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# Analysis of Ti6Al4V P/M Properties Under Thermomechanical Compression Tests

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## Abstract

Since titanium powder metallurgy poses opportunities for the manufacture of a range of components, there now exists the need to establish its performance characteristics under industrial conditions that these components need to operate under.

In line with this, there is a need to analysing amongst others the mechanical properties of Ti6Al4V P/M [1, 5] under various thermo-mechanical conditions and compression tests.

The main objective of the research is to study and compare the properties after forging of high quality Ti6Al4V powder metallurgy alloy with that of titanium ingot. Both samples has been manufactured under the same thermo mechanical conditions. P/M alloy will be prepared from the mixture of elemental powders, and will have the chemical composition of that of ingot Ti6Al4V alloy as per ASTM 1580-1 standard. Powder mixtures will be fully densified by hot compaction under precisely controlled conditions using the Thermal Technology Inc. press at AGH University of Science and Technology in Poland.

Various physical tests will be conducted including mechanical property tests and microstructural analysis. Additionally simulations will be performed using simulation software, GForm ™ , using parameters used on actual forgings. Results will be compared to physical tests performed earlier.

## 1. Introduction

South Africa is rich in natural titanium resources, currently at about 14% of the world's raw titanium, and the fourth biggest supplier and have been identified as a potential to serve as an economic driver.

South Africa however has no means of increasing the value of the raw titanium other than producing low cost titanium sponge and exporting the sponge to foreign countries. Titanium ingot and powders must then be imported at great cost of up to 100 fold the cost of titanium sponge. The potential for further development however have been identified.

There are two avenues that are currently addressed. The first is that of reducing the cost of powders by developing novel ways of producing the powder [3, 4]. If some breakthrough can be achieved locally it will have a significant impact on development of South Africa's titanium industry with downstream benefits.

Reducing these costs will enable South Africa to complete on an industrial scale thus enabling the production of powder metallurgy products for Aerospace, automotive and medical applications. Further sub-categories such as jewellery design, art and sports equipment can also be exploited.

The second avenue is that of powder metallurgy component production processes. Extensive testing has been performed on Ti6Al4V over the last few years [2, 7] too obtain suitable properties that match or exceed that of current titanium ingot production methods. One of these methods, compression tests under various thermo-mechanical conditions, will be analysed in the following study.

## 2. Description

As forged samples were received. Figure 1 illustrates the as forged sample for Ti6Al4V P/M and Figure 2 illustrates that for Ti6Al4V ingot. As can be seen these samples are structurally identical and it will be impossible differentiating between the samples through visual inspection.

Fig. 1. P/M Ti6Al4V forged alloy

Fig. 2. Ingot Ti6Al4V alloy

Initial sample was prepared using the Struers Discotom-5 cutting machine. It was confirmed that the sample was too tough to be cut on this machine and further samples were cut using a manual cutting tool. This method, although producing a rougher surface, would create a surface not affected by microstructural changes due to heat of cutting. Additional time would be allocated to produce a flat surface for microstructural analysis.

Sample was set in a solution of cold mount acrylic resin and allowed to dry for 15 minutes. Samples were then ground until surface was flat and free from imperfections. Additional polish with SiC disks from 220 to 1000 was used to polish samples to a mirror like finish.

Microstructural analysis to be performed on three different areas in question from each sample as indicated in figure 3.

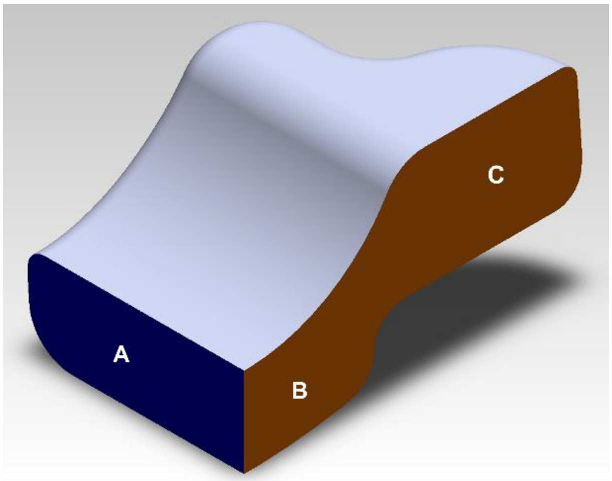



Fig. 3. Graphical representation of sectional areas to be investigated

Initial forging trails using numerical simulations have been performed using actual forging data indicated in table 1 below.

Table 1. Numerical simulation data

| | |
|---|---|
| Material investigated | Ti6Al4V fully densified compacts |
| Billet size | Φ35 mm x 49 mm |
| Initial billet temperature | 900 °C |
| Die temperature | 300 °C |
| Die material | High Cr, high C steel |
| Press specifications | 400 T screw press<br>Static lower tool, moving upper tool<br>Coupled tooling |
| Deformation boundaries | 1 mm before die in contact |
| Surrounding conditions | Ambient air (20 °C) |

Areas mentioned in figure 3 will also be analysed after numerical simulations are completed.

