

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/363093841>

# APPLICATION OF CERAMIC AND POLYMER COMPOSITES IN AEROSPACE INDUSTRIES

Article · June 2020

CITATION

1

READS

430

1 author:



[Shrinivasa D.](#)

Vidya Vardhaka College Of Engineering

15 PUBLICATIONS 7 CITATIONS

[SEE PROFILE](#)

## APPLICATION OF CERAMIC AND POLYMER COMPOSITES IN AEROSPACE INDUSTRIES

SHRINIVASA D, DR G V NAVEEN PRAKASH, DR RISHI J P, RAKSHITH GOWDA D S, AMRUTH E & GURUDATTA H M

Department of Mechanical Engineering, Vidyavardhaka College of Engineering, Mysore 570002, India

### ABSTRACT

*This paper reviews about the potential of ceramic and polymer matrix composites for aerospace applications. Composites (ceramic, metal and polymer) are finding replacements for lone metals parts. Composites especially, ceramic and polymer matrix, are extensively used in aerospace applications for variety of parts. Ceramic matrix composite materials with properties like high temperature stability, high hardness, high corrosion resistance and good versatility have been widely used. Since ceramic matrix composite materials have good thermal conductivity, they are mainly use in high-temperature sections of aircrafts like exhaust nozzle. Metallic composites with high strength are used in aircraft's main body section i.e. fuselage. Polymer Matrix composites finds application in the hypersonic vehicle in the combustor. In this review recent development in the advanced composites for aerospace application are discussed.*

**KEYWORDS:** Ceramic Matrix Composite, Polymer Matrix Composites, Hypersonic Vehicle

**Received:** Jun 10, 2020; **Accepted:** Jun 30, 2020; **Published:** Sep 04, 2020; **Paper Id.:** IJMPERDJUN20201055

### INTRODUCTION

The need and development of new aircraft materials have been growing due to the rapid increase in aerospace industry. The main parameter considered while selecting aircraft materials are the reduction of cost by reducing the weight and making the materials as light as possible. This in turn results in greater efficiency which further reduces the aircraft production cost. The materials adopted for aircrafts have been changing ever since 1906, where it all started from wood and later Al-based alloys were replaced after 1927 [1]. The change from wood to Al-based alloys made lot of difference because of their mechanical properties. They have been dominant in aerospace industry for more than 80 years. The main reason for replacing Al-based alloys with composites is due to their high strength to weight ratio, outstanding corrosion resistance and superior fatigue resistance.

The increase demand in aircraft speed is served by composites such as ceramic matrix composites which can with stand the temperature 1400 °C [2]. Ceramic matrix composite materials with properties like high temperature stability, high hardness, high corrosion resistance and good versatility have been widely used in recent times. Some of the ceramic matrix composites are silicon carbide (SiC), aluminium nitride (AlN), silicon nitride (Si<sub>3</sub>N<sub>4</sub>). Since ceramic matrix composite materials have good thermal conductivity, they are mainly use in high-temperature sections of aircrafts like exhaust nozzle [3].

And also Metal matrix composite materials having properties like high fracture toughness, high yield strength, low thermal expansion and suitable wear resistance plays a key role for the aerospace industry in selection of composites for aircraft parts. Though steel plays a vital role in aerospace industry, its uses have been drastically reduced due to factors such as low strength to weight ratio and poor corrosion resistance relative to advanced

composites [4]. Polymer matrix composite (PMC) with properties like high strength to weight ratio, outstanding corrosion resistance are its biggest advantage. Apart from natural fibers reinforced PMCs, in the military aircrafts carbon nanotube reinforced PMCs are used [5].

## MATERIALS USED

The criteria for choosing a material for aircraft engine should fulfill demands such as good high withstanding temperature mechanical properties and good corrosion resistance at higher working temperature. Fretting wear, and stress corrosion cracking will be some of the key factors considered for future selection of materials for aerospace industry. Many researches are happening to find several ways to reduce the weight of aircraft materials. One such way is the use of organic matrix composites. These matrix materials are known for improving structural efficiency and reduction of weight. They have capabilities to sustain damages that are not visible by naked eyes. While selecting from a large range of different types of materials, for the application of aircraft, it is always selected based on type of utilization.

### Al Based Alloys

The advantages and disadvantages of different types of materials are given in Table 1.

**Table 1: Advantages and Disadvantages of Specific Materials**

| Material                   | Advantages                                                | Disadvantages                                                |
|----------------------------|-----------------------------------------------------------|--------------------------------------------------------------|
| Aluminium alloys           | Low manufacturing cost, high toughness, low density.      | Corrosion, weldable, high strength alloys only used at 94°C  |
| Titanium alloys            | High operating temperature High corrosion resistance.     | High initial cost, high notch sensitivity                    |
| Low alloy steel            | Low raw material cost, moderate toughness, high strength, | rigorous heat treatment for high strengths                   |
| Corrosion resistant steels | Corrosion resistance reduced manufacturing costs.         | Low strength relative to the high-strength low-alloy steels. |
| Polymer matrix composites  | Light weight, high stiffness, high strength, low density, | Difficult to identify the damages                            |

In any commercial aircraft, 99% of the structural materials comprise of aluminium, steel and titanium alloys. There is a continuous frequent changes which concentrates on improving factors like resisting crack-growth and fracture toughness. Some of the new advanced materials like 7075-type alloys have improved fracture toughness and strength without reduction of other properties. Materials like 7050, 7175 and 2124 are used in commercial aircrafts and fighter aircrafts as well. 2124-T81851 used on F-16 and F-22 use thick plate and still low in weight.

