International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 2, 2019 (Special Issue)

Graphite Reinforced Polymer Composites: A review

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***Abstract*—** Graphite is an allotrope of carbon which is available in natural form. High values of Young's modulus, fracture strength, thermal conductivity, specific surface area and fascinating transport phenomena leading to its use in multifarious applications like energy storage materials, liquid crystal devices, mechanical resonators and polymer composites. Composite has enriched their exclusive properties by the graphite and also its modified forms. When graphite is mixed with the epoxy, this results into thin carbon sheets which sensitively improve the physical property uniformly at very minor loading. Epoxy composite has the enriched properties was also stated. In this manuscript brief review is done in the area of fabrication and properties of polymer composites which is reinforced by natural graphite. Basically, drilling which is a major challenge from the aspect of **machining the composites; has also been discussed in the paper.**

***Keywords*— Graphite, epoxy, graphite oxide.**

I. INTRODUCTION

A. Polymer-

Polymer is made by two words, first is poly (poly means many) and second is mers (which means units or parts) when combined gives a polymer. Polymer means "many parts". Generally, polymers consist of two or more than two smaller mers (units) combined either naturally or synthetically to produce the macromeres or macromolecules. It can also be stated that the addition of many monomers results into polymer. Polymer has high molecular weight approximately 10000 or more than 1000000 g/mol. after combining the many mers or units. Polymers have great specific strength, admirable chemical stability, electrical insulating qualities, & also in better process capability and little cost. Polymers are extensively useful in the arena of electrical field, medical field, energy & industrialized area from previous times.

II. GRAPHITE

Carbon is positioned at 6^{th} in periodic with 6 atomic number. Carbon exists as coal, graphite and also in form of rhombus (diamond) in lesser quantities. Carbon has basically three types of allotropes that is Diamond (C60), graphite (C70) [1,2] and the recently added fullerene – related materials [3]. Carbon based nanomaterial is carbon Nano fiber [4,5] and carbon nanotubes [6,7].

Fig. 1. Graphite

Graphite is also called black lead or plumbago. Some different type of carbon (manufactured carbon) created are synthetic diamond and synthetic graphite, diamond-like carbon, coals, carbon black, glassy carbons, adsorbent carbon etc. for and also it depends on the different type of field like anodes other electrically links, greases, more concert tennis rumpuses, airplane, ultrafast semiconductor, spacecraft composites [8,9] etc. Above this different type of carbon forms could be recognized to the property of carbon exclusive hybridization qualities. The structure of C atom is that $1s^2$, $2s^2$, $2p^2$ (ground state). There is a gap (energy) among the 2s and 2p detours which enables the advancement of first 2s e^{-1} to an unoccupied greater energy 2p detour. This type of e^{-1} promotion permits the carbon to mongrelize into sp, sp^2 & sp^3. This type of configuration has different structure type that sp bonding provides to raise the chain type structures and that of sp^2 which provides to raise the planar hybridization and also sp^3 bonding provides the tetrahedral structures.

In this paper a brief introduction of Graphite Reinforced Polymer Composite material and discussion on its quality, structure and application of graphite composite, the various modifications have been dealt in addition to the areas where they are used.

In advance, now the graphite is used as a well-designed polymer composite. The material of graphite is included as stuffing that is the C found thermally established, virtual 2-dimensional planar are coated soled material. Graphite and its improved form mention the single property to composite as great surface area, mechanical and barrier qualities as well as thermal and electrical conductivity compared to polymer. Well dispersal of graphite filler is subjected to the choice of proper production procedure, including in-situ polymerization, melt blending & solution mixing. The corresponding importance of polymer (graphite created nanomaterial, tasks, manipulation area upcoming characteristics of the material has been overviewed.

Generally, there are two types of graphite present viz. natural graphite and synthetic graphite. Natural graphite is further divided into three types:

Amorphous graphite, Flake graphite and High Crystalline graphite

Traditional demand for graphite is largely to the steel industry where it is used as a component in bricks which line blast furnace ("refectories") as a line far ladles and as an agent to increase the carbon content of steel. It is also used in automotive industry like in clutch materials brake linings, liners and brake linings. Graphite is also a second hand in other industrial areas which includes lubricants,

carbon burnishes far electric motors, fire retardants, insulation and also used in reinforcement product.

