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HOT-DIE FORGING OF Ti-10V-2Fe-3Al

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Introduction

Ti-10V-2Fe-3Al is a β Titanium alloy invented by TIMET with a β transus temperature of 800°C. The alloy is being considered for many aircraft applications requiring excellent strength-toughness combinations (1, 2). The superior hot workability of the alloy has been discussed, but until now that factor alone (without considering the property advantages) has not provided sufficient justification to substitute this alloy for the α+β alloys, such as Ti-6Al-4V since Ti-10V-2Fe-3Al is a more expensive alloy to produce. The purpose of this study was to investigate if the reduced forging temperatures and loads would make it feasable to replace the isothermal forging techniques when forging Ti-10V-2Fe-3Al and Ti-6Al-4V with a Hot-Die forging technique using steel dies. In isothermal forging the die materials are Mo-based or Ni-based and a switch would have a large impact on the cost structure.

Experimental Setup and Process-model

The Hot-Die upsetting tests were done in a 400 kN computer-controlled press (3) using steel dies with an initial temperature of 550°C (Fig. 1). The billets, diameter 100 mm height 16 mm, were heated to 750, 825 and 900°C, respectively and upset with 4 mm/s and 16 mm/s.

The forces necessary to forge the material to a given height were calculated with a process model (Fig. 2) and compared with the experimental data. The model calculates the forces using the slab-method and also takes into account the heat transfer between billet and die as well as heat losses to the surrounding and adiabatic heating of the billet. The final die and billet temperatures were also calculated. The process-model has been described elswhere (4, 5).

The model was used to simulate isothermal and hot-die forging conditions of Ti-6Al-4V and Ti-10V-2Fe-3Al to compare die loads (die stresses) for different die materials.

Results and Discussion

The agreement between model and experiment was very good (Fig. 3). The limitation used in the calculations was the final billet height. When using the low velocity (4 mm/s) the cooling of the billet was larger during the deformation giving rise to almost identical forces independent of initial billet temperature. The model was used to simulate isothermal and hot-die forging conditions of Ti-6Al-4V and Ti-10V-2Fe-3Al respectively to compare die loads (die stresses) for different die materials. The better forgability (lower flow stresses) of the β-Ti class alloys makes it feasible in isothermal forging to

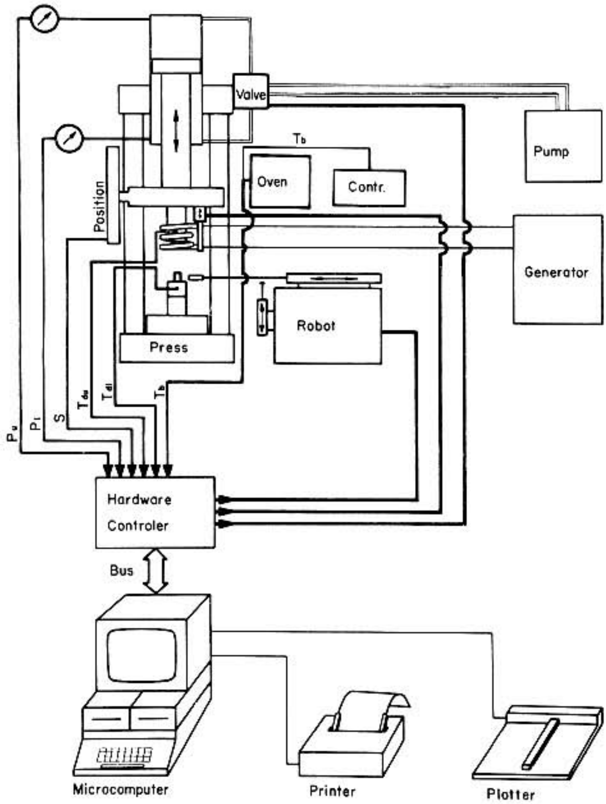


Fig. 1: Schematic layout of the computer-controlled press.

