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The microstructure evolution and nucleation mechanisms of dynamic recrystallization in hot-deformed Inconel 625 superalloy

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ABSTRACT

Hot compressions tests of Inconel 625 superalloy were conducted using a Gleeble-1500 simulator at different strains between 900 °C and 1200 °C with a strain rate of 0.1 s^{-1}. Optical microscope, transmission electron microscope and electron backscatter diffraction technique were employed to investigate the microstructure evolution and nucleation mechanisms of dynamic recrystallization. It was found that both the size and fraction of dynamically recrystallized grains increase with increasing deformation temperature. However, the size of dynamically recrystallized grains almost remains constant with increasing deformation strain. The dominant nucleation mechanism of dynamic recrystallization in Inconel 625 superalloy deformed at 1150 °C is the discontinuous dynamic recrystallization, which is characterized by the bulging of the original grain boundaries accompanied with twining. The continuous dynamic recrystallization characterized by progressive subgrain rotation occurs simultaneously in dynamic recrystallization process, although it can only be considered as an assistant nucleation mechanism at the early stage of hot deformation.

1. Introduction

Nickel-based superalloy Inconel 625 was developed as a solid-solution-strengthened alloy containing relatively high levels of chromium, molybdenum, carbon and niobium [1,2]. It is widely used in aeronautical, aerospace, chemical, petrochemical and marine applications, due to its good mechanical properties, processability, weldability and resistance to high temperature corrosion on prolonged exposure to aggressive environments [3,4]. To obtain a superior performance, the microstructure of the alloy during hot deformation should be controlled [5–8], which is closely related to the dynamic recrystallization (DRX) process [9–14]. Thus, much attention has been paid to the nucleation mechanism of DRX in nickel-based superalloy.

Recently, the microstructure characteristics, recrystallization behavior and mechanisms of DRX in nickel-based superalloys have been extensively studied by hot torsion or hot compression [15–18]. However, there are few reports on the microstructure evolution and the exact operating mechanisms of DRX in Inconel 625 superalloy during hot deformation. The aim of the present study is to investigate the influence of temperature and strain on the DRX microstructure evolution of Inconel 625 superalloy during hot deformation, and to clarify the nucleation mechanisms of DRX.

2. Experimental

2.1. Specimen and heat treatment

A forging bar of Inconel 625 superalloy with a nominal diameter of 200 mm is used in the present study, and the chemical compositions of the specimen are listed in Table 1. A mixture of extensively serrated and bulging grains is the main feature of the as-received materials, although some deformation twins are also observed, as shown in Fig. 1.

Cylindrical specimens with dimension of Φ 8 × 12 mm were machined from the center part of the forging bar. The specimens were annealed at 1200 °C for 30 min followed by water quenching to room temperature to obtain a fine homogeneous γ phase with carbides solute in the matrix. Equiaxed grains are presented in the annealed Inconel 625 superalloy with an average grain size of 81 μm, and some annealing twins also exist, as shown in Fig. 2.

2.2. Hot compression and microstructure characterization

Hot compression tests were carried out on a Gleeble-1500 simulator at different strains between 900 °C and 1200 °C with a strain rate of 0.1 s^{-1}. Based on the deformation map of nickel-based superalloy [8], the lowest deformation temperature is selected as 900 °C to induce the DRX process during deformation. Each specimen was heated to the setting temperatures at a rate of 10 °C/min by high frequency induction heating equipment attached to the

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