispersion Evaluation

Different methods have been used to improve the dispersion quality of nanoparticle; some researchers have modified the surface chemistry of nanoparticles to enhance the interfacial compatibility with the polymer. The general ideas of surface modification are to coat the inorganic nanoparticle with an organic layer by physical

treatments or chemical bonding. A details description of surface modifications of nanoparticles can be found in a review paper by Monika et al. [5]. Briefly speaking, nanoparticles are physically treated with a surfactant to form a layer on the surface of the particle via secondary forces. This reduced the surface energy of the particles which eases their dispersion in the polymer precursor. On the other hand, nanoparticles are chemically treated with preferred reactive groups on the surface of the nanoparticle to form strong bonding between the particle and the polymer. However, in both methods, the modifiers need to penetrate the particle agglomerations, which is very difficult to achieve with the on hand mixing methods.

### **1.3 Disparity between Micro and Nano Particles**

Although particles dispersion plays the foremost role in enhancing polymer's properties, it is also greatly influenced by the size of particles. Smaller particles have higher surface area (at same particle volume fraction) and, thus greater surface interactions among the particles. This is what makes the dispersion of nanoparticles difficult. The disparity between micron-sized particles and nano-sized particle has been addressed by many authors. Both Micro and Nano Particles were dispersed by the common method like sonication, three roll-mill, twin screw extruder, shear mix and mechanical mix. A twin screw extruder was used to disperse both nanoparticles and microparticles where a large amount of agglomeration of nanoparticles and microparticles were observed. Improvement in modulus was increased with microparticles whereas it was reduced in case of ultimate strength. However, the extent of improvement in tensile modulus and ultimate tensile strength were reported with the increase of nanoparticles and microparticle volume fractions. Carbon nanoparticles (CNTs, Graphene and Nanodiamond) were dispersed through the sonication method with the aid of a dispersant whereas the alumina microparticles were mixed using a mechanical stirrer.

## **2. TYPE OF REINFORCEMENT PARTICLES**

### **2.1. Micro particle**

**Santos, et al. in 2017** [6] studied biomedical properties of Bonelike® in the polymer mats reduced the activation energy for thermal degradation from 134 kJ·mol<sup>-1</sup> to 71 kJ·mol<sup>-1</sup>, for the neat PLLA membranes down, calculated for the hybrid composite membranes. The microcrystalline cellulose and PVA and the resulting suspension was poured into Alumina (Al<sub>2</sub>O<sub>3</sub>) plates, dried in a woven at 60 °C for two days and then the samples were sintered at 1300 °C using a heating rate of 4 °C·min<sup>-1</sup>, followed by natural cooling inside the furnace.

**Sorrentino, et al. in 2014** [7] showed formation of micro- or sub micro-cells in Cellular thermoplastic fibre matrix and the expanded graphite (EG) particles reinforcing fibres resulted in a significant enhancement of the impact properties.

**Padmavathi et al. in 2015** [8] studied the properties of carbon fiber reinforced SiC + ZrO<sub>2</sub> composites. The addition of ZrO<sub>2</sub> to the matrix from 5% to 20% improves the room temperature tensile properties of the composites. The tensile strength and fracture energy of CF/SiC+ ZrO<sub>2</sub> composites are, superior compared to that of CF/SiC composites.

**Wu et al. in 2017** [9] studied tribological performance of ZrB<sub>2</sub> particles into epoxy matrix with a low content can significantly enhance the tribological performance of epoxy composites. The ZrB<sub>2</sub> particles content of 5 vol% is the optimum filler content in decreasing the friction coefficient and coefficient of wear K.

**Liang et al. in 2017** [10] studied the effects of the content and the length-diameter ratio (aspect ratio) of the carbon fibers on the electric conductive. When the short-cut CF weight fraction increased from 16% to 29%, the PTC transition temperature of the HDPE/short-cut CF composites increased from 130 °C to around 136°C; while when the triturated CF weight fraction increased from 35% to 40%, the PTC transition temperature of the HDPE/triturated CF composites increased from 123°C to around 131°C.

**Kajtar et al. in 2017** [11] showed the characteristics of polymer/zeolite desiccant composites. The deformability of most composites is small and decreases with increasing zeolite content. Interfacial adhesion between the matrix polymer and zeolite is not very strong although quantitative determination is hampered by various factors.

**Laouchedi et al. in 2017** [12] studied composite material based on epoxy resin filled with local clay fillers powders possessing different structures. It was observed that the glass transition temperature varies from 403 K to 413 K. Obtaining a good dispersion and interaction between the resin and the fillers, the clay fillers cannot be used without prior chemical treatment.

