International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

EVOLUTION IN MATERIAL FOR AIRCRAFT STRUCTURES

Riddhi Yadav [1], Prachi Wankhade [2], Shreya Londhe [3]

[1]Ms. *Riddhi Yadav*, AISSMS IOIT Pune, Maharashtra, India
[2] *Ms. Prachi Wankhade AISSMS IOIT Pune, Maharashtra, India*
[3] *Ms. Shreya Londhe, AISSMS IOIT Pune, Maharashtra, India*

---***---

Abstract - *The next generation of aerospace is expected to witness several transformative developments. Along with the developments there arises a need for finding a material which best suites to the manufacturing of the components and basic structures which are essential for the developments. Recent advances in aircra49ft materials and their manufacturing technologies have enabled progressive growth in innovative materials such as composites, Al based alloys, Ti based alloys and much more. However, these materials will have some limitations such as insufficient mechanical properties, corrosion resistivity, stress corrosion cracking and fretting wear. Due to this there comes a need to find material which will be having all the properties and will be cost friendly as well. This review introduces the recent advancements in the development of composites for aircraft applications. Then it focuses on the studies conducted on composite materials developed for aircraft structures, followed by various fabrication techniques and then their applications in the aircraft industry.*

Key Words: Carbon Fiber, Tesile Test, Plastic, Metal Fiber.

1.INTRODUCTION

The accelerated growth in the modern aviation industry has led to advancements in aircraft materials. The primary motivators include cost reduction, weight reduction, and extension of the service life of the components in the aircraft structures. The use of lightweight materials improves mechanical properties and fuel efficiency, flight range, and payload, as a result reducing the aircraft operating costs. The proper selection of the material is crucial in designing the aircraft structure. Composite materials have been preferred extensively for the development of several military and commercial aircraft. Although aerospace materials have made significant advances, there exist some significant challenges such as inadequate strength, which is insufficient to meet the
increasing demand for lightweight materials. There is a revolution underway in commercial aircraft manufacturing today and it can be summed up in one word: composites. There are many good reasons for aircraft manufacturers to use composites and for airlines to want composites to be used in their fleets.
Many composite materials achieve relatively greater strength characteristics compared with traditional metallic materials, reducing aircraft weight and thus reducing fuel cost per passenger carried. Composites are more resistant than metal to fatigue from repeated take off/landing cycles, resulting in fewer costly inspections over the aircraft's lifes single use plastics and more time spent. The properties of the composites fabrication techniques, and their applications in various aircraft structures are also discussed. Finally, the challenges and the future scope in the development of aircraft materials are presented, followed by a summary. Advanced composites play a key role in aerospace innovation. Airbus has pioneered the use of composites and other advanced materials in aircraft design and manufacturing, resulting in an industry-leading product line of economical and environmentally-friendly jetliners – from the single-aisle A320 Family to the 21st century A380 flagship. The latest development in the field of aerospace materials arises from the use of application-specific materials. The A380, which at 61% has the lowest percentage of aluminium by weight of all flying Airbus models, has 20 different alloys and tempers compared to the 6 utilised on the A320/330 aircraft. Airbus was the first manufacturer to make extensive use of composites and other advanced materials for producing large commercial aircraft, beginning with the A310 jetliner – based fin box. Airbus pioneered the larger-scale use of composites for aviation over the course of some three decades.

1.1 • World's plastic crisis

Plastic pollution has become one of the most pressing environmental issues, as rapidly increasing production of disposable plastic products overwhelms the world's ability to deal with them. Plastic pollution is most visible in less-wealthy Asian and African nations, where garbage collection systems are often inefficient or non-existent. But wealthy nations, especially those with low recycling rates, also have trouble properly collecting discarded plastics.
Plastics made from fossil fuels are just over a century old. Production and development of thousands of new plastic products accelerated after World War
II to the extent that life without plastics would be unimaginable today. Plastics revolutionized medicine with life-saving devices, made space travel possible, lightened cars and jets—saving fuel and lessening pollution—and saved lives with helmets, incubators, and equipment for clean drinking-water.
The conveniences plastics offer, however, led to a throw-away culture that reveals the material's dark side: Today, single-use plastics account for 40 percent of the plastic produced every year. Many of these products, such as plastic bags and food wrappers,

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

are used for mere minutes to hours, yet they may persist in the environment for hundreds of years.