Graphite is useful and very important part of our everyday life but it is rarely seen or heard of. It's also used in lithium ion battery (LiB) industry. It has been extending at over 20% per year due to the proliferation of mobiles or cell phones, cameras, laptop and also in the power tools and other hand-held devices. Graphite is used as an anode material in battery and there is no substitute to it. In present time its growth is hybrid and used in all electric vehicles. It is also a critical component used in the fuel cell, flow battery and consumer electronic.

A. Property of Graphite

Generally, graphite exists in two forms that is pure carbon and other being diamond. Graphite occurs in 2-dimensional planar molecule structures whereas diamonds have 3-dimensional crystal structures. Graphite generally occurs as flakes which are multiple layer of graphene held together by weak bonds. It is an outstanding conductor of the heat, power and also have maximum natural strength and stability to temperature in addition of 3600°C and is unaffected to organic attack. At the same time, it is one of the brightest of all reinforcing agent and has the highest lubricity. Generally, Graphite exits as non-metal, but it has also many properties of metal.

Physical properties of Diamond and Graphite		
Property	***Diamond***	***Graphite***
Appearance	Transparent	Soft, slippery to touch
Hardness	Very hard	Moderate
Thermal conductivity	Very poor	Good conductor
Electrical conductivity	Poor	2250
Density(kg/m^3)	3510	Dry cell, electric arc, lubricant, pencil lead
Uses	Jewellery	Soft, slippery to touch

TABLE NO.1

B. Application of graphite

The use of graphite is in many types of field where its use is very useful and also very important for that application because of its extraordinary properties. Graphite is used in chemicals industries for making the different types of chemical instruments. Graphite is used in nuclear industries for making the various type of nuclear component and also used in electrical industries for making the various type of electrical parts like as electrical machine components. It is used in mechanical industries and also used in automobile factory where different types of component of motorbike, cars etc. are made by the graphite. Graphite is also a very good lubricant, so it is used as lubricant for different types of field graphite is also used in stationery factories for making or producing pencils. The most useful application of graphite is in the aerospace sectors where its use is very valuable because of its different types of useful properties. Graphite is also used in refractories industries, coating, paints industries, and also in the batteries where it is used to make the terminals of batteries generally.

C. Modification of graphite

In the major state of graphite, it exists like a layer substantial, Graphite is widely used as a packing and also as a polymer composite and layer of graphite is deserted to diffuse throughout the polymeric matrix. Graphite does not relieve numerous remaining changes and therefore it is dissimilar as compare to silicate mud material.

There is no reactive ion group that exists on its graphene layer in its natural form. Generally, there are 3 types of treatment method by which graphite is modified and those are as follows:

1) Graphene oxide (graphite oxide)
2) Graphite intercalated compound (GIC)
3) Expanded graphite (EG)

2-D crystal (graphene) were well-thought-out as the thermodynamically unbalanced and hereafter hypothetically incredible to that it occurs in the unrestricted state [8,9] and were approved as only "academic" material [10]. Although the scenario has changed by the discovery of unrestricted standing graphene in 2004[11] and incite the interest of material scientist and shortened substance physicists [12,13]. For the detection, Geim and Novoselov got the 2010 Nobel award in physical science.

a) Graphene oxide (GO)

Graphene oxide has another name i.e. graphite oxide, when we treat the graphite flakes with the oxidizing agents, we get the graphitic acid or graphitic oxide. So that on the graphite surface the polar groups are introduced [14]. Brodie was made the GO in 1859 by the feedback of graphite flecks through potassium chlorate & furious nitric acid [15]. After some years a quicker and harmless process for research had been gone, GO is manufactured by the Hummers and Offeman by reaction of potassium permanganate anhydrous sulfuric acid, sodium nitrate and anhydrous sulfuric acid, that is broadly used in at present [16]. The structure of GO within the graphene sheets (contain epoxide & OH sets) & at the sheet edge (contain COOH and other sets) has been represented in Fig. 2. Dissimilarly GO is electrically insulating.

