International Journal Of Core Engineering & Management
Volume-5, Issue-9, December-2018, ISSN No: 2348-9510

COMPOSITE MATERIAL: A REVIEW OVER CURRENT DEVELOPMENT AND ITS SCOPE IN AEROSPACE APPLICATION

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Abstract

Materials play a significant role in the blooming of human civilization and country's infrastructure. The importance of materials in modern world can be realized from the fact that much of the research is being done to apply new materials to different components. However it is natural for a design engineer to rely on trusted and tested materials, but now the world is changing .Today composite materials have changed all the material engineering. The evolution of composite materials has given an opportunity to various designers to use new and better materials resulting in cost reduction, increase in efficiency and better utilization of available resources. Some examples are cascades for engines, leaf spring, curved fairing and fillets, replacements for welded metallic parts, tubes, cylinders, ducts, blade containment bands, medical devices, electronic devices, sports goods etc. In aerospace approximately 50% of the airframe is made from composites due to their high specific strength, light weight and stiffness. The aim of this paper is to present the current scenario of application composites in industries and go towards the approach of composite material in future direction with its advantages, disadvantages and their applications in aerospace industry, automobile sector, manufacturing industries etc. A brief review of composites usage in aerospace sector is first given. The nature of composite materials behaviour and special problems in designing and working with them are then highlighted. The issues discussed relate to the impact damage and damage tolerance in general.
Keywords: composites, aerospace, prepregs, Reinforcement fibers, ceramics, fatigue.

I. INTRODUCTION

Composite materials have been used for thousands of years, e.g. they have manufactured bricks with the help of mud which is thousand-year-old technology. Now days, we all depend on composite materials at some aspects of our lives. Composite materials are used in large volume in various engineering structures including spacecrafts, airplanes, automobiles, boats, sports' equipments, bridges and buildings. Widespread use of composite materials in industry is due to the good characteristics of its strength to density and hardness to density.
Composite materials are materials made from two or more than two materials with considerably differ in physical and chemical properties, that when combined, make a material with appearances

International Journal Of Core Engineering & Management
Volume-5, Issue-9, December-2018, ISSN No: 2348-9510

different from the individual components.

Composites comprise strong load carrying material is known as reinforcement and weaker materials is known as matrix. One may define a composite as material as a materials system which consists of a mixture or combination of two or more micro constituents mutually insoluble and differing in form and/or material composition.

1.1 Materials
The term composite could mean almost anything if taken at face value, since all materials are composed of dissimilar subunits if examined at close enough detail. But in modern materials engineering, the term usually refers to a “matrix” material that is reinforced with fibers.
Examples of composites are steel reinforced concrete (metals + ceramics), vinyl-coated steel (metals + polymers),fiber reinforced plastics (ceramics + polymers).
Many composites used today are at the leading edge of materials technology, with performance and costs appropriate to ultra demanding applications such as spacecraft.

Material	E (GPa)	σb (GPa)	εb (%)	P (Mg/m³)	E/ ρ (MJ/kg)	σb / ρ (MJ/kg)	Cost (Rs/kg)
E-Glass	72.4	2.4	2.6	2.54	28.5	0.95	61.6
S-Glass	85.5	4.5	2.0	2.49	34.3	1.8	1232-1848
Aramid	124	3.6	2.3	1.45	86	2.5	1232-1848
Boron	400	3.5	1.0	2.45	163	1.43	18480-24640
HS Graphite	253	4.5	1.1	1.80	140	2.5	3696-6160
HM Graphite	520	2.4	0.6	1.85	281	1.3	12320-36960

Table 1: Properties of Composite Reinforcing Fibers.

As seen in Table 1, the fibers used in modern composites have strengths and stiffness’s far above those of traditional bulk materials. The high strengths of the glass fibers are due to processing that avoids the internal or surface flaws which normally weaken glass, and the strength and stiffness of the polymeric aramid fiber is a consequence of the nearly perfect alignment of the molecular chains with the fiber axis.
The large scale use of advanced composites in current programs of development of military fighter aircraft, small and big civil transport aircraft, helicopters, satellites, launch vehicles and missiles all around the world is perhaps the most glowing example of the utilization of potential of such composite materials.

II. AEROSPACE STRUCTURES AND FEATURES

Important requirements of an aerospace structure and their effect on the design of the structure are presented in table 2.