**Kim et al. in 2017** [13] studied the relationship between the thermal conductivity of composites and the volume expansion of EG, which is considered favorable for forming thermal transfer pathways and is effective at enhancing the thermal conductivity of composites. The thermal conductivity was dominantly determined by the efficient formation of 3D thermally conductive EG filler networks and the construction of favorable pathways for phonon transport caused by direct contact between the EG fillers with larger volume expansion.

**Zhu et al. in 2017** [14] studied the thermal conductivity and dielectric properties of the HGM and nitride powders filled composites with an immiscible LDPE/epoxy blend matrix depend on the volume ratio of LDPE to epoxy. The composition of the composite that gives the optimum combination of thermal conductivity and dielectric properties is 15 vol% BN, 15 vol% HGM, 21 vol% LDPE and 49 vol% epoxy, and corresponding thermal conductivity,  $Dk$ , and  $Df$  values are 0.7 W/(m·K), 3.12, and 0.011, respectively.

**Jang et al. in 2017** [15] studied the surface-modification of BN/epoxy composite for the improvement of thermal conductivity. To enhance the dispersibility of BN in epoxy resin, the silane materials with different main carbon chain were introduced on the BN surface through sol-gel reaction. The enhancement of thermal conductivity could be achieved by controlling the surface property of BN.

The Table 1 describes different methods of dispersion of nano-particles in various composites

**Table 1.**Methods of dispersion of nano-particles in polymer composites

| Materials                  | Solution | Functionalization Agent            | Dispersion method | Properties  | Ref  |
|----------------------------|----------|------------------------------------|-------------------|---|------|
| ZrB <sub>2</sub> Particles | Ethanol  | —                                  | Ultra sonication  | Decreasing the friction coefficient and coefficient of wear                           | [16] |
| TiB <sub>2</sub> Particle  | Ethanol  | Acetone, Ethanol and Ethyl acetate | Ultra sonication  | Enhancement of thermal stability, thermal conductivity, hardness and tensile strength | [17] |
| Alumina                    | Acetone  | Chromic-sulphuric acid             | Mechanical mix    | Increasing level of adhesion between the alumina and the thermoplastic polyester      | [18] |
| Bamboo particles           | —        | —                                  | Mechanical mix    | Tensile strength 15.79%<br>Flexural deformation 39%                                   | [19] |
| Silicon carbide            | —        | —                                  | Mechanical mix    | Flexural strength 110%<br>Specific strength 112%                                      | [20] |

## 2.1. Nano particle

### *Nano Particle Dispersion*

An overview of the various processes involved in the dispersion of nanoparticles in liquids, and subsequent stabilization. It has been recommended that [2], this can be achieved by mixing the powder with drops of suitable liquid media slowly until it forms a thick paste. De-agglomeration (including de-aggregation) using a de-agglomeration tool. Sufficient shear energy is needed to break down aggregates/agglomerates, preferably to their optimum primary particle size; what is often termed as a “good dispersion” will thus consist chiefly of primary particles with only a minimum of loose aggregates and agglomerates. Ultimately, it is the surface properties of the nanoparticles and their interaction with the aqueous media (as measured by parameters such as zeta-potential, hydrophobicity and adsorption capacity to specific analyses in the liquid media) that will determine stability; it is not surprising therefore that the addition of surfactants, for example, can lead to marked changes in its interfacial properties and thus stabilized.

**Mohanty, et al. in (2013)** [21] showed the dielectric breakdown performance of alumina/epoxy resin nanocomposites and found the remarkable improvement in breakdown voltage. Epoxy nanocomposites containing 2 wt.% of alumina particles results in increase of breakdown voltage by 91% and breakdown time by 155% as compared to neat epoxy. Author used mechanical vibrator for well dispersion of alumina particles with epoxy.

**Jiang, et al. in 2017** [22] showed the effect of Bamboo fiber on the crystallization behavior, interface structure and mechanical properties of Hydroxyapatite/poly(lactic-co-glycolic)composites was investigated. He found n-HA (nano hydroxyapatite) powers were highly dispersed in absolute ethanol and dichloromethane mixture solution with the volume rate of 1:1 by ultrasonic treatment.

**Ning, et al. in 2015** [23] studied the mechanical properties CFRP laminates in which Mode-I fracture toughnesses of can be improved significantly with introduction of GO reinforced epoxy interleaf into the interlaminar interfaces. Generally, as the GO loading increases, the fracture toughness initially increases up to a peak, and then decreases. The optimum area density of GO is  $2 \text{ g/m}^2$ , which brings about remarkable 170.8% and 108.0% increases in Mode-I fracture toughness and resistance, respectively.

**Molazemhosseini, et al. in 2013** [24] studied the friction coefficient of PEEK/SCF hybrid composites with 1 and 2 wt% nano-SiO<sub>2</sub>, leads to a decrease in friction coefficients. However, there is no specific trend in terms of the composite contains 1.5 wt% nano-SiO<sub>2</sub>.

