FIBRE METAL LAMINATES (FMLs) FOR ADVANCED AEROSPACE APPLICATIONS

Gurmail Singh Malhi[1], Shneha Borah[2], Sonu Sharma[3], Ajin Branesh[4], Arundhati [5]
[1-4]Department of Aerospace Engineering, [5]Department of Civil Engineering, Chandigarh University, Gharuan, Punjab, India

Abstract

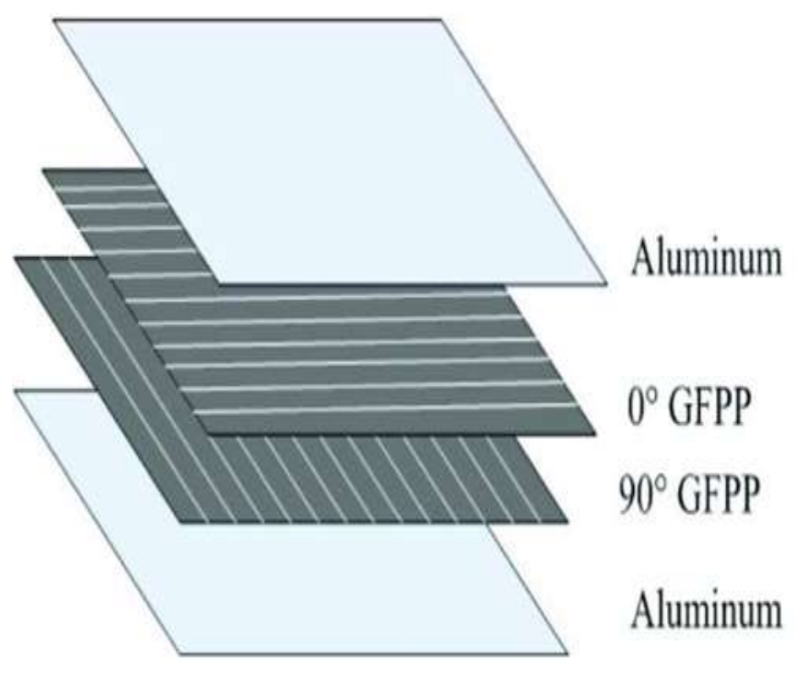
The aviation sector has become more and more dependent on lightweight, high-performance structures over the past few decades, which has significantly accelerated the development of improved models for fiber-metal laminates (FMLs). Fibre-reinforced adhesives and thin metal layers that interlace to form fiber-like composite materials are called fiber-metal laminates (FMLs). The mechanical characteristics and manufacturing process of two leading FMLs :GLARE (glass-reinforced aluminium laminate) and ARALL (aramid reinforced aluminium laminates) is studied to the other classical materials like aluminium, the findings show their better behavior. FMLs are a very desirable candidate material for future aircraft structures due to its inherent corrosion resistance, superior fatigue behavior, damage tolerance, reduced component count and significant weight reductions. In a nutshell, the review provides a thorough overview of FML in the context of contemporary aviation by highlighting its compositions, properties, advancements, existing weaknesses, and recommendations for new lines of inquiry.

Introduction

- Fibre-reinforced adhesives and thin metal layers that interlace to form fibre-like composite materials are called fibre-metal laminates (FMLs). These layers are conceded to be correlated with each other via mixed substance matrix material.
- FMLs combine metal and composite characteristics, effectively addressing fluctuations in fatigue, corrosion, bearing strength, impact resistance, and reproducibility.
- The leading FMLs include ARALL (Aramid Reinforced Aluminium Laminates) and GLARE (Glass-Reinforced Aluminium Laminate) which are studied in order to analyse their mechanical properties and compare with traditional material like Aluminium.