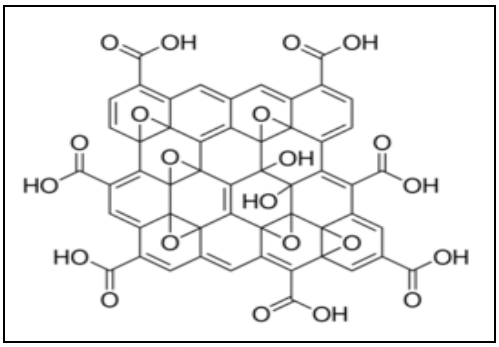

Fig. 2. Graphene oxide shows the carbonyl, epoxy, carboxyl and hydroxyl groups [17]

b) Graphite intercalation compounds (GICs)

When ingression of submicroscopic coatings to other chemical types among the sheets of graphite cloud matrix then Graphite intercalation compounds are formed. In GICs, electrons are contributing to the introduced species by the

graphene layer. There are two types of GICs, first one is; when graphite interpolated the electron givers similar alkali metals (Exp. - K, Na, many other.) which are distinguished by equally donor-type GICs, while other is made by e^{-1} receiver similar acids, halide ions & halogens are recognized like receiver – form GICs. In this type of GICs HNO_3, H_2SO_4, per chloric caustic & selenic caustic are included. Circumstantially, the furthermost normally GIC is graphite bisulfate to arrange GNPs aimed at producing the polymer/graphite nanocomposite & feedback arising among graphite & H_2SO_4 can be conveyed as shadows [18]:

$$n\ (graphite)+nH_2SO_4+ n/2[O]\rightarrow n\ [graphite.\ HSO_4] +n/2H_2o$$

where O is known as the oxidant and graphite. HSO_4 is the GIC

c) Expanded graphite (EG)

Expanded graphite are like graphite intercalation compound. The derivative of expanded graphite is a functional carbon material and those can be applied in different type of field like as sealed material, lubricant absorbents, fire retardants, extraordinary power batteries conductors and armed material. EG is obtained by the treatment of natural graphite flakes to sulfuric acid monitored through ruthless thermal shock. This is also showing the layered structure like the layered silicon and has moral relationship to carbon-based compound and polymers [19].

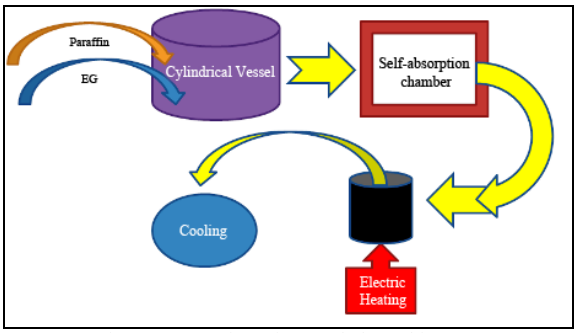

Fig. 3. Preparation of expanded graphite [20]

d) Graphene

Generally, graphene has only one layer of carbon atom or a sheet of monolayer of carbon atom which is strictly bound in a hexagonal honeycomb lattice. In the further extension we can say that graphene is also known as the allotrope of carbon and it is also a form of a level of sp^2 banded atom with molecular bond size of 0.142 nanometer.

The Vander Waals forces acting between the layers of graphene in graphite and by this they are held. Graphene is very thin compound which is one atom weight (1 square meter weight approx. 0.77 milligram) and very strong compound (apraxia. 100-300 times tougher as compare to steel and have tensile stiffness 150,000000 psi). At the room temp. it is the finest conductor of heat (at 4.84+- 0.44) * 10^3 to (5.30+_0.48) * 10^3 W.m-1-k-1) and also this is the best conductor of electricity (this is obtained by electron flexibility at values which is more than 200,000 cm2, V-1. s-1).

