Volume : 1 | Issue : 5 | Nov 2012 • ISSN No 2277 - 8160

Research Paper | Engineering

Advancements in Composite Materials Aand Their Applications in Engineering and Technology

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ABSTRACT

Among the major developments in materials in recent year are composite materials, as they offer several outstanding properties as compared to several conventional materials. Composite materials have found increasingly wide applications in aircraft, space vehicles, offshore structures, electronics, automobiles, boats, and sporting goods. New developments in composites are continually taking place with a wide range of polymeric, metallic and ceramic material being used both as fibers and matrix materials. Research and development activities in this area are concerned with improving strength toughness, stiffness, resistance to high temperature and reliability in service. Many composites materials are composed of just two phases; matrix and dispersed phase.

KEYWORDS: Composite materials, Stiffness, Power Transmission, Automotive Industry

1. Commercial Applications of Composite Materials

Composites materials find wide applications in aircraft and rocket components due to their excellent strength to weight ratio; a few of them are pipes, sporting goods and military helmets, military and commercial aircrafts and rocket components, helicopter blades, automotive bodies, leaf spring, drive shafts, ladders, pressure vessels, boat hulls and various other structures etc. Down on the ground, designers of the full range of products, which include clothing, athletic gear, appliances, furniture, office supplies, home entertainment systems, packaging, computer systems, boating, camping gears and housing have called on material technology for new composite systems that make better products. Shoes are one examples of a line of products making use of new composite systems. Look at inflatable basketball and tennis shoes to find the air chambers and wide variety of polymers in the form of rigid plastics, soft foams, dense foams, nylon mesh and hard rubber.[4]

Recently developed composite is granite particles in epoxy matrix. It has high strength, good vibration damping capacity and frictional characteristics. It is used as machine tool beds for some precision grinders. In order to eliminate application limitations imposed by ordinary materials; composite materials may be extended to other commercial utilizations which require durable services at unconventional environmental conditions.[2]

1.1 Why we Require Composites?

A composite material or composite is a complex solid material composed of two or more materials that, on a macroscopic scale, form a useful material. The composite is designed to exhibit the best properties or qualities of its constituents or some properties possessed by neither. The combining of the two or more existing materials is done by physical means, as opposed to the chemical bonding that takes place in the alloys of monolithic solid materials .A true composite might be considered to have a matrix material completely surrounding its reinforcing material in which the two phases act together to produce characteristics not attainable by either constituent acting alone. Note that the insoluble phases or main constituents in a composite do not lose their identity. This is not true of solids, which are metallic alloys or co-polymers, whose phases are lost to the naked eye because these phases are formed as a result of natural phenomena. In other words, steel is a multiphase metal alloy but is not considered composites by some because their phases are not formed in separate processes but originate in a single manufacturing process. This discussion reveals that the definition of a composite is still somewhat arbitrary.

1.2 Why we use composites?

1) To increase stiffness, strength or dimensional stability at high temperatures while under strain conditions in a corrosive environment.
2) To increase toughness (impact strength), high temperature resistance.
3) To increase mechanical damping and design flexibility.
4) To reduce permeability to gases and liquids.
5) To modify electrical properties (e.g. increase in electrical resistivity).
6) To decrease water absorption and thermal expansion.
7) To increase secondary uses and recyclability and to reduce any negative impact on the environment.

2. Development of Composites and Recent Advancements

Technologically, most important composites are those in which the dispersed phase is in the form of a fiber. Hybrid composites are relatively new and obtained by using two or more fibers in single matrix and they find applications such as light weight land, water and air transport structural components and light weight orthopedic equipments. The combination is made so as to achieve improved mechanical property and maintain low cost. Composite materials have been used from earliest time. Mongol bows of the thirteenth century utilized animal tendons wood, silk, and adhesives. The ancient Israelites used straw to reinforce mud bricks. The early Egyptians fabricated a type of plywood. Medieval swords and armor are examples of our present-day laminated metal materials.

