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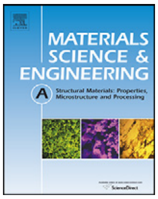

Research on the dynamic recrystallization behavior of GCr15 steel

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ABSTRACT

The dynamical recrystallization (DRX) of GCr15 steel was investigated at deformation temperatures of 950–1150 °C and strain rates of 0.1–10 s^{-1} on a Gleeble-3800 thermo-mechanical simulator. The stress–strain curves at lower strain rates are typical of the occurrence of DRX and exhibit a peak in the flow stress before reaching steady state. The flow stress at higher strain rates increases rapidly to the maximum too, but followed by a steady region. The microstructures after deformation certify that DRX takes place in all specimens. And the results show that DRX occurs more easily with the decrease of strain rate and the increase of deformation temperature. Using regression analysis, the DRX activation energy of the steel, the relationship of critical strain and deformation conditions were determined. In order to determine the recrystallized fraction under different conditions, an approximate model based on the stress–strain curves was investigated, and the kinetic model for DRX was established.

1. Introduction

Dynamic recrystallization (DRX) is of interest because it softens metals during hot forming and plays an important role in their microstructural evolution. Whilst the microstructural change can affect the macroscopic characteristics of workpiece. In addition, it affects the mechanical properties of the formed product, such as strength, ductility, toughness and resistance against corrosion. So it is of great importance to investigate the DRX behavior and austenite microstructural evolution of metals.

Considerable research [1–13] on the DRX behavior of different steels has recently been carried out, but few investigators have focused their studies on the DRX behavior and microstructural evolution of GCr15 steel. In the present paper, the effect of different deformation conditions on the DRX behavior of the steel will be described in detail. The work is helpful in optimizing thermo-mechanical production of GCr15 steel product.

2. Experimental material and procedures

GCr15 steel employed in the present investigation is provided in the form of bar with the diameter of 15 mm by Dongbei Special Steel Group. The initial microstructure of the material is lamellar pearlite and the chemical composition is 0.99C, 0.24Si, 0.31Mn, 0.010P, 0.003S, 1.44Cr, 0.05Ni, 0.12Cu and 0.02Mo, all numbers given in wt.%.

Before the experiment, the compression specimens, with the diameter of 8 mm and the length of 12 mm, were machined with their cylinder axes parallel to the axial line direction of the bar, and smooth end faces of specimens ensured a single stress state during the deformation. The single hot compression tests were carried out on the Gleeble-3800 thermo-mechanical simulator. Fig. 1 shows the heat treatment and deformation process of the steel. All specimens were heated to 1150 °C at the heating rate of 5 K/s. After heated for 8 min at 1150 °C to produce the desired initial austenite grain size and ensure that the specimens had a uniform starting temperature, the specimens were cooled down to the deformation temperatures of 950, 1000, 1050, 1100 and 1150 °C and deformed at strain rates of 0.1, 1, 5 and 10 s^{-1}. The stress–strain curves were obtained from the load–displacement data. Immediately after each test, the specimens were quenched in water to retain the crystal boundary of high temperature austenite microstructures. Finally, the specimens were sectioned through the longitudinal axis, and the microstructures were examined by optical microscopy. In order to compare these microstructures with initial ones without deformation, a specimen was heated to 1150 °C and held for 8 min, then immediately cooled down to room temperature without deformation and examined by optical microscopy.

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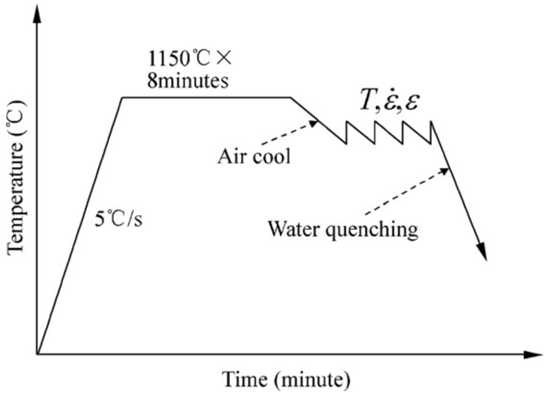

Fig. 1. Heat treatment and deformation process of the steel.

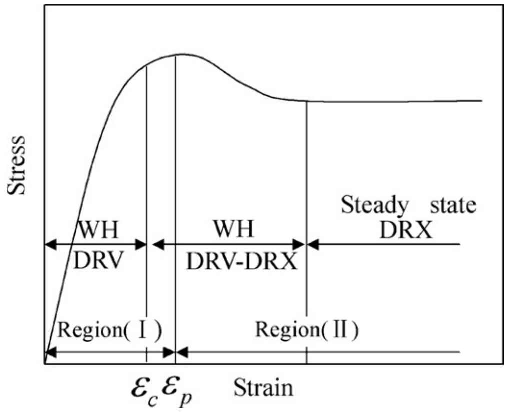

Fig. 3. Schematic diagram of the stress–strain curve for DRX.