Another property of graphene is that it uniformly absorbs the light across the observable and nearby infrared part of the spectrum (pix=2.3%). It cab be surprising to recognize the C is additional furthermost plentiful form within the humanoid figure. Also it is 4th furthermost plentiful element out of the world (by quantity) later H_2, He, O_2. There properties create the C, organic source of all know existence to the earth.

Since the application within different type of scientific disciplines have fulminated by the discovery of graphene and have the major gains being made particularly in high frequency electronics, bio-chemical and magnetic sensors, ultra-wide bandwidth photo detectors, and energy storage.

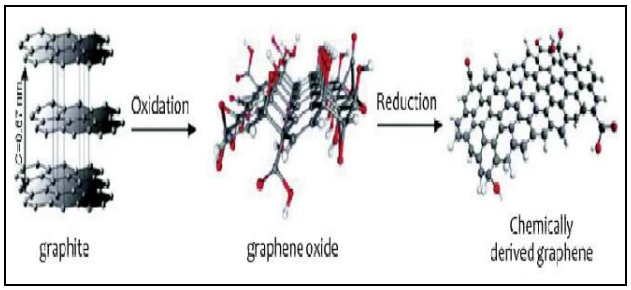

Fig. 4. Conversion process of graphite into graphene [22]

III. Composite Material

Composite material is defined as that combination of 2 or more than 2 distinct phase and has bulk property and should be of better quality than the individual specimen. Composites are known as resources that contain 2 or more than 2 chemically & actually dissimilar stages parted by a different interface. The dissimilar structures are joint carefully to attain an arrangement with further valuable essential or functional qualities that is almost non-achievable by several of the component only. Composites, the marvel constituents are attractive, a crucial fragment of present constituents, reason of this benefits are that small mass, oxidization resistance & faster assemblage. These are broadly used as constituents in creation of airplane assemblies, electrical packing to medicinal tools, & planetary automobile to household construction. For better quality, need the composite materials arise. In composites, particles are dispersed and in alloy particle are dissolved.

Matrix (Bigger quantity) + Reinforcement (Smaller quantity) → composite material

A. Types of composite material-

1) Ceramic matrix composite (CMC`s)
2) Metal matrix composite (MMC`s)
3) Polymer matrix composite (PMC`s)

IV. Procedures of Producing Polymer/Graphite Composite

A. In situ polymerization

In this type of technique, a chemical reaction is involved and gives a very fine and also a thermodynamically stable phase (reinforcing) in a matrix.

a) Process

Particles are interpreted in monomer liquid or as compare to low molecular weight precursor as well as in their solution. After formation of homogeneous mixture, add

the initiator and then exposes this to source of light or heat etc. And after this nanocomposite is formed when polymerization is performed. Synthesized polymers are called thermosets. This is done either in a mould cavity or other in situ situation. Generally, this thermoset has covalently crossed linked which means it is not allowed to regain its original shape or reshape. The first nanocomposite developed by the situ polymerization was Nylon -6.
In this different type epoxy phenolic, bismoloimide and cyanate polymers as thermosets were used to manufacture the nanocomposite.

B. Solution compounding

In this method, the polymers are mixed in a solvent and after this we dispersed filler in this resulting solution. After completing this mixing process, removal of solvent takes place, after that regularly prepared and then provide size and profile to composite. This type of procedure is similarly used in electrical conducting material (amalgams) that have very less percolation threshold. This method is prevented or avoided because of large amount of removal of solvent and associated environment pollution for used of large scale of production.

C. Melt blending

By the industrial point of view this directly effects the cost so this is preferred for composite preparation and this is also an environmentally friendly process, also in this type of process the solvent is not required for the preparation of the composite material. This melt bending can be adopted by our traditional mixing equipment like extruder two roll mills and internal mixer and also these are available as large compounding units. The filtration threshold is occurring at 3 weight% expanded graphite (1.4 volume %), 5.7 wt. % MEG, 14 wt. % GNP& 6vol% FG [21].