**Borrego in et al. in 2014** [25] studied the Fatigue behaviour of glass fibre reinforced epoxy composites enhanced with nanoparticles. The effect of the addition of small amount of nanoclays and multi-walled carbon nanotubes into epoxy matrix on the fatigue behaviour of glass fibre composites was analysed. Good dispersion into the matrix was achieved for 1% nanoclays, while for higher content and for MWCNTs nanoparticles the dispersion technique was apparently ineffective.

**Santos et al. in 2015** [26] studied the mechanical properties of silica nano-particle/epoxy composites. No improvements in the flexural strength were observed when silica particles were dispersed in the HGFRCS. The use of 2 wt% of silica nanoparticles enhanced the tensile modulus (11.6%), the tensile strength (28.80%) and the flexural modulus (13.20%) of HGFRCS. The tensile modulus of the epoxy polymer can be increased up to 17.8% when 2 wt% nanosized silica inclusions are added. The tensile strength of epoxy polymer was also improved when 1 wt% of nano silica was dispersed.

**Feng et al. in 2015** [27] studied the Compressive and interlaminar shear properties of carbon/carbon composite laminates. Compared with C/C laminates, the OCS, ICS and ILSS of CNT-C/C laminates increase by 32%, 115% and 108%, respectively, and the OCM and ICM also increase by 11% and 46%, respectively.

**Puch et al. in 2014** [28] studied the mechanical properties of unreinforced and short carbon fibre reinforced Nylon 6/multiwalled carbon nanotube-composites. Enhancement of Young's modulus and the tensile strength is substitution of SCF obtained by MWCNT.

**Diaz et al. in 2017** [29] studied the thermal stability and mechanical performance of isotactic polypropylene nanocomposites compared pristine graphene with functionalized graphene. Comparison of indentation and tensile measurements reveals the disparity of results at high loadings and especially for the nanocomposites with modified filler. This suggests that the orientation of graphene during the mechanical loading can be an important aspect of the overall mechanical reinforcement that, in turn, can be facilitated by the interaction of the short polymer brushes attached to the graphene surface with the PP matrix.

**Roenner et al. in 2017** [30] studied the mechanical and flammability properties on epoxy samples with increasing amounts of nano-silica. At a loading of 36%, the nano-particles were able to double the toughness and increase the flexure modulus by 50%. The glass transition temperature was decreased by 30 °C.

**Karimi et al. in 2017** [31] studied the thermal mechanical properties of the chemically bonded epoxy-silica hybrids prepared from two different types of organically modified silanes i.e., aminopropyl- and aminophenyl-trialkoxysilane. The stiffer phenyl interphase provided by aminophenyl-trialkoxysilane gave relatively large damping in the  $\tan \delta$  curves, higher increase in the modulus, tensile strength and glass transition temperature (T<sub>g</sub>) and more reduction in the coefficient of thermal expansion in comparison to propyl group present in aminopropyl-trialkoxysilane.

**Pourhashem et al. in 2017** [32] studied the barrier properties of polymer coatings via incorporation of Graphene Oxide (GO) nanosheets. Although all nanocomposite coatings regardless of the kind of filler show superior corrosion resistance compared to neat epoxy coating, superior enhancement in corrosion protection is achieved for epoxy/A-GO nanocomposites which can be attributed to amine end-groups of A-GO compared to epoxy end-groups of G-GO sample.

**Zakaria et al. in 2017** [33] studied the effect of GNP and MWCNT on the mechanical, thermal and dielectric properties of epoxy nanocomposites at various filler loadings. The tensile strength and flexural strength of the Epoxy/GNP were enhanced about 11% and 17% respectively, whereas the tensile strength and flexural strength of the Epoxy/MWCNT were enhanced to about 26% and 29% respectively. The thermal conductivity and dielectric constant of the Epoxy/GNP showed significant improvement of up to 126% and 171% respectively, and the Epoxy/MWCNT showed an improvement up to 60% and 73% respectively.

The various methods of dispersion and its effect on the different properties of the composites have been presented in the Table 2.

