Behavior of Materials in the Presence of Particles Additive Technique: A Review

Fares Mohammed Laid Rekbi

Abstract− Recently, engineers and researchers have been concerned about how to improve the behavior of materials used in manufacturing. Ensuring the compatibility of particle, as main constituents with other reinforcement, in composites for specific behavior is essential. In this review, we attempt to list the salient features of experimental as well as numerical investigation on characteristics composite materials with adding either micro- or nano-particles, which is one of the ways to express it. The behavior of composites materials such as mechanical enhanced with different form, size, type and nature of particle additives. The bibliography review concludes that it would be important to investigate extensively the features of this technique in order to get more discoveries and developments of materials experimentally and numerically. Some contributions have identified the research gaps and deduced that the potential application of particles as additive agents in composites have not beenmore explored.

Keywords− Particles, Nanocomposites, Composite Materials, Behavior.

NOMENCLATURE

PP	Polypropylene.
NPs	Nanoparticles.
MWCNT	Multi-walled carbon nanotubes.
TSP	Tamarind seeds powder.
NS	Nanosilica.
GNPs	Graphene nanoplatelets.
FWP	Filament winding pipes.
CSR	Core-shell rubber.
LVI	Low- velocity Impact.
HVI	High- velocity Impact.
SEM	Scanning electronic microscopy.
IT	Infrared thermography.
FMLs	Fibers metal laminates.
CFRP	Carbon fiber reinforced pipe.
GF-SMC	Glass fiber sheet molding.
NFRBC	Natural fiber reinforced biocomposite.
NFRP	Natural fiber reinforced polymer.
MAPP	Malcated polypropylene.
Phc	Per hundred compounds.
NDT	Nondestructive testing.

I. INTRODUCTION

The researchers are interested in improving the properties of materials where this provides potential opportunities to create better industrial and sustainable materials for use in several application fields. For example, Lee Byoung-Ho et al. [1] demonstrated that the breaking strain and tensile strength of natural fiber reinforced composites becomes lower than that of the pure PP matrix, this can be explained by both voids and the interfacial adhesion fiber/matrix in the composites. These reasons make engineers to find solutions to them, such as nano or macro particle additions. It has led to great and growing interest, both in academia and industry area. To achieve the desired technical effect in the final composite, what is known as an additive is used, which is incorporated into the materials to become an essential part of the final material. Composite material reinforced with nano particles, also named nanocomposites are being investigated worldwide in recent years. Generally These types of materials produce with mixture of most than two materials producing new material with the nano range dimension [2]. And by incorporation of the particle are on a weight basis for the advanced composite[3]. From Mohajerani Abbas et al. [4] and Venkatesh Nagasarny et al. [5] particles sized in dimensions (diameter, with, length and thickness) range of 1 up to 100 nanometres and ultrafine are defined nanoparticle. The nanoparticles (NPs) also are defined as the combination of molecules or atoms up to millions and are frequently named simply clusters or nano clusters from theoretical point view [6]. Venkatesh Nagasarny et al. [5] noted that the metallic nanoparticle is important because of their ideal optical, magnetic, electrical and chemical properties. The NPs could be seen in the nanotube, particles and powder forms, etc. such as clay, carbon nano-powder and carbon nano-tubes which are the widely used nano-particles [7]. The table 1 is summarized the class of NPs which are to organic and inorganic in nature [8].

Table. I
EXAMPLE OF NANOPARTICLES NATURE

Organic	Inorganic
Coir nanofiller	Silica (SiO_2)
Carbon black	Titanium dioxide (TiO_2)
Cellulosic nanofiller	Calcium carbonate ($CaCO_3$)
Natural particles, etc.	Polyhedral oligomeric silsesquioxane (POSS), etc.

The huge number of applications of nanocomposites is in great and continuous growing at faster rate these days, in engineering, medicine and Ultraviolet protection gels and anti-corrosion barrier protection … etc.[2], [9]. The use of nanoparticles reinforced polymer matrix composite

Manuscript received September 21, 2022; revised April 13, 2023.

Fares Mohammed Laid REKBI is with Research Center in Industrial Technologies (CRTI), P. O. Box 64, Cheraga 16014, Algiers, Algeria. (Email: f.rekbi@crti.dz)

Digital Object Identifier (DOI): 10.53907/enpesj.v3i1.122

materials (Fig. 1) in engineering application is increasing due to their high strength/stiffness to low weight ratio, corrosion resistance, ease of fabrication economically efficient properties and environmentally friendly [10].

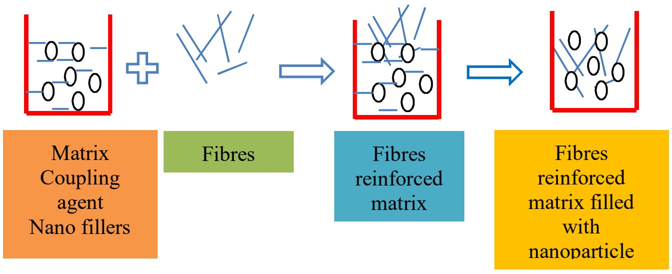


Fig. 1: Formation of fiber reinforced matrix filled with nanoparticle.

One of the challenge fields that a more study has been carried out about them is adding the nanoparticle such as (SiO_2) [11]-[12], nanosilica [13]- [14], nanoclay [15] -[16], grapheme [17] and grapheme oxide and nanozirconia [18], titanium dioxide (TiO_2) [19]-[20], matrix filled with cork powder [21], Tamarind seeds (TSP) powder [22] into the composite materials. The incorporation of the particle by dispersed it in the matrix (Fig. 1) [11], coated the fibers (Fig. 2) [23] or a direct addition of particle into composite [24]. Very often, homogeneous distribution of the nanosized particles is problematic and aggregation phenomena is a major subject in composite materials having spherical nanoparticles [3].

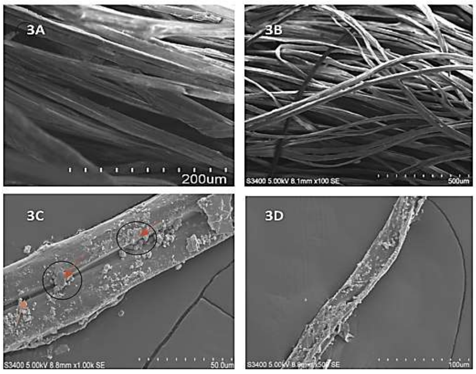


Fig. 2: SEM observaion (a) and (b) uncoated silk fibers, (c) and (d) SnO coated silk fibers with uniform distribution of nanoparticles [32].

Recently several papers appear on reinforced composite with particles additive based nano or macro particle, with limited attention on different behaviors and which parameters influenced it that. For example, Shalwan A and Yousif B F [25] noted that the mechanical and tribological performance of date palm fiber/epoxy reinforced composites DPFERCs get improved by graphite particle additive but high weight of it deteriorates the mechanical behaviors. The essential aim of this study focus on the more understands on the parameters influenced on the behaviors of these materials.

II. Applications of the Nanocomposite Materials

For example, the optimizing and improvement of physical properties of functional nanocomposites allow new application e.g., in electronics, microocptics, energy conversion or storage [26]. Metallic nanoparticles give wide range of application in therapeutic, vehicles for gene and biotechnology [5]. In what follows the most potential use in construction are presented. The expected benefits of carbon nanotubes are mechanical durability and crack prevention in concrete makes it competitive for use in construction application materials. Also, the titanium dioxide nanoparticles TiO_2 are added to concrete to improve its properties, is used as an excellent reflective coating added to paints, cements and windows for its sterilizing properties [27]. In addition to all these construction applications may find the nao-SiO_2 used for increase the compressive strength of concretes by filling the pores. In addition to applications, Wu Yingji et al. [28] proved the possibility of a new nanocomposite material for automotive applications based on ZnO particle addition. Presting H and Konig U [29] noted that the automotive industry is diverse or manifold with the application on nanotechnology by used of nanocomposite materials. Also, to fluid transportation application, Di Chengrui [12] demonstrated that the used of additives on the filament winding structures for this application to produce part such as pipe or tube. The use of nano material fiber composites in fields of intelligent communication, barrier packaging and higher value printing also addressed in study of Kamel S [30] he noted that the paper and pulp industry is a material which gives an excellent fields for developing nanomaterials. Abd-Okail Mohamed et al. [31] investigated in the one of the recent vital area used in renewable energy field is wind energy. They confirmed the possibility to fabricate wind turbine blade is used to generate energy with addition the nanoparticle in the based composites materials.

III. Why Particles Addition?

a. Fiber surface modification: the chemical inert properties of carbon fibers surface lead to weak interfacial adhesion fibre/resin [33]-[34].
b. Hydrophilic and hydrophobic nature: the hydrophilic property of natural fiber lead to weak interfacial adhesion fibre/matrix [8].

