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LASER BEAM WELDING OF AIRCARFT FUSELAGES MADE FROM HIGH STRENGTH ALUMINUM LITHIUM ALLOYS

THE TASK

A number of innovative products for long-distance passanger aircrafts have been developed in recent years, in particular in the area of fuselage structures. Manufacturers using metal structures benefit from the introduction of laser technology to weld high-strength aluminum alloys. Smaller planes such as regional jets are now experiencing a similar innovation thrust. The weight has to be reduced in order to meet emission restrictions, and for manufacturing smaller planes this implies an even higher cost pressure.

The weight-to-cost target is very well met with the aluminum lithium alloy 2198, which has a lower mass density, a higher elastic modulus and a higher mechanical strength as previously used aluminum alloys. The Fraunhofer IWS participated in the EU project "Clean Sky". The task was to develop welding concepts for the lower part of an aircraft fuselage structure made from the 2198 alloy. Part design and laser welding process had to be developed and a lower fuselage panel with reduced weight had to be fabricated.

OUR SOLUTION

In a first step a lower fuselage panel of 1600 x 900 mm^2 was designed as a CAD model using classical calculation methods. Starting with this model, so-called T-butt joints were defined as smaller test areas for testing processes to weld the hard-to-weld 2198 alloy. Numerous small samples were welded and mechanically tested under static and cyclic conditions.

The low thickness of 1.2 mm of the skin sheets in the area of the weld seam was a particular challenge. The laser has to be very precisely controlled to minimize the thermal effect of the weld seam on the appearance of outside panel.

Stringer strip samples made from the 2198 alloy and welded with optimized parameters were analyzed for mechanical load resilience (Fig. 2 a). These were idealized samples. Their purpose is to validate the preliminary finite element model (Fig. 2 b). The results were then applied to develop the final finite element model for calculating the entire panel and estimating panel buckling and panel failure loads.

The finite element model was subsequently geometrically expanded to enable complex calculations for weight optimization with respect to load handling capability. The structure was optimized for compression loads and the CAD model was refined to implement a welding solution. Fixtures were designed and the welding strategy was tested. The 5-stringer panel was fabricated as a testable demonstrator.

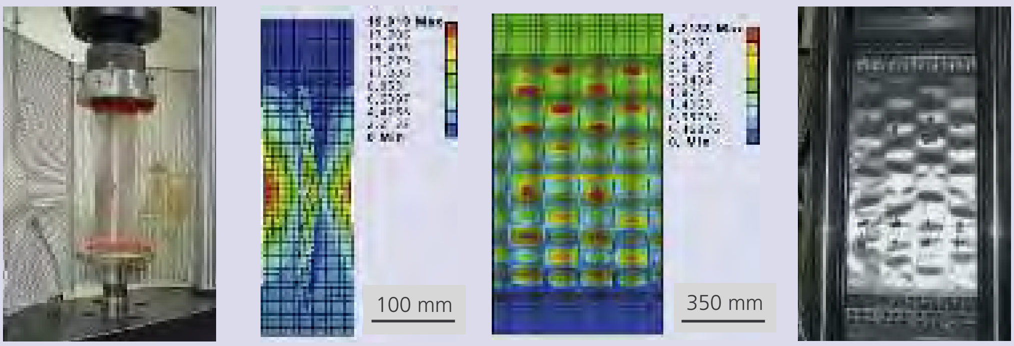
RESULTS

The welding process requires double-sided simultaneous laser beam welding. Two CO_2 laser beams are oriented at low angles with respect to the skin sheet to weld the stringer. Prior to the welding processes, the material surface is wet chemically cleaned. The material is also typically sensitive to form hot cracks, which can be avoided by using adapted weld filler materials.

A finite element simulation was performed for a 1600 mm x 900 mm metallic structure with 5 stringers, 3 frames, a minimum skin sheet thickness of 0.9 mm and a weight of less than 7 kg. The result showed that this panel would still withstand the required maximum load as well as overloading (Fig. 2 c)

An experimental pressure test was performed with the panel at the Fraunhofer Institute LBF in Darmstadt. Similar to the simulation, the panel was mounted in a tenter frame and compression loaded. The resulting buckling behavior and critical failure loads were determined as shown in Fig. 2 d

Compression load and simulation model of a 1-stringer strip sample and a 1600 x 900 mm^2 test panel



2 a b c d

The finite element simulation conservatively estimated a critical failure load of 99 kN. The experiment yielded a slightly higher failure load of 103 kN.

Therefore the boundary conditions used in the finite element model proved to be acceptable. It was also demonstrated that it is possible to fabricate a lightweight panel from the high-strength aluminum lithium alloy 2198, which reliably withstands the required loads.

The Fraunhofer IWS welding technology for very thin walled and large test structures is also suitable for cost efficient manufacturing. To exploit this lightweight design technology for the actual manufacturing of regional jets, it is necessary to perform a barrel test in a next step.

1 Passanger aircraft

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