Conventional Hot Extrusion

A rough comparison can be made using the preceding figures between conventional hot extrusion and hydrostatic extrusion. Conventional extrusion tooling would cost, perhaps, 1/3 the cost of the hydrostatic extrusion chamber. But, a conventional operation would generally require additional facilities to heat the tooling and billets. For simplicity, these additional heating costs can be assumed equal to the reduced tooling costs. If so, the press costs for the two processes are essentially the same.

The production rate for conventional hot extrusion should be significantly higher than in the hydrostatic extrusion process since both seal problems and the fluid handling systems are eliminated. A production rate of 80 billets per hour was used in this analysis. Although such a rate could be expected with good handling equipment for steel, titanium, molybdenum, and beryllium, it is doubtful for 7075 Al because of the problem of extrusion cracking at extrusion exit speeds much greater than about 5 fpm. Therefore, the conversion cost estimates for hot extrusion of 7075 Al are quite low, probably by a factor of about 10. At any rate, at a production rate of 80 billets/hour, the conversion cost per extrusion is \$0.59 (\$46.96/hr ÷ 80 billets/hr). No fluid or seals are required for hot extrusion and the lubrication costs were assumed negliglible. Because of its high L/D ratio, the billet dimensions used for the hydrostatic extrusion analysis could not be used in the hot extrusion process. The hot extrusion process is further differentiated from hydrostatic extrusion in that it is capable of making larger single-pass reductions than the hydrostatic extrusion process for many materials, except for perhaps the relatively softer nonferrous materials such as aluminum and copper. So that the hot extrusion process was not unduly restricted, the hot extrusion billet was assumed to be 3-1/8-inch diameter. This diameter corresponds to a unit stress on the billet of 180,000 psi in a 700-ton press. This stress level is often used as the maximum practicable tooling stress in hot extrusion. Applying a L/D factor of 3 to the billet diameter results in a overall billet length of 9-3/8 inches. For billets of this size, billet weights for the materials considered are given in Table XXXVII.

As in hydrostatic extrusion, die life is critically important to the economics of conventional hot extrusion. Using the same formula and die cost used to evaluate hydrostatic extrusion, conversion costs for hot extrusion were determined for a range of extrusions per die and for five materials. The results are given in Table XXXVIII.

Comparison of Hydrostatic Extrusion and Hot Extrusion Conversion Costs

It may be seen from the data in Table XXXVIII, that die life is a very significant factor affecting conversion costs. If the tenuous assumption is made that the die life is equal for each process, it is apparent that the conversion costs for hydrostatic extrusion are lower up to a die life of 15 extrusions, equal at 15 extrusions, and higher for a die life above 15 extrusions. However, the assumption of equal die life for both processes is not realistic. A die life of one or two hot extrusions per die is not uncommon in commercial practice. Even when costly ceramic inserts are used in hot extrusion, the die life seldom extends above 25 extrusions. On the other hand, a die life of 250 to 500 extrusions can reasonably be predicted for hydrostatic extrusion. The predictions are made by comparing the hydrostatic extrusion process with the cold forging process. In cold forging the stem pressures are in the range of 300,000 psi to 350,000 psi and thus the die stresses in the two processes are comparable. In cold foring of steel, die lives of 50,000 pieces are common. Typically each forged piece may measure only 1-1/2 inches long, but after 50,000 pieces this is equivalent to extruding 75,000 inches of rod. The hydrostatic extrusion billet in this study was assumed 30 inches long. If this billet was reduced 10 to 1, 300 inches of extruded product would be produced per extrusion, or a die life of 250 extrusions would be equivalent to 75,000 inches of a forged product. If the billet was reduced only 5 to 1 a die life of 500 extrusions would be predicted. One could then realistically compare the cost for a die life of 200 extrusions in the hydrostatic extrusion process with the corresponding costs for hot extrusion for a die life of, say, 5 extrusions. From this view point, the hydrostatic extrusion process looks attractive over a wide range of die life and materials.

There are basic differences between hydrostatic extrusion and hot extrusion processes that could not be eliminated in this analysis. Foremost, the hydrostatic extrusion process produces a product with an excellent surface and good dimensional control. However, a hot extruded product often requires a sizing operation and for some materials the extrusion must be machined all over to produce a satisfactory surface.

Until pilot production runs are made using hydrostatic extrusion techniques to evaluate die life, seal life, and overall process yield, a more rigorous analysis of extrusion of rounds is not possible. It can be concluded, however, that the good possibility of much better die life in hydrostatic extrusion makes it potentially very economically attractive compared to conventional extrusion.

Conversion Costs to Produce Ti-6Al-4V Titanium Alloy Tubing by Hydrostatic Extrusion

Ti-6Al-4V titanium alloy tubing was selected for this part of the economic analysis because it was extruded by hydrostatic means during this contract and the assumptions made herein were based to some extent on the experimental work. Ti-6Al-4V alloy tubing is relatively difficult to fabricate, particularly for small-diameter (less than 1/2 inch), thin-walled tubing. It is, however, available commercially as a specialty item. Unalloyed titanium tubing, on the other hand, is easier to fabricate and is produced commercially. The selling prices for Ti-6Al-4V are quite high when compared to unalloyed titanium tubing. The cost figures for both materials are included in this analysis for comparison with cost estimates for producing tubing by hydrostatic extrusion.

This analysis is based on the experimental work performed on this contract, extrapolated to a production process. Therefore the diameters and lengths involved in this analysis have not been produced, but appear technically feasible. Three examples will be used to estimate the cost per foot to produce titanium tubing. One will be based on actual experimental results previously reported, i.e. 0.750-inch OD x 0.613-inch ID