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Composite Materials in Aerospace Applications

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ABSTRACT

Composite materials are widely being used in aerospace, automobile & constructions etc. Due to their light weight and high strength properties they have become essential parts of aerospace industry, up to 35-45 percent (weight ratio) composite materials are used in making of an aero plane frame. In the first part of this paper composite materials are introduced with their properties and types, in second part evaluation of composite materials in aerospace uses and history is given. Some famous aircrafts like Boeing and Tejas and many more are briefly described that in which part how much composite materials are used.

Keyword: **composites, Carbon fiber reinforced polymer (CFRP), carbon fibers, matrix, fiber reinforcement, aerospace applications, Civil Aircrafts, Military aircrafts.**

I.INTRODUCTION

Composite materials are made by combining two or more dissimilar materials, combined in such a way that the resulting composite material or composites possesses better properties .which can't be obtained with a single constituent material. Composite material consists of bulk material and reinforcement of some kind reinforcements are added to increase the strength and stiffness of the matrix and found mainly in fiber forms.

Composites are being used since 4000 BC to made bows, using Wood, Horn, Sinew (Tendon), Leather, Bamboo and Antler (Deer horn). Wood is a natural composite of cellulose fibers in a lignin matrix [1]. Composite materials are used in Aircrafts for primary (random and dielectric panels) and secondary (doors, ring tips, ducts and fairing) structures.

Composites are divided into three main types:-

Polymer matrix composites: These are the most common type of composites also known as FRP (fiber reinforced polymers). Polymer based resins is used as the matrix and natural fiber, carbon, glass are used as reinforcements.

Metal matrix composites: These are used in automobile industry mainly Aluminium is used as matrix with fiber of silicon carbides**.**

Ceramic matrix composites: Mainly used in high temperature environment such as furnaces manufacturing equipments etc. Mainly ceramics are used as matrix and silicon carbides and boron nitrides are used as short fibers.

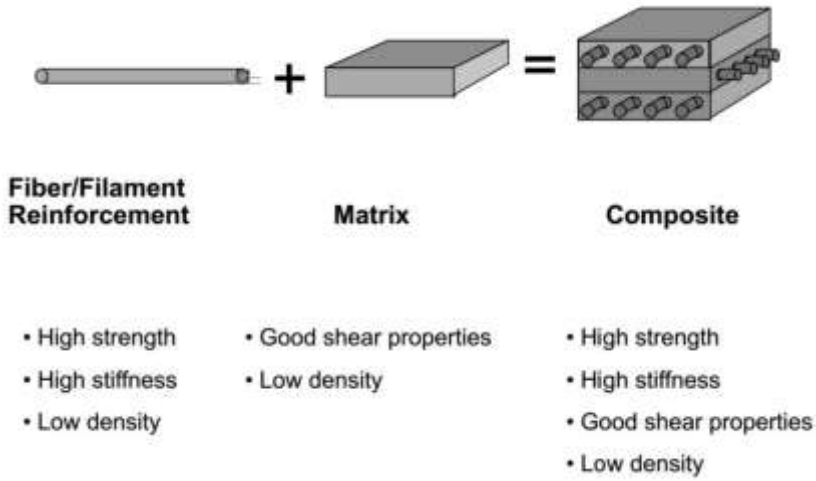

Figure 1:- Composition of Material [2]

Properties of composite materials:-

Light weight: This feature is necessary for all Aerospace program and its effect is Semi monologue construction, thin-welded box or stiffened structure the use of low density materials like aluminum alloys and composites it has high strength and stiffness.

High reliability: This feature applicable for all space programs its effect was strict quality control extensive testing for reliable data and it's was also certification which are proof of design.

Passenger safety:- This feature is applicable for only passenger aircraft is used fire retardant materials and its extensive testing of crash worthiness.

Durability-fatigue, anti corrosion properties: Composite materials are not affected by seam (humidity) and other corrosive chemicals, because of this property composite are also used in bridges and naval ships.

Aero dynamics performance: It is used in aircraft and reusable spacecraft and its effect was highly Complex loading. The wings have thin flexibility which cause it make them deformed shape aero elasticity.

All weather operations: Composite materials are not affected by slightly change in temperature and weather conditions.

Easy to manufacture: on composite materials all manufacturing process like casting, extrusion pressing, etc can be easily done that reduce number of components.

