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Manifestation Of Carbon Composites In Technical Textile

S. Karthik[1] , C.S.Gopika[2] , R Loganathan[3] , P.Abarna[4]

[1] Assistant Professor, Department of Textile Technology, Jaya Engineering College, Chennai.
[2] Student of M.Tech Department of Textile Technology, Jaya Engineering College, Chennai
[3] Professor, Department of Textile Technology, Jaya Engineering College, Chennai.
[4] Assistant Professor, Department of Civil Engineering, Jaya Engineering College, Chennai.

texhod@jec.ac.in

Abstract

In this fast-moving world development of lightweight, high-strength and durable materials are very important and one of the emerging material is carbon fibers which are strong, lightweight, low thermal expansion, fatigue resistant, impact resistant, flame retardant, etc. Carbon fibers are mainly used to reduce the weight of material with high strength and stiffness thus they are mostly used in aeroplanes, high-speed cars, windmill blades etc. Thus the application of carbon as a composite is an evolving field that has wide scope in the coming future. Still composite manufacturing gets problems with uniformity over the entire system and time consumption for carryout the nondestructive test to avoid the failure of the product. Thus quality assurance throughout the production is important in the production of the composite compared to other materials like steel or aluminium in this paper, the carbon yarn manufacturing the different carbon-reinforced composites application in automobiles, aerospace, and space, its quality assurance over the manufacturing process and the carbon composite market are discussed.

Keywords-carbon fiber, carbon composite, aerospace, automobile

INTRODUCTION

Carbon fibers which are having 90% carbon content with a diameter of 5-10 micrometers. They are thinner than a human hair. They are much stronger and less weight than steel and aluminum and consist of different properties which include high strength-to-weight ratio,high chemical resistance, temperature tolerance,good fatigue resistance,thermal conductivity,low thermal expansion etc. The main precursor for carbon fiber is Poly acrylonitrile and they are carbonized at high temperature to produce low to high-modulus fiber. They are then formed into nonwoven, uniweave,2D woven,3D woven,2D braided,3D braided,knitted etc. They are made into different composite as reinforcement materials using different manufacturing methods which include vacuum fusion, filament winding,wet spray-up mold etc using different resins as a matrix which include epoxy,po lypropylene etc. Due to their high strength to light weight property, they are used as reinforcement material in composite in aerospace, automobiles, wind blades etc.In automobiles initially they were used in high-speed racing cars to reduce the weight of some components thus increasing its speed and efficiency later they have been included in other cars.

In heavy lift launch vehicles also the carbon composites are used where Li Al alloy replaced by carbon composite in cryo tank which reduce the weight and fabrication cost.In airplanes, the revolutionary step taken by Boeing 787 by manufacturing 50% of airplane parts using composites. They include the main parts like the fuselage, wings and tail. While coming to the quality of composite as they are anisotropic materials different defects like debonding, resin-rich, porosity, wrinkle etc will occur during the manufacturing. Thus different nondestructive test methods are used to check the quality during the manufacturing process which include ultrasonic, infrared thermography, acoustic emission etc.Thus the quality of the composite is assured and maintained throughout the process. Thus carbon fiber and its composite application is an emerging field and it has a good future as the application is endless due to its unique property.

A.CARBON YARN

A. 1) Carbon yarn manufaturing

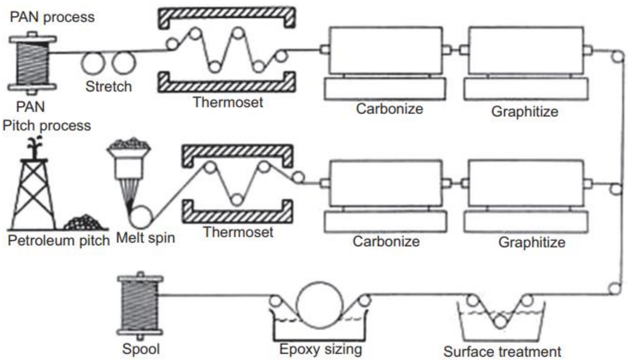

Fig. 1.Carbon yarn manufacturing

Carbon fiber is mainly produced commercially using the precursor Polyacrylonitrile (PAN) and they are also manufactured from the pitch. Figure 1 explains the carbon yarn manufacturing process where the PAN fiber is fully stretched, heated at high temperature in the absences of oxygen by the carbonization process and all the elements like nitrogen, oxygen and hydrogen get eliminated here and the fiber structure consists of only carbon thus it will form fiber with 90% carbon. The surface treatment will be carried out in order to make it compatible with the resin and continued with the sizing and wounding over the spool. Thus the carbon yarn is produced.

