ABSTRACT

The purpose of the program was to develop the manufacturing capabilities of the hydrostatic-extrusion process. Specific applications studied were fabrication of wire, tubing, and shapes from relatively difficult-to-work materials such as refractory-metal alloys, high-strength steels, aluminum alloys, titanium alloys, beryllium, and other selected materials. Phase I was concerned with process optimization and Phase II with direct process application.

As part of Phase I, the effects of critical process variables on pressure requirements and product quality were studied for wrought and powder materials ranging from relatively high-strength easy to work materials such as aluminum alloys and steels to the relatively more difficult-to-work materials such as Ti-6Al-4V titanium alloy and superalloys. With these materials, fluids and lubricants tended to be the factor controlling pressure requirements and product quality. With almost every material extruded the limit in extrusion ratio was set by the design pressure capacity of the container except for the aluminum alloys where the limit was set more by the efficiency of the lubrication system.

In the hydrostatic extrusion of brittle materials, die design proved to be the most significant factor controlling the production of sound, good quality extrusions. New die-design concepts have opened up new fields for the application of hydrostatic extrusion to brittle materials.

Except for the aluminum alloys, the hydrostatic extrudability of the above range of materials was also investigated at 400 and 500 F. Again, fluids and lubricants were developed to enable the production of good quality extrusions. Of particular interest here was the wide range of lubricants that operated successfully at this temperature level.

As part of Phase II of the program, tubing, mill shapes and wire were produced from a variety of materials. For tubing, the floating-mandrel arrangement enabled higher extrusion-ratio capabilities than those for solid rounds. An analysis of the beneficial effects of the floating-mandrel arrangement is given.

T-sections were extruded from round billets and were re-extruded into smaller T-sections. Materials evaluated here were 7075-0 aluminum, AISI 4340 steel, Ti-6Al-4V alloy and Cb752 columbium alloy. The problem of sealing against leaks between the T-billet and die in the re-extrusion of shapes was overcome to some extent following the evaluation of several methods of sealing.

In the reduction of T-sections and wire, a technique of hydrostatic-extrusion drawing developed at Battelle was used. This method, called the HYDRAW technique, was used to reduce wire of Ti-6Al-4V alloy, beryllium, and TZM molybdenum alloy wire at single pass reductions of up to 60 percent. That reduction appeared to be by no means the limit of single-pass reduction achievable with these materials.

During the experimental program, a study of high-pressure container designs was made. Several design concepts that were analyzed are presented in detail in this report. The most promising concept for containing fluid pressures up to 450,000 psi in large-bore containers was that of using pressurized-fluid support as in the ring-fluid-ring design. This and other designs were analyzed on the basis of fatigue-strength criterion, which is believed to be a new and more sound basis for the design of high-pressure containers.