## 3. Results

Numerical simulation data obtained using G-Form™ yield material flow results, temperature gradients, stress and strain results as can be seen in figure 4-6. Further measured data must still be analysed including microstructural analysis of key areas described in figure 3.

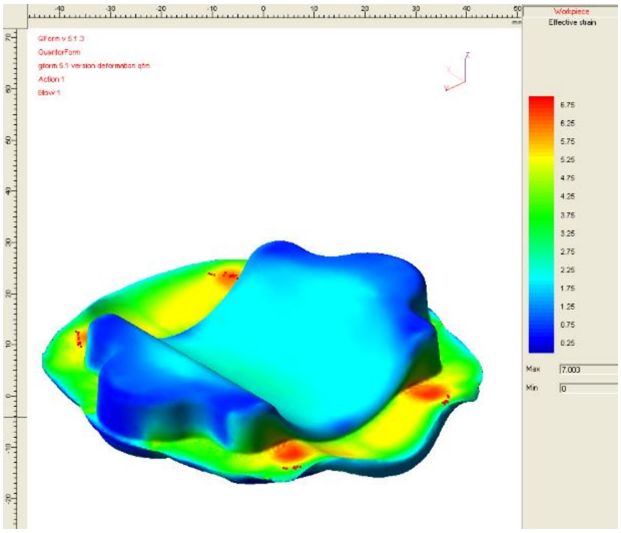


Fig. 4. Effective strain at end of simulation

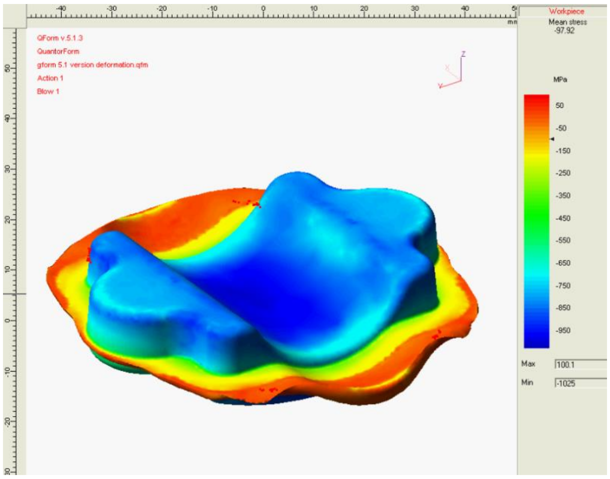


Fig. 5. Mean stress distribution across the sample at end of simulation

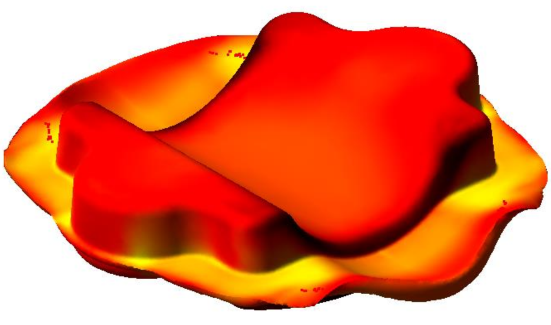


Fig. 6. Temperature gradient at end of simulation

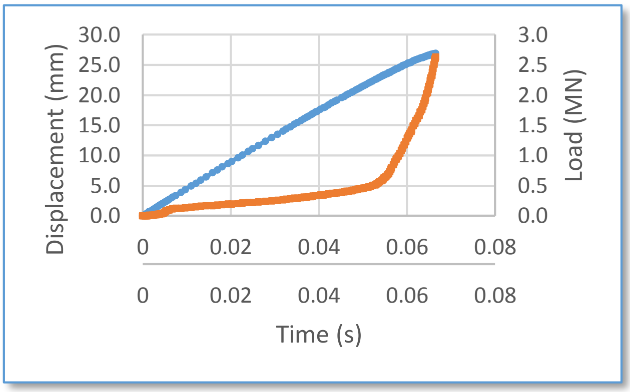
Effective strain range from 0 to 7 across the sample was calculated (Fig. 4).

Mean stress distributions range from -1025 MPa to 100 MPa across the sample was obtained (Fig. 5).

Temperature at end of simulation raised by 103 °C in areas of the flange (Fig. 6).

These occurrences will be examined in future microstructure analysis to determine it has any effect on final microstructure and mechanical properties [6].

In graph 1 below the displacement is uniform with a slight decrease as the load increases but bearly noticable. The load drastically increases as the material is work hardened during plastic deformation.




Graph 1. Prelimianry simulation data obtained from numberical simulation

## 4. Conclusions

At this stage in the analysis no conclusions can yet be made. Further analysis has to be performed to determine the effects of the severe deformation, the temperature rise, strain rate and temperature of dies on the microstructure.

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