ALUMINUM ALLOY DEVELOPMENT

FOR THE AIRBUS A380 — PART 2

Airbus-Alcan integrated product teams were set up in the very early days of aircraft definition in order to take up the most challenging airframe development effort ever. Last month, Part 1 outlined the way the teams worked together as well as the investment efforts made by Alcan Aerospace to support the A380 program. Part 2 shows how this teamwork led to the development, qualification, and production of a complete series of new alloys for the wing and fuselage aluminum structures.

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The Airbus A380 is a double-deck, four-engine airliner that can carry 555 passengers. It is the largest passenger airliner in the world, with a length of 240 feet and a wingspan of 262 feet. Image courtesy Airbus.

The large size of the A380 aircraft, the corresponding loads, and the targeted structural weight, led to significantly higher requirements for alloy properties. This meant that improvements had to be made in the two major design axes, static performance and/or damage tolerance. To achieve these goals, the Alcan-Airbus Integrated Project Teams worked to both extend and qualify existing alloys, and to develop new dedicated alloys. Figure 1 shows the major structural design criteria of A380 wing, fuselage, and empennage structures, with the associated major alloy characteristics.

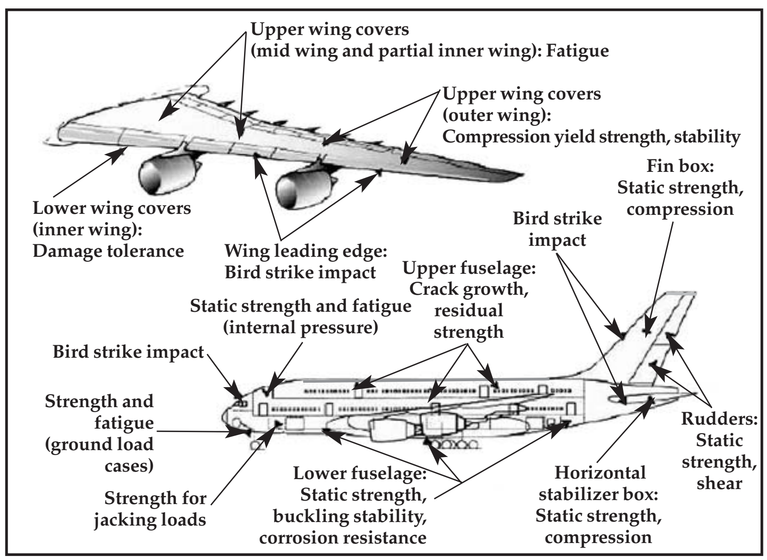

Fig. 1 — Major structural design criteria and associated alloy characteristics of A380 wing, fuselage, and empennage. Courtesy of Airbus SAS.

Extension of existing alloys

The long dimensions of some of the A380 structural parts made it necessary to fabricate some of the existing alloys in thicker gauges or larger cross-sections. The Al 7010/7050-T7651 alloy was one of those considered for extension, primarily for two applications:

• **Wing ribs:** The 7010/50-T7651 alloy was the traditional spar and rib alloy/temper of all the most recent existing Airbus aircraft. The size of the very large integrally machined inboard ribs (with typical width by length of about 2.3 x 3.8m) and of some of the highly loaded ribs with thickness up to 200 mm made it necessary to extend existing qualification up to this last maximum gauge.

• **Upper outer-wing:** The traditional concept of stringers riveted to skin was replaced by the concept of stringers and skin both machined from plate. An obvious result was a large increase in the corresponding plate thickness up to 90 mm, with an envelope size of about 3 x 8 m. Qualification of the corresponding processing route, including casting of a new large ingot, was achieved by the Ravenswood plant, which was the only one

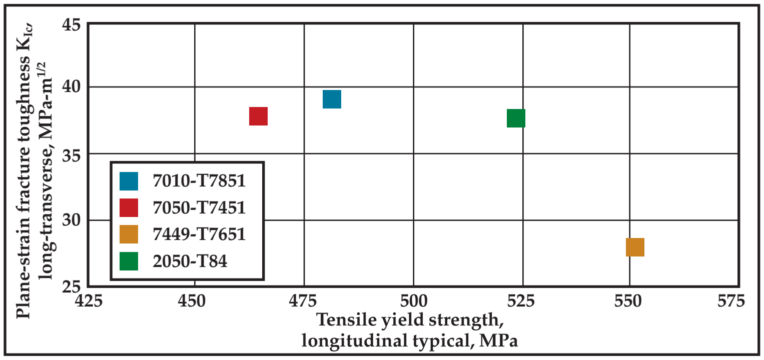

Fig. 2 — Property balance of advanced new alloys versus incumbent for intermediate gauge plates with thickness = 50 mm. Data has been normalized by the density of ref. 7050-T7451.