1)Carbon yarn to fabric:
Carbon yarn is produced to different fabric in order to make the composite which include woven,knitted,braided etc which are explained in figure 2.They are produced by automated preform fabrication process.Mainly unidirectional and 2D fabrics are used commonly in the production of composite where the other types are used for special applications.

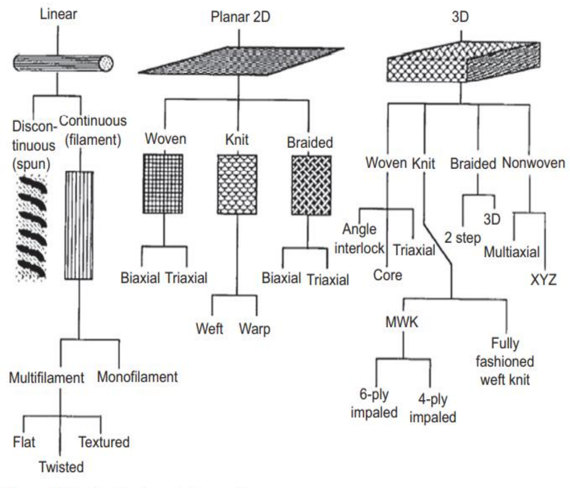

Fig2.Different Carbon fabric

a)Composite manufacturing: A composite material is a material that is produced from two or more constituent materials. These constituent materials have notably dissimilar chemical or physical properties and are merged to create a material with properties, unlike the individual elements.It consists of reinforcement which is commonly the fiber or the fabric which give mechanical property like strength to the material here carbon fiber or fabric is used in carbon composite and the next part is the matrix which binds the reinforcement material together and will acts as the bonding part and which will also convey the external force to the different layers of the material, Normally different resins are used as a matrix which includes epoxy, polypropylene, etc. Thus the composite consists of different materials and will be combined in order to produce a new product with different properties. Different composite manufacturing methods are used now a days, few of them are:

- Hand layup
- Vaccum infusion method
- Filament winding

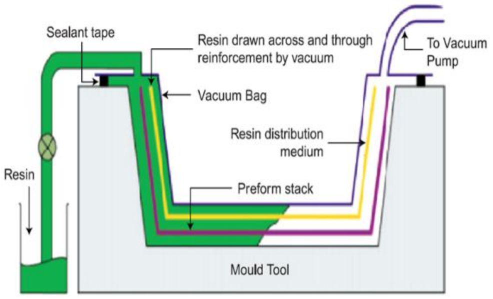

Fig 3: Vaccum infusion method

Here as per figure3 the vacuum infusion method where the mold is applied with the releasing agent.As per the requirement the number of fabrics is laid and using the vacuum bag and the vacuum pump the system is vacuumed and the resin is spread uniformly over the layers and its cured. Another method is the filament winding method as per figure 4 which the roving is dipped over the resin and winded over the rotating mandrel at a particular angle.

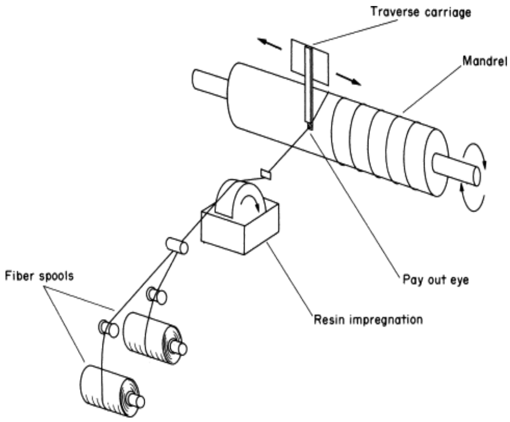

Fig4:Filament winding

II. CARBON COMPOSITE IN AUTOMOBILES

Fig5.carbon composite prepared for automobile

Carbon composite which are widely used in automobiles where the reduction of weight is highly required in order to reduce the fuel consumption and improve the fuel efficiency.By reducing the fuel consumption which will reduce the CO_2 emission and will be eco friendly.Thus using the different resins like PA 66,PPS,PPA and the carbon fiber or fabric as reinforcement are used to produce the composite.Here different industrial process like stamping,thermoforming,overmolding etc are used in the composite production and finally the finished product are used in seats, chassis components, doors, roof etc.