use other die materials in dies used for complicated parts: for instance exchanging Mo-base alloys with Ni-base alloys (6). In the calculations isothermal forging of Ti-6Al-4V between TZM and IN 100 dies and Hot-Die forging of Ti-10V-2Fe-3Al between St 2344 Steel dies was compared. The yield stress of the die material over the average forging pressure

$$K = \frac{\sigma_{0,2\ Die}}{\bar{\sigma}}$$

was judged to be the relevant parameter. The K-factor is three times larger when isothermally forging Ti-6Al-4V at 900°C than when Hot-Die forging Ti-10V-2Fe-3Al between St 2344 steel dies. The dies had an initial temperature of 550°C and the initial billet temperature was 850°C. The results indicate

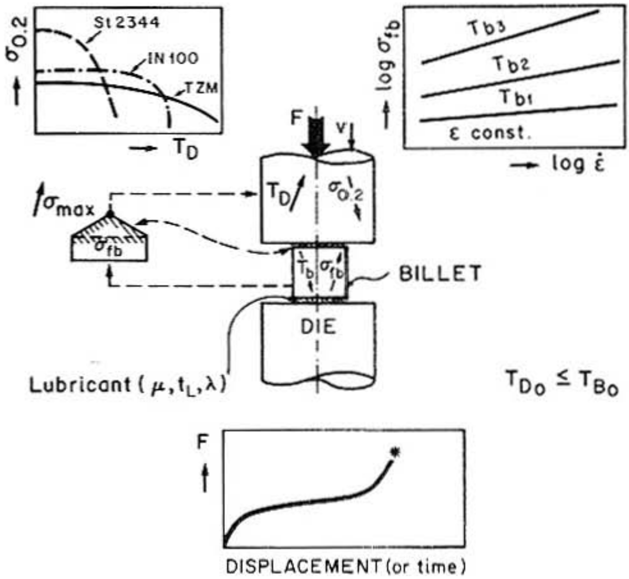
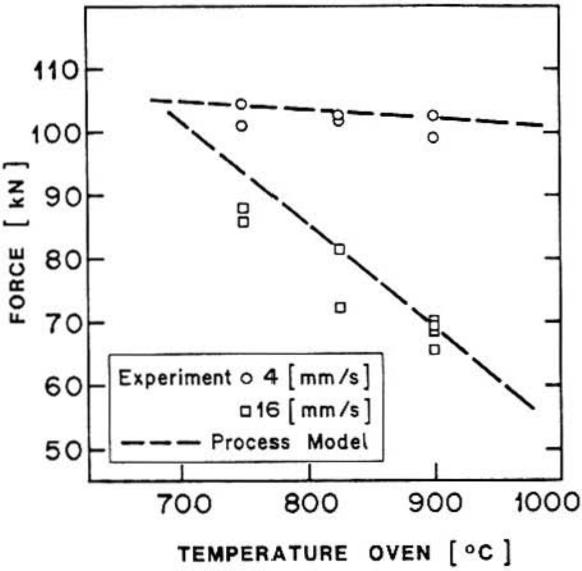


Fig. 2: Hot-Die Forging System. The system consists of three main parts, the die, the billet and the lubricant (or thermal layer). Schematically are seen; die flow-stress ($\sigma_{0.2}$) as function of die temperature (T_D), billet flow stress (σ_{fb}) as a function of deformation speed ($\dot{\varepsilon}$) and temperature (T_b), maximum die stress (σ_{max}) and the force (F)-displacement curve.

that only fairly simple geometries can be forged near-net shape with this method.

The microstructure of the hot-die forged samples were examined both in the as forged condition, and after solution treatment at 745°C. Large differences in deformation through the cross section were found: deformations were much higher at the center of the billet than at the surfaces (Fig. 4). This is an expected result since the billet is not isothermal, but instead has lower temperatures at the surfaces. Higher forging velocities resulted in more equiaxed and larger grained microstructures. This is while higher forging velocities lead to higher billet temperatures.

