Mechanical Characterization of Graphene based Hybrid Polymer Composite with Recent Applications: A literature review

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ABSTRACT

Carbon is one of the most fascinating element in the periodic table, its categories many elements, many people's bedded from antediluvian times [graphite and diamond] and some learned 10-20 years [fullerenes and nanotubes], a new allotrope of carbon, that is Graphene is one of the hottest topic in recent research field, due to its prodigious mechanical, electronic, thermal and magnetic properties. Graphene and its derivates are being studied in every field and technology. In this article; we focus our study on the mechanical behavior of a hybrid composite. Carbon fiber hybrid with graphene sheet polymer composite exhibits special properties on the mechanical section.Various researchers are going in study behavior of carbon based polymer composites. Carbon fiber is one of the most recent developments in the field of composite material. The compounding of carbon fiber admitting graphene resulted in various hybrids. This paper review, recent epoch advance in hybrid based reinforced polymer composite.

Key Words: graphene, carbon fiber, hybrid composite, thermoset polymer, mechanical properties.

1. Introduction

1.1 Carbon:

In many engineering applications, carbon based material are extensively used due to its superior mechanical properties, such as abject density, high aspect ratio, high specific strength as well as modulus and noteworthy electronic and optical property. Carbon fiber are known to companies many dissimilar chemistries, syllable structure and size characteristics **[1] [2].** There are several chemical element of carbon of which the best known are graphite, diamond **[3].** The forcible properties of carbon vary widely with the allotropic form. For example, diamond is highly apparent, while graphite is unintelligible and black. Diamond is the most difficult naturally-occurring material known, while graphite is gentle. Under normal conditions, allotropes of carbon have the highest thermal conductivity **[4].**

1.2 Carbon fiber:

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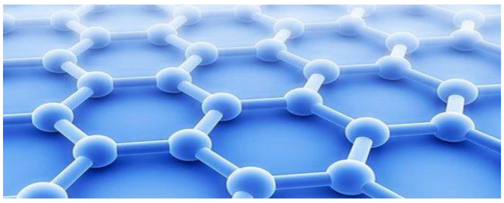
Fig[1] Carbon fiber

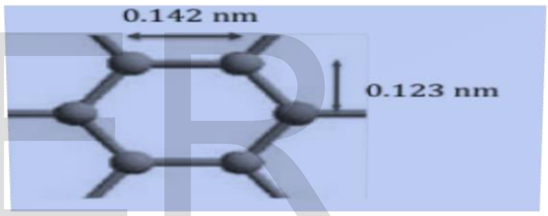
Carbon fiber was originally developed for space technology, but has now been followed in many other field of manufacture like aero plane wings. Generally the term "carbon fiber" is used to refer to carbon filament thread. They are commercially manufactured from three different precursors' rayon, polyacrylonitrile (PAN) and petroleum pitch. They are mainly used in aerospace industry due to its outstanding mechanical properties combined with low weight. It's a real hi-technology material, which provides very good structural properties, better than of any metal. This material is known for its high specific stiffness and strength. The material has a beneficial combination of good mechanical properties and low weight. There are several thermal advantages of carbon fibers make them a candidate for high temperature applications include thermal stability, low thermal expansion, high thermal conductivity, ablation resistance and thermal shock resistance with the diminish in its cost over recent years because of its ease in manufacturing. It is fast becoming one of the leading materials in many areas, including sport equipment, transport, scientific experiments and watches. The major focus of today's researchers is on the polymers of carbon fibres. . As carbon fibre gives self lubricating property, no lubrication is needed and therefore, carbon polymeric materials are used generally in bearing material **[5].**

1.3 Graphene:



Fig[2]1 atom thin layer of graphene sheet**[6]**

Graphene is a dilute layer of pure carbon; it is a single, tightly packed stratum of carbon atoms that are attached together in a hexagonal honeycomb structure. It is an allotrope of carbon in the structure of a plane of sp2 bonded atoms with a molecule bond length of 0.142 nanometers **[7].** This one-atom-thick crystal can be seen with the naked eye because it absorbs approximately 2.6% of green light **[8]** and 2.3% of red light **[9].**



