ABSTRACT

Hydroforming is a technique that uses hydraulic pressure to form tubular shapes with complicated materials. In tube hydroforming, a pressurized fluid is passed through a hollow tube to cause deformation in the tubular structure to the desired shape.

Tube hydroforming is especially ideal for making complex automobile components, such as exhaust system, chassis and radiator, among others. This method offers several advantages, including improved structural integrity of the product, components with uniform thickness, fewer secondary operations and less dimensional variations.

However, the causes for failure in tube hydroforming are classified under three types: buckling, wrinkling and bursting. The major cause for tube failures is the incorrect application of pressure and axial feed. Therefore, to achieve better formability in tubular materials, it is suggested to monitor process parameters and optimize them.

The present study evaluates the tube formability characteristics for aluminum, copper and brass in hydroforming. Experiments were carried out by varying the process parameters, such as punch displacement, fluid medium, tube thickness and die semi-cone angle, and the outcomes reported. The initial tubular materials were of 38 mm diameter, 1.5 mm thickness and
106 mm length. The identification of tools, materials and methods to evaluate their mechanical properties was done prior to experimental work.

At first, formability evaluation test was carried out, without annealing of materials, at die semi-cone angle of 20° and the expected bulge diameter was 54 mm. After several trials, leakage of oil at pipe joints and side wall was noted. Moreover, as was supposed, the formed component was not satisfactory, primarily because of unannealing. From among the formed components of aluminum, the maximum bulge diameter obtained without failures was 42.57 mm.

In order to improve formability, the materials were annealed in a heavy-duty electric furnace for 2 hours and allowed to cool inside it. The annealing temperatures were 413°C for aluminum, 525°C for copper and 550°C for brass. Subsequently, tube formability experiments were carried out at semi-cone angle of 20°. From among the formed components, the maximum bulge diameter obtained for aluminum was 53.73 mm, for copper was 48.66 mm, and for brass was 44.45 mm. Hence, the tube formability of aluminum and copper was better than that of brass. Bursting failure occurred in a few brass components.

Later, with a die semi-cone angle of 12° and after annealing of the materials, tube formability experiments were carried out. For the semi-cone angle of 12°, the expected bulge diameter was 48 mm. Initially, after applying a punch displacement of 30 mm, better deformation was obtained but pressure developed was high. To prevent a high pressure build-up, punch displacement
was reduced to 15 mm and 20 mm and experiments were repeated. According to the results, a bulge diameter of 46.9 mm was obtained for aluminum and of 45.48 mm was obtained for brass, without failures. The study revealed that annealing improves the formability of aluminum, brass and copper materials.

For the formed aluminum components, deformed grid circle patterns, major strain and minor strain were determined and shown in forming limit diagrams. According to this, the strain values were in a safe region. For all the formed components of aluminum, copper and brass, the thickness along X and Y was measured and found that thinning occurred at the bulge region.

From simulation analysis, bulge diameters of formed aluminum components were determined and found to be agreeable with experimental bulge diameter. The experimental pressure values for aluminum and brass were determined and found to be closer to theoretical values for components formed with a semi-cone angle of 12°. In the end, tube formability, the effects of annealing, the effects of different semi-cone angle and the effects of punch displacement were evaluated and presented.