

## ABSTRACT

The alloy Ti-2.7Al-5.7Fe-6Mo-6V (wt%), commercially known as Timetal 125, is used as a high strength fastener in aerospace assemblies. Very little information is available on its properties and processing, and this study investigated its consolidation from low cost elemental powders, to achieve the minimum mechanical properties for use as a high strength fastener. Reactions during alloying and its beta transus were investigated by differential thermal analysis. The  $\alpha+\beta$  phase region was established to lie between 590°C and 800°C by thermal analysis, metallography and XRD. The alloy was consolidated to ~99% theoretical density by semi-centrifugal casting, and spark plasma sintering of the blended powders. Various heat treatments were undertaken, and the microstructures were evaluated by optical and scanning electron microscopy. Tensile properties, hardness and density were measured after each heat treatment, to establish the optimal combination of mechanical properties.

The experimental Timetal 125 style alloy was found to be a metastable beta titanium alloy, which could be strengthened by ageing. It had a microstructure consisting of alpha grains with fine beta precipitates in the as-cast condition, while the sintered samples had acicular precipitates and larger grains, due to the unusually long period that was required to sinter the samples. The ultimate tensile strength was >1500MPa, and elongation was ~3% in the as-cast condition, thus failing to conform to the Airbus EN6116 standard's specification for ultimate tensile strength and elongation for a high strength fastener in the as-cast or sintered condition. After annealing the castings at 900°C for 1 hour, the ultimate tensile strength decreased to ~760MPa, while elongation increased to ~15%, which still did not conform to the Airbus standard, due to the low strength. The alloy was solution-annealed at 900°C, followed by water quenching to retain a fully  $\beta$ Ti microstructure. The minimum properties for the Airbus standard were achieved after ageing between 500°C and 590°C for 1 hour, with an ultimate tensile strength of ~1285MPa, and elongation of ~6.3%.

The strengthening depended on the amount and morphology of  $\alpha$ Ti precipitates from ageing. The  $\alpha$ Ti/ $\beta$ Ti ratio increased with increasing temperature and holding time (shown by XRD), up to 590°C where the precipitates progressively transformed to  $\beta$ Ti. Extending isothermal holding time coarsened the precipitates, which was deleterious to strength. There was generally a positive correlation between mean grain size and temperature or holding time, although competing transformations suppressed grain growth, particularly after heat treatment close to transformation

temperatures. Although grain size had an effect on the strength of the Timetal 125 style alloy, the main mechanism was precipitation hardening by the secondary  $\alpha$ Ti. Extended ageing resulted in the formation of allotriomorphic alpha titanium, and a corresponding decrease in the ultimate tensile strength.

It was not possible to subject the sintered samples to tensile testing, due to their shape. However, the sintered samples were less porous and had higher Vickers' values than the castings, suggesting they had similar, if not higher tensile strengths. The acicular precipitates in the sintered samples were possibly martensite or omega titanium ( $\omega$ Ti, Pearson symbol *hP3* and space group *P6/mmm*) although they were too fine to be detected by X-ray diffraction and too fine to analyse separately by energy dispersive X-ray spectrometry.