Simple constitutive analysis of AA 7075-T6 aluminium alloy deformed at low deformation temperatures

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The tensile stress–strain behaviour of AA 7075-T6 aluminium alloy deformed at temperatures in the range of 123–248 K, at strain rates between 0·0023 and 0·21 s^{-1} has been analysed in order to develop a rational constitutive description of the material under such deformation conditions. The constitutive formulation has been derived on the basis of the mechanical threshold stress model developed at Los Alamos National Laboratory. The constitutive equation thus proposed is able to separate the contribution of the different components that give rise to the mechanical strength of the alloy. It has been determined that the flow stress of the material arises mainly from the contribution of three different components: athermal barriers to dislocation motion, solid solution and precipitation hardening and work hardening (dislocation–dislocation interaction). The flow stress in each strain increment during the course of plastic deformation is computed recursively from its previous value, before the updating of the deformation temperature and strain rate values. Such a computation is carried out by the numerical integration of the phenomenological work hardening law expressed in differential form. The constitutive description thus proposed provides an accurate prediction of the experimental values of both the flow stress and work hardening rate of the material. Moreover, its formulation in differential form provides a reasonable description of the stress changes that could take place when arbitrary temperatures and strain rate paths are imposed to the material during plastic deformation. It is shown that the formulation is general enough for describing also the constitutive behaviour and stress changes of a different aluminium alloy deformed under hot working conditions, where the material exhibits positive work hardening before achieving saturation at large strains.

Keywords: Constitutive description, AA 7075-T6 aluminium alloy, Low deformation temperatures

List of symbols

A material parameter
b Burgers vector/nm
c_p heat capacity
$d\sigma_\varepsilon/d\varepsilon$ work hardening rate/MPa
e engineering strain
g_0 experimental normalised activation energy
g_{0i} experimental normalised activation energy
$g_{0\varepsilon s}$ experimental normalised activation energy
k Boltzmann constant/J K^{-1}
N number of experimental data points
s engineering stress/MPa
S $(T,\dot{\varepsilon})$ ratio between the current flow stress and the mechanical threshold stress or flow stress at 0 K
T absolute temperature/K
T_0 initial specimen temperature/K

ε effective strain
$\dot{\varepsilon}$ effective strain rate/s^{-1}
$\dot{\varepsilon}_K$ material parameter/s^{-1}
$\dot{\varepsilon}_{Ki}$ material parameter/s^{-1}
$\dot{\varepsilon}_{K\varepsilon s}$ material parameter/s^{-1}
θ_0 initial work hardening rate/MPa
μ, μ (T) temperature dependent shear modulus/GPa
μ_0 shear modulus at 0 K/GPa
ρ density/kg m^{-3}
σ current flow stress/MPa
σ_a athermal flow stress component/MPa

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