Nature has provided composite materials in living things such as seaweed bamboo, wood and human bone. Such materials were recognized for their strength and light weight when used in the construction of the first all composite, radar-proof airplane the Mosquito- around 1940. Composite materials in the form of sandwich construction showed that primary aircraft structures could be fabricated from these materials. World War II saw the birth of glass-fiber-polyester composites for radomes and secondary aircraft structures, such as doors and fairings, which were designed and placed in to production. Glass-fiber composites were recognized as valid space materials when they were picked for fabrication and production of Polaris submarine missile casings. In industries, new thrust for "design for automation," designers seek to reduce the number of components in a product, eliminate mechanical fasteners and design to facilitate assembly by robots. Composites offer great promise to help meet at least some of these goals. [5]

3. Applications and Utilizations

Composites are the primary contender for following applications. In each of these fields, the work is at a very early stage of development, but progress will be greatly assisted by the results attained in the aircraft and aerospace sectors.

3.1 Automobile and Automotive Industry

There are basic differences in the approach adopted when considering the application of composites in the aerospace and automobile industries. This is primarily due to the production requirements of the two activities. In aerospace and defense, the design of the structure is optimized to provide the required performance and the manufacturing process is subsequently selected on the basis that it is capable of achieving the desired design. In contrast, the automotive industry requires a rate of manufacture, which is capable of producing components within a specified unit cost. Therefore, manufacturing processes, which are suitable for volume output, are the primary consideration and design of a component must be tailored for that fabrication process.[3]

In the case of a high-performance sports car, the cost of manufacture is high in the first place owing to advanced design, better workmanship and small production runs. Hence the concept of increased performance due to the incorporation of composite material makes sense. In racing cars, the picture is again different; a racing car is built to win races and if this can be helped by weight saving, increased structure strength, the possibility of a more advanced aerodynamic design or better road-holding, then the use of carbon-fiber reinforced plastics is fully justified. Today, much thought is being given by the makers of racing cars to the possibilities of new materials including advanced fiber composites. 'Society of Automobile Engineers' has revived the use of carbon fibers in vehicle design, giving possible applications such as bearing materials, connecting rods, push rods, propeller shafts, axel castings and even spring hanger bearings. It is stated that, owing to the relatively high cost of carbon fibers, that will be used first in applications where a small quantity can be put to good advantage.[3]

3.2 Power Transmission Industry

A number of possibilities exist for utilizing the outstanding mechanical properties of carbon-fiber. In one of these used is uses is use of carbon-fiber to reinforce a metal; thus , in electrical transmission lines, the fiber strengthens the copper or aluminum conductors and allows greater distances to be used support towers. It is very doubtful whether normal transmission lines will ever justify carbon-fiber incorporation, but, in cases where extra long spans are necessary as in rivet crossings, its use may prove advantageous and justify the extra cost.

In the development of super high speed electric trains, the overhead conductors must be as free as possible from sagging and from deflection by the upward force of the pantograph; otherwise excessive wear and arcing will take place. In this case, there is a very real incentive to provide overhead lines of the maximum rigidity and carbon-fiber may be used to reinforce the copper conductor, the latter also acting as the matrix material. It is likely to be many years, however before widespread use is made in these areas. In the area of electronics and sound productions, one possible application is for high quality loud speaker cons, where the combination of high stiffness and low weight are ideal for improved frequency response.[7]

3.3 Mechanical Engineering

Aspects of Mechanical Engineering which are of particular interest at the present time, are :-

1) Bearings.
2) Components and structures for fast surface transport, example railways.
3) Gears, high-speed rotating machines.
4) Machine tools and medical applications.
5) Structures such as towers, cranes etc.

In the area of transport, British railways have carried out work with carbon-fiber gear wheels, which are able to run without lubrication. Further work with reinforced-plastic gears is being undertaken by the Production Engineering Research Association (PERA), where a range of plastics reinforce with carbon, boron, glass and asbestos is being evaluated to produce machine-tool gear-boxes which will be much less noisy and which will not require lubrication. In a reinforced-plastic gear wheels, the amount of fiber needed is small and therefore cost effectiveness appears to be attainable even today. In the area of high-speed rail transport, it is possible that carbon-fiber in conjunction with glass fiber may find use on structural members and bodywork but the main problem will be the cost of the carbon-fiber. The use of light weight composites may be considered for other high-speed reciprocating machinery to reduce inertia and increase performance. Towers and masts are obvious applications for composites where their low weight coupled with strength and stiffness allows cost saving and greater safety factors or greater heights to be achieved. One interesting area combines mechanical engineering and medical applications. North American Rockwell Corp. have found that certain carbon-fiber composites are chemically, biologically, and physically compatible with the fluid and tissues in the human body. It is possible that bones, joints etc. may be partly or wholly replaced by CFRP, but, before any widespread use may arise, considerable effort must be spent on trails.[7]

