Theoretical Review of Composite Materials in Fighter Aircraft

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Abstract

Composite material emerged a huge demand in the field of aerospace widely, from the mid of twentieth century. In the study, it has been observed that extensive use of composite material is found in Eurofighter aircrafts. In this paper, the study of four different types of composites that are widely used in fighter aircrafts were described. These are Carbon Fibre Reinforced Polymer (CFRP), Glass FIbre Reinforced Polymer (GFRP), Aramid Fibre Reinforced Polymer (AFRP), and Al-SiC Metal Matrix Composites. The Characteristics, Property, environmental resistance and implementation for fighter aircraft were also discussed. From the point of material interaction with environment such as flammability, problem and risk in freshwater, and influence with saltwater, sunlight and wear resistance are investigated. Comparative studies of four types of composites are discussed to understand the relationship among the materials. Further, challenges involved in composite material are also discussed in this paper. For each composite material, a brief outline about fabrication process and ways to reduce manufacturing cost.

Keywords: Composite materials, CFRP, GFRP, AFRP, Al-SiC, Metal Matrix Composites

Introduction

In the present scenario the countries in this world are in a race of creating better weapons with advanced technologies. Every country spends enormous amount on its defence budget every year according to their need, so they need more certain results in their combats with their weapons for which they need the latest technologically advanced weapons. For any country, air force has a significant and an important role, whatever may be the situation, temperament of the country (attack or defence) fighter aircrafts can decide the result and can change the course of any combat. Fighter aircrafts have proved themselves right from the time of the First World War.

Fighter aircrafts has different requirements such as Durability-Fatigue and corrosion, Multi-role or functionality, all- weather operation, Fly-by-wire system, High reliability, Stealth, Aerodynamic performance, light weight (Herbst, 1980) . As discussed by Mangalgiri(1999) for the fighter aircrafts weight is very important. To reduce the weight of the fighter aircraft low density material is use but it should be noted that the strength and stiffness of the material is not compromised. The material used for building the aircraft should have high fatigue limit and should be tested (aluminium alloys have no fatigue limit). For the multipurpose aircrafts efficient design and usage of composites are essential. The aircraft must bear the environmental and weather resistances such as water, sunlight, air, lighting etc. the fly by wire system must be more efficient with the extensive use of computers and electronics. EMI (Electromagnetic interference) shielding protects the aircraft generated signals from being disrupted from the external signals. Aerodynamic performance of the fighter aircraft is enhanced by highly complex loading, complex contoured shapes and by making the wings thin and flexible. The stealth technology main goal is to make the aircraft invisible in the radar which could be enhanced by coating the aircrafts with a material that absorbs the radar signal.

By considering the above needs of the fighter aircraft the material must have some unique properties. This void can be fixed using composites and specially the use of advanced fibre reinforced composites. Composite materials have the potential to maintain dimensional and alignment stability in space. It has low dielectric loss during radar transparency. Composites show high degree of optimizations which leads to high directional strength and stiffness (Mangalgiri, 1999).

As this paper concentrates the different types of composite material used in fighter aircraft. The materials such as Carbon Fibre Reinforced Polymer (CFRP), Glass Fibre Reinforced Polymer (GFRP), Aramid Fibre Reinforced Polymer (AFRP) and Ceramic Aluminium-Silicon Carbide Composite would be considered (Cheon, (2019)). These materials are being used in the aircrafts in different proportions in different parts according to the necessity. The specifications of the material are illustrated below.

Carbon Fibre Reinforced Polymer (CFRP)

This material is lightweight due to its low density and it is very much durable as compared to other non-composite materials. It has a high tensile strength, and they are also considered as excellent conductor of electricity. It has also been observed that carbon fibre does not change in ultraviolet spectrum if proper resins are used in it. Soutis(2005) explained about the journey of Carbon Fibre Reinforced Polymer from being a small demonstration technology to big technology advancement. And this paper also highlights about its cost which was very high in beginning but eventually became low due to advancements. This paper explains about the benefits of using this material which includes the corrosive resistance, its durability, reduced mass, and scrap. But it still has some drawbacks & challenges such as the effective cost, the material must be inspected and repaired time to time and its ability to bear the damages. And always there would be a factor of uncertainty of being replaced by a new technology. Apart from these this paper concludes that for primary components of the aircraft it is more feasible rather than secondary components of the aircraft.

Glass Fibre Reinforced Polymer (GFRP)

Sathishkumar et al.(2014) elaborates about the different types of mechanical and chemical properties of Glass Fibre Reinforced Polymer was discussed and stated along with its classifications. Some important observations were there in this research paper such as water absorption was observed for different and unique environmental factors with variable time interval and then it was concluded that the mechanical characteristics depreciated with the absorption of water. It was also observed that with the rising value of weight fractions of fibre glass v_F the values Flexural& Ultimate tensile strength also increased. It was observed that the value of the Young's modulus got bigger with the fibre glass v_F. The Friction coefficient was observed and interpreted from various angles and orientations of the fibre and it was analysed that less low wear was there for the high concentration of fibre associated into the polymer.

