# IX

# HYDROSTATIC EXTRUSION OF Ti-6Al-4V TITANIUM ALLOY ROUNDS

Experiments in the hydrostatic extrusion of Ti-6Al-4V alloy were directed mainly towards developing an efficient lubrication system for extrusion ratios of 3.3 and 4:1. Work on this alloy in the previous program[1] had indicated that lubrication was the major problem because, even though extrusions were obtained at ratios up to 4:1, stick-slip and very poor finishes were obtained using the lubricants then developed. Moreover, when the lubricant broke down to an extent where metal-to-metal contact took place the alloy tended to gall or adhere severely to the die.

In this program, extrusions of excellent quality were achieved following the development of a few lubrication systems. At room temperature, it was found necessary to apply an anodized coating prior to billet lubrication. At elevated temperatures, however, billet lubricants alone were satisfactory and no benefit was gained by the use of the coating. Table XIX gives data obtained in the evaluation of lubrication systems at room temperature and Table XX gives the data obtained at 400 and 500 F.

## Extrusion Ratio

Ti-6Al-4V alloy has a high yield strength and consequently the maximum practical extrusion ratio attainable within the 250,000 psi pressure capacity of the current tooling was 4:1. The pressure data obtained are plotted in Figure 19 for three temperatures (80, 120, and 400 F) to indicate the developments made during the program and the possibilities in the future. The curve designated 120 F originated from data obtained in the previous program at ratios ranging from 1.6 to 4:1[1]. It is seen by extrapolation that extrusion ratios of greater than 10:1 may be possible at pressures of about 400,000 psi, providing efficient lubrication can be achieved at those pressures.

## Lubrication at 80 F

### Evaluation of Billet Lubricants Without Billet Coatings

While the application of a fluoride-phosphate coating, C2, gave the best results in the previous program[1], ten billet lubricants were evaluated in this program without billet coatings with the aim of developing an efficient and low-cost lubrication system. Section I of Table XIX gives the data obtained under constant extrusion conditions with these lubricants. Without exception, each trial resulted in either stick-slip or seizure at the billet-die interface.

Lubricants L24 through L27 and L39 contained substantial quantities of iodine. The purpose of the iodine was to react chemically with the billet surface to form a product that would offer less frictional resistance than the titanium alloy itself. Except for L27 and L39, these iodine-containing lubricants appeared to reduce the tendency towards stick-slip but the improvements were not significant. With lubricant L39, which contained

TABLE XIX. EXPERIMENTAL DATA FOR 80 F HYDROSTATIC EXTRUSION OF Ti-6Al-4V ROUNDS

Die angle - 45 degrees (included) Billet diameter - 1-3/4 inches
Fluid - Castor oil Billet surface finish - 60 to 120 microinches

| Extrusion Ratio[a] | Stem Speed | Billet Lubrication[b] | | Extrusion Pressure, 1000 psi | | | | Type of Curve (Fig. 26) | Length of Extrusion, inches | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Breakthrough | | Runout | | | | |
| | | Coating | Lubricant | Stem | Fluid | Stem | Fluid | | | |
| | | | | | Section I | | | | | |
| 3.2 | 6 | -- | L17 | 240 | 222 | 240 | 117 | C4 | 1 | |
| 3.3 | 6 | -- | L17 | 244 | 225 | 242 | 222 | C4 | 1 | |
| 3.3 | 6 | -- | L17 | 202 | 188 | -- | -- | C4 | 6 | |
| 3.3 | 6 | -- | L17 | 239 | 219 | 232 | 213 | D3 | 7 | |
| 3.2 | 6 | -- | L24 | 202 | 190 | 216 | 198 | C1 | 11 | |
| 3.3 | 6 | -- | L25 | 224 | 210 | 212 | 196 | C1 | 11 | |
| 3.2 | 6 | -- | L26 | 223 | 203 | 210 | 186 | D1 | 12 | |
| 3.3 | 6 | -- | L26 | 152 | 114 | -- | -- | -- | -- | $P_b$ not reached; fluid apparently s |
| 3.2 | 6 | -- | L27 | 217 | 196 | 219 | 188 | C4 | 5 | |
| 3.3 | 6 | -- | L28 | 245 | 226 | -- | -- | -- | 1 | $P_b$ not reached |
| 3.2 | 6 | -- | L28 | 249 | 225 | -- | -- | -- | -- | Billet cocked; die broke |
| 3.3 | 6 | -- | L28 | 240 | 224 | -- | -- | -- | -- | $P_b$ not reached |
| 3.3 | 6 | -- | L29 | 240 | 225 | 237 | 222 | C4 | 1 | |
| 3.2 | 6 | -- | L29 | 262 | 235 | -- | -- | -- | -- | $P_b$ not reached |
| 3.3 | 6 | -- | L29 | 246 | 222 | -- | -- | -- | -- | Billet cocked; die broke |
| 3.3 | 6 | -- | L30 | 214 | 202 | 212 | 200 | C4 | 1 | |
| 3.2 | 6 | -- | L30 | 250 | 223 | -- | -- | D1 | -- | Billet cocked; die broke |
| 3.2 | 6 | -- | L30 | 228 | 207 | 240 | 208 | D3 | 9 | |
| 3.3 | 6 | -- | L31 | 240 | 223 | 235 | 220 | C4 | 1 | |
| 3.2 | 6 | -- | L31 | 264 | 237 | -- | -- | -- | -- | $P_b$ not reached |
| 3.3 | 6 | -- | L32 | 226 | 210 | 221 | 208 | C4 | 1 | |
| 3.3 | 6 | -- | L39 | 268 | 240 | -- | -- | -- | -- | $P_b$ not reached |
| 3.3 | 6 | -- | L39 | 276 | 242 | -- | -- | -- | -- | $P_b$ not reached |