3.4 Marine Engineering

Its main thrust areas are:-

1) Hovercraft
2) Sailing-boat masts
3) Hydrospace
4) Ships propeller

Hovercraft bears some resemblance to aircraft such that structural weight is an important factor if maximum payload is to be achieved. Hovercraft depends on air pressure from fans to maintain a small clearance from the water so that, in effect, mechanical energy is used to provide the lift as in an aeroplane. Additional advantage may be derived from fabrication of the hovercraft propellers from carbon-fiber composites to save weight and to reduce vibration by means of the damping factor of these materials relative to metals.[3]

Sailing-boat masts are a natural application for carbon fibers since the main problem is one of stiffness relative to weight and CFRP can provide and ideal solution. In order to derive the maximum benefit from a sailing boat, the sales must be attached to a stiff mast that does not bend and whip in strong winds, otherwise the angle of the sail alters and performance suffers. One method of using carbon-fiber is to bond another skin on to a metal mast; in this way, considerable increase in stiffness is obtained in minimum fabrication and fiber cost. However, for the maximum performance an all-carbon mast will be superior but the extra cost may be difficult to justify. Ships propeller at first thought do not present a viable application for carbon-fiber since metal has ample strength and is cheap. However, large propellers may weigh 30 tons are more, which have to be supported by the shaft bearings of the propeller shaft. The bearing and shaft have to be large and friction absorbs a considerable amount of power. Such an application is very unlikely within the next few years, but in the next decade large propellers may be given serious consideration. [2]

3.5 Sports Equipment

The last two decades have seen a notable increase in the degree of professionalism in the sports world and in almost every field of sport, there are financial incentives. It is logical to suppose therefore, that the professional sportsman will demand the very best from his equipment. Already a number of applications have been established where CFRP may provide improved performance as a result of strength or stiffness coupled with low weight. Indeed, it is fair to state that sports equipment may prove to be one of the first and also largest users of carbon-fiber composites. Examples are:-

1) Bows, arrows, Golf clubs.
2) Canoes, Oars, Skis, Yacht masts.
3) Fishing rods.
4) Racing car bodies
5) Tennis, squash, and cricket bats.

3.6 Process Plant Applications

Corrosion resistance, strength and ease of fabrication make composites, particularly glass reinforced plastics, admirably suitable for process plant applications. Large and complex GRP components are readily produced in small quantities and the installed cost of GRP plant is highly competitive with that manufactured from other traditional materials e.g. Stainless steel, rubber-lined steels etc. Storage tanks, pressure vessels, pipe work, stacks and ducting systems. Majority of process equipments are basically thin, cylindrical shells. Vessels are frequently required to contain hazardous, corrosive and toxic substance; operating temperatures may range from 0 to 1.100 C and operating pressures are usually in the range 0.10 bar absolute.[6]

In chemical process plant applications, the provision of a corrosion-resistant lining is an essential feature of the design and it is often this consideration, which leads to the selection of GRP in the first instance. With regard to chemical inertness, both glass-fiber and carbon-fiber composites frequently show similar resistance to chemical attack, but usually the resin properties are the determining factor. In the case of strong alkali solutions, it has been shown that carbon has the advantage over glass, which is readily

3.7 Medical

Lightweight, attractive stiffness characteristic and bio-compatibility has meant that composite materials are finding application in number of areas in the medical sector. External components such as artificial limbs are those, which are the most similar to conventional engineering structures and here high specific properties, fatigue resistance and flexibility of manufacture can all be used to advantage. The chemical inertness of carbon-fiber has led to a number of surgical applications

where the material is used in conjunction with metallic and polymeric materials. Carbon composites are being implanted into cartilage to promote biological resurfacing of damaged areas. The open wave structure of the material promotes cell growth along and between individual fibers ultimately resulting in suitable repair. In a related application carbon-fiber plates are being employed in the repair of damaged ligament. Loops of material are passed through holes drilled in the adjacent bone structures and then their length adjusted to achieve the correct tension for the particular patient.[2]

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