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Characterization of a microstructurally heterostructured α/α'-β metastable titanium alloys to tune strength / ductility trade-offs using powder metallurgy.

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Abstract

Titanium's high strength-to-weight ratio, high toughness, and corrosion resistance make it suitable for a wide range of aerospace and biomedical applications. To meet these requirements, a wide range of alloys are used, ranging from α and α + β to β and metastable β alloys. The latter exhibit a very high level of ductility and work hardenability compared to conventional α + β alloys. This behavior is explained by a synergistic effect between dislocation glide and Transformation Induced Plasticity (TRIP) / Twinning Induced Plasticity (TWIP), known as the dynamic Hall–Petch effect. However, these plastic mechanisms are triggered at relatively low energy levels, leading to a low yield stress compared to Ti6Al4V. A simple method, based on powder metallurgy and solid-state sintering, was developed to tune the strength/ductility trade-off between TWIP Ti14Mo and Ti6Al4V. Powder blends with different relative powder fractions were prepared to cover the entire spectrum from Ti6Al4V (100%) to Ti14Mo (100%). These powder blends were consolidated through Spark Plasma Sintering (SPS). After optimizing the powder size to ensure non-interdiffused areas within Ti14Mo constituents (to preserve the metastable TWIP effect), dense and homogeneous multi-alloys with heterostructured microstructures were successfully produced. Strength/ductility trade-offs were successfully achieved with controlled work hardening capabilities. These high work hardening capabilities were attributed to plastic motion hindered at grain boundaries, twin boundaries, and constituent interfaces, observed by EBSD, and optical micrograph after Kroll etching. Moreover, since the constituents do not deform in the same way, deformation gradients are generated, favoring the work-hardening. The toughness was quantified on these ductile materials using mini disk compact tension specimens. Due to the small specimen size, the Load Line Opening Displacement (LLOD) of the crack is followed by a camera device, which monitors the machine displacement during the test. After a fatigue precracking, samples are loaded and then unloaded every 15 microns of LLOD. At each controlled unloading step, crack propagation is quantified using the compliance method. Afterward, an equivalent KIC for ductile material can be quantified. Finally, the crack path was observed using CT scans on the various heterostructured materials. It highlights certain key aspects such as the front-tunnelling effect and the deflection of cracks when they encounter constituents.

Keywords:

- TWIP - Toughness - Titanium alloys