Ti-10-2-3 is normally isothermally finish forged some 25 degrees below the β transus temperature. The α that is produced during this process is termed primary α, and its shape, size, distribution and volume fraction are critical to the final



Material :	Ti-10V-2Fe-3Al
Initial Die Temperature:	550 [°C]
Die Material:	Tool Steel St 2344
Original Billet Size:	Ø 10 × 16 [mm]
Final Height:	5 [mm]

Fig. 3: Comparison between experimental and calculated values when Hot-Die forging Ti-10V-2Fe-3Al.

properties of the material. No primary α was found in pancakes forged above 800°C (Fig. 5). This result was not necessarily expected since the billet temperatures are decreased during forging, and the forging operation is finished in the α+β phase field. Such microstructures are undesirable since subsequent heat treatment introduces a continuous grain boundary α layer, having a detrimental effect upon both fracture toughness and ductility. The pancakes forged with initial billet temperatures of 750°C did contain primary α (Fig. 6). The volume fraction of α was roughly commensurate with what one would expect after isothermally forging at that temperature; the α volume fraction was somewhat higher after thelower speed forging, however. The shape of the primary α was not constant through the cross section: the surface regions (lower temperatures) both at the higher and the lower strain rate contained primary α that was far more elongated than that of the center. Both higher temperatures and higher strain rates are known to

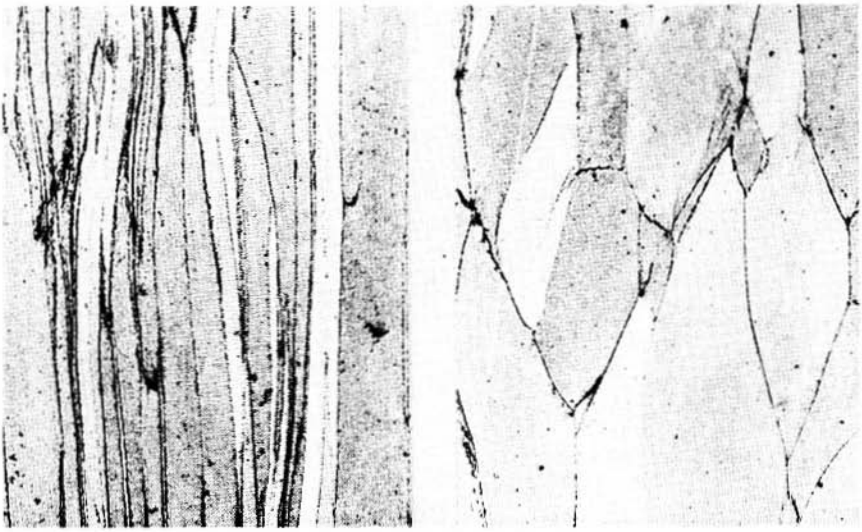


Fig. 4: Hot-Die forged Ti-10V-2Fe-3Al samples forged at 4 mm/s. Billet geometry: Diameter 10 mm, height 16 mm. The preheating temperature was 900°C. The right picture shows the surface and the left the center of the billet in the as-forged condition. 225 x

