Materials and Design 32 (2011) 487–494

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Implementation of a constitutive model in finite element method for intense deformation

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ARTICLE INFO

Article history:
Received 9 June 2010
Accepted 20 August 2010
Available online 24 August 2010

Keywords:
C. Forming
F. Plastic behavior
A. Non-ferrous metals and alloys

ABSTRACT

Since the constitutive information is one of the most important aspects of material deformation analysis, here a new constitutive model is proposed that can investigate the behavior of material during intense deformation better than existent models. The model that is completely based on physical mechanisms can predict all stages of flow stress evolution and also can elucidate the effects of strain and strain rate on flow stress evolution of material during intense plastic deformation. Here as an application, implementation of the constitutive model in finite element method (FEM) is used to compare two methods of sever plastic deformation (SPD) processes of copper sheet; repetitive corrugation and straightening (RCS) and constrained groove pressing (CGP). The modeling results are in good agreement with the experimental data and show that the hardness uniformity and its magnitude for RCSed sheet are higher than that for CGPed sheet. However, the prominence of these processes in strain uniformity depends on pass number.

1. Introduction

Nowadays, it is well known that theoretical and experimental approaches are two master pillars of scientific research activities. Computer simulation techniques have been widely used in scientific study and in some circumstances, they can be reasonable substitutes to physical experiments. One of the most accurate approaches of computer simulation is finite element method (FEM) that now is being used in all branches of science.

Of the most prosperous applications of FEM is on the material deformation modeling [1–4]. However, it is proved that the constitutive information of material, that defines the mechanical response of material during straining, has an important influence on the results of FEM [5], because mechanical response of material is an important parameter that can strongly affect plastic flow localization, fracture and other plastic related phenomena [6]. Therefore, it is necessary to treat the input constitutive information, cautiously. For investigating this aspect of FEM, modeling should be classified in two sections; first, modeling of small deformation and second, modeling of large deformation.

In small deformation modeling, usually isotropic or perfectly plastic conditions are considered as a constitutive behavior. However, using these assumptions, it is not possible to make predictions with sufficient accuracy [5]. So, in some developed FEM codes, simple empirical work hardening descriptions are used. It should be noted that strain, strain rate, temperature and chemical composition are four important parameters that exert significant effects on mechanical properties of materials [6,7]. Although, empirical relations cannot usually consider all of above parameters, but investigations show that using these relations can make acceptable predictions [8]. The major reason of this prosperity is that the described empirical relations are achieved from the tests carried out in condition near to the process condition.

However, for finite element modeling of intensive deformation, the situation is more complex than that in small deformation. As mentioned, simple definitions such as isotropic hardening or perfectly plastic conditions cannot generate acceptable FEM results [5]. In addition, there are not so many empirical constitutive relations for intense deformation condition and also none of existent relations can consider all of the mentioned parameters. The sole semi analytical model that expresses the constitutive manner of material in intense deformation is proposed by Estrin et al. [9]. This model defines the constitutive manner of materials by considering two competitive phenomena; first work hardening and second work softening. Because of some deficiency in the model, it has been modified by Mckenzie et al. [10] and also by the present authors [11,12]. However, there are some principal problems in this model that cannot be modified. First in the model and also in its modified versions, the effects of process temperature and material chemistry are not considered and, second, although the model considers the work hardening phenomenon through

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0261-3069/$ - see front matter
doi:10.1016/j.matdes.2010.08.033