IV. Nanocomposite Behavior

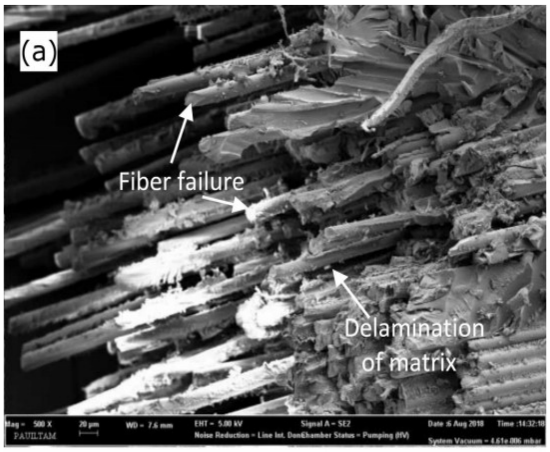
Nowadays, a great deal of researches and papers are in deployment towards more particles to produce a huge variety of nanocomposites. Table 2 listed works on nanocomposites and technology of particles with different scale regarding several fiber/matrix systems, in addition to various including (pipe, laminate, Prosthetic composite and biaxial braider, etc.). Also, to various architectures of fiber (Unidirectional, Long, Short or Weave, etc.), (Synthetic or Natural) and to system of reinforcement (Hybrid or Nohybrid). This addition of particles may be nano as previously mentioned or micro size [38]. Fu Shao-Yun et al. [42] show that are strongly effect of particle size, particle/matrix and particle loading on composite materials toughness and strength, especially particle/matrix adhesion factor. From literatures, Ebrahimnezhad Khaljiri et al. [15] declared that the main objective for adding particles is enhancing and improving the mechanical behaviors of composites, enhancing fiber matrix interfacial [18]-[11] and to make composites could withstand high impact load and improve strength of laminates [7]. Also, improvement the properties of composites such as physical and thermal properties [8]. To increase the surface roughness on case of natural fiber which to provide an additional region for interlocking along with matrix with the chemical bond formations [43]-[19]. So, there is a various contributions by researchers have been conducted to understand the properties of composite materials, these studies included tensile, flexural and impact etc. tests carried out for particles effect on their behavior (Table 3). They observed that are effective improvement on mechanical properties in the case of nanolayers clay addition and that when the polymer is in its rubbery state versus the glassy state, also the dimensional stability, solvent resistance and thermal stability of the glassy matrix can also be increased [10].

Table. II
REPORTED RESEARCH ON EFFECT OF PARTICLE ON COMPOSITES PROPERTIES

Material	Stucture	Addition	Size/ weight	Test	Key funding	Refs.
E glass/Epoxy	Sandwich	Graphene nanoparticule	An outer diameter and thickness of 10-20nm / 0.1%, 0.3% and 0.5% of weight	Tensile	The effect the weight addition of nanoparticle on the tensile strength	[17]
Carbon/Epoxy	Pipe	Multi-walled carbon nanotubes (MWCNT)	/	Impact	Impact behavior of filament winding pipes at cryogenic temperatures	[35]
Carbon/Epoxy	Tube	Nanosilica particles	15 and 25 weight percent in epoxy	Ballistic impact	Incorporation effect of variable amounts of nanosilica (NS)in the matrix	[13]
Glass/Epoxy	Laminate	Micro (nanoclay) and nano (miro-Glass Bubbles)	Nanoclay (6µm) Glass Bubbles 20µm/ 1wt.% weight content	Drop-weight impact	Effect of hybrid from micro and nano fillers additive on impact behavior composite	[36]
Carbon/Epoxy	Pipe	Core-shell rubber (CSR) nanoparticle and nano-SiO_2 rigid particles	/	Tensile, flexural and impact	Effect of addition mechanical behavior of resin and composites	[12]
Carbon/Epoxy	Laminate	Nano-SiO_2	1-8wt.% weight	Low- velocity Impact	SiO_2 nanoparticle effect on impact damage size, flexural strength and impact resistance	[11]
Aluminum-Jute/ Epoxy	Fiber metal laminate (FML)	Nanoclay	0, 1, 3 and 5wt.%	High-velocity impact	Nanoclay particles effect on the impact response of composite	[15]
Basalt/Epoxy	Laminate	Graphene oxide and nanozirconia	0.1- 0.3wt.% graphing oxide and 1-3wt.% nanozirconia	Three point bending test and Dry-sliding wear	Flexural and tribological properties when add grapheme and nanozirconia particles	[18]
Carbon/Epoxy	Laminate	Silica nanoparticles	/	fatigue and Mode I interlaminar fracture	Effect of fiber modification with nanoparticle on the toughness of composites	[14]
Flax/Epoxy	Laminate	Nano TiO_2	0.2wt.% -2wt.%	Tensile, flexural and Water absorption	Effect of fiber coating by nanoparticle on mechanical properties of composite	[23]
Perlon /Kevlar/ Glass	Prosthetic composite materials	Nano AL_2O_3 and SiO_2	0-2% volume fraction	Tensile and fatigue	Effect of volume fraction (V_f)of nanoparticle on fatigue property of composites	[37]
Kenaf/polyester matrix	Composite for automotive application	ZnO	5.9, 12.4 and 18.9wt.%	Tensile, 3-points flexural and water absorption	Effect of ZnO nanoparticle on developing a natural reinforced composites to replace GF-SMC	[28]
Carbon/Epoxy	Flat biaxial braided composite	TiO2	0 to 5wt.%	Impact, flexural and tensile	Evaluation the effect of nanoparticle addition on mechanical properties of braided composite materials	[20]
Plain weave Carbon/Epoxy	Laminate	Silica nanoparticle and silica microparticle	1 and 3.5wt.%	Tensile and impact	The effect of nano and micro silica particle on impact resistance of composite	[38]
Kevlar and Carbon/Epoxy	Laminate	Cork powder	/	Static bending test	Effect of introduce cork powder in matrix on behavior of composite	[21]
Flax/Thermoplastic matrix	Laminate	Tamarind seeds powder (TSP)	5 to 15% of the weight of the matrix	Tensile, bending and moisture absorption	Influence of new developed natural additive material on composites behavior	[22]
Unidirectional E-Glass/polypropylene (PP)	Pultrude composite beam	Nanoclay	0-5 wt.% and 10 wt.%	Compression	Effect of nanoparticle content and pultusion manufacturing process variable on the mechanical properties	[39]

Glass/Vinyl ester	/	Nanoclay	0, 1, 3 and 5wt.%	Free vibration	Effect of additive on vibration characteristics	[40]
Rice husk flour/polyethylene (HDPE)	Injection molding composites	Nanoclay	0, 2, 4 and 6wt.%	Tensile and thermal	Nanofiller addition effect on the thermal behavior and rheological response	[41]
Reed/polypropylene	Injection molding composites	Nanoclay	0, 2 and 4wt.%	Water absorption and tensile	Evaluation the effect of nanoclay particle on mechanical and physical characteristics of the nanocmposite	[16]
Carbon/Glass/Epoxy	Wind turbines blade	Alumina nanoparticle (Al_2O_3) and graphene nanoplatelets (GNPs)	1.5wt.% Al_2O_3+1.5wt.% GNPs And 3wt.% Al_2O_3	Tensile, flexural and hardness	Effect of the dispersion of nanoparticle on microstructure, tensile strength, bending strength and hardness	[31]
Wood flour/HDPE	/	Nanoclay	/	Flexural, tensile and dynamic	Effect of two approach of incorporation of nanoparticle on mechanical properties	[24]

The results of this study show also the damage type on composite (Fig. 3) and the effect of nano particle additive on strength of layered composite structures (Fig. 4), where observed the amount of 0.1% and 0.3% nanoparticle graphene additive led to 9% up to 22% increase in the composite strength. Also, an optimum graphene amount exists in the composites structure and excess amount weight of graphene nanoparticle additive caused a decrease in the strength of composite structures. Through all these observations was found optimum amount graphene additive to be 0.1wt.% and composites was significantly influenced by graphene nanoparticles.



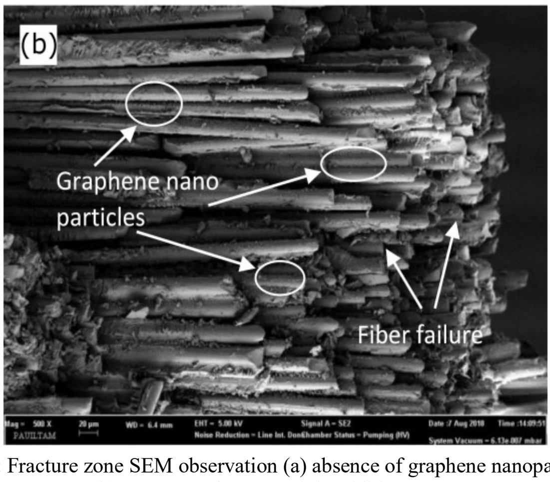


Fig. 3 : Fracture zone SEM observation (a) absence of graphene nanoparticle, (b) presence of nanoparticle additive [17].

