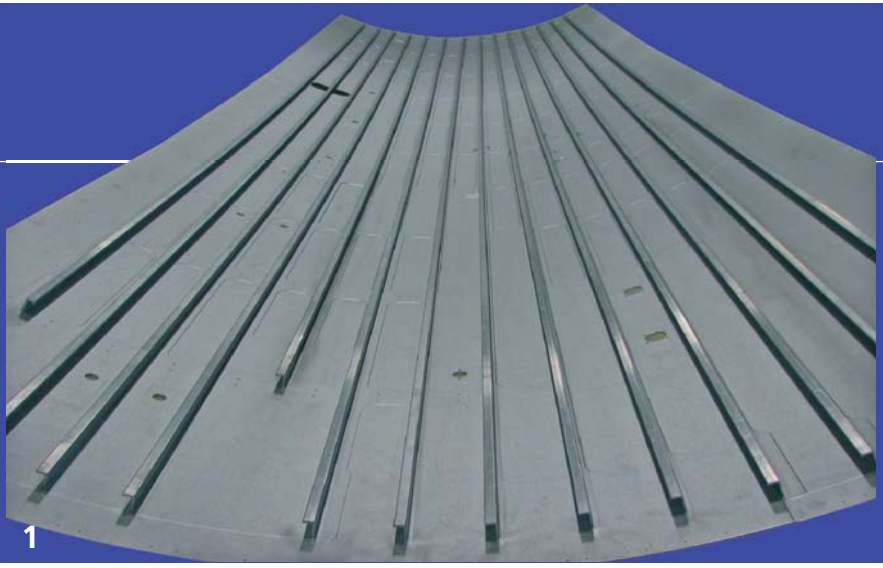


1

FORMING OF SPHERICAL ALUMINUM SHEETS FOR AEROSPACE APPLICATIONS

THE TASK

The steady requirements for lightweight construction and the strong desire for low manufacturing costs of metallic fuselage structures lead to an increasing demand for integral design methods. There are new aluminum alloys based on AlMgSc, which have a lower density, a high strength and better corrosion resistance. They are also very well suitable for laser welding and thus offer reduced weight of the welded parts.

The idea is to manufacture curved fuselage skins with longitudinal stiffening (Fig. 1) by first laser welding the stiffeners to the flat sheets and then bending the sheets to their final shape using a creep-age forming process at elevated temperatures. The new AlMgSc alloys do not show any property degradation when exposed to temperatures in excess of 300 °C, which makes them a good candidate for this manufacturing approach.

Doubly curved or spherical structures pose special challenges. During the forming process they tend to buckle at the edges and thus fail due to tangential compressive stresses. Innovative solutions are needed.