Aramid Fibre Reinforced Polymer (AFRP)

This material shows different characteristics along distinct molecular axis which is known as anisotropic property. Aramid Fibre Reinforced Polymer (AFRP) is also known as Kevlar fibre which is generally yellow in colour. Although it is has high elastic modulus and tensile strength but is more expensive than glass fibre and some of its drawbacks includes low compressive strength and in they absorb moisture and they are considered to be sensitive as compared to Carbon Fibre Reinforced Polymer (CFRP) and Glass Fibre

Reinforced Polymer (GFRP) so it should be necessarily mixed with some water resistant materials so that its moisture absorbing power gets reduced(Imad Shakir Abbood, 2020). Rashid et al. (2005) explains about the effect of high strength concrete beams on the Aramid Fibre Reinforced Polymer (AFRP) and their deflection.

Ceramic Aluminium -Silicon Carbide Composite

This material has highest elastic modulus but with the increase in the concentration of the impurity the elastic modulus also decreases. This material also exhibits high conductivity of heat as compared to Carbon Fibre Reinforced Polymer (CFRP), Glass Fibre Reinforced Polymer (GFRP), Aramid Fibre Reinforced Polymer (AFRP) and is also heavier than these materials due to its high density. It has a low tensile strength than carbon fibre and aramid fibre (Lamon, 2012).

The selection of the material is very important because choosing the will enhance the efficiency and decrease the cost. Earlier just intuition was used to select the material but now there would be the use of much better and scientific approach. Bifurcating these materials with respect to the parameters such as young's modulus, strength, density, thermal expansion, and thermal conductivity. Apart from that environmental resistance would be also taken into consideration and apply our mathematical method to optimize the best material suited for the aircraft.

Figure 1.0: Representing the recycling of fibre in different industries

First to aeronautical industry then passed on to automobile industry then to the sports industry then to the construction industry. The figure 1.0 represents how the fibres are recycled and passed down to different industries (Vieiraa et al. 2016). This shows that our material is also reusable and can be recycled.

Table 1: Values of different materials on basis of their properties.

Materials	Density (kg/m^3)	Young's Modulus (GPa)	Strength (MPa)	Thermal conductivity (W/mK)	Thermal Expansion $*10^{-6}(K^{-1})$
CFRP	1500-1600	69-150	800-1500	1.28-2.6	1-4
GFRP	1750-2600	15-26	138-241	0.4-0.55	8.6-33
AFRP	1200-2890	70-82	2600-3100	0.023-0.030	2.2-2.4
Al -SiC	2800-2890	81-100	290-365	180-200	15-23

Table 2: Different materials grading with the parameters of environmental resistance.

ENVIRONMENTAL RESISTANCE					
	Flammability	Freshwater	Saltwater	Sunlight	Wear resist
CFRP	B	A	A	B	C
GFRD	B	A	A	B	C
AFRP	A	A	A	B	C
Al-SiC	A	A	B	A	B

(A, B, and C denote 'very good', 'good', and 'average')

Table 1 represents comparative data study of different materials with respect to critical parameters such as density, young's modulus, strength, thermal conductivity and thermal expansion. Based on the case studies of these materials, experimental data are collected and tabulated in it. Each and every parameter decides the strong, stiffness and thermal conductivity of the material. Further observations of materials based on environmental resistance are illustrated in Table 2. The impact on environmental resistance plays a vital role influence on the composite materials. Factors like flammability, effect on freshwater and saltwater, influences in sunlight UV rays, and impact on wear friction resistance. Comparative studies are tabulated on grading system as characterized in Table 2 in details.

Conclusion

The wide range of the progression in composite material brought a revolution in the Aerospace industry. In this paper, four types of composite material were reviewed and their relationship was compared among various parameters. From the above property Table 1, it shows the characteristics of material like stiffness, strong and thermal influencing factors. Recalling the concept of stiffness, as the Young's Modulus is higher and proves better stiffness; material will undergo less deformation after being subjected to load. Observing Table 1, it reveals that the Young's Modulus of GFRP is less than CFRP. As a result, CFRP is the stiffest material among all other referred materials. Simultaneously, it can be stated that CFRP has proven to have more strength as compared to other materials. Then, we contrasted those composite materials to measure the thermal conductivity factor influence on the materials. Looking into the comparative Table 1, it shows that Al-SiC Metal Matrix Material is the most thermal conductive which has the ability to conduct heat in a rapid process. In this paper, additional comparative data has been analyzed on environmental resistance and graded them based on several critical parameters. First parameter is flammability, ignition capability of material at atmospheric temperature. Al-SiC and AFRP materials showed a very good resistance to flammable property as compared with other two considered materials. Simultaneously, the study of freshwater effects on all the considered composite material shows a synergistic resistant effect. At the same time, observation has been made under the effect of seawater or saltwater on composite materials. Slight strength reduction was observed on Al-SiC Metal Matrix Composites as compared to other materials. Then, UV effect on the composite material was studied adjacently. Monitoring the comparative composite material exhibits that most of the polymer based composite material suffer delaminating leads to reduced shear strength and flexural stiffness when exposed to sunlight as compared to Al-SiC Metal Matrix Material. Finally, the wear resistance parameter of all the composite material was examined. As a result, Al-SiC Metal Matrix composite material is superior to other polymer based composite material. Appropriate suitability of material can be used in fighter aircraft and can be done on MCDM method to achieve clarity as a designer.

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