BALL FORMING SOLVES CONTOURING PROBLEMS

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Wing panels for the Lockheed L-1011 (photo above) are contoured by a new, patented method called ball forming. Simply put, these aluminum parts are formed by gravity-fed steel balls. The process could replace conventional shot peening in some instances. Magnesium, titanium, and steel are other potential applications.

Ball forming is a modification of conventional shot peening with three important differences: 1. Forming media are steel balls of uniform size and shape. 2. The balls are normally larger than conventional shot. 3. The balls are delivered at lower velocities.

Gravity is sufficient to propel balls with enough force to impart curvatures of 100 in. in radius and larger (depending on thickness) in 7075-T651 aluminum alloy plate. (Plate supplied to the T7651 temper has been solution treated, stress relieved by stretching, and artificially aged for resistance to exfoliation and stress corrosion).

When gravity propelled, balls are simply dropped from varying heights under controlled conditions. To change the impact force, change ball size or drop height.

Basic Equipment — A system for containing, delivering, returning, and storing balls and a work conveyor for moving parts through the ball stream are required.

Ball replacement is negligible because they do not fracture at the low velocities used. This eliminates the need for expensive vibratory particle separation equipment. Screens or grates may be installed to prevent contamination by shop debris.

Because there is little danger from the low-velocity balls, forming may be performed in the open with balls contained by metal or rubber curtains (Fig. 1).

Large Panels Contoured—AVCO’s two ball forming machines can handle aircraft structures up to 7 ft wide and 85 ft long. Each machine has six delivery units capable of supplying more than a ton of steel balls per minute. One operator can control the ball feed rate and drop height for each unit individually or in combination, permitting alteration of impingement pattern or impact force.

Work is moved through the machine by horizontal cars with wing panels supported by simple tables or contour tooling. Car travel speed is adjustable from 1 to 50 ft per min but is normally operated at 2 to 6 ft per min.

Once ball forming parameters are established, the resulting contours are reproducible to a marked degree. This is attributed to the uniform size and shape of the forged steel balls.

Important process factors are the amount of balls delivered, their size and impingement velocity, and the rate of part movement through the ball stream.

Production Procedure — L-1011 wing panels are produced from aluminum plate, clad on the outer surface and machined all over on the inner. The cladding, a high-strength aluminum alloy rather than conventional pure aluminum, provides extra corrosion and stress-corrosion protection. Clad surfaces, however, require more force to ball form.

First, inner surfaces are contoured in localized areas to produce lengthwise contour changes. Clad outer surfaces are then contoured under an elastic prestress to produce chordwise and double contours. Prestressing is accomplished by wrapping the wing panel over special tooling in an overcontoured shape (Fig. 2), allowing for springback.

Simple ball-formed contours are checked with hand templates at several critical wing stations. Egg-crate-type checking fixtures verify complex contours. Then a conventional saturation shot peening with automatic equipment produces a relatively uniform compressive stress over the entire panel.

After saturation peening, contour and fit-up are verified in an assembly checking fixture. Out-of-contour areas are reworked.

Prestress Tooling — Tooling requirements are based on whether the part is ball formed in the free (unrestrained) state or in a deliberately restrained (prestressed) condition. The decision to prestress depends on part size, shape, and thickness; location of pads, cutouts, and tapers; degree of contouring; and surface finish required.

AVCO forms L-1011 wing panels both ways and has found that prestressing permits forming at lower impact forces, resulting in greater contour and surface smoothness. It also helps the plate to form in the right direction and aids reproducibility.

To insure that the elastic limit is not exceeded, stresses applied by the tool are only a modest per cent of
Wing Panels Posed Problem — Specifications called for six basic contoured wing panels up to 80 ft long. Panels had to be machined from heavy-gage clad 7075-T7651 aluminum alloy plate characterized by section changes from inboard to outboard and in localized panel areas. The plate was clad on two sides with a 10-mil nominal layer of 7008 or 7011 aluminum alloy. Contouring was required both chordwise, the length of the panel, and spanwise in certain areas.

Conventional processes such as press and stretch forming have limitations on part size, section thickness, and cutouts, and have undesirable mechanical property effects.

Creep forming seemed to have potential; however, when the cost of the massive tooling required, the difficulty of allowing for metal springback, and the temperature limitation imposed by the heat treated temper were considered, it was rejected.

Process Evolution — Standard shot grades, actually an aggregate of shot sizes, have been used for peening aircraft wing panels. The purpose had been generally for imparting stress-corrosion resistance, enhancing fatigue properties, and mild contouring or configuration correction.

Tests on soft and high-strength clad 7075-T7651 plate showed that shot peening was capable of producing the required contours in thick (up to 0.560 in.) plate when relatively high shot velocities, produced by high-speed rotating wheel machines, were used. However, for the degree of contouring required, the surface finish produced was unacceptable.

Surface roughness exceeded aero-dynamic requirements; and metal folds were common even for the high-strength clad material (Fig. 3, left). Shot peen smoothing (over-peening at lower shot velocities) improved surface finish, but not enough.

The Solution — It was apparent that the impacting shot’s high velocity was responsible for the excessive surface roughness and metal folds. The solution was to lower particle velocity and, to meet forming energy requirements, increase particle size.

Ball-formed surfaces are free of microfissures and metal folds (Fig. 3, right), and surface finish is acceptable without an abrasive polishing post-treatment.

Future Applications — It is predicted that ball forming will augment and in some instances replace conventional shot peening in many particle impact forming applications.

The contouring of magnesium, titanium, and steel, and the mild shaping of wrought forms other than sheets and plates are definite possibilities.