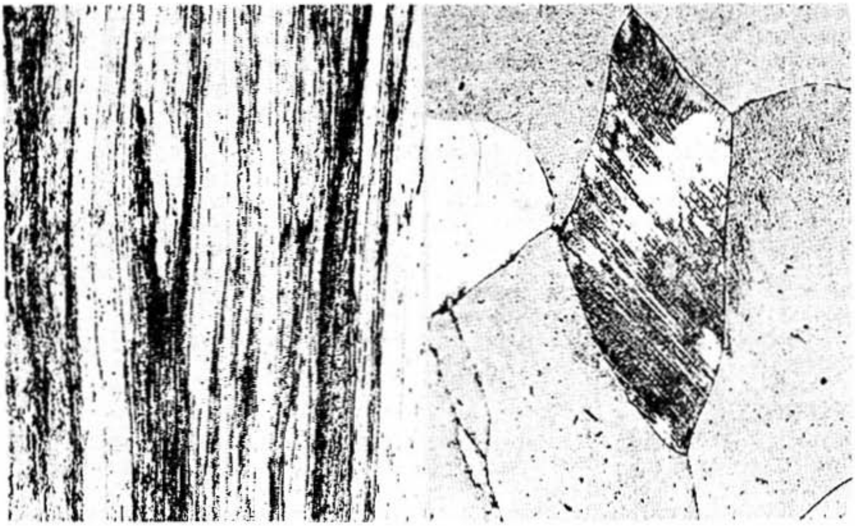


Fig. 5: Preheating temperature 825°C, deformation velocity 4 mm/s, as-forged condition. The right picture shows the surface and the left the center. 225x. Geometry and material as in Fig. 4.

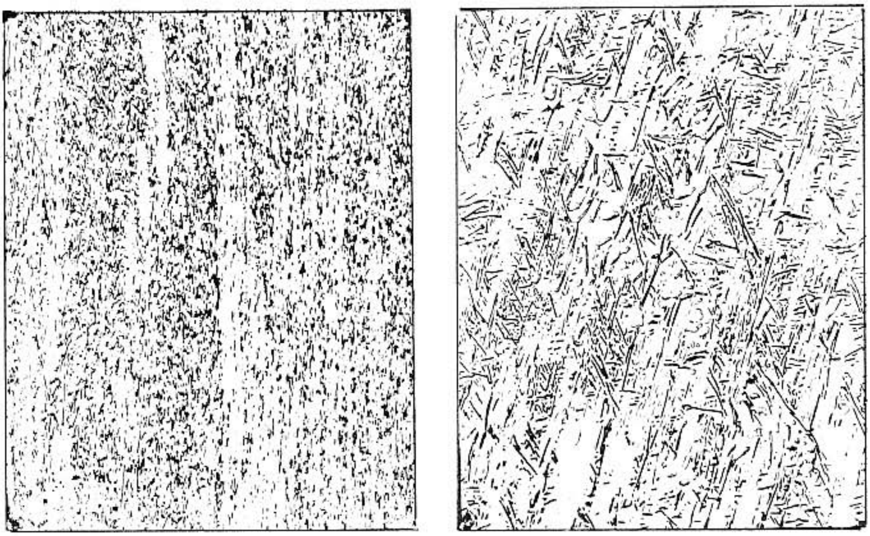


Fig. 6: Preheating temperature 750°C, deformation velocity 16 mm/s, as-forged condition. The right picture shows the surface, the left the center. 225x. Geometry and material as in Fig. 4.

lead to more equiaxed primary α. This result would seem to indicate that morphology is controlled more by strain rate than by temperature, since the surface is deformed at a lower temperature as well as at lower strain rates, but the center is deformed at a higher temperature when forging with 16 mm/s.

The primary α morphology found at the billet surface would be expected to be a high toughness/low ductility morphology (comparatively speaking), and that near the center would be expected to give better ductilities at the expense of toughness. The properties would, therefore, be non-uniform: high toughness at the surface, high ductility at the core. This non-uniformity could be interpreted as an advantage. If one were concerned about fracture from surface defects, a higher surface toughness while maintaining a ductile core would be very desireable.

References

(1) G.W. Kuhlman, T.B. Gurganus: Metal Prog. July (1980) 30.

(2) T.W. Duerig, G.T. Terlinde, J.C. Williams: Met. Trans. 11 A (1979) 1987.

(3) H. Rydstad, C.R. Boër: 11th NAMRC Conference (1983) 211.

(4) C.R. Boër, G. Schröder: CIRP Annals Vol. 31/1/1982 (1982).

(5) C R. Boër, G. Schröder: 20th MTDR Conference (1980).

(6) G. Schröder, T.W. Duerig: In this conference.