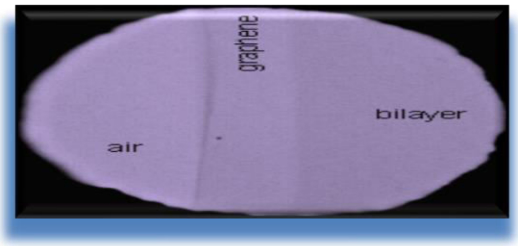
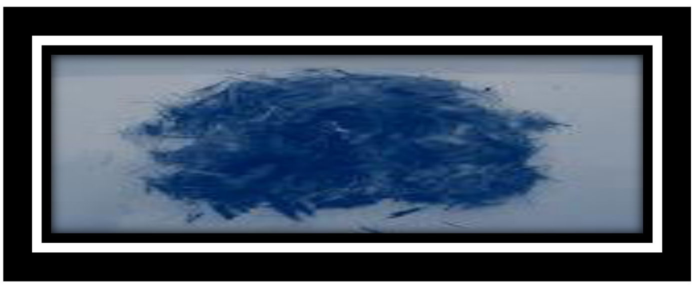


Fig [3] molecule bond length [7]
Fig [4] single layer of graphene paper [8]

If a coffee mug was rolled with a single layer of graphene, it could withstand the weight of a car, a weight of close to 4,000 pounds. Better yet, a single layer of graphene can handle the weight of an



elephant, a burden of at least 2.6 tons. If anyone wants to break through a single sheet of graphene, an elephant would command to balance on a pencil to penetrate graphene's surface **[10].** Graphene has accelerated interest among scientists in various fields because of its surpassing mechanical, optical, electronic, thermal and, magnetic, properties. Graphene was named and studied by Hanns-Peter Boehem together with Ralph setton and Eberhard stumpp in 1961 and after that isolated by Russian born scientists Andre Geim and Konstantine Novoselov in 2004**[11].** After a successive experiments with graphene, Konstantine Novoselov and Andre Geim were awarded the Nobel Prize in Physics in 2010 "for ground breaking experiments regarding the two dimensional material graphene" **[12].** Geim and Novoselov are at present professors at the University of Manchester, England. Because graphene is an important nanomaterial and a great interest among researchers all over the world, it has been discussed in a number of scientific papers. Graphene was voted as one of the top ten issuing technologies by the Massachusetts Institute of Technology in 2008, and it was also selected as one of the top ten scientific encourages in 2009 by science magazine **[13].** The Nobel Prize in Physics, however, is graphene's highest recognition. Graphene is the thinnest and strongest material in the world yet discovered. Because it is thin, graphene is almost fully transparent and light weight, yet it is so dense that not even helium, the littlest gas atom, can pass through it **[14].**

2. Recent graphene applications are:

- Suspending together cellulose based nanofibers, clay nanorods and graphene oxide, researchers from Stockholm University develop a super- insulating and fire retardant foam for house insulation purpose. This foam is fully porous and exaggerates lower thermal conductivity than conventional insulator like polystyrene. It is mechanically corpse, able to sustain high loads and also does not need to be interlaced with organic fire retardants. The researchers think this foam could even be fitted onto older buildings without tampering with their visual aspect **[15].**

- Researchers report that graphene flakes can be used as catalysts for chemical reactions. Researchers from The University of Western Australia made their discovery using computer simulative. This is still a betimes research. The teams now lead the scope of their calculations and find out whether more chemical reactions can benefit from graphene. In summation they want to check more prominent graphene sheets and not just flakes **[15].**

