

Hot Deformation Behavior of 2Cr13 Stainless Steel

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Abstract. The hot deformation behavior of 2Cr13 martensitic stainless steel was investigated through isothermal compression tests using a Gleeble-3500D thermal-mechanical simulator in a temperature range of 1223-1423 K and strain rate of 0.01-10 s⁻¹. The material constants in the constitutive equation are determined by the linear fitting method. The hot deformation apparent activation energy of 2Cr13 martensitic stainless steel is calculated about 363.313 kJ/mol.

1. Introduction

Martensitic stainless steels are corrosion-resistant and long-lasting and can be exploited in a wide range of construction applications. Martensitic stainless steels can work under erosion medium and high temperature [1]. They are usually used for manufacturing components such as pressure vessels, steam generators, and turbine blades. In the past, researches about martensitic stainless steel mainly focus on the corrosion resistance. Fu et al. [2] investigated the influences of silicon plasma immersion ion implantation and nitrogen on the corrosion resistance of martensitic stainless steel. Xi et al. [3] investigated the effect of low temperature plasma nitriding on the wear and corrosion resistance of martensitic stainless steel. Mahmoudi et al. [4] investigated the effects of laser pulse energy, duration time and travel speed on the depth and hardness of surface-hardened laser treated area of martensitic stainless steel and the corrosion properties. Mahmoudi et al. [5] investigated the susceptibility of stress corrosion cracking of martensitic stainless steel which was surface transformed hardened by the U-Bend method. However, little work has been done about the hot deformation behavior of martensitic stainless steel.

In this paper, the hot deformation behavior of 2Cr13 martensitic stainless steel was investigated in the temperature range of 1223-1423 K and strain rate range of 0.01-10 s⁻¹.

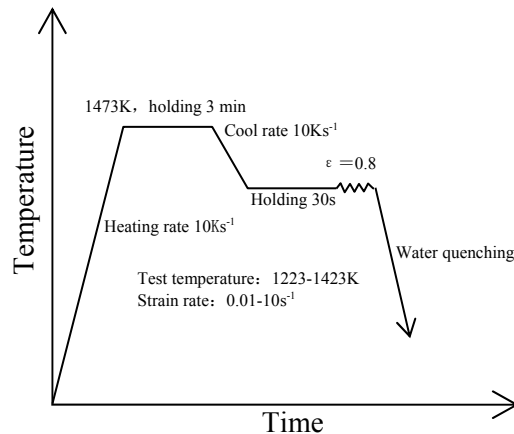
2. Material and Experimental

The material used in the present investigation is 2Cr13 martensitic stainless steel. The chemical composition of the steel is shown in Table 1. The cylindrical specimens with a diameter of 10 mm and a height of 15 mm used in this hot compression test were machined from the as-received hot forged bar. All the specimens were heated with the heating rate of 10 Ks⁻¹ to 1243 K and held for 3 min. Then the specimens were cooled to the test temperature with the cooling rate of 10 Ks⁻¹. The isothermal compression tests were carried out at the temperature of 1223K, 1273K, 1323K, 1373K and 1423 K and strain rate range of 0.01-10 s⁻¹ using the Gleeble-3500D thermo-mechanical simulator. All the specimens were compressed to a true strain of 0.8.



Table 1. Chemical composition of 2Cr13 martensitic stainless steel (wt. %).

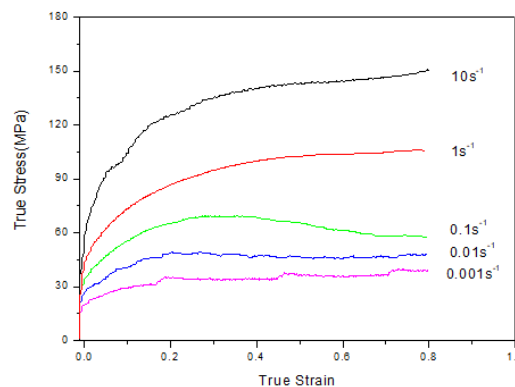
C	Cr	Si	Mn	P	S
0.19	0.131	0.18	0.16	0.02	0.004

**Figure 1.** Schematic representation of hot compression test.

3. Results and Discussions

3.1. True Stress-Strain Curves

The typical true stress-strain curves of 2Cr13 martensitic stainless steel at 1423K are shown in Fig. 2. It can be seen that the flow stress will increase with the increasing of strain rate at the given temperature. When the strain rates are low, such as 0.01s^{-1} , 0.05s^{-1} and 0.1s^{-1} , the flow curves show a single peak followed by a decrease of stress and finally reach a plateau. This indicates the occurrence of the dynamic recrystallization phenomenon. When the strain rates are relatively high, such as 1s^{-1} , 5s^{-1} and 10s^{-1} , the flow curves show no peak stress. This implies the dynamic recovery character.

