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Internal-state-variable based self-consistent constitutive modeling for hot working of two-phase titanium alloys coupling microstructure evolution

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An internal-state-variable based self-consistent constitutive model was proposed for unified prediction of flow stress and microstructure evolution during hot working of wrought two-phase titanium alloys in both single-beta region and two-phase region. For each constituent phase of titanium alloys, a set of constitutive equations incorporating solution strengthening, Hall–Petch effect, dislocation interaction, and dynamic recrystallization were developed using internal state variable method. The effect of second phase on recrystallization was modeled by considering particle stimulated nucleation and exerting drag force on boundary migration. The constitutive equations of constituent phases were implemented into a viscoplastic self-consistent scheme to predict the overall response of the aggregate. Predictions of the model are in good agreement with experimental results of the Ti–6Al–4V alloy and IMI834 alloy. The model can reproduce many features of the hot working of two-phase titanium alloys, including the dependence of flow stress on temperature, strain rate and alloying elements; the increase of strain rate sensitivity with temperature; the stress and strain partitionings between alpha and beta phases; the relatively high apparent activation energy in two-phase region, the decrease of recrystallization kinetics with temperature in two-phase region; and the decrease of recrystallized grain size with Zener–Hollomon parameter in beta working.

1. Introduction

Two-phase titanium alloys have been gaining extensive applications in many industrial domains due to their excellent comprehensive properties (Leyens and Peters, 2003). Hot working is the most applicable forming process of these alloys. During thermo-mechanical processing of metals and alloys, dynamic microstructure changes (such as recovery and recrystallization) are determined by the processing conditions and initial microstructure of materials (Lin et al., 2005). These have great influence on the deformation behavior during processing as well as the mechanical properties after deformation. Modeling the relationship among microstructure changes, plastic deformation behavior and processing conditions is of significant importance to controlling the forming quality of hot formed components. For two-phase titanium alloys, hot working is carried out in both single β phase field and α + β phase field. The coexistence of hcp α phase and bcc β phase causes significant heterogeneous deformation, and complicates the microstructure development as well as the flow stress behavior (Bieler and Semiatin, 2002). It has been found that the β recrystallization kinetics increases with decreasing temperature and increasing strain rate in subtransus working of two phase titanium alloys, which is quite different from

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