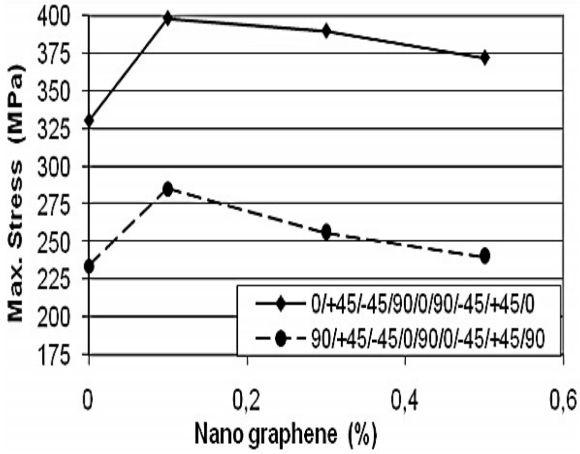


Fig. 4 : Nano particale weight effect on the tensile strength [17].

Aniruddh Vashisth et al. [13] in their experimental investigation on impact of carbon/epoxy tubes loaded in torsion show that when the addition of nanosilica (NS) decreased of the impact damage area by 50%, increased the energy absorbed per unit damage area by 120 and increased the residual shear strength by 38% compared to the material with no NS. While in overall, the incorporation of NS significantly improved the impact tolerance of carbon/epoxy tubes loaded in torsion test, with little change in the glass transition temperature, mass density and elastic modulus. The additive hybridation effect on behavior of composites laminate was performed by Ermiias G Koricho et al. [36], two fillers (nano- and micro) chosen were utilized in their study. The result of visual inspection show that the evolution on the stiffness and peak force with varying energy levels and show that Glass Bubble modified composite laminates are characterized the lower absorbed energy and high peak force with penetration of the impactor through their thickness at high impact energy levels (262J) (Fig. 5). While nanoclay modified composite laminates are characterized by highest absorbed energy, the minimum peak reaction force and without penetration of impactor. But in the case of hybrid modified composites laminates exhibited intermediate absorbed energy and peak reaction force sustained for longer time (Fig. 6).

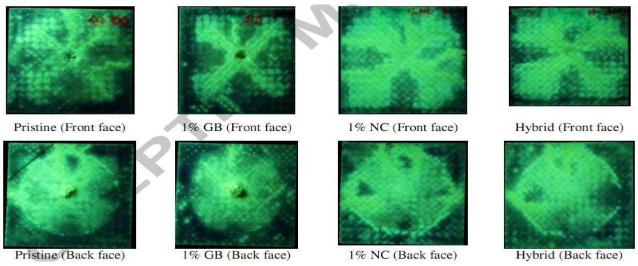


Fig. 5: Evaluation of post- impact by dye penetration method at 260J, Comparaisson images [36].

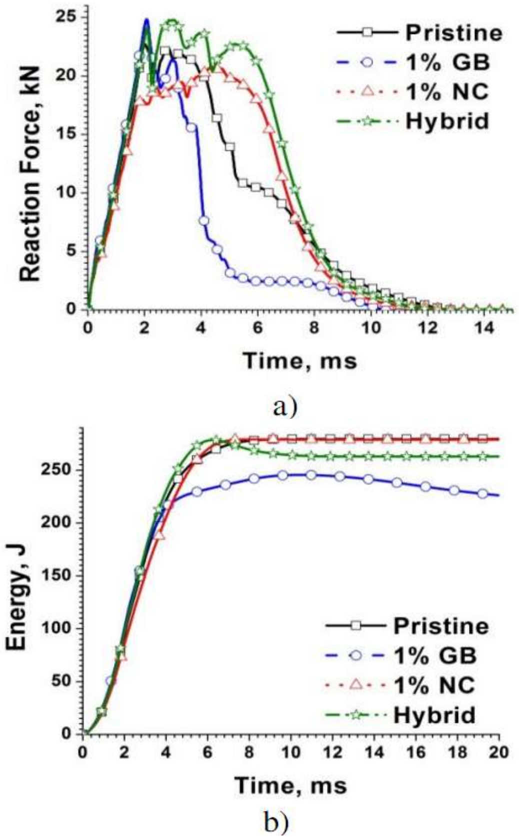


Fig. 6: a) Reaction force-time, b) Energy-time at 262J comparaisonof material behavior [36].

The experimental investigation of Di Chengrui et al. [12] demonstrated that modified epoxy matrix enhanced the mechanical behavior of carbon/epoxy reinforced wound composites pipes, the Young's modulus, interlaminar shear strength and tensile strength were enhanced by 4.56%, 18.9% and 14.0%, respectively, compared with the composites pipe based on unmodified matrix. The authors also mentioned that the preparation process is simple because the resin system is low, so it is of practical implication to market application. Which is highlighted by the SEM observations when shown the fiber was tightly coated by resin, which suggested that the modified resin exhibited a better interface with the fiber (Fig. 7).

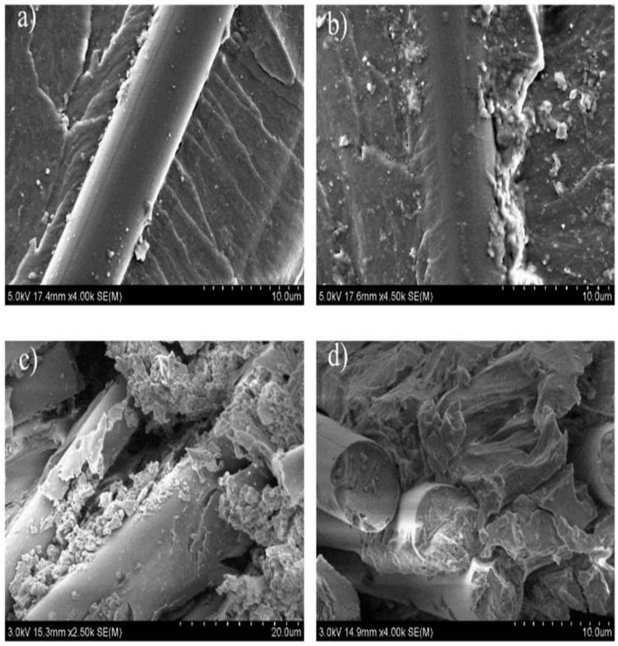
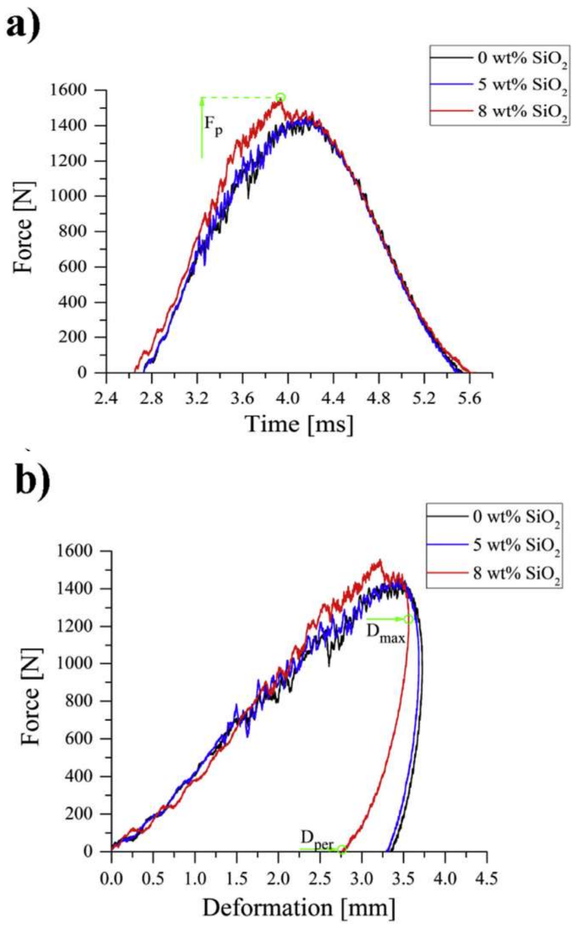


Fig. 7: SEM images of composite materials (a and b) of interlaminar shearfailure surface, (c and d) of tensile fracture surface [12].