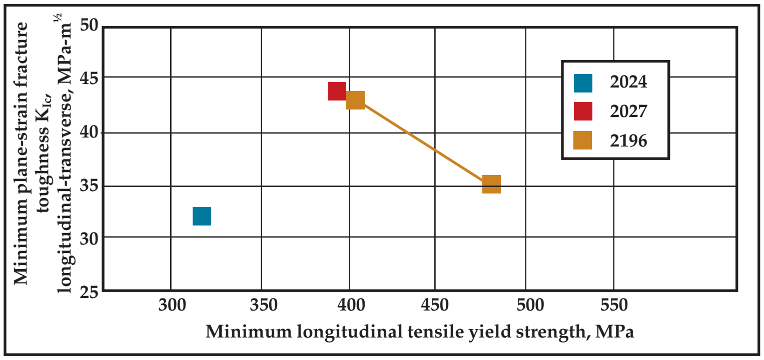

Fig. 3 — Property balance of advanced new alloys versus incumbent. Lower structure extrusion alloys 2196-T8 and 2027-T3511 vs. 2024-T3511.

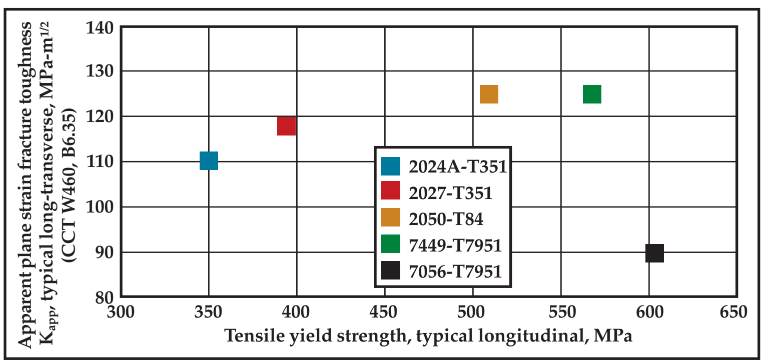

Fig. 4 — Property balance of advanced new alloys versus incumbent for lower and upper structures of medium gauge plates with thickness=25 mm.

able to stretch such a big plate. A low-residual stress (LRS) route was adopted and qualified, which proved very successful, as the alloy demonstrated outstanding response to machining.

• **Alloy 7449**: Extrusions of this alloy were among the existing (but advanced) semi-finished products to be somewhat extended. The larger cross-sections of the wing stringers were validated through dedicated processing in the Issoire plant. In addition, although creep forming was the baseline for the A340, cold mechanical forming was adopted for the A380. The ability to form the alloys in the associated W511 temper, as well as to achieve the required level of properties, was successfully demonstrated through qualification lots jointly agreed upon with the M&P Airbus teams.

• **Alloy 7349**: Similar work was needed for the alloy 7349 small sections that were already in the fuselage stiffeners, seat tracks, and other parts on the A340-500/600. The alloy was confirmed for similar parts on the A380.

Wing alloy development

Considering the increased design values of all the wing structural parts necessary to fulfill the higher criteria, new alloys had to be developed for all wing major parts, such as panels, stringers, spars, and ribs.

• **For spars**, an improvement in both static and fracture toughness levels versus the incumbent 7010/50-T7651 solution was required. Also, spar alloys should display good cold expansion ability and machining behavior. Development loops in the Ravenswood plant led to the qualification of a 7040-T7651 high static, high toughness, LRS (low residual stress) and cold expandable alloy quality. Thanks to a collaborative effort with the machining subcontractors, 7040-T7651 was selected for the two largest spars in the world, the inner front and inner center spars.