Titanium on the other had has low application though it matches all the criteria's while choosing a material for aircraft body. Titanium materials are costly and machining times are almost 15 times higher when compared to materials like aluminum.

GLARE, is an aluminium/fiberglass PMC having good fatigue, corrosion resistance, fire resistance and impact resistance is used by Airbus for its A380 series. And especially focuses on the welded structures are to reduce the manufacturing cost nearly by 25% and reduce the weight by 15%. Titanium matrix composites offer properties for stiffness- driven application and the major drawbacks is high cost. But, due to large and bulk development efforts of titanium will make the expenses fall. New powder metallurgy process produced via laser process is being developed for producing relatively simple shapes. Concentrating on raw materials and processing improvements through organic composites are some initial developments. By increasing volumes and improved compositions, the cost of the material can

be reduced to a small scale. Improved assembly methods like thermoplastic welding and co-cure occurred. Resin Transfer molding, stitches resin film infusion, liquid, resin transfer moulding are some of the processing methods to achieve them. Mechanical properties of some of the Al series based alloys are given in Table2.

**Table 2: Mechanical Characteristics of Some Al Based Series Alloys**

| Alloy      | UTS (MPa) | Yield Strength (MPa) | Elongation (%) |
|------------|-----------|----------------------|----------------|
| 2025-T351  | 428       | 324                  | 21             |
| 2026-T3511 | 496       | 365                  | 11             |
| 2224-T39   | 476       | 345                  | 10             |
| 2324-T39   | 475       | 370                  | 8              |
| 2524-T3    | 434       | 306                  | 24             |
| 7150X-T6   | 808.9     | 776.5                | 14.1           |
| 7075-T6    | 656       | 590                  | 11             |
| 7475-T651  | 552       | 496                  | 12             |
| 2050-T84   | 540       | 500                  | NA             |
| 2092-T83   | 531       | 483                  | 3              |
| 2098-T82   | 503       | 476                  | 6              |
| 2099-T83   | 543       | 520                  | 7.6            |
| 2199-T8    | 400       | 345                  | 10             |

Common 2024 alloys mostly used for aircraft fuselage application where damage tolerance is most of the consideration whereas its low yield strength does not allow him to use in high stress regions. Alloy 2224-T39 has higher yield strength (476 MPa) than conventional 2025 alloy (428 MPa) due to low carbon and silicon concentration than 2025 alloy. 7000 series Al based materials are alloyed with zinc and are heat treatable, hence possess higher mechanical strength than Al-Cu alloys. Al-Li alloys have low density and better mechanical properties than 2000 and 7000 series Al alloys [6]. High-efficiency jet engines produce very hot exhaust gases, hence they need materials that can withstand higher temperature than titanium and super alloys.

## **SUPERSONIC COMBUSTION RAMJET**

In supersonic combustion ramjet or scramjet, the development of ramjet engine is very crucial where the combustion process takes place in supersonic speed instead of subsonic speed. The main parts of a supersonic combustion ramjet are converging inlet, injector for fuel and a converging nozzle. As the supersonic airflow is compressed, the temperature of the fluid rises to such an extent that simple injection of gases fuel is sufficient to combust with the atmospheric oxygen.

The combustion occurs in such a way that it increases the enthalpy of the fluid which in turn results in such a way that expansion throughout the exhaust nozzle leads to high acceleration of air. The principal of expanding the high enthalpy fluid to generate the thrust is similar to standard turbojet engines only that scramjet does not use multiple rotating compressor stage in a inlet. To overcome the mechanical failure of engine, weights of most of the components are reduced eventually. Polymer matrix composites or ceramic matrix composites and metal matrix composites are used to achieve the same[7].

## **COMPOSITE MATERIALS**

### **Ceramic Matrix Composites**

Composite materials used in Airbus 380 are shown in Fig. 1. Most of the outer structural parts are made up of carbon fiber reinforced plastics (CFRP).



**Figure 1: Composite Materials used in Airbus 380 [9].**

Even though ceramic materials exhibit suitable properties like high refractoriness, due to their brittle nature they are often restricted. Fiber reinforcement has been utilized to improve the strength and toughness. Researches on finding the factors which impact these properties are discussed. It is concluded that, even though their application in diverse and contribute equally in development of such materials, particularly the effect that matrix micro-cracking might have on the thermal, mechanical stability of reinforced-ceramic system, should be fully evaluated before considering ceramic- matrix composites for replacement for such conventional materials [10]. Ceramic matrix composite (CMC) have higher temperature resistance and are capable of reducing weight. Compared to metallic nozzle, the CMC nozzles last longer. Nearly 6% of the fuel is reduced by replacing CMC's which have capabilities of withstanding 2700 °F (1482 °C). Two factors play a main role in reduction of fuel burn. First higher temperature capability of CMC's, and second weight of CMC's is nearly one- third of high-temperature alloys[11].