- International wheel producer Vittoria published a new range of bicycle race wheels that are built from graphene-enhanced composite materials. The new wheels (called Qurano) are the most beneficial wheels offered by Vittoria, and they say, these are the quickest wheels in the world. The company explains that adding graphene to their carbon-fiber matrix built wheel rim improved the material properties by 10-30%. The graphene brings down temperature build-up; it increases spoke-hole strength and improves the lateral stiffness **[15].**

- Researchers from China's Beijing Institute of Technology developed graphene-based springs that can operate as actuators. Those springs are very light and release good thermal and electrical conductivity. They are also easy to usable and work in rough conditions. Most springs today are metal. There have been efforts to create carbon-based springs which are lightweight compared to the metal springs, but that exhibit imperfect elasticity. But these latest graphene springs are very elastic nature, they can be extend to 480% of their original size and maintain stable elastic property even after being stretched 100,000 times to 300% of their size**[15].**

- Rice lab of materials scientist Jun Lou produced the new cathode, one of the two conductors in batteries, from nanotubes that are seamlessly stuck to graphene and replaces the costly and brickle platinum-based materials often used in earlier versions. The first is that they're low-cost, because they can be manufactured in a normal area, researcher said. "There's no need for a clean room. They're quasi-transparent, so they can be employed to glass, and they can be used in dumb light; they will even work on a cloudy day" **[16].**

- Some years ago, researchers at Northwestern University have depicted that graphene anode hold energy improve than graphite anodes, with 10 times faster charging. In lithium ion batteries, the charge- expressing lithium ions circulate from the lithium fuel cell through the cathode and anode, yielding away their charge to power the battery. Charging backs up the process, leading to freshly charged lithium ions. The execution of the battery depends on the ability of the anode to hold lithium ions **[17].**

- The University of Wisconsin researchers produced transparent optogenetic brain implants. The most brawny brain implants being built recently have exactly this same requirement. ITO is generally used for brain implant but now graphene based optogenetic brain implant is used. ITO is generally too corpse and too brittle for brain implants. Even if it could be made conciliatory, the high temperatures required to process it are inappropriate with many of the materials (like parylene) that are used in the implants. Furthermore the foil bandwidth of ITO is insufficient to fully exploit the wide spectrum of new UV and IR capable optogenetic proteins that have researchers fairly excited. The answer, now coming forth from multiple labs throughout the cosmos is to build flexible, thin electrode lays out from graphene **[18].**

- Researchers at Rice University in Texas have formulated a knot using stronger carbon fiber by mixing graphene oxide flakes. Researchers at Rice University use an environmentally friendly chemical extraction process; a unique process that is patented to the university, to extract graphene flakes from graphite. The pitch particles are two nm in size, which makes our flakes about ten thousand times larger **[19].**

3. Hybrid composite:

Hybrid composites are those having two or more different reinforcements in a single matrix. These hybrid composites have rewards over regular composites if one wishes to tailor the material to the requirement of structures under design or to reduce the cost. In principle several different types of fibers can be incorporated into a hybrid system but in practice it is likely that a combination of only two types of fibers would be more useful. Carbon and glass fibers are often used in the same polymeric resin matrix to form hybrids. Carbon fiber provides strong, stiff and low density reinforcement but is relatively expensive and brittle; in order to circumvent these limitations of carbon fiber one can use glass fibers along with carbon fiber to make a hybrid composite at relatively lower cost. Graphene have also been used as reinforcing or filler material for the preparation of hybrid composite owing to their superior mechanical properties and compared to conventional reinforcements. We mainly focus on graphene hybrid with carbon fiber polymer composite. These composite exhibit stupendous mechanical as well as electronic properties .Polymeric materials are recently increasing demand for high technology applications because of their improved physical characteristics. Promote an efficient method to improve the mechanical performance of polymeric material is the addition of fillers as reinforcement into the polymeric matrix. It has already been evidenced that the introduction of even a small fraction of a graphene component can dramatically improve the mechanical performance of the variety of the polymeric matrices and some extraordinary reinforcing and functional properties. Some researchers have been reported very recently. Graphene materials and their various derivatives show tremendous potential in revolutionary enhancement of mechanical, thermal, and chemical properties of polymeric materials relevant for a wide range of emerging demanding applications