1.2 How plastics move around the world?

Most of the plastic trash in the oceans, Earth's last sink, flows from land. Trash is also carried to sea by major rivers, which act as conveyor belts, picking up more and more trash as they move downstream. Once at sea, much of the plastic trash remains in coastal waters. But once caught up in ocean currents, it can be transported around the world.

On Henderson Island, an uninhabited atoll in the Pitcairn Group isolated halfway between Chile and New Zealand, scientists found plastic items from Russia, the United States, Europe, South America, Jasingle use plastics, and China. They were carried to the South Pacific by the South Pacific gyre, a circular ocean current.

2. Literature Review

The evolution of aircraft that fly farther and faster has been a consistent goal of aircraft designers. Achieving this goal has required new materials with other attributes in addition to strength and light weight. For example, aircraft that fly at higher speeds require higher temperature capability materials due to frictional heating. As a consequence, skin materials have progressed from wood and fabric used in the early aircraft to advanced alloys of aluminum, titanium, and polymer matrix composites containing high-strength carbon fibres. Perhaps the most sophisticated aircraft ever built in the western world is the SR-71 Blackbird, which had an all Ti alloy skin. This military aircraft was used for high altitude reconnaissance missions and was apable of speeds in excess of mach 3. The lessons learned from military oper ation of the SR-71 showed what practical limitations existed for commercial supersonic flight, especially above mach 2, where the skin tempera tures exceed the capability of Al alloys. As a consequence, there has not yet been a large super sonic vehicle produced and entered into scheduled service that flies at these speeds. The Soviet Tupo lev design bureau did produce several all-Ti Tu 144 aircraft but even in their economic system, it was not considered practical. The Concorde operates at mach 1.8 and is an Al airplane. Even so, it has not been economical to operate and is being retired from revenue service despite its technical success. Damage tolerance became recognized as an important issue in 1954 when three Comet jet air planes, manufactured with 7075-type aluminum, crashed. The cause of the crashes was attributed to premature fatigue failure of the pressurized fuselage associated with stress concentrations at windows and hatches. Today, fracture toughness and fatigue crack growth have been incorporated as a primary design criterion in many products in the same manner as strength was used 35 years ago. In fact, newer, higher toughness Al alloys for fuselage skins have enabled significant weight reductions through removal of some of the circumferential frames that serve, among other things, to arrest a running crack. This is discussed in detail later and is mentioned here as an example. Beginning in the '80s, jet powered flight had become "a given" and other considerations for air craft such as fuel costs, the revenue opportunities associated with increasing range and payload, and reducing landing weight fees again returned the technical focus to weight reduction but without sacrificing life. Then, in the '90s, the realization of the benefits of extending the life of the aging air craft fleet resulted in a technical focus on improved damage tolerance and improved corrosion resistance. One response to this requirement was the possibility of retrofitting existing aircraft with newer and advanced alloys. This was done extensively in the case of the B-52 bomber and other military aircraft. In the case of commercial pro ducts, derivative aircraft models and the emergence of new, large twin engine aircraft was more representative of product trends.

3. Methodology

Composite material is a material that consists of strong carry-load materials which are embedded in a somewhat weaker material. The stronger material is commonly referred to as reinforcement and the weaker material is commonly referred to as the matrix. The reinforcement provides the strength and rigidity that is needed. The matrix or the binder helps to maintain the position and orientation of the reinforcement and is somewhat more brittle. This is a image showing the composite structure of the material after the addition of Fibers/Filament Reinforcement to the Matrix