**Table 2** Methods of Dispersion of Nano-Particles in Composites and its effect on properties

| Materials      | Solution                     | Func. Agent                                       | Dispersion method           | Properties  | Ref. |
|----------------|------------------------------|---|-----------------------------|---|------|
| Graphene       | Distilled water              | (NH <sub>4</sub> ) <sub>2</sub> HP O <sub>4</sub> | Bath Sonication + Mech. mix | Improvement in Tensile strength, and strong interfacial interactions between Particles and Matrix                 | [34] |
| Func. Graphene | 1-Methyl-2-Pyrrolidone (NMP) | Xylene  | Mechanical mix              | Improvement in electrical conductivity, and other mechanical properties like Nano-indentation, tensile strength   | [35] |
| Func. Graphene | Anhydrous Toluene            | Ethylene diamine (EDA)                            | Bath Sonication             | Improvement in Tensile strength, modulus and ductility  | [36] |
| Func. Graphene | Ethanol                      | DMF   | Bath Sonication + Mech. mix | Improvement in EMI shielding  | [37] |
| Func. MWCNT    | Acetone                      | Cyanate ester                                     | Bath Sonication + Mech. Mix | Flexural strength (59%), Impact resistance (45%), Tensile St. (32%)   | [38] |
| Func. Graphene | Deionized water              | Polypyrrole                                       | Bath Sonication             | Improvement in load transfer between the reinforcements and epoxy matrix  | [39] |
| MWCNT          | —                            | —   | Bath Sonication             | Maximum enhancement of K <sub>ic</sub> was 19.5% which was obtained for the nano composite with 0.5 wt% of MWCNT. | [40] |
| MWCNT          | —                            | —   | Bath Sonication             | Negative temperature coefficient (NTC) -10.6%   | [41] |
| Graphene       | —                            | —   | Bath Sonication             | Tensile strength 11%<br>Flexural strength 17%   | [42] |

|                |                       |                                 |                                      |   |      |
|----------------|-----------------------|---------------------------------|--------------------------------------|---|------|
|                |                       |                                 |                                      | Thermal conductivity 126%<br>Dielectric constant 171%   |      |
| MWCNT          |                       |                                 | Bath Sonication                      | Tensile strength 26 %<br>Flexural strength 29%<br>Thermal conductivity 60%<br>Dielectric constant 73% | [42] |
| Graphene       | PAMAM                 |                                 | Ultra sonication                     | Flexural strength 78%<br>Modulus 50% Compressive strength 41%   | [44] |
| MWCNT          |                       |                                 |                                      | Shear strength reduced by 30%<br>High modulus   | [45] |
| N-CF           | Dimethyl formaldehyde | Nitric acid                     | Mechanical mix +<br>Ultra sonication | Surface roughness 61%<br>Coefficient of friction 10%  | [46] |
| Graphene       | Acetone               |                                 | Mechanical mix                       | Fracture energy 150%<br>Thermal expansion coefficient 30%   | [47] |
| Nano-diamond   | DMF                   | H <sub>6</sub> N <sub>2</sub> O | Mechanical mix                       | Flexural modulus 36.4%<br>Tensile strength 28.1%  | [48] |
| Func. Graphene |                       | Sodium alginate                 | Mechanical mix                       | Tensile modulus 62%<br>Tensile strength 40%   | [49] |
| Silica         |                       |                                 | Tip sonication +<br>Bath Sonication  | Tensile modulus 11.6%<br>Tensile strength 28.80%<br>Flexural modulus 13.20%                           | [50] |
| Silica         | NaOH solution         |                                 | Ultrasonic                           | Compressive strength 27%<br>Flexural strength 28.8%   | [51] |

N. B.: Func. Graphene = Functionalized Graphene

**Detomi, et al. 2014** [52] studied the statistical effects of using ceramic particles in glass fibre reinforced composites. The addition of ceramic particles at the upper side of the samples provided an increase on the flexural strength and specific strength up to 110% and 112% respectively against the un-reinforced baseline. The dispersion of micro-ceramic particles into glass fibre composites provided no significant change on the bulk density of the composites. An enhancement of the flexural strength was observed when the silica particles were added to the upper side of the sample.

**Moumen and Tarfaoui in 2017** [53] studied the dynamic properties of carbon nanotubes reinforced carbon fibers/ epoxy textile composites under low velocity impact. By addition of 1% CNTs the dynamic properties increased in composite panels up to 13%. Decreasing in the dynamic properties was observed for composites with 4% of CNTs. Film nanocomposite with 1% of CNTs was good, but above its concentration nanotubes started aggregating. So the aggregation increases with increasing the CNTs content. Rebound velocity is important in the case of composites with 1% of CNTs. Therefore the material behavior becomes more rigid with presence of nanotubes.

**Thomas et al. in 2012** [54] studied the mechanical properties showed significant improvement with low loading of nanofillers. The tensile and flexural modulus showed more than 50% increase with 3 wt% filler loading. Dielectric constant of the composites increased with respect to the filler content at room temperature as well as for different temperatures owing to the increased polarization by the fillers.

## CONCLUSION

This paper features the impact of scattering of small scale and nano fillers in the polymer framework on the different physical and mechanical properties of the composite materials. It was watched that the different properties of the composite materials are enhanced when nano particles are added to the polymer framework when contrasted with that of smaller scale particles fortifications. In any case, the shot of molecule agglomeration is more if there should be an occurrence of higher substance of nano particles than that of smaller scale particles, consequently unique care which is consolidated in this audit paper, must be considered while managing the nano particles in contrast with the miniaturized scale particles to accomplish better all-round properties of the last items.

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