4. Mechanical Characterization of composites:

Reinforcement of fibers is done in a matrix in order of obtain high strength and high modulus. Thus the fibers should possess higher modulus than the matrix material, so as to transfer load to the fiber from the matrix more effectively. Polymer reinforced fiber composites fulfil these criterions and therefore have drawn world-wide attention as a potential for the composites of future. Carbon fiber (CF) reinforcements for polymer matrix composites started to be used for commercial production in the 1960s. For a wide range of potential applications, especially in mechanical engineering, aviation, automotive industries, Carbon Fiber is primarily preferred for composites materials usage due to its excellent properties, such as high specific strength, modulus and stiffness, performance to weight ratio, high thermal stability, high conductivity, self-lubrication and corrosion resistance**[20–22].** Another one graphene's stand-out properties is its underlying strength. Due to the strength of its 0.142 Nm-long carbon bonds, graphene is the firmest material ever disclosed, with an ultimate tensile strength of 1.3 x 10^{-7} GPA compared to 4 x 10^{-7} GPA for A36 structural steel, or 3.757 x 10^{-7} GPA for Aramid (Kevlar). Not only is graphene extraordinarily strong, it is also very light weight at 0.77 milligrams per square meter (for comparison purposes, 1 square meter of paper is hardly 1000 times harder). It is often said that a single layer of graphene (being only 1 atom thick), enough in size to cover a whole football field, would weight under 1 single gram. Graphene also contains elastic properties, being able to retain its primary size after strain. In 2007, Atomic force microscopic (AFM) tests were accomplished on graphene sheets that were suspended over silicone dioxide cavities. These efforts showed that graphene sheets (with thicknesses of between 2 and 8 nm) had constants in the region of 1-5 n/m and a Young's modulus of 0.5 TPA. Again, these greatest figures are based on theoretical prospects using graphene that is unflawed containing no imperfections whatsoever and currently very costly and difficult to unnaturally reproduce, though production techniques are steadily improving, ultimately diminishing costs and complexity **[23].** Sticky tape, kitchen blender, DVD burner (light scribe technology approach) and heptanes water interface film formation, these are the some ease method which is used in home to produced graphene **[24].**

Table [1] approximate material properties value of carbon fiber

Mechanical properties: (Carbon fiber)	Young's modulus: 70GPa Tensile strength: 600 MPa Shear modulus: 5GPa Density: 1.6 g/cc Poisson Ratio: 0.1
Mechanical properties : (Graphene)	Tensile strength: 130 GPa [25] Young's modulus:0.5 - 1 TPa [25] Tension rigidity: 340 GPa·nm [25] Surface tension: 54.8 mN/m[26] Flexural rigidity: 3.18 $GPa\cdot nm^3$ [25] Thermal conductivity: 2-4 $kW\cdot m^{-1}K^{-1}$ (freely suspended graphene)[27] Distance between adjacent layers of graphene in graphite: 3.4 Å [28]

Miller Sandi g. et al.**[29]** examined the interfacial strength and physical property of functionalized graphene epoxy nanocomposite FGS contents 0,0.10,0.25 and 0.5wt% were mixed with epoxy resin in a jar and solicited at room temperature for 4hr, curing agent D230 was stirred into the mixture and poured into a mold. He was also prepared nanocomposite with modified FGS, 0.5gm of FGS and 2gm of octadecylamine were refluxed overnight in anhydrous N-methylpyrollidinone. Result showed that phyllosilicate reinforced composite has shown that a consequence of high surface area of nano fiber is the articulated effect. The interface of composite nanoparticles must be dispersed into the matrix for proper bonding of composite. Modified FGS composite reduce the resin toughness due to loss of chemical bonding between functionalized graphene sheet and epoxy matrix. The addition of ackylamine to the system had a negative effect on the resin toughness however nanocomposite prepared with 10% excess amine in the epoxy display a significantly increase in toughness than neat epoxy, due to better interfacial bonding and optimized epoxy amine ratio in the composite formulation. Covalent bonding between amine and graphene sheet would strengthen the fillers matrix interface.FGS resin composite display up to 40% reduce in co-efficient of thermal expansion and also enhance dimensional stability.

