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Investigating hydrogen induced Ti3Al embrittlement in Ti-6Al-4V using TEM

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Temporary hydrogen alloying (THA) can refine coarse-grained as-cast Ti-6Al-4V microstructures and improve tensile strength. However, it can also reduce the tensile ductility to severe embrittlement because of hydrogen promoted titanium aluminide (Ti3Al) precipitation.[1] The effect of oxygen concentration above a 0.33 wt.% threshold on Ti3Al promotion is known.[2] The effect of residual hydrogen concentration above a 150-ppm threshold on Ti-6Al-4V embrittlement is also known.[3] Less Known is the effect of hydrogen on the promotion of Ti3Al precipitation, and the effect of precipitated Ti3Al on tensile ductility. This study investigates hydrogen promoted Ti3Al precipitation, and its effects on the tensile ductility of hydrogenated-dehydrogenated (HDH) Ti-6Al-4V.

A hydrogenation-dehydrogenation (HDH) treatment was used to refine a coarse-grained Ti-6Al-4V microstructure with the intention of optimizing its tensile strength and ductility. Microstructure evolution was characterized using X-ray diffraction (XRD), electron backscatter diffraction (EBSD), energy dispersive spectroscopy (EDS) and transmission electron microscopy (TEM). Oxygen and hydrogen concentrations were quantified using inert gas fusion (IGF).

The results indicate that HDH treatment does not refine the coarse network of prior beta grains, but it alters the coarse Widmanstätten microstructure by nucleating submicron beta grains within the individual lamellae. The HDH modified microstructure had higher ultimate tensile strength (UTS) in the order of 100 MPa. The dehydrogenation temperature affected tensile ductility; the lowest dehydrogenation temperature (675 °C) had the highest ductility loss in the order of 75%. Increasing the dehydrogenation temperature recovered ductility until full ductility was recovered at 750°C. The ductility loss was not caused by residual hydrogen or oxygen but was caused by the embrittling effect of hydrogen induced Ti3Al which remains in the microstructure even after hydrogen removal, and only completely dissolves at a Ti3Al solvus temperature of 750 °C. The results demonstrate that HDH treatment alters the initial coarse-grained Ti-6Al-4V microstructure to extents that significantly improve strength, but it also promotes Ti3Al precipitation and its concomitant embrittlement. To improve ductility, the dehydrogenation treatment should be controlled to optimize Ti3Al dissolution.

References

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Apply to be considered for a student ; award (Yes / No)?

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Primary authors: VILANE, Velile (Nelson Mandela University); KNUTSEN, Robert (UCT EMU); WESTRAADT, Johan (Nelson Mandela University)

Presenter: VILANE, Velile (Nelson Mandela University)

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