**Figure 2.** Typical true stress-strain curves of 2Cr13 martensitic stainless steel at 1423K .

3.2. Constitutive Equation Establishment

The relationship among the stress, the strain rate and the deformation temperature during the plastic deformation process of metallic materials can be expressed by Eq. (1) [6].

$$Z = \dot{\epsilon} \exp\left(\frac{Q}{RT}\right) = f(\sigma) \quad (1)$$

Where σ is stress, $\dot{\epsilon}$ is strain rate, Q is the activation energy of deformation, T is the absolute temperature. It can be seen from this equation, the Z parameter is also considered as a function of stress. It's obviously that the Z parameter is also considered as a function of stress and can be related to the stress in different ways [7]:

$$Z = f(\sigma) = A' \sigma^{n'} \quad (2)$$

$$Z = f(\sigma) = A'' \exp(\beta \sigma) \quad (3)$$

$$Z = f(\sigma) = A [\sinh(\alpha \sigma)]^n \quad (4)$$

Where A' , A'' , A , n' , n , β , and α are material constants and $\alpha = \beta / n'$. The Eq. (2) is preferred for relatively low stress while the Eq. (3) is suitable for high stress. The Eq. (4) can be applied in a wide range of strain rate and temperature. Thus, the Eq. (4) is used to investigate the hot deformation behavior of 2Cr13 martensitic stainless steel in this study.

Substituting the Eq. (2), Eq. (3) and Eq. (4) into Eq. (1) and taking the logarithm and rearranging separately, the following equations can be gained:

$$\ln \dot{\epsilon} = n' \ln \sigma + \ln A' - (Q / RT) \quad (5)$$

$$\ln \dot{\epsilon} = \beta \sigma + \ln A'' - (Q / RT) \quad (6)$$

$$\ln \dot{\epsilon} = n \ln(\sinh(\alpha \sigma)) + \ln A - (Q / RT) \quad (7)$$

The peak stress values were used as the characteristic stresses to calculate the material constants as shown in Fig. 3. As shown in Fig. 3(a) and Fig. 3(b), the mean values of β and n' were determined as 0.06 and 7.346, respectively. The values of n and $\ln A$, which can be calculated from Fig. 3(c), are 5.434 and 30.862, respectively. The value of activation energy is determined as 363.313 KJ/mol as shown in Fig. 3(d).

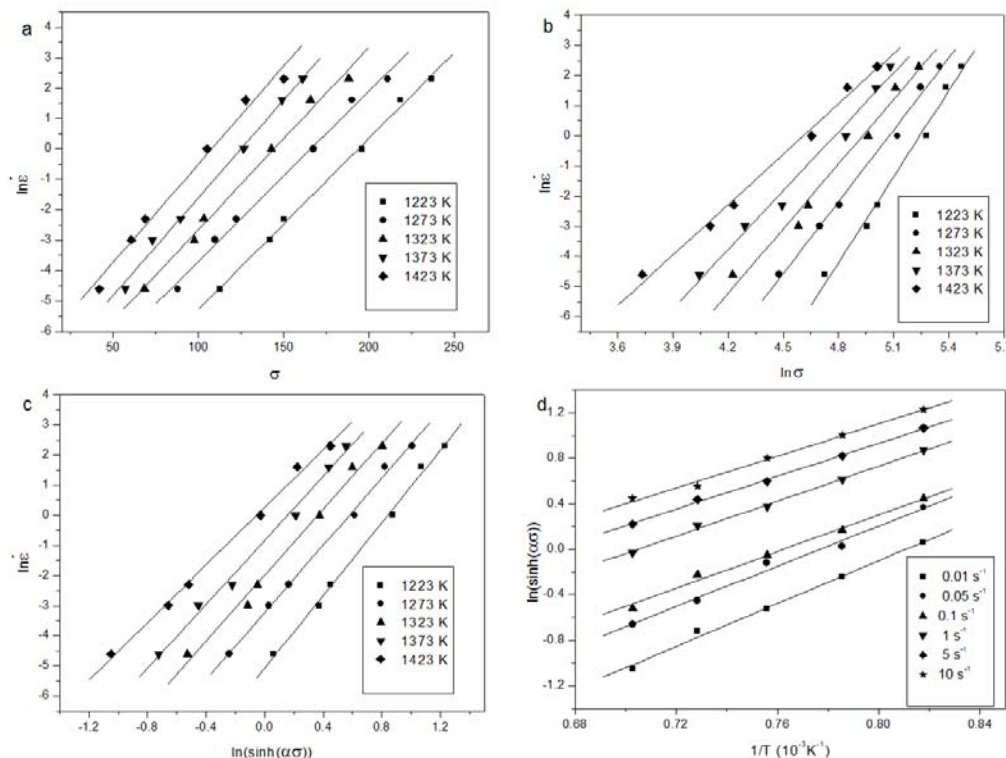


Figure 3. Plots used for the determination of material constants.

Thus, the constitutive equation for 2Cr13 martensitic stainless steel can be expressed as follows:

$$Z = \dot{\varepsilon} \exp\left(\frac{363313}{RT}\right) = 2.53 \times 10^{13} \left[\sinh(0.0082\sigma)\right]^{5.434} \quad (8)$$

4. Conclusion

The hot deformation behavior of 2Cr13 martensitic stainless steel has been studied by hot compression tests in strain rate range of 0.01-10 s⁻¹ and the temperature range of 1223-1423 K. The deformation temperature and strain rate have obvious effect on the flow stress of 2Cr13 martensitic stainless steel. The hot deformation apparent activation energy of 2Cr13 martensitic stainless steel is calculated as 363.313 KJ/mol.

Acknowledgments

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