

# 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  $\text{CuAl}_2$  and  $\text{Al}_2\text{CuMg}$  phase. Its defining characteristic is exceptional **damage tolerance** (resistance to fatigue crack propagation), which dictates its use in aircraft structures subject to tension.<sup>3</sup>

## 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. <sup>13</sup>
Magnesium (Mg)	1.2 – 1.8	Strengthening via $\text{Al}_2\text{CuMg}$ phase. <sup>13</sup>
Manganese (Mn)	0.3 – 0.9	Increases strength; controls grain structure. <sup>13</sup>
Iron (Fe)	Max 0.50	Impurity. <sup>13</sup>
Silicon (Si)	Max 0.50	Impurity. <sup>13</sup>
Zinc (Zn)	Max 0.25	Trace. <sup>13</sup>
Titanium (Ti)	Max 0.15	Grain refiner. <sup>13</sup>
Chromium (Cr)	Max 0.10	Trace. <sup>13</sup>
Aluminum (Al)	Remainder	Base. <sup>13</sup>

## 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) <sup>36</sup>
Yield Strength	345 (50)	324 (47)	MPa (ksi) <sup>36</sup>
Fatigue Strength	140 (20)	140 (20)	MPa (ksi) <sup>38</sup>
Shear Strength	283 (41)	283 (41)	MPa (ksi) <sup>38</sup>
Elongation at Break	18%	19-20%	% <sup>36</sup>
Fracture Toughness ( $K_{IC}$ )	30-40	30-40	MPa $\sqrt{m}$ <sup>39</sup>
Hardness (Brinell)	120 HB	120 HB	HB <sup>36</sup>

**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).<sup>40</sup>

## 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.<sup>35</sup>
- **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.<sup>35</sup>

## 6.5 Applications

- **Aerospace:** Fuselage skins (Alclad), lower wing skins, shear webs.<sup>41</sup>

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