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Constitutive equations and dynamic recrystallization: empirical and physical approaches.

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High speed material forming produces intense and fast strains. The latter, associated with the high speed of deformation inherent to the processes, induce considerable heating of the pieces. Zones of strain localization appear, such as shear bands. On the other hand, other parts of the piece are almost not affected by strain in some cases. Modelling of such phenomena then implies the use of constitutive equations valid over a very wide range of strain, strain rate and temperature.

After an overview of torsion tests and results, a compilation of 304L stainless steel available stress-strain curves is presented. A first empirical model, based on the Voce equation, is proposed to describe the rheology of metals in such deformation conditions. All parameters are fitted to the set of experimental curves. This model sets forth two fundamental differences with the classical Johnson and Cook (1983, 1987) constitutive equation. First, the strain, strain rate and temperature effects are coupled together. Second, stress increases with strain until a steady state value. Furthermore, observations of the parameter variations point out a new criterion that defines a range of temperatures and strain rates where recrystallization occurs.

A second physical constitutive equation based on discontinuous dynamic recrystallization is then proposed. This model is able to predict the evolution of microstructure during deformation of low stacking fault energy materials. Average grain size and average dislocation density are determined as functions of material parameters. Furthermore, the predicted flow stress correctly represents the shape of experimental stress-strain curves. The full exploitation of the steady state results enables the identification of all parameters. A new method is then proposed to estimate grain boundary mobility. Finally, two simplified versions of the model are proposed to provide solutions suited to finite element code.

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