Stem Speed

Based on work with Ti-6Al-4V alloy solid rounds, where higher stem speeds gave improvements in lubrication, stem speeds for tubing were increased from 6 ipm to 20 ipm with the aim of determining its effect on pressures and finish. Because of the large stem-to-extrusion area ratio, the tube exit speed was 150 fpm at a stem speed of 20 ipm. (As a contrast, Ti-6Al-4V alloy tube of similar dimensions is produced at about 1 fpm by conventional techniques.) The higher stem speed provided a product equally as good and did not change the pressure requirement compared with that obtained at the lower stem speed.

Re-Extrusion of As-Extruded Tube

A single trial (Trial 517) was conducted in which the extruded tube obtained in Trial 485 was to be reduced further to a wall thickness of 0.014 inch. This represented a low ratio of 1.8:1 which was selected to keep the pressure requirements relatively low. It was expected that the work-hardened material would require higher pressures than the starting material for a given ratio. At a fluid pressure of 39,000 psi, the tube billet buckled and split, rather than upset, under the resulting high unbalanced axial pressure of 200,000 psi. It is estimated from the pressure data plotted in Figure 30 that, if the tubing had been annealed before re-extrusion, a product might have been obtained under the above conditions. Extrusion might have taken place at about 20,700 psi. The unbalanced axial pressure at this level is estimated at about 120,000 psi – lower than the critical pressure of about 135,000 psi that would cause upsetting.

XVI

HYDROSTATIC EXTRUSION OF SHAPES

The extrusion of shapes from round billets and re-extrusion of shapes to smaller dimensions was explored for four materials in this program. Efforts were mainly directed toward investigating the process variables for the production of T-sections. The production of a re-entrant channel section from a round billet was investigated near the end of the program.

Die Design for the Extrusion of Shapes

Die Design for the Extrusion of Shapes From Round Billets

The dies used for the extrusion of solid rounds to T-section were of two basic designs shown in Figure 31. The first to be evaluated was the single-angle die (Figure 31a) with an intersecting T-shaped orifice. The compound-angle die (Figure 31b) design differs in that the conical entry is defined by a 45-degree conical surface leading into a 160-degree conical surface, the latter circumscribing the T-opening. This design offers the potential advantage of reducing die machining costs. Also, it permits the die bearing surface to be less irregular, which may be an advantage during extrusion. However, it was recognized that the relatively flat area near the T-opening would raise the extrusion pressure over that obtained with the "single-angle" die but the extent of this pressure rise had to be determined by experiment.

Early versions of the compound-angle die were made in one piece. However, cracking of the die occurred on occasion, and in an attempt to circumvent this problem, a three-piece design as shown in Figure 31b was used. The three-piece T-die design consists of a die insert, a conical shell insert, and a die case. The die insert was sized for a hand press-fit into the die case. The main advantage of this design is that a worn die insert or shell insert would be cheaper to replace than the whole die itself.

The die-orifice dimensions for two dies of each design are given in Figure 31. The dies are identified by a simple designation in the table for easy reference in the discussion.

The construction of the re-entrant channel die was similar in principle to the three-piece T-die design shown in Figure 31b. The insert and its orifice configuration are shown in Figure 32. Like the compound angle-T-die, the insert was supported by a die case having an orifice of the same profile.

Die Design for Re-extrusion of T-Sections

Several re-extrusion dies were constructed to enable the reduction of previously hydrostatically extruded T-sections. Figure 33 shows the geometry adopted. Here again a die insert is located in a die case. The die profiles were designed to take most of the reduction on the width of the T-legs and only sufficient reduction on the extremities of the