Flow stress and ductility of AA7075-T6 aluminum alloy at low deformation temperatures

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ABSTRACT

The present investigation has been conducted in order to develop a rational approach able to describe the changes in flow stress of AA7075-T6 aluminum alloy with deformation temperature and strain rate, when this material is deformed at temperatures in the range of 123–298 K at strain rates in the range of 4×10^{-4} to 5×10^{-2} s^{-1}. The constitutive formulation that has been advanced to accomplish these objectives represents a simplified form of the mechanical threshold stress (flow stress at 0 K) model developed at Los Alamos National Laboratory (Los Alamos, New Mexico, USA). Thus, it is assumed that the current flow stress of the material arises from both athermal and thermal barriers to dislocation motion. In the present case, the effect of three thermal barriers has been considered: solid solution, precipitation hardening and work-hardening. The first two effects do not evolve during plastic deformation, whereas the last one is considered as an evolutionary component of the flow stress. Such an evolution is described by means of the hardening law earlier advanced by Estrin and Mecking (1984) [20]. The law is implemented in differential form and is integrated numerically in order to update the changes in strain rate that occur during tensile tests carried out both at constant and variable crosshead speed. The extrapolation of the hardening components from 0 K to finite temperatures is accomplished by means of the model earlier advanced by Kocks (1976) [19]. The results illustrate that the constitutive formulation developed in this way is able to describe quite accurately both the flow stress and work-hardening rate of the material, as well as temperature and strain rate history effects that are present when deformation conditions change in the course of plastic deformation. The evaluation of the ductility of the alloy indicates that the changes in this property are mainly determined by deformation temperature rather by strain rate. When deformation temperature decreases from 298 to 123 K, ductility also decreases from ~35 to 24%. However, despite these relatively small variations, significant changes in the fracture morphology could be observed on the fracture surfaces of the examined specimens, with the predominance of a mixed ductile-brittle mechanism at lower temperatures.

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1. Introduction

Aluminum alloys are widely employed as structural materials owing to a number of advantages, which include a high strength to density ratio, good ductility, formability and elevated corrosion resistance. Due to these characteristics, such materials are used in a number of important engineering applications that span from low to room temperature.

Particularly, AA7075-T6 aluminum alloy has been extensively used in the aircraft and aerospace industry owing to its high mechanical strength, lightweight, dimensional stability, good vibration-damping characteristics and stiffness, which makes it suitable for a number of weight-critical structural applications as, for example, in some electro-optical devices, sensor and guidance components for flight and satellite systems, aircraft and structural components for helicopters.

Moreover, this alloy has been extensively employed as structural material in pressure cells at low temperatures due to the fact that it has a high neutron transparency, good machinability and because some data concerning its cryogenic mechanical properties are known, although there is some scatter regarding its ductility [1].

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