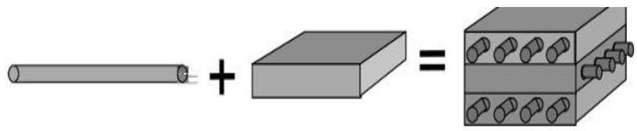

Fig.-1 Fiber Reinforcement

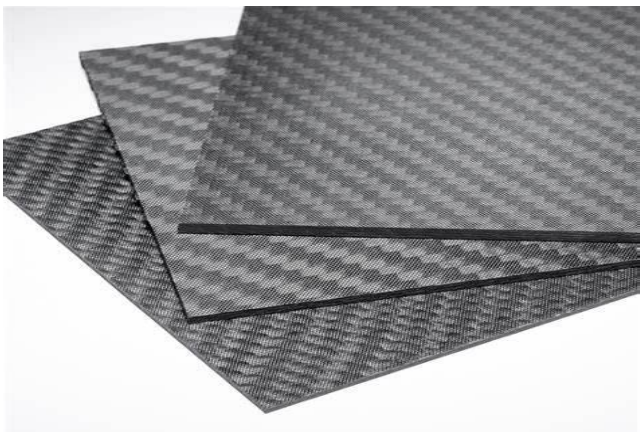

Fig. -2 Carbon Fiber Sheet

1.Precursor Preparation

For SINGLE USE PLASTICS-based carbon Fibers, the process begins with the dissolution of SINGLE USE PLASTICS in a solvent to create a viscous solution. The solution is then

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

extruded through spinnerets to form continuous filaments. These filaments are stretched to orient the molecular chains and improve mechanical properties.For pitch-based carbon Fibers, petroleum or coal tar pitch is heated to reduce its viscosity and then extruded through spinnerets to form filaments.

2.Precursor Pre-Oxidation
SINGLE USE PLASTICS-based precursors undergo a pre-oxidation step, where the filaments are exposed to temperatures between 200-300°C in the presence of air. This initiates the cross-cyclization reactions necessary for stabilization.Pitch-based precursors may also undergo a similar pre-treatment to remove volatile components and increase carbon yield

3.Stabilization
The pre-oxidized SINGLE USE PLASTICS Fibers or pre-treated pitch Fibers are then subjected to higher temperatures (200-300°C) in an inert atmosphere (e.g., nitrogen) to complete the stabilization process. This step converts the precursor material into a thermally stable intermediate with a high carbon content.

4.Carbonization
The stabilized Fibers are heated to temperatures exceeding 1000°C in a controlled atmosphere (e.g., nitrogen or argon) to induce pyrolysis. During carbonization, the remaining non-carbon elements (such as hydrogen, oxygen, and nitrogen) are driven off, leaving behind a carbon-rich structure.

5.Graphitization
Optionally, some carbon Fibers undergo a graphitization process to further improve their properties. Graphitization involves heating the carbonized Fibers to temperatures up to 3000°C in a controlled inert atmosphere. This promotes the rearrangement of carbon atoms into a more ordered graphite-like structure, resulting in higher strength, modulus, and thermal conductivity.

6.Surface Treatment
After carbonization or graphitization, the surface of the carbon Fibers may be treated to enhance adhesion with matrix materials in composite applications. This can involve chemical treatments, such as oxidation or plasma treatment, to introduce functional groups on the surface, or the application of sizing agents to improve compatibility with resin matrices.

7.Sizing Application
Sizing agents, typically composed of resins or polymers, are applied to the surface of the carbon Fibers to provide protection against abrasion, improve handling characteristics, and enhance bonding with matrix materials in composite fabrication.Throughout the manufacturing process, quality control measures are implemented to ensure the consistency and performance of the Carbon Fibers products. This includes monitoring and controlling parameters such as precursor composition, processing temperatures, heating rates, Fiber properties, and surface treatments.
Advanced analytical techniques are often employed to characterize the structure and properties of carbon Fibers at various stages of production.

3. Testing

- Test results for tensile strength check

1.Tensile strength

Typical tensile strength values for carbon fibers can range from 1500 MPa to 7000 MPa, depending on the specific type and quality of the fibers.

Example result: Tensile strength of carbon fibers tested = 3000 MPa.

2.Modulus

Carbon fibers are known for their high modulus of elasticity, which can range from 200 GPa to 700 GPa.

Example result: Modulus of elasticity of carbon fibers tested = 500 GPa.

3.Strain at failure

Carbon fibers exhibit low strain at failure, typically in the range of 1% to 2%.

Example result: Strain at failure of carbon fibers tested = 1.5%.

4.Ultimate elongation

Carbon fibers have limited elongation before failure, often less than 1%.