• **For ribs**, mostly governed by static strength and modulus, higher strength was required for weight reduction. The 7449 alloy, initially developed and industrially produced as very high-strength wing panels for A340-500/600, was tested in higher gauges up to 100 mm, in an over-aged T7651 temper (Fig. 2). Alloy 7449-T7651 was selected to fly on all low-gauge (thickness<=100mm) A380 wing ribs, as well as for the rib caps of the few composite ribs.

• **For lower wing stringers,** higher strength was needed. Alloy development work was run by the R&D teams, leading to the definition of a zirconium-containing 2xxx alloy, registered at the Aluminum Association as 2027. As shown in Fig. 3, fracture toughness and fatigue strength were increased. The 2027-T3511 alloy was then selected for the A380 lower wing stringers.

• **For upper wing covers,** A380-800F offered the opportunity to qualify and produce a new alloy, AA7056. This was because the design requirements for freighters are slightly different from those of the passenger version. Wing cover alloys required much improved fracture toughness, associated with possibly a slight reduction in the required static level. Alloy 7056-T7951 was qualified with an impressive 40% improvement in fracture toughness over 7449, and was selected as baseline for these A380-800F upper wing panels.

• **For the lower cover**, alloys needed high fracture toughness. Therefore, Alcan developed the 2024A-T351 plate solution, which is produced for various structural items, and has been extended recently for service as A330 lower wing panels (Fig. 4). The zirconium-containing 2027 alloy was also developed at a later stage with improved static strength and toughness versus 2024A-T351; it found application on the lower outer wing panel of A380-800F, as well as on the lower structure of the A340-600 center wing box.

• **For lower wing structures,** third-generation Al-Li alloys were approved for A380-800 and A380-800F. The alloy of interest for lower wing structures was 2050-T84, cast in the Alcan Dubuc (Canada) dedicated foundry; it was recently qualified and has entered production in the Issoire plant. Figure 4 shows much better strength, higher

Alcan Aerospace advanced alloys and their main applications on the Airbus A380-800 and A380-800F aircraft

Form	Alloy/Temper	A380 application	Comments
Plates	7056-T7951	Upper wing panels	A380-800F
	7449-T7951	Upper wing	
	2024A-T351	Lower wing reinforcement	
	2050-T84	Lower wing reinforcement	
	2027-T351	Lower outer wing panel	A380-800 F
	7010-T7651	Upper outer wing panel, Heavier gauge wing ribs	Integrally machined
	7040-T7451	Fuselage main frames, cockpit window frames, beams, fittings…	
	7449-T7651	Lower gauge wing ribs	
	7040-T7651	Wing Spars	Inner front & inner center
Heavy sections	7449-T79511	Upper wing stringers	
	2027-T3511	Lower wing stringers	
	2196-T8511	Floor-beams	
Small sections	7349-T6511	Seat rails, stiffeners of center wing box	
	7349-T76511	Fuselage stiffeners	
	2024HS-T432	Fuselage frames	
	6056-T78	Fuselage stiffeners	Associated with 6056-T78 sheet
	6056-T6	Fuselage stiffeners	Associated with 6156Cl-T6 sheet
	2196-T8511	Floor structure, fuselage stiffeners	
Sheet	6056-T78	Pressure bulkhead below cockpit floor	
	6156 Cl -T6	Fuselage panels	

toughness, and reduced density of this alloy versus LW incumbent solutions.

Fuselage alloys

Alcan had to develop a full series of very different alloys for the fuselage structure. The fuselage is a combination of many different parts and product forms that are subjected to many different types of load. Airbus chose the Laser Beam Welding (LBW) technology for welding stiffeners to skin on several panels.

• **The 7040-T7451 plate alloy** was selected for several fuselage applications, such as integrally machined main frames, cockpit window frames, beams, and fittings. It offers significantly improved static strength and toughness properties versus the incumbent 7010/7050-T74 solution. Improved properties are due to the lower (Cu, Mg) solute content that is optimized at a level just below the solubility limit, thus making it compatible with high strength and good fracture toughness. Furthermore, the alloy is processed by a technology that results in low residual stress, which means minimized machining distortion. It also offers a low-cost alternative to forgings. Alloy 7040-T7451 has been developed and qualified in both the Ravenswood and Issoire plants for thickness up to 220 mm.