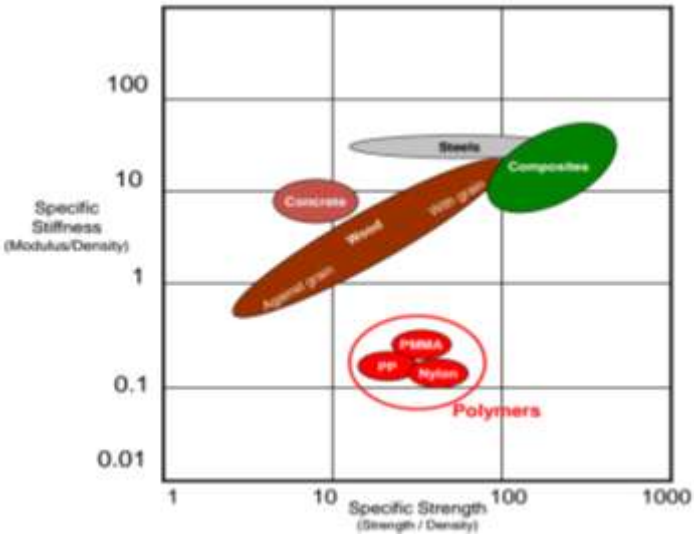

Figure 2: specific stiffness vs. specific strength [3]

Use of composite materials in aerospace:-

Firstly Boron reinforced- epoxy composites were used in US F-14, F-15 fighter aircraft around 45 years ago composites were used in primary structures firstly but now development in their properties and strength made them usable in primary structures like wings fuselage. Initially percentage of composite structural weight was around 2% in F-15 and increased to 19% in F-18.

Composite materials are extensively used in euro fighter bombers transport aerospace applications. The stealth bomber have some interesting case for such type of Fighters radar absorbing material must be added to exteriors of the aircraft therefore composite materials are used in primary structures.

Composite materials are also widely used in commercial transport to save fuel and to increase load carrying capacity. First use of composite was in Airbus in 1983 in latter because of composite material 2000 parts (excluding the fasteners) of metal fine were reduced fewer the 100 [4].

After the successful uses composite materials were used for entire tail structure in A320, and other parts like belly skin, fin fairings, trailing edge bottom access panel and deflectors, trailing edge flaps, spoilers, wheel doors, nacelles, main gear fairing doors etc. were also composite made.

In aerospace use of GLARE (glass fiber reinforced aluminium alloy), CFRP (Carbon fiber reinforced plastics) were extensively used.

In Boeing 777 before 12 years ago percentage of composite material was 20 -22% and now after 12 years in Boeing 787-50% weight is of composite material and around 1600 lb weight is saved.

1. Military Aircrafts:-

A) GENERAL DYNAMICS F-111 WING-PIVOT FITTING:-

The F-111 is a created by Lockheed Martin using the general dynamics in Fort Worth, Texas. It is a swing wing fighter Bomber the wings are attached at the horizontally at the main body of the aircraft, during takeoff or landing and there are expand back at high speeds. Starting of the productions some of the aircraft crashed and the reason was designed to premature fatigue cracks in the forged- Steel wing pivot fitting.

The first solution is that the metal gets thicken which reduce the stress level and increase the endurance limit. And the other solution is that used Boron epoxy doubler to reduce the stress level this suggested by Dial and Howth. The doubler also called Boron-epoxy band aid it works like a band aid because of it protects cracks.

For new aircraft these problems of cracking at checked during the production was run and the wing pivot fitting when aircraft is not built that's the reason did not chance any fatigue crack.

When the aircraft already designed the using pivot fitting and the Boron epoxy doubler put was simply then the savings of 23% cost in the 1960s when the Boron epoxy cost is $100 per pound.

2) VOUGHT A-7 SPEEDBRAKE:-

The Vought A-7 Speed brake is also using the composite material. This also knew as now Northrop Grumman, the A-7 the sinking fighter bomber, the A-7 Speed brake drop from the bottom of the aircraft to reduce speed. This composite speed brake is easier design with two jogged bears getting loads in various directions.

There are one more problem to created the speed brake with the graphite-epoxy were in the zone here needed to dispatch or pivot spot.

3) VOUGHT S-3A SPOILER:-

Another considerable use is a spoiler created by Vought which also known as now Northrop Grumman for the Lockheed S-3A. The Lockheed S-3A is a subaqueous searching plane. The spoiler is a comparatively minar pendant like part in the wings.

For designing the composite spoiler the base is a variable thickness skin. On one side, but with the composite material these problems are not conducted. That's why sustain to construct it up at the sides and its core like a honeycomb. Then the composite spoiler manufacturing is very simple.