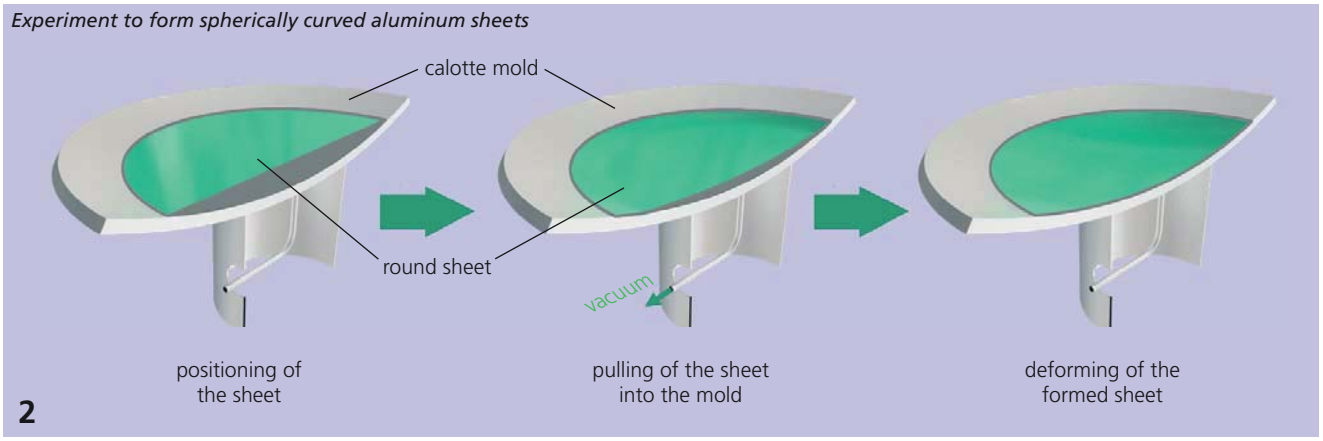
OUR SOLUTION

The Fraunhofer IWS Dresden participates in the aerospace research program "LuFo V" and studies forming technologies of large area, thin-walled and spherical aluminum structures. Solutions are worked on to reduce buckling.

A spherical shell segment serves as a generic model. The shell has the same curvature in both directions. The approach is to iteratively determine critical sheet or round blank diameters above which the sheets buckle. These diameters are determined as a function of curvature and sheet thickness. Round sheets with diameters larger than the determined critical diameter will buckle, smaller diameter sheets will not.

Figure 2 shows schematically how the experiments are performed. Circular round sheets are pulled into the calotte shaped mold.

Experiment to form spherically curved aluminum sheets



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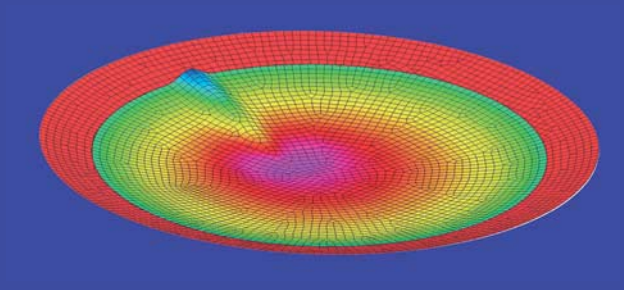


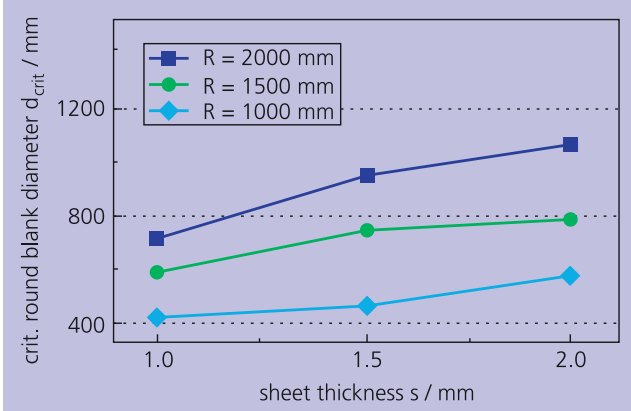
5

RESULTS

The experiments (Fig. 3) were performed with three sheet thicknesses (s = 1, 1.5 and 2 mm), which are typical for airplane applications. Three calotte-shaped molds had radii of R = 1000, 1500 and 2000 mm. This combination yielded altogether 9 critical round blank diameters $d_{crit} = f(s, R)$ for the buckling threshold. The experimental results showed very good correlation with data obtained from FE simulations (Fig. 5).

The results (Fig. 4) show that thicker sheets as well as larger radii of curvature (i. e., smaller curvature 1/R) yield higher critical sheet diameters.

Comparison of experiments and FE simulations for the forming of spherical aluminum sheets



4

Subcritical and thus buckle-free formable aluminum sheets are shaped at elevated temperature (for AlMgSc ϑ_{max} = 325 °C) and constant pressures (vacuum pressure $p_{vak} \approx$ 1 bar) for about 2 hours. The creep effect or stress relaxation achieves low elastic spring back and small residual stresses. The mechanical properties of the final part are not significantly impaired.

The forming of larger structures without buckling requires additional efforts (e. g. a blank holder). The Fraunhofer IWS Dresden is performing more work on this topic.

1 *Spherical fuselage shell with laser beam welded reinforcing stringers*

3 *Forming experiments with round sheets that are supercritical to buckling*

5 *FE simulation of a forming experiment with round sheet that are supercritical to buckling*

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