It the statistics (for) percolate threshold of dissolve miscellaneous GC and expanded graphite in PS is absent then it is mentioned by previous for first type of manufacturing in situ polymerization. Also second type solution compounding, it is obtained by observation or it appears in this type of melt blending process, the percolation threshold is at advanced level as compare to different another type of in situ polymerization and solution compounding.
The comparison of ISP and SC technique or process, a very fine balance is obtained between the mechanical and electrical qualities. In spite of the results, these cannot be retranslated straightly relatively to the report of these 3 techniques primarily because identically nanocomposite cannot be studied by this point. Even difference in molecular weight make it more special like as viscosity, etc.

D. Combination of mixing techniques

The electrical and the tensile property of different composite (polymer\graphite) is organized by the mixing of different type of way like in situ polymerization etc. with more than one procedure master batch blending, melt blending, etc. This mixing approach involves the different technique compulsory; when viscosity of system increases rapidly then solvent is decreased in reference of epoxy matrices.

So several authors have adopted this type of combinational approach because by this a good filler dispersion is obtained in different polymeric system.

V. GRAPHITE REINFORCED POLYMER COMPOSITE

Graphite Composite materials are prepared by the joining of reinforcement into the matrix. Mixture of the graphite & matrix delivers greater features as compared to materials only. In composites the graphite convey bulk masses & are main feature in the substantial qualities. The resin supports to handover weight among graphite & impasses the constituents collected. Graphite composite has excellent mechanical qualities that are incomparable to another constituent. Graphite composite materials are tough, rigid, & frivolous. This type of graphite composite material is chosen everywhere due to frivolous weight and greater concert is dominant, like constituents aimed at rockets, warrior airplanes, & high-speed automobile. The material is saved below tightness although this is impassioned below extraordinary temp. (>1000°C). Factually, graphite composite is costly, that restricts its usage as individual extraordinary submissions. Yet previous 15 years, due the capacity of graphite, it enlarged the engineering procedure and enhanced the value of graphite composites. Nowadays graphite composite is frugally feasible in various submissions like game things, enactment ships, enactment automobiles, & great enactment industrialized equipment. A submission of Graphite Composite Material is tremendously multipurpose. The engineers are choosing since an extensive variability of graphite & resins to get the wanted substantial qualities. Similarly, material width & graphite positioning could be adjusted aimed at every submission.

A. Properties of graphite composite

Properties of graphite composite material are different like light weight, relative stiffness and very high strength. In transportation, less weight equates, to more fuel saving and improved acceleration. Graphite composite materials have also high temperature and weathering resistance, it has also the high chemical stability. So graphite composite materials have many types of properties due to which it is used in different types of applications.

B. Application of graphite composite

Application of graphite composite material is in various types of fields. Such as graphite composite material are used in aerospace industries (in this different type part of aero plane like airplane wings etc. are made by the graphite composite material because it has the light and also high strength, high temperature resistance etc. Graphite composite materials are used in automobiles industries (generally this type of graphite composite material is used for making the engine component of automobile) and also in the transportation industries (because of light weight of graphite composite material so this is used in this type of field more). Graphite composite material are also used in marine industries for making different types of component of ships and used in engine part of ships. Graphite composite material is also used in chemical industries for making the different types of instruments, bikes and used for different component in chemical industries. Furthermore,

graphite composite material is also used in mechanical, civil, electrical, and also used in electronic industries, in this types of industries graphite composite material are used for making the different types of machine component, instruments, etc.

a.) Applications for High Specific Stiffness

Graphite composite is normally used where high stiffness and low weight is required. Many of metal which is generally used for the application of structural which have similar type of stiffness which is approximately 100 × 106. If any application where high stiffness and light weight is required, then graphite composite is only one for fulfilling this requirement.

