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Constitutive Modeling of Ti-6Al-4V at a Wide Range of Temperatures and Strain Rates

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Abstract

Constitutive equations, as extremely useful computational/numerical tools in describing metals' thermomechanical behavior, strongly depend on crystal structure, chemical composition and the range of applied strain, strain rate and temperature. Therefore, utilizing one constitutive equation for a wide range of field variables (strain, temperature, and strain rate) is less likely to accurately capture the behavior observed in experiments. It is particularly challenging to derive an inclusive constitutive model for a multiphase alloy such as Ti-6Al-4V, considering its phase transformation (HCP-BCC crystal structure change), variation in reported chemical compositions and a spectrum of different microstructural morphologies. In this work, a microstructures-based constitutive relation based on the Voyiadjis-Abed (VA) model is presented to describe the thermoviscoplastic behavior of Ti64 Alloy by additively decomposing the coupling effect of temperatures and strain rates on yielding and strain hardening. The present modeling is compared with the empirical relation of Johnson-Cook (JC) at a wide range of temperatures (up to 1000 K) and strain rates (up to 6000 s^{-1}). The isothermal and adiabatic deformation behavior of the alloy are predicted and compared using three different sets of experimental results. The findings of this work suggest that the VA model is more capable in predicting the thermomechanical behavior of the alloy, with at most a 5% deviation compared to experimental results.

Keywords: Constitutive Modeling, Ti-6Al-4V, Temperature, Strain rate