The FML is composed of:

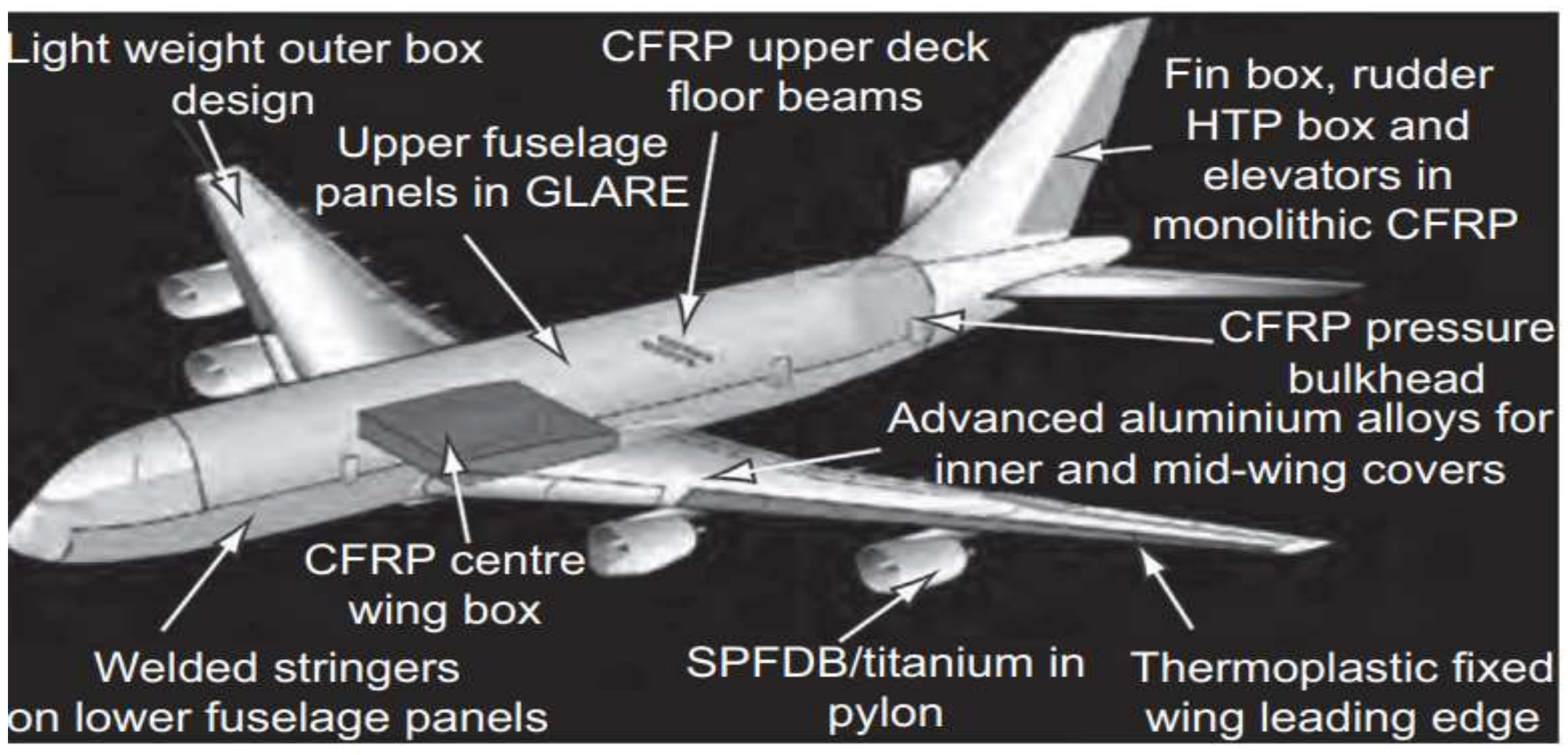
1. Metal Layers(typically constitute around 30% to 70% of the total laminate thickness): Aluminum or Titanium Alloys are commonly used metals due to their high strength-to-weight ratio and fatigue properties.
2. Composite Layers: Fibres embedded in a polymer matrix, such as epoxy or polyimide resin(Fiber-Reinforced Polymer Matrix).Common fibre types include carbon, glass, or aramid fibers, chosen for their specific mechanical properties.
3. Adhesive Layers (optional, constitute only a small percentage of the total laminate thickness): Used between the metal and composite layers to enhance bonding and transfer of loads across the interface



