Mesoscale Priority Research Direction

Optimizing Flow Stress of a BCC Metal at $T/T_m<0.1$

Opportunity

Brittle BCC iron is changed to ductile steel by alloying wherein dislocation mobility is increased and the fracture stress is raised above the flow stress.

BCC molybdenum has attractive properties yet it's use has been restricted due to it's historically brittle behavior (<3% elongation) after welding.

Data shows ~20% tensile elongation in an experimental Mo, Zr, B, C alloy following GTA welding in 6mm plate.

Understanding the parallel mechanisms of ductility in BCC Mo are enhanced by new analytical tools.

Meso Challenge

Dislocation mobility is related to the Peirels-Nabarro force and is associated with the Homologous Temperature.

T/T_m for steel is 0.17; for Mo it's 0.1. Mo shouldn't have ~20% elongation until 490K and yet Zr, B and C change fracture morphology from typical brittle intergranular cleavage to more ductile transgranular fracture.

The Meso Challenge is to understand the mechanisms.

Approach

Atom probe tomography was used to evaluate grain boundaries.

Further study is needed to determine the mechanisms whereby the flow stress is elevated above the fracture stress to allow dislocation mobility and ductility.

X-ray Laue diffraction would allow understanding of the stress fields at grain boundaries and the beneficial role of ppm element segregation.

Impact

Mo has unique properties for high energy density applications such as lithium cooled space fission power (e.g. SP-100 and JIMO), if weldment ductility were much improved. Niobium alloys have been suggested for some applications but their creep strength is too low.

At some future time the US will again have funds to go deep into space; weldable Mo and nuclear power are mandatory.

References: Google, "AJ Bryhan"; M.K.Miller, etal ScriptaMet 46 (2002) 299-303

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