Carbon composite in automobiles not only reduces its weight it also improves strength and they have good crash performance as they absorb the impact energy. They are highly durable, high corrosion resistance, easily moldable and bend resistance. Thus carbon composites have a good future in automobiles.

III. CARBON COMPOSITE IN AEROSPACE

As the airplane ticket cost is high the Boeing company planned to make the airplane with reduced cost and improved efficiency. They have produced the Boeing 787 with 50% composite material in which 23 tons of carbon fiber is used. Here the different parts of Boeing 787 were wrapped with the prepreg UD tapes, slit tapes, and woven fabrics in order to reduce the weight and improve fuel efficiency. Here Torayca 3900-series carbon fiber-reinforced toughened prepreg using IM T800S fiber are used.

Fig 6(a)&(b)

Fig6.composite in Boeing 787(a)experimental wing structure using composite(b)production line wing structure of composite

IV. CARBON COMPOSITE IN SPACE

As space research is very advanced and they require durable and weight material in order to reduce fuel consumption, carbon composite has high scope in this field. As NASA during research with the carbon composite, they have produced the cryo tank which will be applicable for the future heavy-lift launch vehicle. Compared to Li-Al alloy composite saved 30% of its weight and the design of the composite reduced the fabrication cost by 25%. Figure 7 shows the cryo tank produced with carbon composite.

Inspection Method	Major detected defects	Strength and limitation
Visual inspection	Surface crack, delamination, impact damage	Simple, rapid, inexpensive, Sub-surface flaws cannot be detected, should be used along with other detection methods
Optical Coherence Tomography (OCT)	Cracks, delamination, voids	3D high resolution imaging, Not suitable for carbon fiber composites due to making the object opaque for imaging
Microscopy (light microscopy, SEM)	Cracks, voids, delamination, fiber breakage	Evaluation of crack initiation and propagation, SEM sample preparation takes time, infield inspection not possible, small sample size studied
Tap test	Delamination, cracking	Can be used for moisture sensitive composites, simple, inexpensive, Insufficient sensivity for field applications
Acoustic emission	Cracks, delamination, Fiber breakage	Suitable for field tests, high sensitivity, only suitable for detection growing flaws, defect size and location difficult to obtain, sensitivity affected by surrounding noise, not suitable for thick specimen
Ultrasonic	Cracks, delamination, voids and foreign objects	Depth and location of flaws can be determined, can be used when only one side access to composite is possible, hard to detect the defects in region near the probe
X-ray radiography	Foreign inclusions, Cracks, voids, fiber alignment, fiber splitting	thick section of composite can be inspected, Poor image contrast, High cost due to OH&S associated with ionising radiation
X-ray computed micro-tomography	Cracks and micro-cracks, voids	3D images reveals the nature and shape of defects, in service damages including delamination hard to detect without penetrant, higher cost due to OH&S
Compton backscattering diffraction	Cracks and micro-cracks, voids, porosity, fiber misalignment	One-sided inspection possible as well as tomographic imaging, layer-by-layer inspection of object, Higher cost associated to the control exposure of personnel to ionising radiation.
Infrared thermography	Voids, cracks, foreign inclusions, delamination, impact damage	Rapid area coverage, remote sensing possible, one-sided inspection possible, anisotropy masks indications

Fig7.cryotank,composite laminate applied using robotic arms

	Fiber type	Tensile strength/MPa	Tensile modulus/GPa	Strain/%	Density/g/cm^3	Filament diameter/ µm
Toho	IM600	5790	285	2.0	1.80	5.0
Hercules	IM7	5300	275	1.8	1.77	5.2
Toray	T800H	5490	294	1.9	1.81	5.0

TABLE I. CARBON FIBER SPECIFICATION USED IN CRYOTANK

above Table 1. gives the specification of carbon fiber used in the production of cryobank. Here Toho, Hercules and Toray are the carbon yarn producer for cryotank fabrication. Thus still research is going on in order to improve the uniformity and efficiency of carbon composite in cryotank.