Kausar Ayesha **[30]** examined the mechanical properties of coated carbon fiber reinforced with epoxy composite. Carbon fiber was dipped into Ecaprolactam, polyoxyethylene and N-acetylcaprolactm and graphene oxide obtained by hummer method. The mixture was sonicated and heated slowly, for the preparation of composite, modified fiber tow was dipped into the epoxy resin and maintained at 80^0 c and drawn through a wire drawing die of 1 mm diameter. Polyamide-6 was in situ polymerized to form a coating layer over the surface of carbon fiber. Result showed that, tensile strength and modulus increased significantly when moving from polyamide to modified CFs based composite. Neat polymide had strength of 1055 MPA, while 1wt% PA6-GO-CFs composite has strength of 1120 MPA. Strength was further enhanced with the addition of 3, 5 and 10wt% fiber in matrix to 1218, 1356 and 1556 MPA respectively; addition of graphene oxide also increased the tensile modulus of the composite. Neat polymer had modulus of 220 MPA, while PA6-GO-CFs of 1, 3, 5 and 10wt% had values of 345,456,642 and 1011 MPA respectively. The maximum increased rate is 32% and 78% in strength and modulus in the case of composite with 10 wt%.

Gudarzi m **[31]** moazzami et al examined the dispersion and bonding strength of graphene polymer composite, by using hummer method, synthesized graphite oxide or homogeneous dispersion of graphene oxide was obtained by sonication of the GO suspension in H_2O for an hour and centrifuging for 10 min. Isophoronediamine was used to functionalize GO sheet to increase compatibility of GO sheet with epoxy resin. SEM was used to evaluate the morphology of graphene, graphene oxide and fractured surface of the composite. Results showed that flexural modulus of epoxy increased monotonically 0.4% functionalize graphene oxide. Ultimate flexural stress increased by addition of graphene nanosheet reaching up to 170MPA, due to strong bonding between nanosheet and matrix arising covalent bond. Approx 30% and 12% increase in young's modulus and ultimate strength by addition of 0.4% volume of functionalized graphene oxide as compare to neat epoxy.

Kong h.x**. [32]** present CNT/graphene and CNT/GO hybrid with polymer composite. A thin layer of reduced graphene oxide was first deposited on Sio_2/Si substrate through electrostatic adsorption which was then coated with the layer of carbon nano tube. It was observed that the absorption of multi wall nanotubes onto the reduced graphene oxide film considerably decreased its sheet resistance without compromising much on transparency, double layered structure showed excellent adhesion strength, which is important for various practical applications. Various methods have been used to prepare carbon nanotubes/graphene/reduced graphene oxide hybrids, which is solution processing, vacuum filtration chemical vapor deposition. Result showed that both the hybrid composite improved mechanical, thermal and electrical property, the fiber with a 2:1 volume ratio of single wall carbon nano tubes to graphene oxide showed an increase in tensile strength and elastic modulus by 80% and 133% respectively.

Puertolas j.a. et al.**[33]** examine that, the use of graphene as a filler in ultra high molecular weight polyethylene show lead to increase in mechanical property especially in stiffness and resistance. In general, the concentration of graphene was found to be very critical for strengthens of UHMPE. At initial condition, filler enhance mechanical property at a lowest concentration, but after that initial stage the material showed decrease in performance with increasing filler loading, all these graphene/UHMWPE composite present an optimum concentration with respect to mechanical properties. These result are a compromise between the outstanding intrinsic properties of the filler and the segregated structure formed around UHMPE powder, additionally the agglomeration of nano particles prevent wrapping by the polymer the consequently cause a lack of adhesion with the matrix and formed microstructure flaws such as micro-crack. Graphene/UHMPE composite such as polymerization filling techniques used .So the mechanical properties of these carbonaceous composite are strongly conditioned by the consolidation process and particularly by the dispersion of the nanofiller.