Landowski Michal et al. [11] demonstrated the effect of SiO_2 nanoparticle on flexural behavior, impact resistance and impact damage size. As a result of the study, they are seen that the SiO_2 nanoparticle addition make significant influence on mechanical behavior of carbon/epoxy composite laminates, especially in term of impact damage behavior. Where these results in 3 parameter terms: absorbed energy (Ea), a peak impact force (Fp) and permanent deformation (Dper) (Fig. 8).



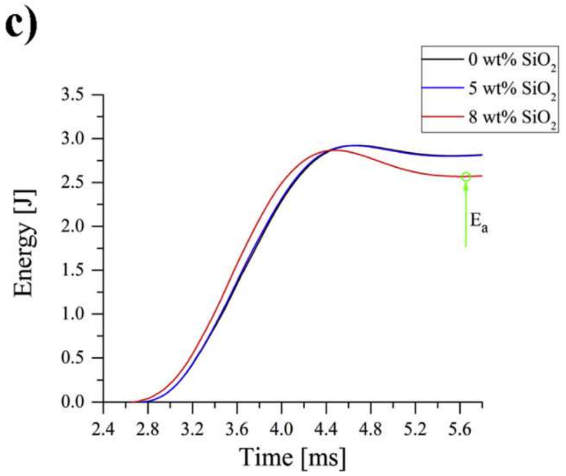


Fig. 8: a) force-time, b)Force-deformation, c) Energy-time for 0, 5 and 8wt.% SiO_2 at impact tests [11].

Also, by nondestructive evaluation via infrared thermography method (IT) (Fig. 9) the impact damage results for the different weight percent of SiO_2 nanoparticle (0, 5, and 8%) were illustrated, the authors concluded that from this analysis diminution of the damage area with increasing nanoparticle content. Also, it was observed a transition in properties of SiO_2 peak strength at 5% and initiation of decrease in impact damage size associated with energy absorbing mechanisms of crack branching and crack deflection due to nanoparticle agglomerates phenomenon.

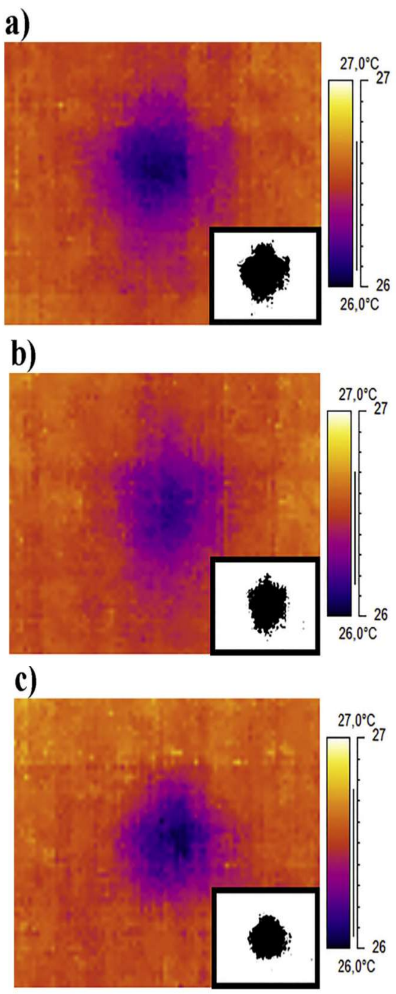


Fig. 9: Infrared thermography images of impact damage area, a) 0%, b) 5% and c) 8% of SiO_2 nanoparticle [11].

In another one part study carried out by Ebrahimnezhad-Khaljiri Hossein et al. [15] the nanoclay particle with various percentages (0, 1, 3 and 5wt.%) effect on the impact response of fibers metal laminates (FMLs) from aluminum-Jute fiber and epoxy matrix was investigated. The results of the study showed that the incorporation of nanoclay was effective in formation of the limited velocity energy, absorbed energy (Fig. 10), damage area (Fig. 11) and delamination length (Fig. 12).

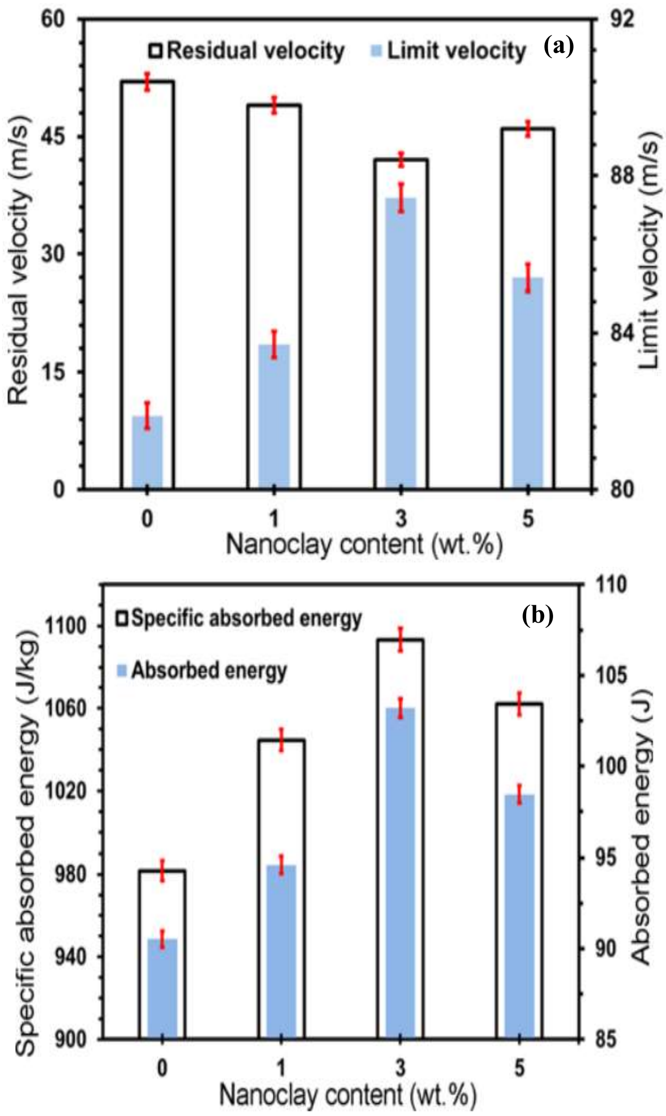


Fig. 10: FMLs impact results (a) limit velocity impact and the residual velocity, (b) the specific absorbed energy and absorbed energy [15].

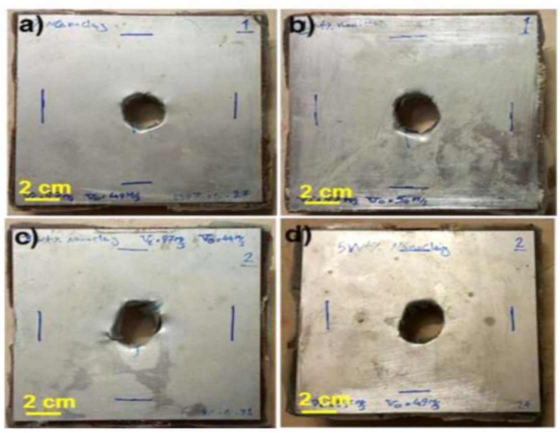


Fig. 11: Photographs of damage area in FMLs with nanoclay 0wt.%, 1wt.%, 3wt.% and 5wt.% of a), b), c), d), respectively. [15].

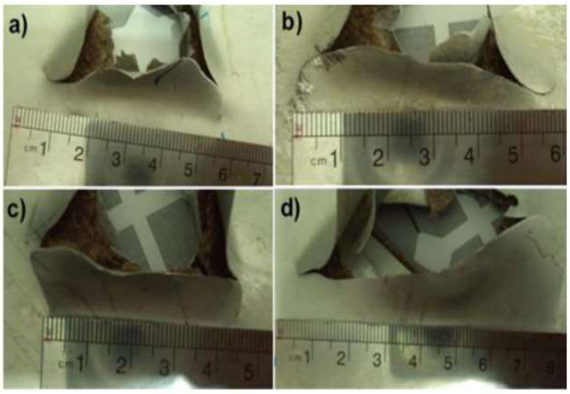


Fig. 12: Images of delamination length in the fibers metal laminates with nanoclay 0wt.%, 1wt.%, 3wt.% and 5wt.% of a), b), c), d), respectively. [15].

