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Hot compressive deformation behavior of a new hot isostatically pressed Ni–Cr–Co based powder metallurgy superalloy

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ABSTRACT

The hot compressive deformation behavior of a new hot isostatically pressed Ni–Cr–Co based powder metallurgy (P/M) superalloy was studied in the temperature range of 950–1150 °C and strain rate range of 0.0003–1 s^{-1} using Gleeble-1500 thermal simulator. The dynamic recrystallization-time–temperature (RTT) curve was developed and the constitutive equation of flow stress during hot deformation was established. The results show that the flow stress decreases with increasing deformation temperature and decreasing strain rate. The flow stress represents as the characteristic of dynamic crystallization with the increasing of strain at the deformation temperatures lower than 1100 °C and strain rates higher than 0.0003 s^{-1}. The beginning time of dynamic crystallization has no linear relationship with deformation temperature in the condition of strain rate lower than 0.01 s^{-1}. Besides, the experiments verify that the hyperbolic sine model including the variable of strain reflects the changing law of flow stress during the hot deformation process.

1. Introduction

The γ' precipitate strengthened Ni–Cr–Co based superalloy combines excellent oxidation resistance with mechanical properties at high temperatures. The powder metallurgy (P/M) route has been found to be attractive for the manufacture of turbine components in Ni–Cr–Co based superalloys [1,2]. While hot isostatic pressing (HIP) and other techniques are developed for powder consolidation, the need for a subsequent isothermal forging process is well recognized because deformation processing at elevated temperatures helps in mitigating the undesirable effect of prior particle boundaries (PPB) [3,4]. The trial and error methods are generally employed in selecting the hot deformation processing parameters while the recently developed technique of numerical simulation is found to be very useful in optimizing workability and controlling microstructure [5,6]. Based on the published chemical compositions of the typical third generation P/M superalloys [7–9], a new Ni–Cr–Co based P/M superalloy was designed with the aid of the thermodynamic calculation results [10] and d-electron theory [11,12]. Compared with the first and second generations P/M superalloys, the new alloy is designed for thermal stability in long time service condition and controls the precipitation of topologically close packed (TCP) phases. It produces the mass ratios of Al/Ti and Nb/Ta to be of unity, in order to achieve the desired combination of properties [13]. It also adds a certain amount of Hf, to enhance the comprehensive performance [14]. The alloy possesses heat resisting properties up to about 760 °C. The excellent working and mechanical properties make it a potential material for gas turbine applications as well as high-temperature attaching parts. The related researches on the isothermal forging process [9,15] indicated that the hot deformation process of the third generation P/M superalloys became more difficult because more alloying elements were added in. Meanwhile the mechanical properties of superalloys are highly sensitive to the microstructural evolution during hot deformation. So the hot deformation behavior of the third generation P/M superalloys is one of the most important research topics in recent years.

Constitutive equation can be used to describe the change of flow stress with the variation of processing parameters such as deformation strain, temperature and strain rate [16]. It is one of the most important inputs for the numerical simulation of isothermal forging. Bruni et al. [17] studied the flow behavior of Nimonic 115 with the variation of processing parameters and established a constitutive model of flow stress. Thomasa et al. [18] discussed the

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