Lin Xiuyi et al**. [34]** examined the mechanical property of graphene oxide hybrid with carbon nanofiber composite. In the experiment, CNF and GO sheet were mixed at different volume in water to obtain hybrids with a total mass of 40 mg, and then the hybrid dispersion was filtered through filter. Hybrid papers with GO sheet ranging from 0 – 100% were prepared. Result showed that the neat GO sheets were ease to straighten as compare to other carbon nanofiber and hybrid papers. The tensile strength and young modulus of hybrid papers measured as a function of graphene oxide content. Resulted showed that both property consistently increase with increasing graphene oxide loading. The presence of water was shown to play an important role in determining mechanical property because of water molecule serve as basic building block of hydrogen bond which exhibited the interaction between GO sheet and carbon nano fiber. The size of GO sheet has effect on mechanical properties. In this research, three different GO sheet size samples were prepared. Result gives the variation with respect to the precursor GO size with about 184% and 386% higher young modulus and strength.

Wang guoxiu et al. **[35]** examines characterization of graphene nanosheet chemical modified with poly 4 styrene solfonate. He used hummer method to produced graphene oxide by natural graphite powder, and then exfoliates to generated graphene oxide nanosheet by ultrasonication. Now poly was added into graphene oxide nanosheet dispersion. During the hydrothermal reaction, graphene oxide reacted with PSS and was simultaneously reduced by hydrazine to graphene nanosheet-PSS. Pristine graphene nanosheet and chemically modified graphene nanosheet were analyzed by XRD, TEM and HRTEM. Result showed that, the crystal structure of graphene nanosheet on the nanometer domain was maintained intact after chemical modification. Result also state that, the graphene nanosheet floated on water when no surfactant was added, on adding poly during the reduction process. Hydrophilic graphene nanosheet were obtained, which could be well dispersed and formed a homogenous solution.

Zheng et al. **[36]** determined that Young's modulus depends on the functionalization and molecular structure of the functional groups connected to a graphene sheet, assigned to the binding energy between the operable groups and the graphene, as well as sp2-to-sp3 conversion.

Geng Yan et al**. [37**] produce GNP, GONP and graphene sheet using chemical modification method. A stable graphene sheet was obtained by steps. This is:

Natural graphite flakes
+ Ultrasonication GNP
oxidation GONP
Formic acid →
reduction

Graphene sheet

AFM was employed to characterize the degree of exfoliation of graphene sheet, in 3d view of graphene sheet; graphene surface was rough on the macroscopic scale with some wrinkles, due to existence of functional group as well as the space resulting from the evaporation of solvent. The particle sizes of graphene sheet were reducing significantly because they were dispersed in water in a colloidal state.

5. Conclusion:

In this article; we studied the recent applications in graphene by improving its reinforcing with the matrix, so as to get better mechanical properties. It is authorize that both graphene and carbon fiber show assure as reinforcements in superior nano composites. They have prodigality of stiffness, strength, versatile and firm. This means that the nano composites had prominent mechanical properties. Carbon and graphene based hybrid polymer composites demonstrate superior mechanical properties compared to the neat polymer or traditional composites. Carbon fibers were treated with a simple yet efficient method that resulted in the deposition on their surface of a high density of uniform and well dispersed graphene particles as well as sheet. The number of studies of different polymer matrices showed that, there were significant improvements in the mechanical properties of the nano composites by using different matrix. Graphene has lots other fascinating attributes that allow its application to several exercises, such as, its, mechanical, magnetic, and thermal properties. Different researchers are used to predict the mechanical properties of the graphene - carbon hybrid polymer nano composites with various successes.

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