In this study the nanoparticle weight percent effect was been addressed and analyzed, where observed the higher impact properties on case of the FMLs with the 3 wt.% nanoclay when compared with the other laminates. The limited velocity reached to 87m/s, 103.2J absorbed energy, 7.6cm damaged area and 1093J/kg specific absorbed energy. The authors noted that the effect of nanoclay on the improvement of adhesion between aluminum layer and composite core led to minimum delamination length (Fig. 13). From Fig. 13(a), it observed that the adhesion fiber/resin is weak because the epoxy resin cannot be seen on the Jute fibers surface. The authors returned this reason to the hydrophilic nature of the natural Jute fibers led to effect on the mechanical properties of the materials. But the authors noted that adhesion between fibers and resin was improved when addition of nanoclay into the matrix from 1 up to 3wt.% which can be observed in figure Fig. 13(b) and Fig. 13(c). In the case of 5wt.% nanoclay addition, they were seen the adhesion between matrix and fiber has been reduced Fig. 13(d).

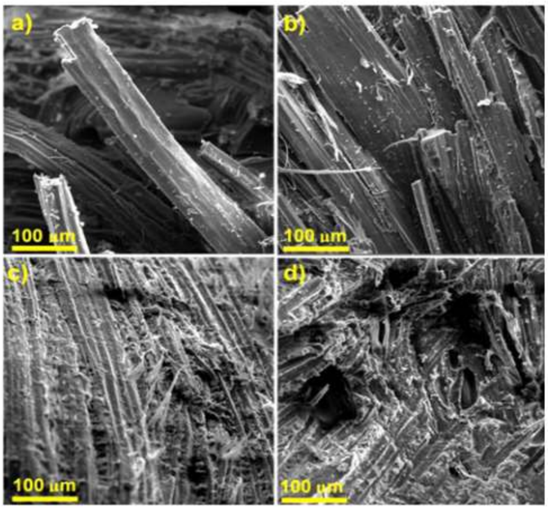


Fig. 13: Fracture surface of FMLs after high-velocity impact test with nanoclay, a) 0, b) 1, c) 3 and d)5wt.%, SEM images [15].

Also, concerned the conclusions of this investigation the authors mentioned a phenomenon characterized the natural fiber, which is the fibrillation phenomenon (Fig. 14) helps to absorbed the energy in composite materials.

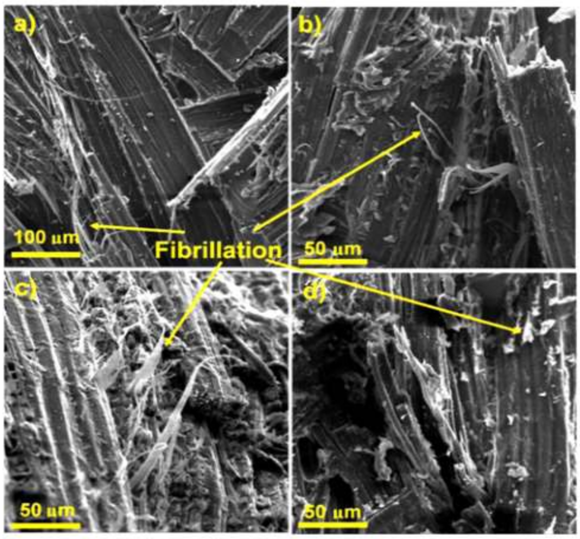


Fig. 14: Fibrillation phenomenon of Jute fibers, a)0, b)1, c)3 and d)5wt.%, SEM images [15].

The Fig. 14(a) show the fibrillation of the jute fibers is very low by addition of 1wt.% nanoclay. Where observed this phenomenon increased up to maximum value belongs to the laminates containing 3wt.% nanoclay particle (seen Fig. 14(b) and (c)). Also, the Fig. 14(d) shown the reduced of the Jut fibers fibrillation compared with the 1 and 3wt.% nanoclay composites. These led to declare that 3wt.% is the optimum percentage of nanoclay addition. Davood Toorchi at al. [18] were used the additive alone and by hybridation in their work, by using the graphene oxide and nano-zirconia. In this study, the laminate composites with various amount (0.1, 0.3 and 0.5wt.%) and (1, 2 and 3wt.%) of graphene-oxide and, nanozirconia, respectively. or hybrid system from graphene-oxide/nanozirconia in the resin were manufactured, their tribological property and flexural behavior were investigated under dry-sliding wear and three point bending, respectively. The results show that graphene-oxide loaded sample with the 0.3wt.% filler content demonstrated the maximum improvement up to 33% in flexural strength property, while for nanozirconia particle enhanced laminates, the highest flexural strength shown in the specimen with 1wt.% nanozirconia by increasing up to 29% . Also, the positive effect of nanohybrid system of additive on flexural strength is observed specially when hybridization of 0.1wt.% graphene oxide with 1wt.% nanozirconia which increasing up to 50% (Fig. 15). All these results due to enhance of fiber-matrix interfacial. However, the authors declared that the the flexural strength of laminates is declined probably in the case of hybridization of higher loading content on nanofilles (3wt.% nanozirconia and 0.5wt.% graphene oxide), due to the formation of nanofiller agglomerates phenomenon within the interface or matrix (Fig. 16).

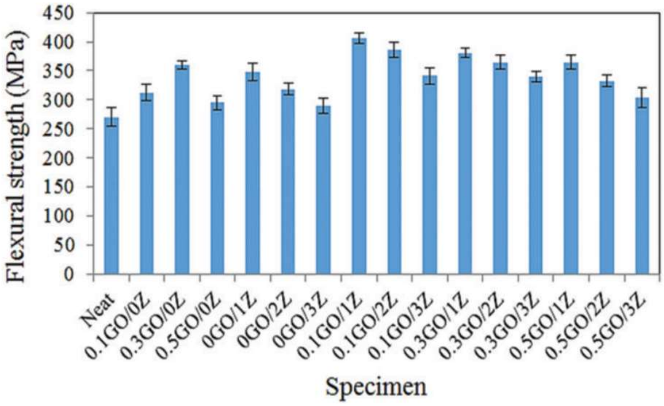


Fig. 15: The variation results of flexural strength values Vs. addition content [18].

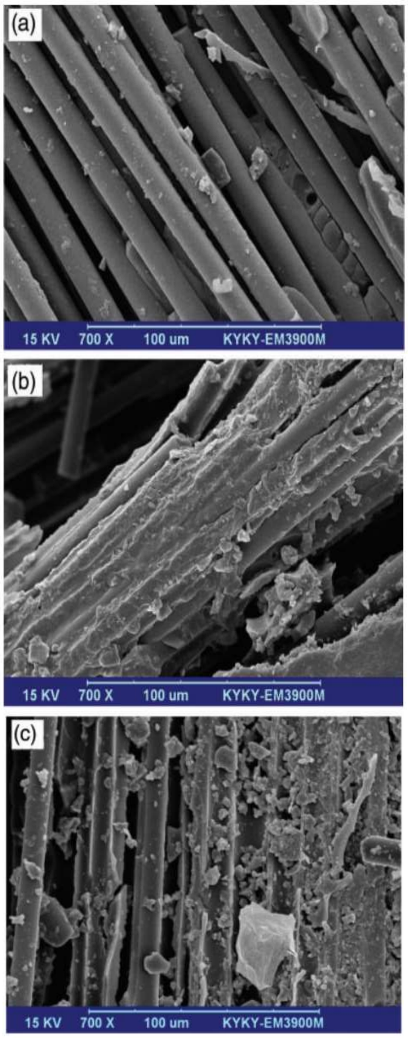


Fig. 16: SEM images of fracture surface images (a), (b) and (c) neat basalt fiber-epoxy laminate, multiscale 0.1w.t% graphene oxide plus 1wt.% nanozirconia-enhanced sample and multiscale 0.5wt.% graphene oxide plus 3wt.% nanozirconia- enhanced sample, respectively. [18].

The results of the tribological analysis show the stats of the surface and damage mechanisms. The matrix cracking, fiber/matrix debonding and fiber breakage observed on the worn surface of the neat basalt/epoxy laminate Fig. 17(a). But the addition of nanofilles enhancing of interfacial between matrix and basalt fibers and the laminate has a smooth surface Fig. 17(b). However, roughness surface for the laminate composites for the worn surface of multiscale 0.5wt.% graphene oxide + 3wt.% nanozirconia filled basalt/epoxy composite Fig. 17(c).

