CONTROLLED PEEN FORMING

Peen forming is a dieless forming process performed at room temperature. During the process, the surface of the workpiece is impacted by pressure from small, round steel shot. Every piece of shot impacting the surface acts as a tiny hammer, producing elastic stretching of the upper surface as shown in Fig 1. The impact pressure of the peening shot causes local plastic deformation that manifests itself as a residual compressive stress. The surface force of the residual compressive stress combined with the stretching causes the material to develop a compound convex curvature on the peened side. When curvatures are formed within the elastic range of the metal, the core of the metal remains elastic with a small, balancing, residual tensile stress. Other mechanical forming processes that require overforming with subsequent springback induce high tensile stress. Although high tensile stress can be minimised by stretch forming techniques, stretch forming is usually not performed on tapered or sculptured sections.

The size, velocity, and angle of impingement of the shot as well as the distance of the wheels or nozzles (the wheels or nozzles propel the shot) from the workpiece are automatically controlled in specially designed machines.

APPLICATIONS

Peen forming is used to form large or small panel-shaped objects that do not contain abrupt changes in curvature. The process is capable of rolling, stretching, or twisting the material to develop the shape. Obtaining compound or saddle-backed shapes is also possible. The aircraft industry uses peen forming to form the wing panels on civilian and military aircraft.

Peen forming is applicable to all metals and can be performed on tapered or integrally stiffened machined panels, honeycomb skins, and isogrid (diamond patterned) panels. This process is usually best suited for forming complex shapes having radii within the metal's elastic range. Metal thicknesses in aluminium range from 1.2-50mm; in high-strength steel alloys, the thickness range is from 0.40-25.0mm. Workpiece sizes currently being formed are 4.2m wide x 30m long, and contour tolerances are approximately ±0.63mm. Table 1 shows the curvatures obtained in different metal thicknesses of aluminium when the shot size is varied.

Parts formed by peen forming exhibit increased resistance to flexural bending fatigue. Another distinct advantage with peen forming, unlike most other forming methods, is that all surface stresses generated are of a compressive nature. Although peen-formed workpieces usually require shot peening on one side only, both sides have compressive stresses on the surface. These compressive stresses serve to prevent stress corrosion cracking. Workpieces which have been cold formed by other processes are often shot peened to overcome the harmful tensile stresses set up by the bending process. Sharp bends, such as right-angle flanges and deep-drawn or spun shapes, are not suitable for this process.

MACHINES

Peen forming is usually performed by automatic machines within a cabinet enclosure. When close tolerances are required, forming is performed manually, by skilled technicians. Two basic types of machines are used, differing only in how the peen forming media is delivered to the part being formed.

In nozzle-type machines, compressed air or gravity is used to propel the steel shot to the workpiece. These machines may have as many as 20 nozzles, and each nozzle is capable of delivering 23kg shot/min to a specific location or area of the workpiece. Each nozzle is independently controlled by a pressure gauge and shut-off valves. The nozzle direction is adjustable so that the optimum angle of impingement can be achieved.

Nozzle-type machines can automatically compensate for varying curvature requirements along the workpiece length or width. This compensates for cutouts, skin reinforcements, as well as distortion caused by machining stresses or heat treatment, can also be compensated for with these machines.

Fig 2 shows a nozzle-type gantry peen forming machine. In this machine design, the gantry, which houses the nozzles, traverses over the workpiece while the workpiece is stationary. Another machine design has the workpiece moving through the stationary machine that houses the nozzles.

Centrifugal wheel peen forming is another method by which the shot media is delivered to the workpiece. These machines use solid-state electronic controls to regulate rotating speeds of a paddle wheel that flings the shot at the workpiece. A typical wheel can deliver 136kg shot/min. Production-type centrifugal wheel machines have 6-8 wheels, providing the machine with a capacity to peen form using more than 900kg shot/min. The ability to deliver shot media at a controlled velocity in such large volumes permits higher production rates on these machines than obtainable on nozzle-type machines.

Workpieces formed by centrifugal wheel machines are usually of broad, uniform cross section, with all areas accessible to the shot stream. Minor changes to the shot stream direction can be made by indexing the position of the shot delivered to the wheel paddle.

STRESS PEEN FORMING

Stress peen forming is an auxiliary technique of applying an external mechanical load on the workpiece to assist the peen forming operation. The workpiece to be formed is stressed in an arc within 90% of its material yield point and then peen formed to the required specifications. The pre-stressed radii are critical and is developed mathematically and experimentally so that the material's yield point is not exceeded prior to peen forming. Mechanical or hydraulic devices are designed to deflect the workpiece for specific applications.

Pre-stressing increases the effect of peen forming in one direction and sharply decreases the effect in the opposite direction. The radius of curvature induced by stress peen forming on a specific thickness of metal can be as large as four times the radius obtainable by peen forming without any external stress.

Metal Improvement Co Inc carries out peen-forming of wing skins for the aerospace industry, and in the past fuselage skins have been shaped — Concorde is an example. The first aircraft that used this method was the Constellation. Metal Improvement has a Division in Chester, near from British Aerospace where the lower wing skins are formed for the Airbus. This develops the complex shapes from flat, integrally machined surfaces, such that peen-forming is the final process and all machining and heat treatment have been completed.