The original metal spoiler weights is 5.8 kg and the graphite epoxy with honeycomb core spoiler weights is 3.7 kg, that's a savings in weight in Vought is 39% approximate. The original metal spoiler is expensive to the graphite epoxy design these data is not actual but that's true from above the composite material is very useful for comparing to the metal spoiler.

4) BOEING F-18:-

The Boeing F-18 is comprehensively used composite material. It is created by the McDonnell Douglas Northrop Grumman. The several spotted areas are the composite material in main structure like tail, surfaces, fin, wings, doors and other parts of the whole plane. Which are the complementary structures.

The crucial issue in the design for use of second generation part by composite material and also the crucial role in the aircraft of composite material is that ,the composite material saving the total weight 8 -10% easily. When

compared to the saving rate of composite material with metals the savings rate is higher and the percentage saving rate is 25 -35% probably.

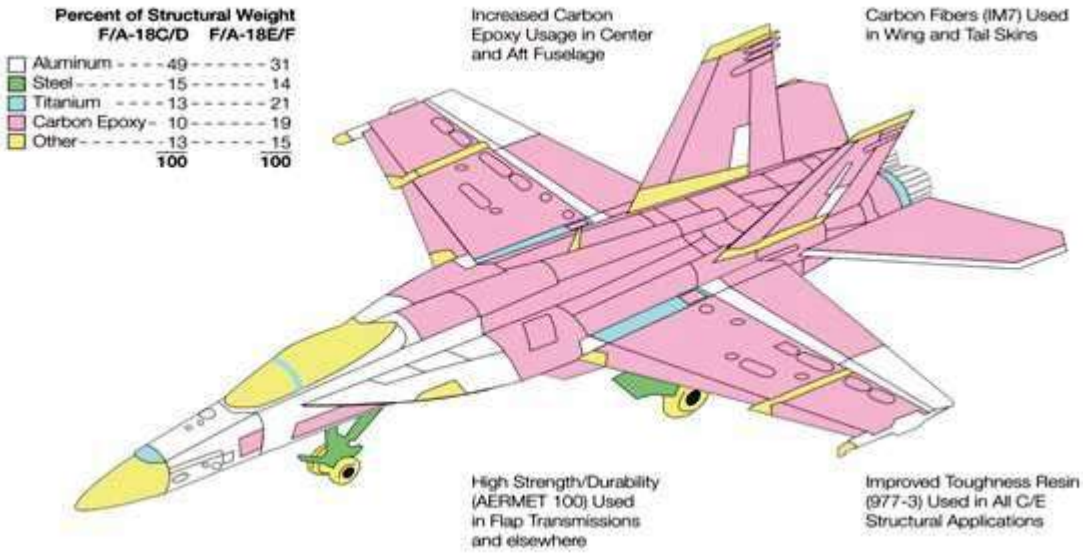

Figure 3:- F-18/D Composite Materials Usage (courtesy of Boeing) **[4]**

5) BOEING AV-8V HARRIER:-

It is also created by the McDonnell Douglas, the main part of the aircraft made by the 172-182 layers of graphite epoxy which is the coarse area. The whole structure using 615 kg graphite epoxy. The titanium is also used at high temperature situations with graphite epoxy which are also able for high temperature function. Another material is also in the development.

6) GRUMMAN X-29A:-

Another aircraft is Grumman X-29a its special feature is that it's sweeping wings. In metal aircraft to avoid the Aerodynamic divergence with the help of especially concertized at the dominant weight. This type of feature contains only a few aircraft. The composite material structure can be Spartan through layer by layer in flaky concertized to successfully resist and avoid aerodynamically divergen.

7) NORTHROP GRUMMAN B-2:-

The Northrop Grumman created the Northrop Grumman B-2 for stealth bomber. Its external or outer part made by composite material because of their radar absorption properties and their ability to be formed which change the radar cross section in minimum of the aircraft and the other details is not to be openly these also not open for the Lockheed Martin F-117A stealth soldier.

8) HAL-Tejas:-

The multi role light fighter plane manufactured by India with the help of Aeronautical Development Agency. It has a pure double Delta wing configuration the Tejas used CFC material for up to 47% of its frame including in the

doors and skin, Wings etc. Composite materials are used to create an aircraft the mainly two features or properties lighter and stronger at the same time. Compare to all metal design the percentage of LCA's is highest to used CFC's is one of contemporary aircraft of its class. Apart from creating the plane with more lighter in there are also fewer joints or rivets, which the reliability and prevents it for structural fatigue cracks.