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Requirement	Applicability	Effect
• Light-weight	All Aerospace Programmes	▪ Semi-monocoque construction * Thin-walled-box or stiffened structures ▪ Use of low density materials: * Wood * Al-alloys * Composites ▪ High strength/weight, High stiffness/weight
• High reliability	All space programmes	▪ Strict quality control ▪ Extensive testing for reliable data ▪ Certification: Proof of design
• Passenger safety	Passenger vehicles	▪ Use of fire retardant materials ▪ Extensive testing: Crashworthiness
• Durability-Fatigue and corrosion Degradation: Vacuum Radiation Thermal	Aircraft Spacecraft	▪ Extensive fatigue analysis/testing * Al-alloys do not have a fatigue limit ▪ Corrosion prevention schemes ▪ Issues of damage and safe-life, life extension ▪ Extensive testing for required environment ▪ Thin materials with high integrity
• Aerodynamic performance	Aircraft Reusable spacecraft	▪ Highly complex loading ▪ Thin flexible wings and control surfaces * Deformed shape-Aero elasticity * Dynamics ▪ Complex contoured shapes * Manufacturability: N/C Machining; Moulding
• Multi-role or functionality	All Aerospace programmes	▪ Efficient design ▪ Use: composites with functional properties
• Fly-by-wire	Aircrafts, mostly for fighters but also some in passenger a/c	▪ Structure-control interactions * Aero-servo-elasticity ▪ Extensive use of computers and electronics * EMI shielding
• Stealth	Specific military aerospace applications	▪ Specific surface and shape of aircraft * Stealth coatings
• All-Weather operation	Aircraft	▪ Lightning protection, erosion resistance

Table 2

Further, the structure has to meet the requirements of fuel sealing and provide access for easy maintenance of equipments.
For spacecraft the space environment–vacuum, radiation and thermal cycling-has to be considered and specially developed materials are required for durability.
Reinforcements like carbon fiber along with advances in polymer research to produce high performance resins as matrix materials have helped meet the challenges posed by the complex designs of modern aircraft.

III. USE OF COMPOSITES IN AEROSPACE STRUCTURE

It is to be realized that in order to meet the demands in table 1, it is necessary to have materials with a peculiar property-set. The use of composites has been motivated largely by such considerations.
The composites offer several of these features as given below:

- Light-weight due to high specific strength and stiffness
- Fatigue-resistance and corrosion resistance
- Capability of high degree of optimization: tailoring the directional strength and stiffness
- Capability to mould large complex shapes in small cycle time reducing part count and assembly times: Good for thin-walled or generously curved construction
- Capability to maintain dimensional and alignment stability in space environment
- Possibility of low dielectric loss in radar transparency
- Possibility of achieving low radar cross-section

These composites also have some inherent weaknesses:

- Laminated structure with weak interfaces: poor resistance to out-of-plane tensile loads
- Susceptibility to impact-damage and strong possibility of internal damage going unnoticed
- Moisture absorption and consequent degradation of high temperature performance
- There are multiplicity of possible manufacturing defects and variability in material properties.

Even after accepting these weaknesses, the projected benefits are significant and almost all aerospace programmes use significant amount of composites as highlighted in the figure below.

Fig no. 1

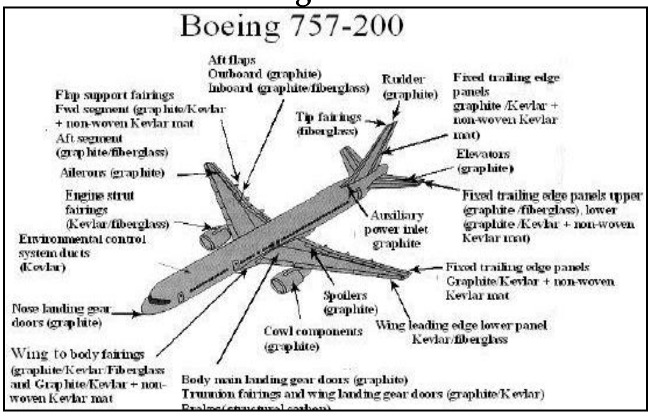
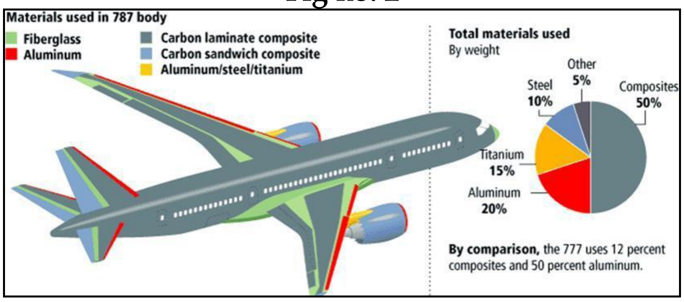