V. COMPOSITE QUALITY CHECK

As the composites are anisotropic materials the entire material will be having different defects during its manufacturing which include delamination, debonding, broken fibers, void, wrinkle etc. Thus in order to assure the quality of the material different inspection methods are carried out during production, Thus the different evaluation methods, the defects detected and their strength and their limitation are explained in table II.

TABLE II. DIFFERENT COMPOSITE INSPECTION METHOD AND ITS ADVANTAGES AND LIMITATIONS

VI. INLINE QUALITY ASSURANCE

At the DLR Center for Lightweight Production Technology (ZLP) in Stade and Augsburg developed in-line quality assurance which enables the monitoring and evaluation of individual manufacturing processes during different production stages along with a non-destructive testing method which monitors compliance with previously defined manufacturing tolerances based on particular properties, and any deviations can be recognized and assessed by the analytical software system. For semi-finished products and components with properties that indicate defective structures, they are immediately removed from the production line in order to prevent any further expensive and unnecessary manufacturing procedures. Thus they cost-effective.

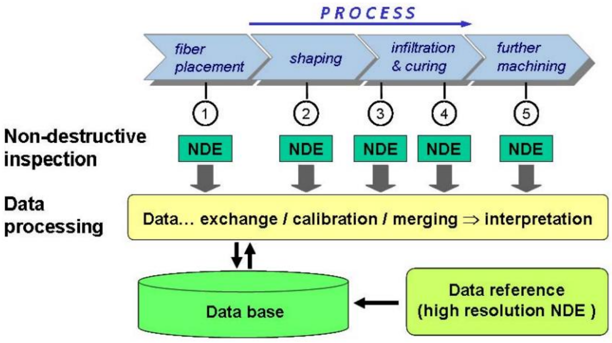

Fig 8.Principle of inline quality assurance system based on NDE method

VII. CARBON COMPOSITE APPLICATION MARKET

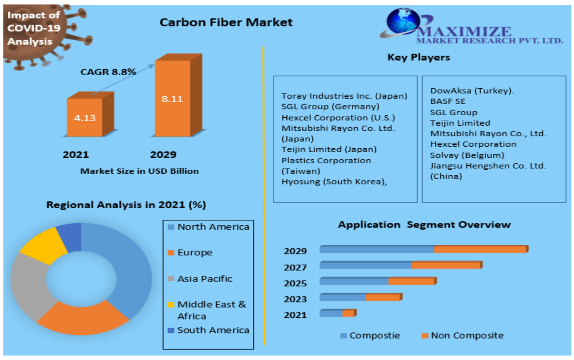

Fig 9:market trend of carbon fiber and composite

As the application of carbon composite in a different fields is increasing due to its unique property and thus they are improving year by year. Going through different applications discussed throughout the paper shows a hike in future since the fuel consumption needs to be reduced in order to overcome the scarcity of non-renewable sources, weightless and strong materials like carbon will boom in the future market.

Thus while going through the market hikes year by year the carbon market is going up and while going through the application segment compared to non composite applications, the composite application shows much hike. Thus the market shows that innovation in a different field will definitely increase the market and it shows that carbon composite has a great future as a composite.

CONCLUSION

Thus while going through the different applications of carbon composite shows a huge scope and the innovative idea in this field will give a better life for the technical textile. As the different methods of fabrication of carbon fiber need to be improved and the cost of the carbon fiber needs to be reduced by improving the manufacturing technology of carbon fiber.

Thus the application of carbon fiber in technical textiles is unlimited as the high strength-to-weight ratio will ultimately give a product with the endless application. Thus the latest technology needs to implement to produce much uniform product and needs to assure a high-speed quality check method. Thus the carbon composite will make the humans move to space with less cost and high efficiency. Thus the carbon composite application is endless as they are weightless.

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