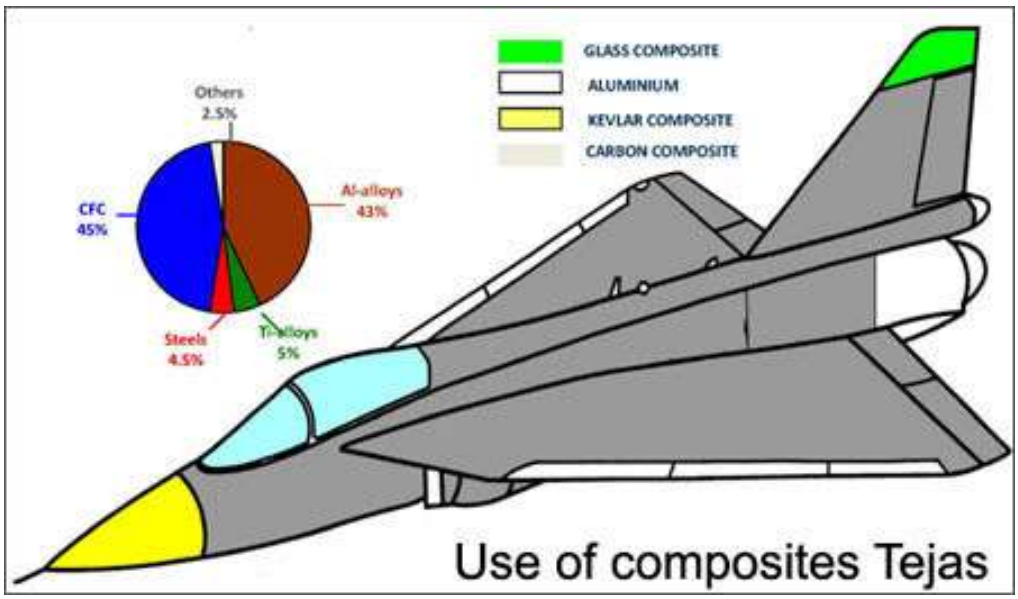

Figure 4 : use of composite materials in HAL Tejas [5]

9) LOCKHEED MARTIN F-22:-

The Lockheed Martin F-22 flow as an air superiority soldiers first time in 1997 the aircraft structure mainly used 25% composite material and another to manufacture techniques in the section 1. 2.4.2 resin transfer molding (RTM) Permits thickness much difficulty visualized parts such as Wings spars that are 1/3 the weight of the metal spar and the 22% cheap in cost and the rejection rate is half. Stereotype tape stored for the form of large flat pieces such as wing has not rivets then the flight controlling surfaces are frictionless moving to the less drag.

2. Civil Aircrafts:-

A) LOCKHEED L-1011 VERTICAL FIN:-

The vertical fin of the Lockheed L-1011 placed at the interior structural part of the fin. The tail contains a thick strong Pole which called spar it is more long comparatively a man like 20 feet or more but its weight minimum as that pickup by a man easily. There is a problem is that to covering in attach the both composite part to each other and in structural test of the vertical fin where it's chance to fails. Reinforcement were then designed and fin completed its design task

This fin getting lighter weight then with aluminium construction and but also show that the cast intent of this type of construction in comparatively to other metals.

The cost of the aluminium fin on the left side of figure and graphite epoxy fin on other side. It must add the fabrication cost in the full cost before can make comparison which is valid. Graphite epoxy is more than competitive. Graphite epoxy is the supported because it is more cost affected then aluminium. This comparison is almost based on starting cost without getting into account the operating and maintenance construction cost.

B) RUTAN VOYAGER:-

The Rutan Voyager is also one of the most valuable aircraft. Which was flow in the world without stopping in 1989.The man Burt Rutan created entire line of all composite aircraft in the 1980s and 1990s.

C) BOING 777:-

The Boeing 777 is a large double engine wide body aircraft. Entering in the services in 1995 with more use of composite material then any previously making Boeing commercial aircraft. It's primary structure is used 8400kg composite material (approximate value 18500lb) and secondary structure used 10% of the total weight of structure. It contain the large tell which made by Carbon fiber in a toughened epoxy Matrix with properties of a 15-22% weight saving resistance from rusting, improvement in aerodynamics and surface get ability of detect the damage of impact. The two things combine in these aircraft is the glass and carbon used in the wing to body fairings and break are made by carbon-carbon.

