Billet Materials

For most extrusion trials, the billets were machined, from about 2-inch-diameter bar stock, to 1-3/4 inches in diameter. The extrusion ratio was changed by varying the die-opening size. The billets had noses tapered to the same included angle as the die. The length of the tapered nose was such that the tip was at least flush with the start of the die bearing. The length of the cylindrical portion of the billet was about six inches. The surface finish was in the range of 60-100 microinches, CLA, unless otherwise noted. In some trials, billets less than 1-3/4 inch in diameter were used to achieve a specific extrusion ratio through a die whose orifice area was fixed as in the extrusion of T-sections.

Description of the materials used in this program is given in Table I.

Lubrication

One of the objectives of this program was the development of an efficient lubrication system (billet lubricant plus fluid medium) for each of the materials evaluated. These systems were used later in the program in the hydrostatic extrusion of tubing, wire, and shapes. An efficient system is generally one which will require minimum extrusion pressures and provide an acceptable surface finish. Another factor of importance is the cost of lubrication. However, in this program, efforts were directed mainly towards understanding the mechanics of lubrication so that specifications for efficient lubricants could be laid down.

Factors determining efficient lubrication in hydrostatic extrusion may be divided into four areas:

(1) The hydrostatic fluid

(2) Billet lubricants

(3) Billet conversion coatings

(4) Billet surface finish.

All of these factors were evaluated. Billet conversion coatings (Item 3) were studied only when the combination of billet lubricant and fluid failed to provide efficient lubrication conditions. This was particularly the case with Ti-6Al-4V alloy. Billet conversion coatings are formed by chemical treatment which change the composition at the surface. Their purpose is to permit lubricants to function more efficiently. The conversion coatings used were tenacious and tended to deform with the lubricant.

In a previous program[1] it was found that, except with some low-strength materials such as 1100-0 Al extruded at low ratios, the fluid alone was inadequate as a lubricant. The effectiveness of a fluid was found to depend upon the base viscosity and the change in viscosity with pressure. Additional lubrication was sought by adding solid film lubricants (MoS_2 or graphite) or oiliness agents directly to the fluid. However, the direct application to the billet of lubricants in the form of a thick film was found to be more efficient and this practice was used in this program.

TABLE I. BILLET MATERIALS USED IN HYDROSTATIC EXTRUSION PROGRAM

al	Approximate Composition, weight percent	Condition	Source	Properties			
				Ultimate Tensile Strength, 1000 psi	Yield Strength, 0.2% Offset, 1000 psi	Reduction in Area, percent	Elongation, percent
inum	5.5 Zr, 2.5 Mg, 1.5 Cu, 0.3 Cr, balance Al	Annealed	Commercial	33.8	15.5	45.2	23.3
rdened uminum	99.999 Al, 6 wt % dispersion of Al_2O_3	80-85 percent theoretical density	Oak Ridge National Lab. (AEC Activity No. 0440-02041)	--	35.0	--	--
el	0.4 C, 1.75 Ni, 0.80 Cr, 0.25 Mo, 0.75 Mn, 0.25 Si, balance Fe	Mill annealed	Commercial	94.6	55.4	49.0	33.0
oy	6.2 Al, 4.2 V, 0.02 C, 0.0009 N, 0.21 Fe, 0.098 O_2, balance titanium	Mill annealed	Commercial	143.0	135.0	39.0	21.0
owder	6.0 Al, 4.0 V, 50 ppm H, 60 ppm N, 1800 ppm O_2, 900 ppm Fe, 700 ppm C	90% particles sized between -100 and +325 mesh. Balance -325 mesh	Penn Nuclear Co.	--	--	--	--
bing	--	Cold drawn and annealed	Wolverine Tube [produced on Contract AF 33(615)-3089]	--	--	--	--
-sections	--	Commercially hot extruded and annealed	The H. M. Harper Co.	--	--	--	--
enum	0.42 Ti, 0.1 Zr, 0.023 C, Other 0.007, balance molybdenum	Stress-relieved	Climax Molybdenum Co.	107.0	90.0	--	17.0
		Recrystallized		76.0	50.0	39.0	38.0
	1.54 BeO, 98.46 Be	Hot pressed block	Brush Beryllium Co.	51.2	36.9	--	2.5
	19.0 Cr, 52 Ni, 5.2 Cb + Ta, 3.0 Mo, 0.9 Ti, 0.8 Al, 0.05 C. 0.35 Mn, 0.35 Si, balance Fe	Hot worked solution-treated	Latrobe Steel Co.	--	--	--	--
	15.0 Cr, 26 Ni, 1.25 Mo, 2.15 Ti, 0.2 Al, 0.3 V, 0.05 C, 1.4 Mn, 0.4 Si, balance Fe	Hot worked solution-treated	Allegheny Ludlum Steel Corp.	--	--	--	--