Example result: Ultimate elongation of carbon fibers tested = 0.8%

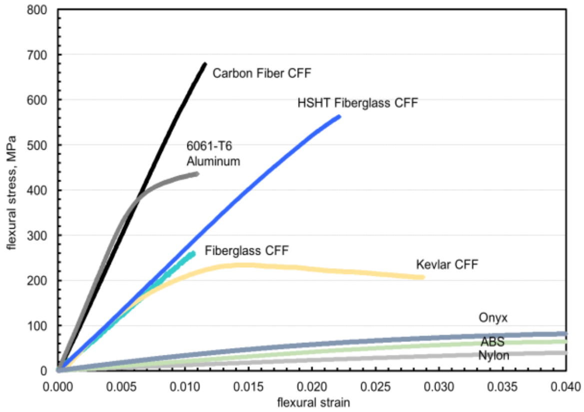

Chart No.1 Flexural Stress vs Strain

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

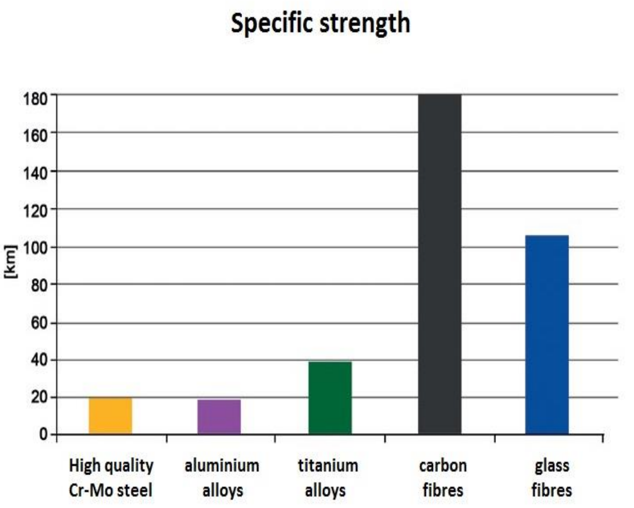

Chart No.2 Specific Strength

3. CONCLUSIONS

Furthermore, carbon fiber's superior fatigue resistance and ability to dampen vibrations contribute to a smoother and more comfortable flying experience for passengers. Reduced vibrations also benefit sensitive electronic components and avionics systems, improving their reliability and longevity. Additionally, the use of carbon fibre enables designers to optimize weight distribution and balance within the aircraft, enhancing stability and maneuverability. Moreover, the lightweight nature of carbon fibre allows for increased payload capacity or extended range, providing airlines with greater flexibility in route planning and operational efficiency. This can result in reduced operating costs and increased profitability for airlines. Additionally, carbon fiber's compatibility with alternative fuel in systems, positions it as a key enabler for the development of more sustainable aircraft platforms. In conclusion, carbon fiber presents a compelling solution to the challenge of finding a replaceable material for aircraft components. Its combination of exceptional strength, durability, lightweight, and environmental sustainability makes it well-suited for the demanding requirements of modern aviation. As advancements in manufacturing techniques continue to drive down costs and improve efficiency, carbon fiber is poised to play an increasingly vital role in the future of aircraft construction, paving the way for safer, more efficient, and more sustainable air travel.

REFERENCES

[1] Mr. Ashish Apate, S. Kumar, N. H. Ambhore, Hybrid Laminates: Advancements in Multi-Material Machining Processes for Fiber Metal Laminates (FML) - A Comprehensive Review, Tuijin Jishu/Journal of Propulsion Technology, Vol. 45, Issue 02, 2024.

[2] Sarat Singamneni1*, Yifan LV1 , Andrew Hewitt2 , Rodger Chalk2 , Wayne Thomas2 and David Jordison2 1 Department of Aerospace Engineering, Auckland University of Technology, Additive Manufacturing for the Aircraft Industry: A Review.

[3] James C. Williams a,∗ , Edgar A. Starke, Jr. b a Materials Science & Engineering Department, The Ohio State University, 142 Hitchcock Hall, 2070 Neil Ave, Columbus, OH 43210, USA, Progress in structural materials for aerospace systems, VA 22903, USA Accepted 31 August 2003.R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[4] Maria MRAZOVA, Advanced composite materials of the future in aerospace industry, The Faculty of Operation and Economics of Transport The Air Transport Department Univerzitna 1, 010 26 Zilina, Slovak Republic mraz.marie@gmail.com DOI: 10.13111/2066-8201.2013.5.3.14

[5] Mr.Apate, Ashish Shankarrao. "Crack Detection of Cantilever Beam by using FEA." (2020).

[6] Sharma, Mohit, et al. "Carbon fiber surfaces and composite interphases." *Composites Science and Technology* 102 (2014): 35-50.