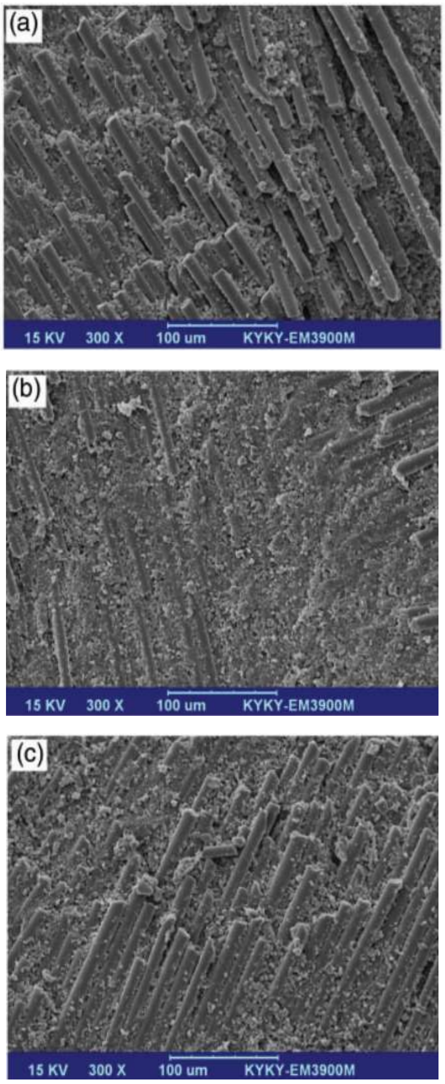


Fig. 17: SEM images of the worn surface (a), (b) and (c) neat basalt fiber-epoxy laminate, multiscale 0.1w.t% graphene oxide plus 1wt.% nanozirconia-enhanced sample and multiscale 0.5wt.% graphene oxide plus 3wt.% nanozirconia- enhanced sample, respectively. [18].

Joshua J Jensin et al. [7] mentioned in their study the value equal 0.25wt.% is an optimum doping content of the MWCNT doping to reach maximum damage response of carbon fiber CFRP laminate. Also, at this the optimum doping content value observed increasing in the energy absorption up to 18.03% in addition to 23.65% reduction in the rectangular damage area as compared to neat CFRP composite laminates (Fig. 18).

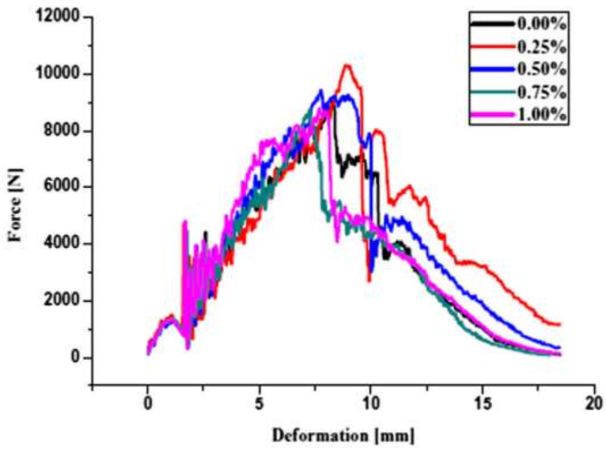


Fig. 18: Graph of force vs. deformation for different laminates [7].

This time by modification of fibers, Prasad Vishnu et al. [23] performed experimental study to evaluate flexural, tensilewater absorption and interlaminar shear strength of unmodified and flax fiber composites coated by nano TiO_2. They observed that in the results of this study an improvement in mechanical behavior on terms of tensile, interlaminar shear strength and flexural values by 22%, 16% and 24%, respectively. Also, reducing in water diffusion coefficient up to 42% on case of fiber coated specimens with 0.6wt.% nano TiO_2, because this optimum percentage represents continuously and uniformly distribution of SiO_2 nanoparticles Fig. 19(a) and (b). However, towards a higher percentage of nanoparticles coating as in the case for 0.8wt.% TiO_2, agglomeration and nonuniform distribution of particles over the fibers is witness (Fig. 19.c-d),(Fig. 19. e-f), (Fig. 19. g- h), (Fig. 19. i- j).

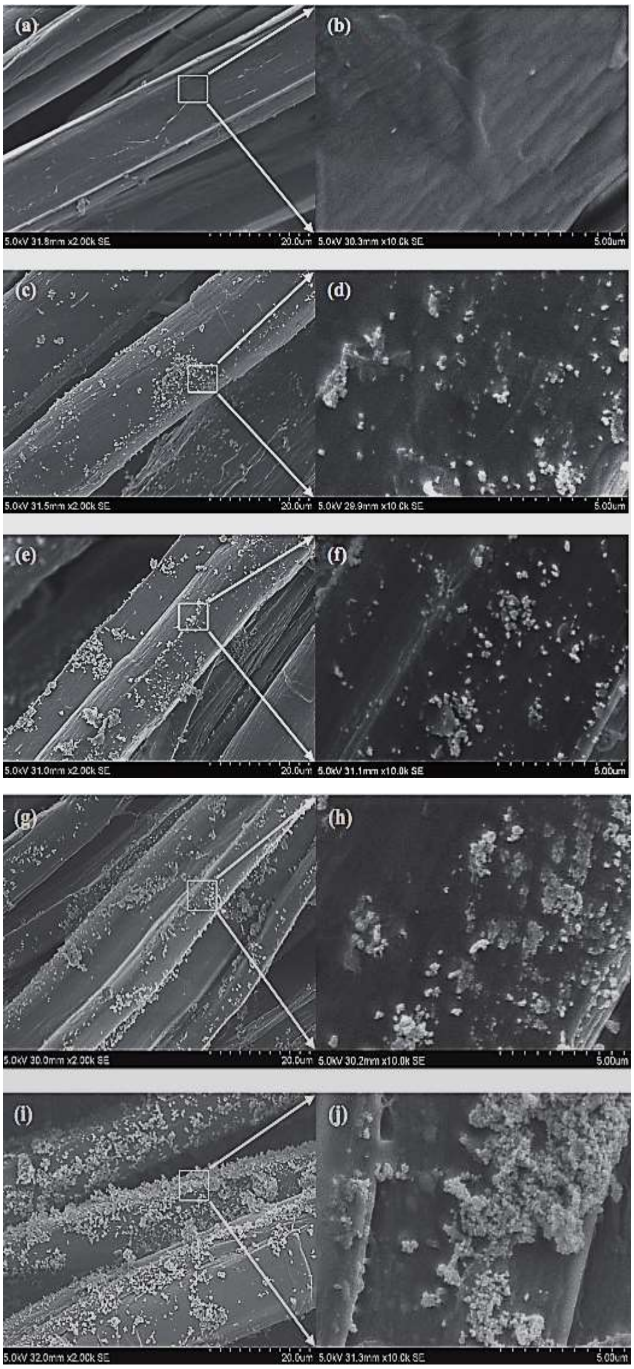


Fig. 19: SEM images of Flax fibers surface coated with TiO_2 at different content percentages (a) and (b) 0wt.%, (c) and (d) 0.2wt.%, (e) and (f)0.4wt.%, (g) and (h) 0.6wt.%, (i) and (j) 0.8wt.%, [23].

A comparison between two nano particle (Al_2O_3 and SiO_2) with different volume fraction (0 to 2%), their effect on fatigue behavior of composites used for manufacture the prosthetic sockets carried out by Al Waily Muhannad et al. [37]. From the results of this study the authors noted that the mechanical behavior, fatigue response and strength property increase with composites reinforcement with nanoparticle. Also, the results showed that the modified with nano SiO_2 is better for fatigue limits than modified with other reinforcement nanoparticle for fatigue limits and the modified for fatigue strength lead to 60% more than fatigue limit without nanoparticle additive. For enhancing natural fiber-reinforced biocomposite behavior by addition zinc-oxide (ZnO) and compared with glass-fiber sheet molding compound (GF-SMC) in term of mechanical properties an experimental study was carried out by Wu Yingji et al. [28]. A newly developed biocomposite (ZnO12.4%-NFRBC) showed that increasing in flexural behavior, tensile strengths and water resistance by (121%), (38%) and (76%), respectively. when addition 12.4% ZnO nanoparticle, led to the this novel biocomposite for automotive application comparable on term of mechanical behavior as GF-SMC while the production consumed 9.2% less energy and reduced the environmental burden up to 33.2% from life cycle assessment. Also, led to high potential of the newly developed (NFRBC) to replace (GF-SMC) on automotive application. The use of the ZnO nanoparticle in the composites was also reported, it was emphasized that the ZnO particles were easily adsorbed from the fiber surface, which indicated good surface compatibility fiber/ZnO particles (Fig. 20). Same phenomena was observed by authors on the case of other inorganic particle such as aluminum hydroxide ($Al(OH)_3$) and magnetite (Fe_3O_4) which adhered on the surface of natural fibers.