• **A 6xxx alloy weldable by LBW** was required by Airbus for various lower shell fuselage panels, as well as for a pressurized bulkhead located under the cockpit in the front nose. Such LBW concepts were selected for their benefit in both cost and weight.

For the last application, no specific development was needed, since Alcan proposed the low density (2.70 g/cm^3 vs 2.78g/cm^3 for 2024) 6056-T78 sheet that is already produced for some panels of A318 single aisle aircraft.

The T78 temper had been developed previously for an IGC-free sheet material that could function without cladding. However, a small T78 extrusion qualification program was needed to show that if both sheet and stringer were subjected to an identical T78 aging practice, then the welded combination could be successfully post-weld aged.

• **Alloy 6156** was developed for the lower shell fuselage application. Damage tolerance behavior of the 6056 chemistry was too short for the design criteria, and an HDT version had to be developed: the result was 6156. Because the alloy needed high strength, a T6 temper was required; therefore, it had to be clad in order to avoid intergranular corrosion.

Considering the specificity of the 6156 chemistry, a dedicated chemistry was developed for the clad material to adjust the corrosion potential difference between the clad and matrix alloys. This led to the definition of a clad/matrix alloy combination that was qualified by Airbus.

Figure 5 illustrates the relative property level of 6156Clad-T6 sheet and other incumbent alloys, showing that 6156 displays a 10% toughness ben-

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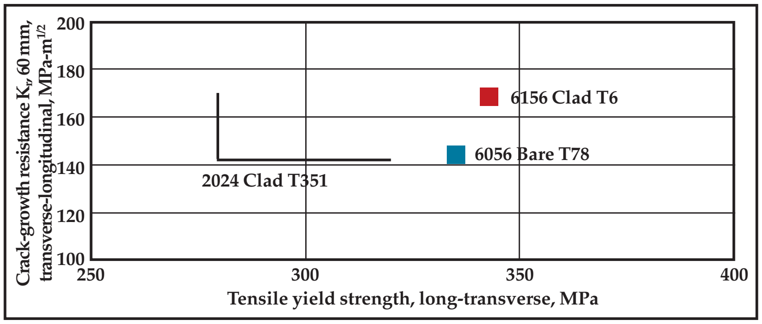

Fig. 5 — Relative main properties of 6156Cl-T6 and other sheet alloys. The graph shows the strength and toughness property balance. Sheet specimens were tested as W = 760 mm CCT panels extracted from sheet approximately 3 mm thick.

efit over 6056-T78. As for the T78 bare solution mentioned above, a T6 temper had to be qualified on the associated stiffeners. Alloy 6156 fuselage panels are currently produced in the Issoire sheet shop for A340- 500/600 and A380 panels.

• **Alloy 2024-T432** : Extruded sections were chosen for many fuselage frames, due to their weight and material usage efficiencies. Keeping the appropriate level of strength over the required forming sequence was a challenge that Alcan took up with a dedicated new temper 2024-T432, enabling about 10% strength benefit over incumbent 2024 while providing a very satisfactory bend-forming behavior. This solution is currently produced by the Montreuil-Juigné extrusion plant.

Aluminum-lithium alloys

The availability of Al-Li products was considered to be an opportunity for Airbus on the A380 Early design studies investigated advanced third-generation Al-Li extruded sections for the main deck floor-beams. For this purpose, Alcan qualified and produced alloy 2196 in a standard T8 temper. Alloy AA2196 is the higher-lithium-containing alloy of the Weldalite family, with density 2.63 g/cm^3.

As shown in this section, A380-800 & -800F benefited from many new dedicated wing and fuselage alloys and alloy qualities developed by Alcan, the applications of which are summarized in the table. Older alloys such as 2024, 7010, 7050 or 7075 survive only in very small quantities in the aircraft.

Future alloy development

A continued R&D effort, initiated through additional integrated product teams, has led to the definition of still more advanced alloys, including third-generation Al-Li low density alloys, and probably more important, of innovative concepts. All these could serve in A380 future activities, if required, as well as on any future airframes. It is believed that such ideas as local tailoring of properties or damage-containment features, associated with the new advanced low density alloys and with innovative joining concepts, assure a bright future for metallic structures in aircraft.

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