Fig no. 2



The routes to meet these challenges have evolved around use of the advances in computer technology and analysis methods to implement schemes based on computer aided design, computer aided engineering, finite element methods of analysis and building computer interfaces amongst all aspects of development, namely, design, analysis and manufacturing.

IV. MATERIALS FOR AEROSPACE COMPOSITES

The materials systems which have been considered useful in aerospace sector are based on reinforcing fibers and matrix resins given in table 2 and 3, respectively. Most aerospace composites use prepregs as raw materials with autoclave molding as a popular fabrication process. Oven curing or room temperature curing is used mostly with glass fibre composites used in low speed small aircraft. It is common to use composite tooling where production rates are small or moderate; however, where large numbers of components are required, metallic conventional tooling is preferred. Resin injection molding also finds use in special components.

V. APPLICATION OF COMPOSITE MATERIAL

1. In Aerospace- Approximately 50% component of the airspace is made from composites. The primary benefits that composite components are reduced weight and assembly simplification. There are large scale uses of composites in current program of development of helicopters, military fighter aircraft, small and big civil transport aircraft, satellites, launch vehicles and missiles. Various components of aircraft are fabricated by composites, e.g. rudder, spoilers, airbrakes, elevators, LG doors, engine cowlings, keel beam, rear bulkhead, wing ribs, main wings, turbine engine fan blades, propellers, Interior components etc.

2. In Automotive - Composites are being considered to make low weight, safer and more fuel-efficient vehicles. A composite is composed of a high strength fiber (carbon or glass) in a matrix material (epoxy polymer) that when combined provides magnify properties compared with the individual materials by themselves. Many components like steering wheel, dashboard, seat, roof, hatch, mats, energy absorber, and instrument cluster, interior and exterior panel, leaf spring, wheels, engine cover etc. fabricated by composite materials.

3. In Medical- A composite is a nonviable material used in a medical device and intended to interact with Biological system. Over the centuries, advancement in synthetic materials, surgical technique and sterilization methods have permitted the use of composite material in many ways. Medical practice today utilizes a large number of devices and implants. Composites in the form of sutures, bone and joint replacements, vascular Grafts, heart valves, intraocular lenses, dental implants, pacemakers, biosensors, artificial hearts etc. widely used to replace and/or restore the function of disturbed or degenerated tissues or organs, to improve function, to assist in healing, to correct abnormalities and thus improve the quality of life of the patients.

4. In Electrical field- Composite materials have strength, high modulus; electronic composites emphasize high thermal conductivity, low thermal expansion, low dielectric constant and high/low electrical conductivity depending on the particular electronic applications. Electronics composites can use expensive fillers, such as silver particles, which serve to provide high electrical conductivity. The application of composites in electronics include interconnections, printed circuit boards, interlayer dielectrics, die attach, lids, thermal interface materials, electrical contacts, connectors, heat sinks, housings etc.

5. In Sports- Composite materials are used in sports equipment because they offer ease of transport, resistance, low weight, low maintenance and durability. Initially, natural materials, like wood, were used due to its good shock absorption, but these materials had some drawbacks. The anisotropic nature resulted in low resistance and the variation in properties and high moisture absorption allocate various deformations. The composite material has
characteristics of fatigue resistance break resistance, superior thermo stability, friction resistance,

abrasion resistance and vibration attenuation, and it has light weight, high strength and high design freedom, and can be processed and shaped easily, so it is widely used in sports equipment. There are various goods made of composite materials, including the planning boats, sailing boats, sailboards tennis rackets, badminton rackets, softball bats, ice hockey sticks, bows and arrows etc.