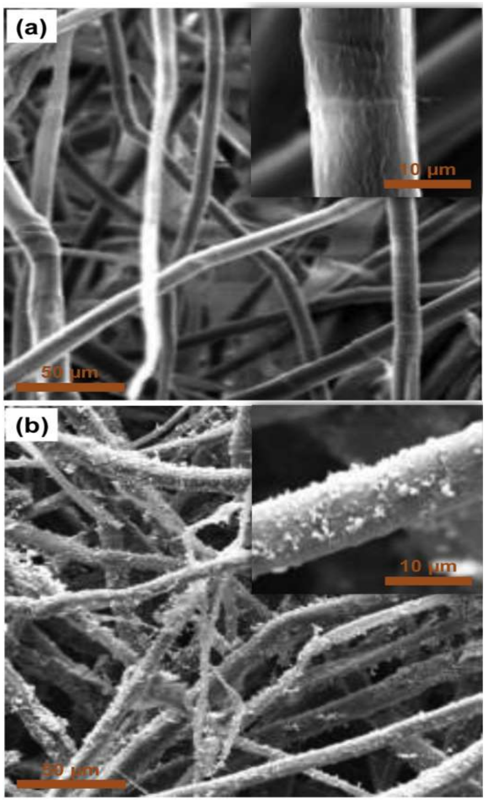


Fig. 20: Surface of Alkali-treated Kenaf fibers (a) before and (b) after loading by 17.8% ZnO nanoparticle, SEM images [28].

Parimala R et al. [20] were performed experimental study contained to evaluate of the mechanical behavior from tensile (Table 3) , flexural (Table 4) and impact test of carbon braided biaxial fibre composite material. The composite were fabricated by adding 0 wt.% to 5wt.% nanoparticles of TiO_2.

Table. III
TENSILE TEST VALUES OF BIAXIAL BRAIDED CARBON COMPOSITES WITH DIFFERENT PERCENTAGE OF TiO_2 NANOPARTICLE [20]

Specimen	Max load (KN)	Ultimate tensile strength (MPa)	Elongation break (%)	Tensile strengt h break (MPa)	Modulus (MPa)
0wt.%	12.03	130.16	24.04	103.67	1224.46
1wt.%	20.70	245.00	27.09	179.01	1658.23
3wt.%	23.66	267.51	29.05	192.55	1884.95
5wt.%	21.56	257.15	28.03	187.66	1724.69

Table. IV
FLEXURAL TEST VALUES OF BIAXIAL BRAIDED CARBON COMPOSITES WITH DIFFERENT PERCENTAGE OF TiO_2 NANOPARTICLE [20]

Specimen	Flexural load (N)	Max flexural stress (MPa)	Modulus (MPa)
0wt.% TiO_2	229.36	165.79	8265.88
1wt.% TiO_2	310.14	217.83	9515.62
3wt.% TiO_2	329.29	254.82	14277.20
5wt.% TiO_2	327.71	245.38	14181.26

After effectively adjusted carried out by researchers of this study with adding nanoparticle of TiO_2 in various percentage, the results show that the 3wt.% of the nanoparticle TiO_2 is the better percentage compared to other three configuration on mechanical behavior in term of flexural and tensile strength. And found that the flexural and tensile properties to decrease in the 5wt.% ,of TiO_2. In addition, the results show that no breakage up to 61dJ for all the samples in impact tests.

Size effect comparison of silica particle (nano and micro) on impact response of Carbon/Epoxy composite carried out by Dos Santos Julio C et al. [38]. The authors performed an incorporation of 1 and 3.5wt.% of both micro and nano-silica particles in plain weave carbon fiber/epoxy composite to evaluate the behavior of materials under impact tests. The authors were concluded that the micro size revealed better impact resistance compared to the nano particle size, when inclusion of 1wt.% of silica Vs. decreased in impact absorption when nano particle addition. This due to the interfacial fiber/matrix was increased by the silica nano sized and which might contribute to the fiber matrix bending weakening. The addition results also showed that the increase in mechanical behavior from tensile strength and modulus in adding nanosilica particle due to attributed to the interlocking of polymeric chains. A natural additive material was used in the study of Selvaraj DK et al. [22]. Powder from tamarind seeds TSP with 5% of the weight of the matrix incorporated in the composite to produce the laminate and compared between another laminate without additive on mechanical behavior (tensile, bending and moisture absorption tests). The mains object of this investigation to develop a new natural fiber reinforced polymer composites NFRP and the influence of a natural additive in the composite. An essential conclude of this study is that the specimens with natural additive has a Young's modulus with increases up to 10% and ultimate tensile strength up to 6% compared to the composite without additive. And due to presence of natural additive material on the surface of the composite, it becomes more absorber than the specimens without additive. All these results indicate that the influence of TSP additive in enhancing the mechanical behavior of composite material is stronger with great scale.

Roy Samit et al. [39] performed compression test of pultruded composites to evaluate and determinate the compressive strength of these generally weak in compression. The authors prepared pultruded composites with nanoclay incorporation for different content (0, 1, 2, 3, 4, 5wt.% and 10wt.%). The compression tests of this material show that increase on compressive properties with increasing clay loadings up to 10wt.%, due to good interaction between the glass fibers silicon based and the silicate clays, indicate of enhanced adhered between matrix and fiber. Najafi Abdollah et al. [16] were investigated in the role of coupling agent (malcated polypropylene MAPP) presence. This study based in incorporation of nanoclay and MAPP with concentration 0, 2 and 4 per hundred compounds (phc) and 0 and 2phc, respectively. The results indicated that the impact response and water uptake of PP/reed flour nanocomposites decreased by addition of nanoclay. However, with nanoclay loading the tensile modulus property and strength of the composites increased. Knowing that these both mechanical and physical analyses properties showed that the biggest enhancement value for the nanoclay loading at 4phc. With proof of that by using the X-ray diffraction analyze, when observed better dispersion of nanoclay on composites and the highlight the role of MAPP coupling agent. Same observation in the work of Njuguna James et al. [44] when proved the role of the coupling agent on enhancing of the behavior such as mechanical properties of the nanocomposites. Faruk Omar and Matuana Laurent M [24] investigated at identifying the best system of incorporation the nanoparticles into composites. The first system involved a direct incorporation of nanoclay particle into material during conventional dry compounding which named (direct dry blending process). The second system consisted of the reinforcement of matrix with nanoparticle, which was then used the melt blending process. It finally, the melt blending process appeared to be the best system of incorporation of nanoparticle in the composites. Table 5 highlights one of the results of mechanical analysis study show the influence of blending process of nanoparticle.

Table. V
FLEXURAL PROPERTIES OF NANOCOMPOSITE ON TWO DIFFERENT PROCESSES OF BLENDING [24]

Blending process	Flexural behavior	
	Strength (MPa)[a]	Modulus (MPa)[a]
Control (no nanoclay)	28.9±1.4[A]	1919.7±112[A]
Direct dry blending (direct mix)	27.1±1.4[B]	2233.8±144[B]
Melt blending	33.5±0.4[C]	2726.9±196[C]

V. CONCLUSION AND FUTURE DIRECTION

In summary, particle materials have been used as precious parts to improve the properties of different existing materials. From this review we concluded that:

- The additive can be added only in minimal percentage to enhance behavior of composites.
- The size, type and hybridization of particles addition are some of the parameters to predict and analyze of behavior and damage modes of the material.
- We found that the use of additive according to tests applications.
- A few recherches studies in case of behavior of sandwich composites with particles addition.
- The use of natural additive type will be potential filler material for composite materials and it is sustainable by nature.

Although significant previous works is done in this area, further work should be conducted for advancement of this research field such as:

- The use of NDT carrying out to ensure zero defect in composites to give good estimation of materials strength.
- Find more investigations to subject the use of coated fibers in the composite materials in the cryogenic conditions for special application such as aerospace applications, because the majority of research on the coated fibers was concentrated studies at the high and ambient temperature environment.
- The search in the behavior of composite materials reinforced by the particle addition in matrix and coated fibers on the same time.
- Conducting in-depth research on incorporation process of the particles.
- Performed numerical investigations to predict the effect of the particles addition on mechanical, thermal and physical properties of materials for different applications.

ACKNOWLEDGMENT

The author would like to thank the Ministry of Higher Education and Scientific Research, Algeria. Also gratefully acknowledges the Algerian General Direction of Research and Development Technology (DGRSDT) for their supports. And thanks to the Direction of Research Center in Industrial Technology-CRTI, Algeria for supporting this study. The author like to thanks to the family and to thanks to the members team of Nondestructive Testing and evaluation by Ultrasound for their patience with him on crossing the path of knowledge.

REFERENCES

[1] Lee, B.-H., H.-J. Kim, and W.-R. Yu, Fabrication of long and discontinuous natural fiber reinforced polypropylene biocomposites and their mechanical properties. Fibers and Polymers, 2009. 10(1): p. 83-90.

[2] Sharma, G., et al., Novel development of nanoparticles to bimetallic nanoparticles and their composites: a review. Journal of King Saud University-Science, 2019. 31(2): p. 257-269.

[3] Hári, J. and B. Pukánszky, Nanocomposites: preparation, structure, and properties, in Applied plastics engineering handbook2011, Elsevier. p. 109-142.

