COLD HYDROSTATIC EXTRUSION OF Ti-6Al-4V TITANIUM ROUNDS

Effort is being continued toward improving lubrication for cold hydrostatic extrusion of Ti-6Al-4V titanium alloy. As discussed in Report V[4], the problems of stick slip and die wear have been encountered with the lubrication systems evaluated previously. The results obtained with new lubrication systems are given in the following section.

Lubrication Systems

The experimental data obtained in the evaluation of several new lubrication systems for Ti-6Al-4V are given in Table 4.

The most promising system developed so far centers around an anodized coating, C3, used in conjunction with Lubricant 17 and castor oil as the fluid medium. The anodized coating was developed by Watervliet Arsenal[5] primarily to improve wear resistance of titanium and has been designated as "titanium hardcoat" by the developers.

The results with C3 coating are given in Items 3 and 4 of Table 4. In Trials 368 and 374 (3.33:1 ratio, 6 ipm stem speed, L17 lubricant), Ti-6Al-4V was extruded with excellent surface finishes, and without any stick-slip during the runout stroke. Only moderate breakthrough pressure peaks (10,000 to 15,000 psi) were encountered at the outset as compared to 25,000 psi obtained with some other lubrication systems. The surface finish obtained was in the order of 25 and 20 to 40 microinches, rms, in the longitudinal and transverse directions, respectively. Furthermore, because no metal-to-metal contact occurred between the die and titanium, no measurable die wear or scoring was obtained. Figure 1 clearly shows the influence of coating C3 on extruded surface quality.

An excellent surface finish was also obtained under similar extrusion conditions but at a stem speed of 20 ipm (Trial 369).

In Trial 376, the extrusion ratio was increased to 4:1. The titanium alloy was extruded with only moderate stick-slip during runout and without the need to preheat the fluid and die, which was the case in Trial 193 of the previous program[1]. However, the extruded surface contained score marks over the back half of the extrusion, indicating lubrication breakdown. The absence of score marks on the tapered surface of the billet, however, indicates that the lubrication system is breaking down only at or very near to the die land. Small transverse cracks were also observed at periodic points along the extruded surface. The crack spacings may be associated with the stick-slip cycles occurring during runout.

In Trial 372, the C3 coating was used in conjunction with L45 lubricant. Extrusion pressure and the shape of the extrusion curve were about the same as that obtained for L45 lubricant and C2 coating (Trial 360). However, the extruded surface quality was considerably better with the C3 than it was with the C2 coating. Also, although appreciable die wear occurred with the C2 coating, essentially no wear was noted with the C3 coating.

TABLE 4. EXPERIMENTAL DATA FOR COLD HYDROSTATIC EXTRUSION OF Ti-6Al-4V ALLOY ROUNDS

Die Angle 45 degrees Billet Surface Finish 60-100 microinches, rms
Fluid Castor oil

ial	Extrusion Ratio	Stem Speed, ipm	Billet Lubrication		Extrusion Pressure, 1000 psi				Length of Extrusion, inches	Comments
					Breakthrough		Runout			
			Coating	Lubricant	Stem	Fluid	Stem	Fluid		
5	3.33	6	None[a]	L17	239.0	216.0	232.0	210.0	6-7/8	Slight P_b peak; increasing severity of stick-slip duri
7	3.33	6	C4	L17	257.0	230.0	230.0	207.0	5-1/2	High P_b peak; severe stick-slip; extrusion and die br
8	3.33	6	C3	L17	230.0	210.0	219.0	198.0	8-1/2	Moderate P_b peak; uniform P_r
4	3.33	6	C3	L17	223.0	206.0	207.0	195.0	9-3/4	Moderate P_b peak; uniform P_r
9	3.33	20	C3	L17	228.0	212.0	218.0	201.0	11-1/8	Moderate P_b peak; uniform P_r increasing slightly to
6	4.0	6	C3	L17	271.0	242.0	242.0	222.0	9	High P_b peak; moderate stick-slip; small transverse
2	3.33	6	C3	L45	243.0	218.0	216.0	196.0	9-1/2	High P_b peak; slight stick-slip followed by uniform
9[b]	3.33	6	C3	L8	272.0	245.0	--	--	0	P_b peak not reached; stopped at indicated pressure
8	4.0	6	C3	L8	275.0	247.0	--	--	0	P_b peak not reached; stopped at indicated pressure
4[c]	3.33	6	None	L26	152.0	114.0	--	--	0	P_b peak not reached. Trial stopped at indicated pre where fluid apparently solidified.
2	3.33	6	C2	L31	248.0	225.0	226.0	205.0	9-1/8	High P_b peak; moderate stick-slip followed by unifo
3	3.33	20	C2	L31	250.0	226.0	224.0	203.0	11-3/8	High P_b peak; uniform P_r
8	3.33	6	C2	L34	242.0	220.0	232.0	211.0	5-1/2	Slight P_b peak; increasing severity of stick-slip duri
9	3.33	6	C2	L35	238.0	213.0	230.0	207.0	4-3/4	Slight P_b peak; moderate stick-slip
6	3.33	6	None	L39	268.0	240.0	--	--	0	P_b peak not reached; stopped at indicated pressure
1	3.33	6	None	L39	276.0	242.0	--	--	0	P_b peak not reached; stopped at indicated pressure
0	3.33	6	C2	L45	242.0	222.0	221.0	197.0	9-7/8	High P_b peak; P_r increased and then leveled off
1	3.33	20	C2	L45	241.0	219.0	219.0	198.0	10-3/4	High P_b peak; P_r increased and then leveled off
3	3.33	20	C2	L49	226.0	210.0	208.0	194.0	11-1/8	High P_b peak; P_r increased and then leveled off
0	3.33	20	C2	L50	249.0	225.0	223.0	200.0	10-1/8	High P_b peak; P_r increased and then leveled off

surface was roughened by grit blasting followed by vapor blasting.
from Trial 378 was used in Trial 379.
364 was made with polyphenyl ether fluid.