There are many examples of the high specific stiffness like the quality of this is generally used in aircraft structure where more stiffness is required and also used of graphite composite material in drive shaft for trucks and also in high performance vehicles where high stiffness more required. So, we can say that, application where more stiffness is required the graphite composite material is used.

b.) Applications for High Specific Strengths

Graphite composite is mostly used in light weighted application in which extremely high strength is required. It means that graphite composite is used where high carrying load is required. Examples of high specific strengths are that where more strength like motorcycle components (skid plate, rock guards etc.) is generally used. And also in aircraft industry, in this aircraft structure is generally made by the graphite composite material. Furthermore, it is also used in space machine like as satellite antenna structure here also high strengths properties are required. And also used in automobile industry for making the racing cars' chassis and other component where high strength is required. Graphite composite material is also used in golf club shaft, fishing pole here high strength is most required.

c.) Applications for Low CTE

The co-efficient of thermal expansion of graphite composite is negative, which means that on heating it will shrink. And when it is put into a resin matrix, then this result that composite become tough, stiff etc. and this composite has zero co-efficient of thermal expansion. Graphite composite is used in high precision and also used in thermally stable application. An example of the low co-efficient of thermal expansion of graphite composite material where it is used is different types of application. In high precision antennas like in space or satellite that stands in space because here high temperature is present so to protect from melts or many other reason, antennas of satellite is generally made by graphite composite material. And also graphite composite material is used in the precision optical devices where very low CTE is required and also used in the scanning and the imaging machines like as the printers, photocopying machines etc. and furthermore graphite composite materials are used to make the metrology equipment.

VI. MACHINING ON GRAPHITE REINFORCED POLYMER COMPOSITE

Now due property of modulus to weight ratios and higher strength to weight ratios, composite materials are used widely, as compared to the metals, and also offers the new prospects for project or design. Though, composite material has the different type of property like anisotropic, reinforced, heterogeneity, non-homogeneous, heat sensitivity so machining of composite material is difficult. Significantly high tool wear rates & loss of work piece are mentioned. There are different types of machining operations like sawing, grinding, turning, milling and also drilling can be done on the composite material by the use of proper operating condition and also tool design traditionally.

Though, operating conditions, tool materials and tool geometry must be adjusted in order to reduce the heat generation and escape announcing the damage by the means of mechanically or thermally. This results into poor surface quality, high tool wear and also cutting rates are reduced. All though when the machining process of composite material is going on then defects into the job, and also tool wear rates is introduced rapidly.

During the machining of composite material, drilling becomes a real-world challenge. A drilling operation of the metal basically has to eliminate the material and also clean the hole. The best machining operation on the composite material is the drilling operation, since numerous holes can be drilled in order to mechanically fastenings.

The quality of the holes and the parameter of tool design effect will be observed during the drilling operation of the composite material.

A. Mechanics of drilling composite materials

Tool wear, speed, tool geometry and feed rate are measured when torque and the thrust is applied on a drill bit. A shrill reduction in perpendicular force by way of the bit arrives into the job is permanently associated by the overview of delamination by mechanical stroke of the tool cracking up the upper layer of work piece.

During the drilling process delamination can also be produced by the more thermal stresses and are generated on the upper layer of material, however, no breaks have been detected in the perpendicular force in this very case in the previous work done by the researchers. By decreasing the feed rates, delamination can be reduced at exit side.

When the cutting edges are entirely engaged, torque is increased sharply during the drilling operation and then increases normally till a extreme value is obtained, trailed through a minor drop when the hole completion.

A great dissimilarity among the torque (cutting) and the maximum Torque is to attribute to more frictional forces among the plots of the drill and on the barrage of the hole. Such as drilling growths, the tool is interacting through the flank of hole over an enhancing the area so that, more resilient torque is creates due to interface of the frictional forces. A little torque is obtained after the entire penetration has occurred which denotes that total torque is the more influence by the friction. An elevated temperature and marginally negative CTE (coefficients of thermal expansion) compound the difficult by holding the drill. To produce a parallel increase and also decrease in the level of

torque, increasing in the point angle and the feed rate of the drill.