[4] Mohajerani, A., et al., Nanoparticles in construction materials and other applications, and implications of nanoparticle use. Materials, 2019. 12(19): p. 3052.

[5] Venkatesh, N., H. Bhowmik, and A. Kuila, Metallic nanoparticle: a review. Biomedical Journal of Scientific & Technical Research, 2018. 4(2): p. 3765-3775.

[6] Ferrando, R., J. Jellinek, and R.L. Johnston, Nanoalloys: from theory to applications of alloy clusters and nanoparticles. Chemical reviews, 2008. 108(3): p. 845-910.

[7] Joshua, J.J., P. Venkatanarayanan, and D. Singh, A literature review on composite materials filled with and without nanoparticles subjected to high/low velocity impact loads. Materials Today: Proceedings, 2020. 33(7): p. 4635-4641.

[8] Saba, N., P.M. Tahir, and M. Jawaid, A review on potentiality of nano filler/natural fiber filled polymer hybrid composites. Polymers, 2014. 6(8): p. 2247-2273.

[9] Kumar, A., et al., Polyacrylamide/Ni0. 02Zn0. 98O nanocomposite with high solar light photocatalytic activity and efficient adsorption capacity for toxic dye removal. Industrial & Engineering Chemistry Research, 2014. 53(40): p. 15549-15560.

[10] 10. LeBaron, P.C., Z. Wang, and T.J. Pinnavaia, Polymer-layered silicate nanocomposites: an overview. Applied clay science, 1999. 15(1-2): p. 11-29.

[11] Landowski, M., et al., Impact damage in SiO2 nanoparticle enhanced epoxy–Carbon fibre composites. Composites Part B: Engineering, 2017. 113: p. 91-99.

[12] Di, C., et al., Study of hybrid nanoparticles modified epoxy resin used in filament winding composite. Materials, 2019. 12(23): p. 3853.

[13] Vashisth, A., et al. Effects of Nanosilica on the Ballistic Impact Tolerance of Carbon/Epoxy Tubes Loaded in Torsion. in Annual Forum Proceedings-AHS International. 2017. American Helicopter Society.

[14] Tsai, S.-N., et al., Fracture and fatigue behaviour of carbon fibre composites with nanoparticle-sized fibres. composite structures, 2019. 217: p. 143-149.

[15] Ebrahimnezhad-Khaljiri, H., R. Eslami-Farsani, and S. Talebi, Investigating the High Velocity Impact Behavior of the Laminated Composites of Aluminum/Jute Fibers-Epoxy Containing Nanoclay Particles. Fibers and Polymers, 2020. 21(11): p. 2607-2613.

[16] Najafi, A., et al., The impact of the nature of nanoclay on physical and mechanical properties of polypropylene/reed flour nanocomposites. Journal of Thermoplastic Composite Materials, 2012. 25(6): p. 717-727.

[17] Tuncer, C. and O. Canyurt, The effect of nanoparticle additive on the mechanical properties of glass fiber composite materials. ACTA PHYSICA POLONICA A 2019. 135(4): p. 752-755.

[18] Toorchi, D., E. Tohidlou, and H. Khosravi, Enhanced flexural and tribological properties of basalt fiber-epoxy composite using nano-zirconia/graphene oxide hybrid system. Journal of Industrial Textiles, 2020: p. 1528083720920573.

[19] Dolez, P.I., et al., Hydrophobic treatments for natural fibers based on metal oxide nanoparticles and fatty acids. Procedia engineering, 2017. 200: p. 81-88.

[20] Parimala, R. and D. Jabaraj. Carbon braided biaxial fiber composite with TiO 2: Mechanical properties. in 2014 International Conference on Science Engineering and Management Research (ICSEMR). 2014. IEEE.

[21] Reis, P., et al., Viscoelastic behaviour of composites with epoxy matrix filled by cork powder. composite structures, 2020. 234: p. 111669.

[22] Selvaraj, D., et al., Influence of the natural additive on natural fiber reinforced thermoplastic composite. Procedia Manufacturing, 2019. 38: p. 1121-1129.

[23] Prasad, V., K. Sekar, and M. Joseph, Mechanical and water absorption properties of nano TiO2 coated flax fibre epoxy composites. Construction and Building Materials, 2021. 284: p. 122803.

[24] Faruk, O. and L.M. Matuana, Nanoclay reinforced HDPE as a matrix for wood-plastic composites. Composites Science and Technology, 2008. 68(9): p. 2073-2077.

[25] Shalwan, A. and B. Yousif, Influence of date palm fibre and graphite filler on mechanical and wear characteristics of epoxy composites. Materials & Design, 2014. 59: p. 264-273.

[26] Hanemann, T. and D.V. Szabó, Polymer-nanoparticle composites: from synthesis to modern applications. Materials, 2010. 3(6): p. 3468-3517.

[27] Olar, R., Nanomaterials and nanotechnologies for civil engineering. Buletinul Institutului Politehnic din lasi. Sectia Constructii, Arhitectura, 2011. 57(4): p. 109.

[28] Wu, Y., et al., Development and evaluation of zinc oxide-blended kenaf fiber biocomposite for automotive applications. Materials Today Communications, 2020. 24: p. 101008.

[29] Presting, H. and U. Konig, Future nanotechnology developments for automotive applications. Mater. Sci. Eng. C 2003. 23: p. 737–741.

[30] Kamel, S., Nanotechnology and its applications in lignocellulosic composites, a mini review. eXPRESS Polym. Lett, 2007. 1: p. 546–575.

[31] Abu-Okail, M., et al., Effect of dispersion of alumina nanoparticles and graphene nanoplatelets on microstructural and mechanical characteristics of hybrid carbon/glass fibers reinforced polymer composite. journal of materials research and technology, 2021. 14: p. 2624-2637.

[32] Shubha, P., et al., Ex-situ fabrication of ZnO nanoparticles coated silk fiber for surgical applications. Materials Chemistry and Physics, 2019. 231: p. 21-26.

[33] L., Y., Property improvement of polyarylacetylene matrix composites by phenolic resins. Fibre Reinf. Plast./Compos, 2001. 3: p. 22-4.

[34] HJ, F., H. YD, and L. L, Influence of fibre surface oxidation treatment on mechanical interfacial properties of carbon fibre/ polyarylacetylene composites. Mater Sci Technol 2004. 20: p. 1655-60.

[35] Memduh Kara, et al., Impact behavior of carbon fiber/epoxy composite tubes reinforced with multi-walled carbon nanotubes at cryogenic environment. Composites Part B, 2018. 145: p. 145-154.

[36] Koricho, E.G., et al., Effect of hybrid (micro-and nano-) fillers on impact response of GFRP composite. composite structures, 2015. 134: p. 789-798.

[37] Al-Waily, M., M.H. Tolephih, and M.J. Jweeg. Fatigue Characterization for Composite Materials used in Artificial Socket Prostheses with the Adding of Nanoparticles. in IOP Conference Series: Materials Science and Engineering. 2020. IOP Publishing.
[38] Dos Santos, J.C., et al., Impact Behaviour Of Hybrid Carbon Fibre Reinforced Composites With Micro And Functionalized Nano Silica Particles. Bccm-3 – Brazilian Conference on Composite Materials, 2016.
[39] Roy, S., et al. Compressive strength enhancement of pultruded thermoplastic composites using nanoclay reinforcement. in 45th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics & Materials Conference. 2004.
[40] Chandradass, J., M.R. Kumar, and R. Velmurugan, Effect of nanoclay addition on vibration properties of glass fibre reinforced vinyl ester composites. Materials Letters, 2007. 61(22): p. 4385-4388.
[41] Kord, B., Nanofiller reinforcement effects on the thermal, dynamic mechanical, and morphological behavior of HDPE/rice husk flour composites. BioResources, 2011. 6(2): p. 1351-1358.
[42] Fu, S.-Y., et al., Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites. Composites Part B: Engineering, 2008. 39(6): p. 933-961.
[43] Arulvel, S., et al., A comprehensive review on mechanical and surface characteristics of composites reinforced with coated fibres. Surfaces and Interfaces, 2021. 27: p. 101449.
[44] Njuguna, J., et al., Natural fibre-reinforced polymer composites and nanocomposites for automotive applications, in Cellulose fibers: bio- and nano-polymer composites2011, Springer. p. 661-700.

Fares Mohammed Laid REKBI was born in Touggourt, Algeria, in 1986. In 2010 received the degree of Master in mechanical engineering, from Mohamed Khider Biskra University. In 2016 he obtained the Ph.D. in mechanical engineering from Mohamed Khider Biskra University, Algeria. He is currently a professor researcher class A at research center in industrial technologies CRTI, Algiers, Algeria. His main research areas are in composite materials, non-destructives testing, bio-composite materials.