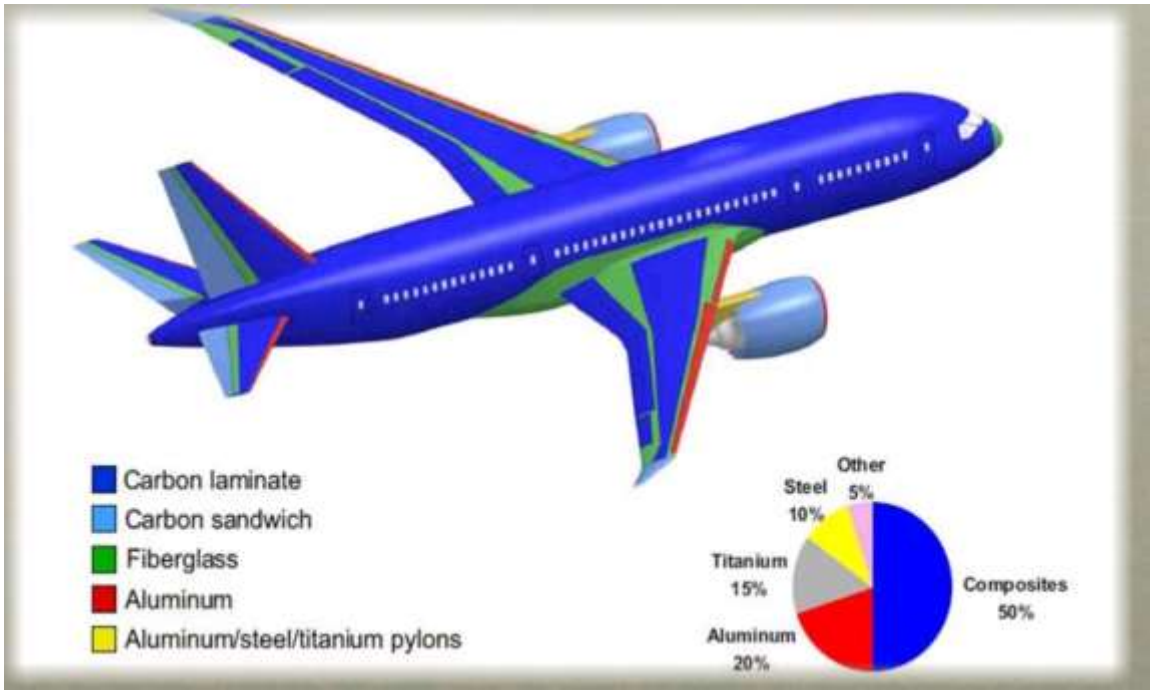

Figure 5: - Boeing 777 (Courtesy of Boeing) **[6]**

D) HIGH-SPEED CIVIL TRANSPORT:-

the more work make under the high speed civil transport(HSCT) which is a take as a successor to the Supersonic transport(SSTs)- the British- French combination the Soviet Tupelov Tu-144 and the never marked U.S. Standard.

For the SSTs, make desirable performance were reached at the outlay of profitability. That is, the speed and range depend on the required of design. HSTC required for profitable standard in maximum temperature structural concepts which are the key for it.

3. Space Applications:-

The composite material used in space application also that the composite material play a important role in the space application. The main thing is that the minimum weight for the space application because the minimum weight reduce the effect of earth forces and it make it lighter in the weight.

A considerable amount of graphite -epoxy structures can be Spartan because of the thermal expansion have micro coefficient. The most benefit is that when it pass around the sun there also it is stable due to this stability in the dimension it also used in Hubble Space Telescope for stabilize and support.

In the other cases the graphite epoxy used for space atmosphere are the releasing of the matrix where they are uncovered to the without the air in space and becoming brittle due to the molecules radiation. These things make it seriously depreciate.

4. Helicopters:-

Because of excellent strength to weight ratio and high fatigue life composites were also used in helicopters to increase payloads. In 1970 first time all composite rotor blades were used. Helicopters also have high weight percentage of composites up to 50%. EX:-V-22 tilt rotor aircraft.

Figure 6:- Aerospace: Use of Composites in LCH **[1]**

II.CONCLUSION

Composite materials are much better than conventional metals and alloys because of their better physical & mechanical properties so and so they are now extensively being used in aero planes, spacecraft and helicopters. There are many other diverse areas where composites can also find application by research on them composite materials and have wide scope in industry. Use of composite material in the LCM resulted in a 40% or above reduction in the total number of parts compared to using a metallic frame. The composite material also helped to avoid about 1900 holes being drilled into the air frame. Use of composites in aerospace industry resulted in reduction of 40% joints and parts compared to metallic frames and also saved time to drill about 2000 holes in sheet of fins, spoilers etc.

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