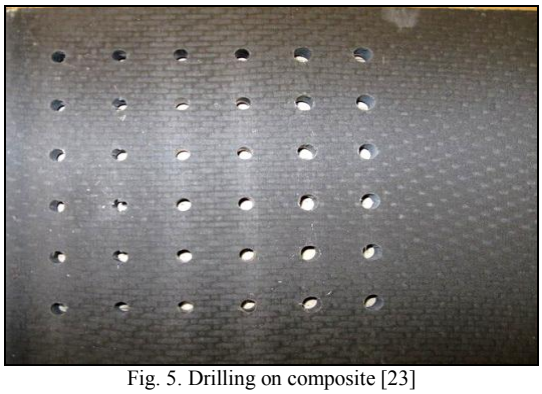

Fig. 5. Drilling on composite [23]

B. Damage incurred though the drilling

Damage is incurred during the drilling process: delamination, thermal alterations, cracks, fiber pullout, interlinear cracks, fuzzing and matrix cratering, in addition to the geometrical defects generally establish in the drilling of the metal. The ratio of diameter of damaged zone to the diameter of non-damaged zone or diameter of the hole is called the delamination factor, extents a higher limit such as the total of holes drilled growths. By the use of different type of drill bits this influenced both the delamination and drill wear.

For different type of composite material various type of drill bits are used for drilling operation and whether drill bits are previously attached to the metal. In various circumstances composites are merged to aluminum and also in parts of titanium, and also the drilled hole must go by the both composite and as well as the metal. It is difficult to drill the same type of titanium tool as composite because tool wear of titanium is difficult.

C. Hole quality

There are many types of ways for describing the quality of drilled hole. By the standardized parameter of roughness, microstructure of surface can be evaluated. Difference among the diameter of drilled hole and the diameter of the tool is known as dimensional error. The roundness of the drilled hole is described by a factor equal to 1/4 the difference among the maxi. and mini. Dia. of the drilled hole. An additional feature condition is loss of the material, which is designated by the thickness of the heat affected region and the dimensions of the delaminated zone.

D. Delamination

In the layered composite, delamination region severely decreases in the weight transport capacity of the portion and also must be circumvented. During the operation of drilling, delamination is introduced by 3 types of mechanisms. The thermal stress manner, stamping out of the uncut sheet near the exit & top layer's peeling up. For determining the level of thrust can induced by the peel-up at entry and also push – out at the exits side this is an easy way to predict or determine the thrust, delamination have been offered. It is assumed that the area of the delaminated is circular and the uncut region is demonstrated as an isotropic rounded dish compressed on his shape to the cut region of the enclose, which is presumed to be inflexible.

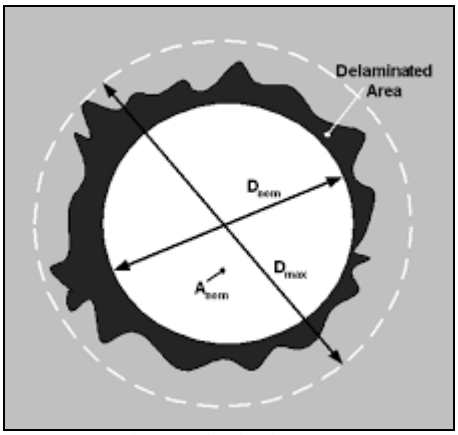

Fig. 6. Delamination [24]

VII. CONCLUSION

• The previous research reveals that very limited work has been performed on this graphite composite and the vast area is still open as regards the machining is concerned.

• Moreover, the Graphite composites exhibits better machining characteristics as compared to other traditional materials.

• Natural Graphite has low cost and is available in huge quantity, so this opens a new era in material science for developing an extensive functional material. Graphite reinforced polymer composites have the different types of properties due to which it is used in aerospace, automobile machine component, etc. because graphite composite material has high specific strength, high specific stiffness, low co-efficient of thermal expansion, high temperature resistance and more suitable for weathers.

• Graphite based polymer composite is prepared by the different type of the handing technique like in situ polymer, melt blending, SC, SSSP & are conferred at this juncture. So, at last graphite composite materials have very exclusive property by which it is used is in different types of field.

• Graphite reinforced polymer composite material is economically for the various type of industries like aerospace, automobile industries, pencil production industries, transportation, etc.

• While machining of composite material; drilling operation imparts a real challenge and use of this drilling operation to make the hole in different type of application like aerospace industry and in automobile industry so there is different type of field where drilling on composite material can be done very well.

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