6. In Chemical Industry- Advantages of composites of fire resistance properties, lightweight, mold ability, and resistance to chemicals has made the material used in the chemical industry. Composites are extensively used is Industrial gratings, scrubbers, ducting, piping, exhaust stacks, pumps & blowers, structural supports, storage tanks, columns, reactors etc. for alkaline & acidic environments. Some applications are drive shaft, fan blades, ducts, stacks, underground storage tanks, casings, composite vessels etc. Internationally, composites applications in chemical industry are a relatively small segment in relation to the total usage of composites.

7. Other- Composites have long been used in the construction for industrial supports, buildings, long span roof structures, tanks, bridge components and complete bridge systems. Composites also exhibit excellent resistance to the marine environment. With the help of composite we make light weight doors, window, furniture, building, bridge etc. for domestic and construction purpose.

Fibre	Density (g/cc)	Modulus (GPa)	Strength (GPa)	Application areas
Glass				
E-glass	2.55	65-75	2.2-2.6	Small passenger a/c parts, air-craft interiors, secondary parts; Radomes; rocket motor casings
S-glass	2.47	85-95	4.4-4.8	Highly loaded parts in small passenger a/c
Aramid				
Low modulus	1.44	80-85	2.7-2.8	Fairings; non-load bearing parts
Intermediate modulus	1.44	120-128	2.7-2.8	Radomes, some structural parts; rocket motor casings
High modulus	1.48	160-170	2.3-2.4	Highly loaded parts
Carbon				
Standard modulus (high strength)	1.77-1.80	220-240	3.0-3.5	Widely used for almost all types of parts in a/c, satellites, antenna dishes, missiles, etc.
Intermediate modulus	1.77-1.81	270-300	5.4-5.7	Primary structural parts in high performance fighters
High modulus	1.77-1.80	390-450	2.8-3.0 4.0-4.5	Space structures, control surfaces in a/c
Ultra-high strength	1.80-1.82	290-310	7.0-7.5	Primary structural parts in high performance fighters, spacecraft

Table 3. Reinforcing fibers commonly use in aerospace applications.

VI. LITERATURE REVIEW

1. Alen John et al. gives a review on the composite materials used for automotive bumper in passenger vehicles. Determining the right material during the selection process is very important. The material selected should meet the expectation of the engineer. The material should be mechanically feasible and should have low cost. Other than the manufacturing of bumpers, the composite materials have a wide range of other potential automotive applications such as body panels, suspension, steering, brakes and other parts of the automobile. Apart from body panels, the current, limited automotive application of composites include bumper systems, leaf springs, drive shafts, fuel tanks, instrument panels, cross wheel beam, intake manifold.
T. Subash et al. discussed about fibers reinforced green composites for aircraft indoor structures applications. These materials provides the benefits in making of the body panels such as in seat cushions, cabin linings, parcel shelves etc., The natural fibers such as jute, kenaf, bagasse, bamboo,

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coir, sisal have proved to be a materials with the high strength in aerospace and automotive industry. These composites show a lower density as compared to traditional mineral composites and have a great potential to make lightweight sustainable finished products that can reduce tremendous amount of energy consumption in the aerospace industry.
Gururaja M N et al. give a review on recent applications and future scope of hybrid composites. This paper presents a review of the hybrid composite materials technology now a day, in terms of materials available and properties, and an outline of some of the obvious, trends and speculative, with emphasis on various applications including some details of smart hybrid composites. Author concluded the application of hybrid composite in automotive, aerospace, marine, wind power etc.
Prof. N.V. Hargude et al. discussed about composite material mono leaf spring. In this paper we have understand it is possible to easy manufacturing a leaf spring using E glass epoxy glass fiber. As per the point of weight reduction it is possible by using composite material. Ride comfort and life of Composite Leaf Springs are also more when compared to steel leaf springs.

VII. CONCLUSION AND FUTURE SCOPE

Composite materials have attractive aspects like the relatively high compressive strength, good adaptability in fabricating thick composite shells, low weight, low density and corrosion resistance. Composite materials have good mechanical, electrical, chemical properties, due to which we can use composite material in many various industries. There is a wide scope of composite material in automotive, aerospace, wind energy, electrical, sports, domestic purpose, civil construction, medical chemical industries etc.
Hence we can finally conclude that:

- Composite materials offer high fatigue and corrosion resistance.
- Composite materials have high strength to weight ratio.
- So they are best suited for various aerospace applications

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