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Short Communication

Modeling constitutive relationship of Ti40 alloy using artificial neural network

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ABSTRACT

Constitutive relationship equation reflects the highly non-linear relationship of flow stress as function of strain, strain rate and temperature. It is a necessary mathematical model that describes basic information of materials deformation and finite element simulation. In this paper, based on the experimental data obtained from Gleeble-1500 Thermal Simulator, the constitutive relationship model for Ti40 alloy has been developed using back propagation (BP) neural network. The predicted flow stress values were compared with the experimental values. It was found that the absolute relative error between predicted and experimental data is less than 8.0%, which shows that predicted flow stress by artificial neural network (ANN) model is in good agreement with experimental results. Moreover, the ANN model could describe the whole deforming process better, indicating that the present model can provide a convenient and effective way to establish the constitutive relationship for Ti40 alloy.

1. Introduction

Titanium alloys have been increasingly and extensively applied in the field of aerospace because of their excellent combination of high specific strength (strength-to-weight ratio) which is maintained at elevated temperature, their fracture resistant characteristics and exceptional resistance to corrosion [1]. Because the gas turbines need to have good mechanical properties and burn resistance for some key parts, burn-resistant titanium alloys have been gradually received much more attentions by the researchers all over the worlds. In the past few years, Alloy C (Ti–35V–15Cr) from USA [2] and Ti–25V–15Cr–2Al–0.2C from UK [3] have been developed and applied in the engines successfully by Pratty, Whitney and IRC, respectively. Ti40 (Ti–25V–15Cr–0.2Si), a stable β type burn-resistant titanium alloy, was developed by Northwest Institute for Non-ferrous Metal Research of China [4]. In the previous reports about Ti40 alloy, fracture criterion [5], burn resistant mechanism [6], mechanical properties and microstructures [7] have been systemically and deeply studied. Although Ti40 alloy possesses better mechanical properties and burn resistance than other burn-resistant titanium alloys, it is still difficult to deform in hot work processing. Therefore, it is necessary to study the influence of hot processing parameters on flow stress during high temperature deformation and the establishment of accurate constitutive relationship model.

The constitutive relationship (equation) describes the correlation of the dynamic material properties with process parameters such as strain, strain rate and deformation temperature [8]. The understanding of constitutive relationship of materials is a foundation in the theory and process of material-forming for designers. Conventionally, the methods of regression analysis and statistic were carried out to obtain the material constants for developing constitutive equations. However, the affecting factors (strain, strain rate and temperature) of flow stress presents highly complicated non-linear and interaction relationship during hot deformation, thus the application range of constitutive model and the accuracy of the predicted flow stress will be limited. The researches conducted by both Guo and Sha [9,10] and Sun et al. [11] have mentioned the drawbacks concerning the development of constitutive relationship using conventional methods.

Recently, with the rapid development of computational materials science, artificial neural network (ANN) technique is the most suitable for resolving such problems. Unlike the regression approach, ANN model has good generalization performance without needing explicit mathematical and physical knowledge of deformation mechanism. It is a novel way to study the high temperature deformation behavior and some efforts have been made to the applications of ANN in some alloys. Li et al. [12] established the predicting model for the calculation of flow stress of Ti-15–3 alloy based on the ANN method. Reddy et al. [13] attempted to develop a back propagation neural network model to predict the flow stress of Ti–6Al–4V alloy for any given processing conditions. Kapoor et al. [14] used the ANN model to predict the deformation behavior of Zr–2.5Nb–0.5Cu, in the strain rate range of 10^{-3}–$10\ s^{-1}$, temperature range of 650–1050 °C and strain range of 0.1–0.5. However, on the basis of ANN, little research work with regard to the constitutive relationship of Ti40 resistant-burn titanium alloy was reported in the past years. Hence, in the present paper, constitutive

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