Aerospace applications

ARALL:

- ✓ Primary target were the secondary structures and fragile deformed structural parts including impact-sensitive locations like lower flap skins and lower wing skins.
- ✓ Beneficial for the pressure-welded fuselage cabin of an airplane
- ✓ Mostly utilized in aircraft cargo doors as a structural material(already developed for Boeing C-17)
- ✓ The lower wing skins of the Fokker 27 and later Fokker 50 commuter aircraft were among the many applications for which significant efforts were made.
- ✓ Approved for use in Mil Handbook 5 and used as the skin material on the military airlifter McDonnell Douglas C17's aircraft cargo door



GLARE:

- ✓ Often employed for aeronautical structures that are subject to impact damages because of its exceptional damage tolerance qualities.
- ✓ Utilised in the Airbus A380's leading edges of its horizontal and vertical tail planes, as well as its main fuselage skin.
- ✓ Applied to cargo liners and fire walls due to flame resistant property.
- ✓ used in the leading edge, forward bulkheads, and cockpit crown

Problem identification

- ❖ Limitations of aluminum such as high density, limited strength and low damage tolerance necessitate the exploration of advanced materials like FMLs.
- ❖ FMLs particularly ARALL and GLARE compensate the the demands of aviation sector by achieving a superior balance of lightness, strength, low weight, fatigue resistance, and damage tolerance.
- ❖ The study further inspects the mechanical properties of ARALL and GLARE by comparing their performances with traditional aluminum alloys used in aerospace structures.

Comparison with traditional aluminium

ARALL

- **Tensile Strength and Stiffness** :Generally higher as compared to ARALL.
- **Stress Concentration Factor**: Lower, indicating higher resilience to stress concentrations.
- **Fatigue and Crack-Initiation Behavior**: Cracks remain mostly in the outer layer, spread slowly, and typically stop, preventing progression to macrocracks.
- **Impact Sensitivity**: Superior fatigue behavior post-impact.
- **Ultimate Gross Area Stress**: Can withstand higher ultimate gross area stress before the aircraft life is compromised.
- **Corrosion Resistance**: Less prone to corrosion since aramid layer acts as a barrier.
- **Weight :** Less as compared to aluminium.

GLARE

- **Glare Reduction**: Superior due to its fiber-metal composition.
- **Weight Reduction**:Significant, enhancing fuel efficiency and overall performance.
- **Fatigue Resistance:** Enhanced fatigue resistance due to the fiber layers that bridge cracks, reducing crack propagation speed and improving durability under cyclic loading.
- **Corrosion Resistance:** Longer lasting protection in harsh environments.
- **Stress Distribution**: Aluminum layers bear greater proportion of stress, while fiber layers help mitigate overall stress impact.
- **Crack Propagation and Fracture Behavior**: Less sudden and catastrophic failure.
- **Fatigue Life and Cycle Performance**: Al has quicker ultimate failure (e.g., 130,000 cycles), whereas no failure in GLARE even after after 200,000 cycles).

Conclusion and future prospects

- ❑ ARALL with its high temperature withstanding capacity, could be used in hot areas and engine nacelles to increases engine efficiency.
- ❑ To endure the severe conditions of space, these composites could be employed in the construction of satellite structures like antenna booms, solar array supports, and payload platforms.
- ❑ The UAV airframes could be built with ARALL and GLARE to improve these demands of lightweight, highly stress-resistant materials for more tasks like mapping, freight delivery, and surveillance.
- ❑ FMLs could also be used to improve efficiency and lessen vibration in the manufacturing of rotor blades, rotor hubs, and other vital parts of rotorcraft, including helicopters.
- ❑ Widespread use of FMLs will open doors for the construction of next-generation, safer, more efficient aircraft aimed at cost reduction, design optimization, and certification.

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