3. Result and discussion

3.1. Stress–stain curves and the microstructures

The stress–strain curves for the steel tested in different temperatures and strain rates are shown in Fig. 2. The curves can indicate the effect of work hardening and microstructural evolution in the specimens.

As is shown in Fig. 2, both strain rate and deformation temperature have a considerable effect on the flow stress. The flow stress increases with the increase of strain rate at the same deformation temperature and strain. On the contrary, the flow stress decreases with the increase of temperature at the same strain rate and strain.

Fig. 3 shows a schematic diagram of stress–strain curve [3] at high temperature when the DRX occurs. The curve represents two distinct regions. In region (I), the deformation of metals shows work hardening to a peak stress followed by region (II) which represents a decrease in stress to a steady state value at large strains owing to the occurrence of DRX. As shown in Fig. 2, the stress–strain curves of the steel deformed at the strain rates 0.1 and 1 s^{-1}, which exhibit a typical DRX behavior, are similar to the curve in Fig. 3. The curves display a rapid initial increase to a stress maximum, characterized by a peak strain and peak stress, followed by a gradual fall to the steady state stress as a result of the DRX in the specimens. In addition, the curves show that as the deformation temperature increases, the stress rises to a peak at smaller strain. It indicates the decrease of the peak strain and the critical strain for the start of DRX and demonstrates that increasing temperature can promote the occurrence of DRX. The possible reason is that the composition diffusion which provides a powerful backing for DRX strengthens at high temperature.

The stress of the steel deformed at the strain rates 5 and 10 s^{-1} increases rapidly to the maximum too, but followed by a steady

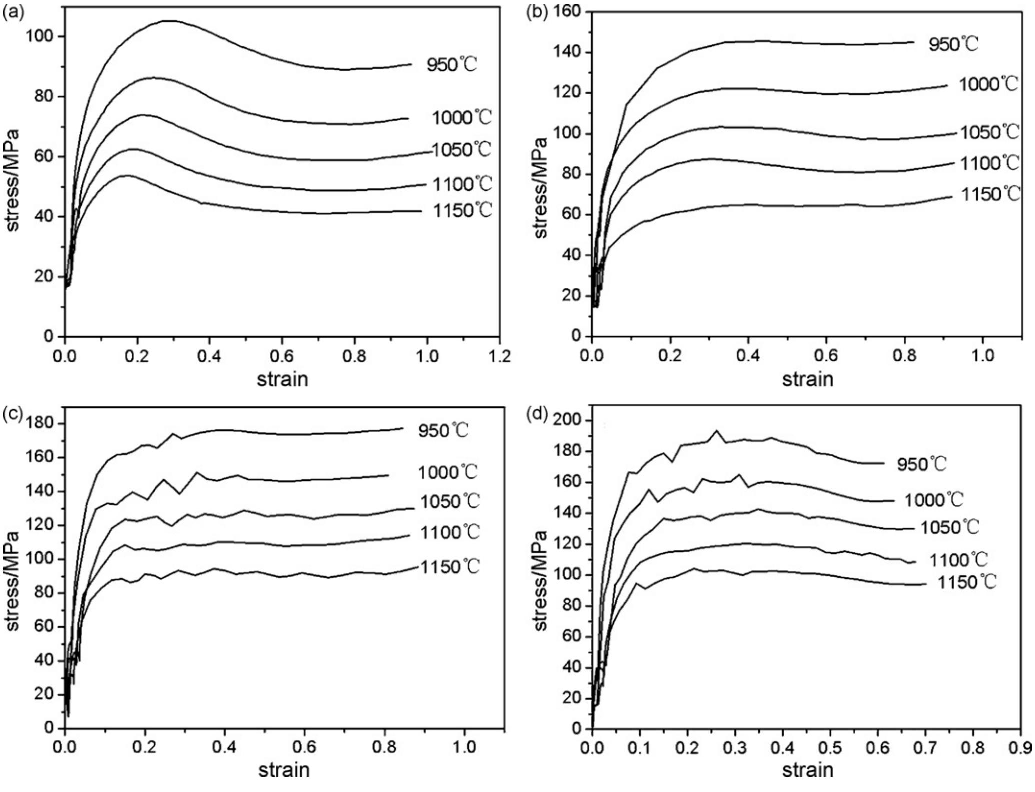

Fig. 2. Stress–strain curves under different deformation conditions ((a) $\dot{\varepsilon} = 0.1\,s^{-1}$; (b) $\dot{\varepsilon} = 1\,s^{-1}$; (c) $\dot{\varepsilon} = 5\,s^{-1}$; (d) $\dot{\varepsilon} = 10\,s^{-1}$).