Aluminium Alloys in Aviation

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An Aircraft is designed to withstand loads from standstill to very high speeds at low level and high altitudes with ambient temperatures in range of +30°C to -56°C. These loads result from Aerodynamic loading, loads encountered during manoeuvring, gusts from turbulence, fuel and cargo weightsand pilot induced control surface loads. These loads induce bending, tensile, torsional or shear loads on parts or even the whole aircraft. It can be considered as a pressurized closed tube subjected to flexing & twisting in different directions in take-off flight & landing. The wings also are subjected to these loads. The aircraft must withstand all these loads safely during the life expectancy of the structure.

Mechanical properties of Aluminium as a pure metal is relatively low to be of any extensive use as stressed members.

In 1903, A German metallurgist, Alfred Wilm developed an alloy of Aluminium (Al) –Copper (Cu) which could respond to heat treatment. He discovered that when 4% Cu was added followed by a heat treatment and a natural ageing process a stronger alloy than pure Aluminium could be obtained. Later in the same decade, an alloy known as 'duralumin' was developed based on the AL-Cu alloy with addition of Magnesium (Mg) and Manganese (Mn) which was to be used extensively in Aircraft in days to come. 'Duralumin' was much stronger than Aluminium with enhanced mechanical properties like toughness. The German 'J-7 Junkers' was the first 'all metal' successful aircraft to be built with extensive use of Duralumin.

Since then, series of Aluminium Alloys were developed (mainly by ALCOA) with the addition of alloying elements like, Mg, Silicon (Si), Zinc (Zn), Mn, Lithium (Li), etc. which could be heat treated to achieve specific physical properties. Strength of Al Alloys vary in Longitudinal (L), Transverse (T) and Long-Transverse (LT) direction to the grain flows and are taken into account in design of structural members. Fatigue properties and Damage tolerance also plays a significant role in the selection of alloys for a particular application within the Aircraft structure.

Ease of fabrication of parts by forming, machining, casting are inherent advantages in use of Aluminium alloys. However, Joining by fusion welding is restricted to few alloys. Alloys of AL-Zn (7075) for example cannot be welded by fusion but has been successfully joined by other methods like friction welding. Friction welding also renders dissimilar Aluminium alloys to be welded and is gaining wide acceptance in recent years. However, the addition of alloying elements, lowered the corrosion resistance of the bulk alloy compared to that of pure Aluminium. Thus, to protect these alloys from rapid corrosion, surface protective treatments are often applied with or without Anodizing.in addition to enhance the corrosion resistance.

Aluminium alloy sheets (2024, 2219 7075 etc) used for aircraft skins are clad ie. a thin layer of pure aluminum is clad on to the surface of the alloy by the manufacturers during production. These sheets are referred to as 'Alclad' Sheets with no cladding is known as 'unclad' (also known as 'bare'). Stress Corrosion Cracking (SCC) resistance of alloys are of significant importance in the selection of Alloys in aircraft design.

Aluminium alloys are classified based on the alloying elements and designated as four digit numbering system series by the International Alloy Designation System (IADS).

In addition, different 'Tempers' can be achieved by manipulating the heat treatment. These Tempers are designated by additional dash number following the alloy designation for Eg., 7075-T6.

THE MOST COMMONLY USED ALUMINIUM ALLOYS IN AVIATION ARE LISTED BELOW		
ALLOY	**KEY PROPERTIES**	**AREAS IN AIRCRAFT USED**
2014	A copper based alloy with very high strength together with excellent machining characteristics. Low corrosion resistance.	Commonly used in Structural applications, Used as forgings, Extrusions
2017	Excellent machinability and high strength.	Structural members
2024	High strength, Excellent fatigue resistance, is desired. Readily Machinable, forming. Age hardenable and extremely ductile in solution heat treated state.	2024 is extensively used as Rivets on Aircraft. 2024-T3 Alclad aluminium sheet are used in aircraft skins, cowls, aircraft structures, lower wing skin. Shear webs, ribs, Forged aircraft fittings. structures & parts where good strength-to-weight ratio needed.
2117	Good fatigue strength, good machining characteristics	Rivets, structural parts
2219	Can withstand relatively higher temperature, Wieldable	Engine intake, cowling. Used commonly as Alclad, Used in welded structures
2090	New Aluminium Lithium Alloys of Higher strength, Better corrosion resistance, Lower weight.	Stiffeners, Bulkheads, Wing leading and trailing edges
6061	Wieldable, Good formability, wide range of mechanical properties can be obtained.	Typical uses are aircraft landing mats, structural components, Tubes. Used as alclad where better corrosion resistance is required
6063		Typical uses are aircraft landing mats, structural components, Tubes
7068	Highest TS among aluminium alloys in T6511	Recently being introduced into Aerospace. UTS approaches 103KSI. As compared to 93KSI for 7075. Expected to be used in high load bearing Airframe structures.
7075	Most common alloy used in Aerospace with high strength with moderate toughness. Fair machinability and corrosion resistance.	Aircraft structural load bearing members, Used as Alclad sheets on wing upper surfaces.
7150	Highest strength among currently commonly available alloys. Controllable fracture toughness. Machinability & corrosion resistance is fair	Used on upper skins of aircraft where higher compressive strength alloy is required.