Aluminum 2024: The Fatigue-Resistant Aerospace Icon

Metallurgical Profile

Aluminum 2024 is the primary alloy of the 2xxx series, heavily alloyed with Copper (Cu). Historically known as "Duralumin," it was the first high-strength, heat-treatable aluminum alloy. Its metallurgy is defined by the precipitation of $CuAl_2$ and S phase (Al_2CuMg). Its defining characteristic is exceptional **damage tolerance** (resistance to fatigue crack propagation), which dictates its use in aircraft structures subject to tension.[3]

Chemical Composition (Weight %)

The high copper content creates strength but also creates galvanic couples within the microstructure, leading to susceptibility to corrosion.

Element	Weight Percentage (%)	Role
Copper (Cu)	3.8 – 4.9	Primary strengthener; reduces corrosion resistance.[13]
Magnesium (Mg)	1.2 – 1.8	Strengthening via Al_2CuMg phase.[13]
Manganese (Mn)	0.3 – 0.9	Increases strength; controls grain structure.[13]
Iron (Fe)	Max 0.50	Impurity.[13]
Silicon (Si)	Max 0.50	Impurity.[13]
Zinc (Zn)	Max 0.25	Trace.[13]
Titanium (Ti)	Max 0.15	Grain refiner.[13]
Chromium (Cr)	Max 0.10	Trace.[13]
Aluminum (Al)	Remainder	Base.[13]

Mechanical Properties

2024 is most commonly used in the **T3** (Solution Heat Treated, Cold Worked, and Naturally Aged) or **T4** (Naturally Aged) tempers. The **T351** temper includes stress relief.

Property	2024-T3 / T351	2024-T4	Unit
Ultimate Tensile Strength	**483 (70)**	469 (68)	MPa (ksi) [36]
Yield Strength	**345 (50)**	324 (47)	MPa (ksi) [36]
Fatigue Strength	**140 (20)**	140 (20)	MPa (ksi) [38]
Shear Strength	283 (41)	283 (41)	MPa (ksi) [38]
Elongation at Break	18%	19-20%	% [36]
Fracture Toughness (K_{IC})	30-40	30-40	MPa$\sqrt{m}$ [39]
Hardness (Brinell)	120 HB	120 HB	HB [36]

Insight: While 7075 is stronger statically, 2024 has superior **fracture toughness** and slows the growth of fatigue cracks. This is why 2024 is used for the **lower wing skins** of aircraft (which are in tension during flight) while 7075 is used for upper wing skins (compression).[40]

Processing Characteristics

- **Corrosion Resistance:** Poor. The high copper content makes it prone to pitting and intergranular corrosion. It is almost always used in **Alclad** form (bonded with a surface layer of pure aluminum) for sheet applications to provide galvanic protection.[35]
- **Machinability:** Good. It machines to a high finish and holds tolerances well.
- **Weldability:** Poor. 2024 is highly susceptible to hot cracking during welding and is generally joined by rivets or fasteners.[35]

6.5 Applications

- **Aerospace:** Fuselage skins (Alclad), lower wing skins, shear webs.[41]

- **Structural:** Precision gears, bolts, couplings, truck wheels