These are summaries of presentations by Alcan personnel during the ASM AeroMat 2007 Conference. Working in synergistic partnerships with users has enabled significant advances in component joining, part unitization, and other processes.

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Alcan Aerospace, together with partner Airbus, has developed a range of aerospace aluminum and aluminum-lithium alloys and processing techniques for plate, wing components, and fuselage parts. A very aggressive R&D strategy emphasizes development of aluminum-lithium products that offer significant premiums in damage tolerance, stiffness, corrosion resistance, and density, while at the same time being competitive in the area of static properties. These new products offer significant advantages in trade studies when compared to composite solutions. At the same time, additional enhancements are being pursued on conventional 2xxx, 7xxx, and 6xxx aerospace alloys, which still constitute the vast majority of airframe applications.

Extruded alloys for the fuselage

The AA2196 aluminum-copper-lithium alloy has been adapted for various extruded profile applications. From rather thin sections such as seat rails and fuselage stiffeners, to thicker sections such as crossbeams, wing stringers, and fuselage frames, a wide range of products can be fabricated of the AA2196 alloy, Fig. 1. The presentation was particularly focused on extruded fuselage frame applications, for which good formability is needed to adapt the extruded section to the shape of the curvature of the fuselage body.

Various industrial process routes were tested on AA2196 extruded sections to evaluate the product performance with minimum overall cost. Because of the high level of deformation, an intermediate solution heat treatment is necessary for some products such as 2024, to achieve the ductility needed for the high level of stretch forming. These process routes are also possible for Al-Li 2196.

The forming itself works well, and the mechanical properties satisfy the criteria. As Fig. 2 shows, the most cost-efficient process route is number 3, which is applied to the alloy in the T4 temper. As a result, an intermediate solution heat treatment at the airframer facility is no longer necessary. Following this process route, the overall final cost of the product can be reduced considerably. High mechanical properties with a high level of elongation can be achieved on the final product.

Results of extensive testing show that high formability levels can be reached via low-cost process routes. In addition, a stable microstructure guarantees a high level of mechanical properties in the final product.

This information is from Advanced Metallic Frames for the Future Metallic Fuselage, by S. Jambu, F. Eberl, and F. Heymes of Alcan; K. Juhl, J.J. Ditterner, and Y. Plessel of Airbus.

Aluminum-lithium alloys

Aluminum-lithium plate alloys have been developed for both low-gauge structures such as wing panels; and medium to heavy-gauge struc-

| Percent by weight of elements in AA2196 extrusion alloy |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Si              | Fe              | Cu              | Mn              | Zn              | Ag              | Zr              |                  |
| <0.12           | <0.15           | 2.5-3.3         | <0.35           | <0.35           | 0.25-0.6        | 0.04-0.18       |                  |

Fig. 1 — Illustration of potential applications for AA2196 extrusions.

Fig. 2 — Possible process routes for the forming of AA2196 extruded fuselage frames.
The principles of chemistry definition were discussed through the use of lithium-copper phase diagrams. (Fig. 3)

Chemistries explored at an industrial scale for upper and lower structure applications led to the definition of Al-Li alloys having the property balance of 7449 and 2024A/2027. (Fig. 4)

For medium to heavy-gauge plates, Alcan developed, promoted, and qualified the 2050 Al-Li alloy. Already processed in industrial quantities up to a thickness of 125 mm (5 in.), the alloy has been shown to provide a very good low-density (d=2.71 g/cm³) alternative to the Al 7050 incumbent alloy. (Fig. 5)

Testing pyramid for the validation of new design and assembly concepts helps reduce weight and cost. (Fig. 6)
Effective property evaluation

Further cost and weight reductions in metallic structures can be achieved through cost-efficient and effective test methods. Principles of testing and concept selection were presented by Dr. F. Eberl and co-workers, who discussed various examples for each level of the test pyramid (Fig. 6).

- **Coupons**: A large number of samples at the coupon level allows assessment of a large number of concepts and specific parameters before moving on to the next stage.
- **Elements**: The detail and element level focuses on special features by applying simplified load cases.
- **Subcomponents**: The subcomponent level partially integrates the environment of the feature to be tested, so that more complex load cases can be tested.
- **Components**: The component level takes into account the real load case, and covers the barrel geometry.

The examples selected focus on monolithic structures generated by the laser beam welding assembling technique. On the coupon level, the laser-beam-welded butt joint was selected as an example. Different alloys can be compared very easily after optimization of welding parameters, including the selection of the filler wire. In Fig. 7, alloys 2198, 2196, and 2139 are compared to a 6156 baseline. All three products show better performance than the highly weldable 6156. Up to 15% strength improvement is possible, in particular for 2198 sheet.

A representative test on the detail and element level is the head tension test of a laser-beam-welded stringer on a fuselage skin. The higher performance of the 2198 sheet and 2196 stringer combination could be confirmed compared to the 6156 sheet and 6056 stringer baseline. After optimization of the welding parameters and the choice of the filler wire, the laser beam welding concept could be applied on shear-compression panels, the so-called subcomponent level. The application of compression, shear, and mixed shear-compression loads on the behavior of the lower shell could be successfully simulated.

In all stress configurations, the applied load significantly exceeded the targeted minimum value. All data were compared to the well established baseline of 6156 sheet welded with 6056 stringers. Therefore, the previous higher performance shown on the coupon level was subsequently confirmed on the subcomponent level.

The integration of new features was also tested on the subcomponent level. For example, the crenulations concept was tested on an AA2139 skin welded to 2139 stringers. A smooth skin containing only the pad-ups under the welded stringers was compared to a crenulated skin. Both panels had the same weight with a different distribution for the crenulated panel, a locally thinner skin with intermediate pad-ups between the stringers.

In a further evaluation, a 30-inch wide five-stringer panel with the center stringer cracked was tested for fatigue crack propagation. Results showed that a 65% increase in lifetime was possible, thanks to the change of the DK in crack propagation direction.

Once the most promising concepts have been selected following completion of the test pyramid, a concluding barrel test can be envisaged.

This information is from Concepts and Concept Validation for Advanced Metallic Structures, by F. Eberl, F. Lemaître, H. Ribes, and S. Jambu of Alcan; and G. Broden of Airbus.

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