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# Constitutive base analysis of a 7075 aluminum alloy during hot compression testing

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ABSTRACT

In the field of deformation process modeling, the constitutive equations may properly represent the flow behavior of the materials. In fact, these valuable relationships are used as a calculation basis to simulate the materials flow responses. Accordingly, in the present study a hot working constitutive base analysis has been conducted on a 7075 aluminum alloy. This has been performed using the stress–strain data obtained from isothermal hot compression tests at constant strain rates of 0.004, 0.04 and 0.4 $s^{-1}$ and deformation temperatures of 450, 500, 520, 550 and 580 °C up to a 40% height reduction of the specimen. A set of constitutive equations for 7075 Al alloy have been proposed employing an exponent-type equation. The related material constants (i.e., $A$, $n$ and $\alpha$) as well as the activation energy $Q$ for each temperature regime have been determined. The correlation of flow stress to strain rate and temperature can be deduced from the proposed equations. Furthermore, a change in deformation mechanism has been realized in the semi-solid temperature range. This has been related to the onset of lubricated flow mechanism during processing.



## 1. Introduction

The 7075 aluminum series are very attractive materials to be employed in the automotive and aerospace industries. This is mainly due to their excellent combination of properties such as high strength to weight ratio, fracture toughness, and resistance to stress corrosion cracking (SCC) [1]. In order to suitably design the thermomechanical processing (TMP) parameters, which are in direct relation to the microstructural evolution and consequently mechanical properties of the final product, a comprehensive study of hot deformation behavior of these alloys is of great importance. To date the previous efforts have been mainly dealt with the influences of TMP parameters on the flow behavior of 7075 aluminum alloys at medium temperature range (up to 450 °C) [2,3]. On the contrary, a little attention has been dedicated on the aforementioned effects at higher temperatures (above 450 °C).

The mechanical behavior of the materials under hot working conditions may generally be evaluated by proper constitutive equations, which correlates flow stress, strain rate and temperature. The uniaxial hot compression testing is usually employed to provide the necessary data to extract the constitutive equations. In the previous investigations, various models have been proposed to predict the constitutive behavior in a broad range of metals and alloys [4,5]. As is well established the exponential model is one of the most extended versions of the hot working constitutive equations. However, the exponent-type equation breaks at low stresses. In latter approach, which was proposed by Sellars and McTegart [6], the flow stress of the material has been described by a hyperbolic sine-type law in an Arrhenius-type equation. This would be applicable over a wide range of stresses.

In the present work, the isothermal hot compression testing of a 7075 aluminum alloy has been carried out at different temperatures and strain rates. Relying on the experimental data, the material constants were determined. Subsequent to this, a set of constitutive equations incorporating the effects of thermomechanical parameters (strain rate and temperature) have been derived to model the plastic flow behavior of the experimental alloy during hot working at higher temperatures (above 450 °C).

## 2. Materials and methods

The experimental 7075 alloy was received as extruded bars, the chemical composition of which is given in Table 1. The optical microstructure of the as-received material is shown in Fig. 1. As is seen, the grains are flattened (pancaked) and the second phases are elongated along the extrusion direction. The cylindrical specimens for uniaxial compression testing were machined from the as-received materials with diameter of 8 mm and height of 12 mm in the extrusion direction in accordance with ASTM E209 [7]. The hot compression tests were carried out with a Gotech-AI7000 servo-controlled electronic universal testing machine equipped with electrical resistance furnace. True stress values were recorded using a high accuracy load cell (Model: SSM-DJM-20 kN) measuring load forces down to 1 kg. True strain values were

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