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A Modified Johnson–Cook Model for Flow Behavior of Alloy 800H at Intermediate Strain Rates and High Temperatures

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A modified Johnson–Cook model for the flow behavior of alloy 800H at intermediate strain rates and high temperatures is presented. The modification is based on a study of the relation between strain hardening and both strain rate and softening parameters. The predicted stresses obtained using the modified model are compared to those obtained using the original Johnson–Cook model. The parameters constitute the two models are determined using the inverse method, Kalman filter. The results show that the modified model fits the experimental data very well for different combinations of strain rates and temperatures, with a mean value of R-squared regression of 0.90 for the modified model and 0.74 for the original Johnson–Cook model.

Keywords alloy 800H, high temperatures, intermediate strain rates, Johnson–Cook model, Kalman filter

1. Introduction

Alloy 800H is a solid solution-strengthened, iron–nickel–chromium alloy with controlled levels of carbon, aluminum, and titanium (Ref 1). The alloy has a high creep and rupture strength and has the ability to resist corrosion at high temperatures; therefore, it has been widely used in applications subjected to high strain rates and high temperatures such as pressure vessels and heat exchanger in nuclear applications (Ref 2, 3). Actually, the strain rate and temperature hot deformations have a significant impact on the plastic flow behavior of alloy 800H, since the dislocation movements are affected by strain rate and softening processes.

Johnson and Cook (Ref 4) presented their famous constitutive model to study the plastic flow behavior of metals at different strain rates and different temperatures. The model can be divided into three parts; one part is related to the strain hardening, another part is associated with the strain rate, and the third part is affiliated to the softening. The model has been widely used to determine material constants for different metals and alloys (Ref 5-8). Also, it has been implemented in finite element packages to predict the flow behavior of metals (Ref 9-11). In fact, the Johnson–Cook model assumes that there is no interaction between the strain hardening, the strain rate parameter, and the temperature parameter, which makes it fail to accurately predict the dynamic behavior for some metals and alloys. To accurately predict the flow behavior of metals and alloys, many modifications for the Johnson–Cook model are presented (Ref 12-17).

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Undoubtedly, the finite element simulations using Johnson–Cook model strongly depend on the determined model parameters. Therefore, an accurate determination of the model parameters is needed. A Kalman filter, an inverse method, is a recursive method to determine parameters from noisy experimental data (Ref 18). The Kalman filter has many advantages; it takes the measurements and parameter noises into considerations, it covers a wide range of the initial selected parameters required to start the Kalman processes, it takes the nonlinear behavior of materials into account. The Kalman filter has been used to identify parameters for different materials (Ref 19-22).

In this work, a modified Johnson–Cook constitutive model to predict the flow behavior of alloy 800H at intermediate strain rates and high temperatures will be presented. The modification is based on a study made between strain hardening and both strain rate parameter and softening parameter. The stresses obtained using the modified Johnson–Cook model will be compared to those obtained using the original Johnson–Cook model. In order to identify the model parameters, the Kalman filter technique will be used to determine the alloy 800H constants in both models. The Kalman filter minimizes the mean square error between measured stresses and predicted stresses. The possible interactions between the model parameters are taken into account during the Kalman filter processes. The experimental stress–strain data used in this work will be captured from the experiments made by Cao et al. (Ref 23).

2. Materials and Experimental Methods

The dynamic behavior of alloy 800H at intermediate strain rates and high temperatures was presented by Cao et al. (Ref 23). In their work, the experiments were conducted in a combination of strain rates 5, 10, and 20 1/s and temperatures 1123, 1173, 1223, 1273, and 1323 K. The microstructure, the chemical composition, and the experimental stress–strain curves at different combinations between the mentioned strain rates and temperatures of the alloy 800H used in this work can be found in Ref 23.