### **Polymer Matrix Composites**

Generally, polymer matrix composites are commonly used in hypersonic vehicle at the highest heat products producing area will be located around the combustor because the pressure is maximum in that area and due to sudden wave boundary layer interaction. To withstand this pressure, it is required to use high temperature materials in the conjunction with the internal thermal extraction methods, they are Nb-Cb752 (2300°C), C-SiC (1600°C) and income (1400°C) that could be used for the design of scramjet combustor. Usually to reduce the load on blades of the turbine, polymer matrix composite (PMC) are utilized, they are mainly present in fan blades of the turbine. The engine of Boeing 777 uses PMC fan blade which was introduced by General Electric (GE). In order rise the toughness of the blades, new techniques have been developed; one such is incorporation of layer of nano composite. [10, 12].

### **CONCLUSIONS**

Ceramic matrix composite materials with several properties like high temperature stability, high hardness, high corrosion resistance and good versatility have been widely used for aerospace applications. Since ceramic matrix composite materials have good thermal conductivity, they are mainly use in high-temperature sections of aircrafts like exhaust nozzle. Metallic composites with high strength are used in aircraft's main body section i.e. fuselage. Polymer Matrix composites are used in the hypersonic vehicle in the combustor.

## REFERENCES

1. Zhang X., Chen Y., Hu J.: Recent advances in the development of aerospace materials. *ProgAerospSci* 97, 22– 34(2018).
2. Chen Y., Xu Z., Smith C., Sankar J.: Recent advances on the development of magnesium alloys for biodegradable implants. *ActaBiomater* 10, 4561–4573(2014).
3. Sommers A., Wang Q., Han X., T'Joel C., Park Y., Jacobi A.: Ceramics and ceramic matrix composites for heat exchangers in advanced thermal systems—a review. *ApplThermEng* 30, 1277–1291(2010).
4. El-Shennawy, M., Adel A. Omar, and M. Ayad. "Similar and Dissimilar Friction Stir Welding of AA7075." *International Journal of Mechanical Engineering (IJME)* 3.4 (2014): 69-86.
5. Prater T.: Friction stir welding of metal matrix composites for use in aerospace structures. *Acta Astronaut* 93, 366–373(2014).
6. Kingston C., Zepp R., Andradý A., Boverhof D., et al.: Release characteristics of selected carbon nanotube polymer composites. *Carbon* 68, 33–57(2014).
7. Boyer R., Padmapriya N.: *Aircraft Materials. Reference Module in Materials Science and Materials Engineering*(2016)
8. Omar, ADEL A., M. El-Shennawy, and M. Ayad. "Study of Wear Behavior of as Cast TiC/7075 Composite." *International Journal of Mechanical Engineering* 4.4 (2015): 45-52.
9. Choubey G., Suneetha L., Pandey K.: Composite materials used in Scramjet- A Review. *Materials Today: Proceedings* 5, 1321–1326(2018).
10. Daoush W., Lim B., Mo C., Nam D., Hong S.: Electrical and mechanical properties of carbon nanotube reinforced copper nanocomposites fabricated by electroless deposition process, *Mater. Sci. Eng. A* 513, 247–253(2009).
11. Viswanathan, R., et al. "Improving Corrosion Resistance of Magnesium Alloy for Aerospace Applications." *International Journal of Mechanical and Production Engineering Research and Development* 9.3 (2019): 769-774.
12. Pora J.: Composite materials in the airbus A380—from history to future. *Proceedings of ICCM13, Plenary Lecture, CD-ROM*(2001).
13. Misra, A.: 12 Composite materials for aerospace propulsion related to air and space transportation. *Lightweight Composite Structures in Transport*. Woodhead publishing 305–327 (2016).
14. Jankowiak A., Blanchart P.: Electrical behaviour of ceramic composite materials for aero- engine igniters. *AerospSciTechnol* 10, 207–216(2006).
15. Ramakrishnan, V., S. Nallusamy, and M. Rajaram Narayanan. "Study on lean tools implementation in various Indian small and medium scale manufacturing industries." *International Journal of Mechanical and Production Engineering Research and Development*, 8 (1), 969 976 (2018).
16. Corman G., Luthra K.: Development history of GE's prepreg melt infiltrated ceramic matrix composite material and applications. *Comprehensive Composite Materials II* 5, 325-338(2018).
17. Dragomir-Stanciu D., Oprisan C., Ianus G., Crismaru I: Study of the influence of ceramic thermal coating on the mechanical resistance of the blades of aircraft engine. *Procedia Technology* 12, 329 – 333(2014).
18. He P., Ma G., Wang H., Yong Q., Chen S., Xu B.: Tribological behaviors of internal plasma sprayed TiO<sub>2</sub>-based ceramic coating on engine cylinder under lubricated conditions. *TribolInt* 102, 407-418(2016).



