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Influences of Process Parameters to Microstructural Evolution in Thermal Deformation of GH4169 Alloy

Fang Qian[1, *], Zhongtang Wang[2]

[1]School of mechanical engineering, Inner Mongolia University for Nationality, Tongliao 028000, China
[2]School of materials science and engineering, Shenyang Ligong University, Shenyang 110159, China

*Corresponding author e-mail: janeeyie@126.com

Abstract. It studied the organization form of GH4169 alloy which had been obtained with different temperatures, strain-rates, deformations and original grain sizes by the high temperature hot compression tests. Influence laws of process parameters to microstructure evolution during hot deformation were gotten. The results showed that the grain group was hybrid when the temperature below 940℃, while complete recrystallization happened above 1020℃. Uniform equiaxed grains had been gotten with the strain-rate below $0.01s^{-1}$, and temperatures between 980-1020℃.

1. Introduction

GH4169 (IN718 in America) alloy based on nickel is one of high temperature deformation alloy with face-centered and body-centered cubic precipitation strengthen, it has excellent comprehensive performance with higher tensile strength and yield strength,better plastic and corrosion resistance at the temperature below 650℃ [1]. Results were obtained about microstructure evolution of GH4169 alloy at home and abroad.Mirshams etc. had studyed the recrystallization model and influencing factors of grain size of IN718 alloy [2]. Cihak etc. had studyed the elimination method of residual stresses and the influence of process parameters on the quality of forgings during turbine forging of IN718 alloy [3]. Kashyap etc. had studyed the microstructure evolution and fluidity during annealing of IN718 alloy [4].Forecast of grain size evolution at hot forging of turbine disk was the same to the actual result of GH4169 alloy by ZHANG Haiyan etc. [5]. LIU Dong etc. had put forward a method to establish material constitutive relationship based on microstructure evolution, it reflected a complex interaction between deformation, heat transfer and evolution [6]. ZHANG Yan etc. had found the relationship between deformation resistance, deformation and strain-rates by the study of behavior during different compression deformation of GH4169 alloy [7]. LI Zhi qiang etc.established the microstructure evolution model during hot compression tests and verified the accuracy of the model [8]. On the basis of all, this article analyzed the impact of process parameters to microstructure transformation such as temperatures, strain-rates, deformation and original grain sizes of GH4169 alloy, it obtained reasonable process parameters which can be a reference to the organization research of high temperature alloy.

2. Thermal simulation experiment

The sides of cylindrical test sample was Φ8mm×12mm,the original organization of the sample was shown as Fig.1 which was obtained with 1020℃ homogenizing treatment temperature and 15min thermostatic treatment.It can be seen that the original organization was uniform and full of equiaxed grains,the average grain size was 13.21μm. Conditions of the tests with Gleeble3500 thermal simulator was:

Temperature (℃): 900, 940, 980, 1020, 1060, 1100;
Strain-rate (s^{-1}): 1, 0.1, 0.01, 0.001;
Deformation: 50%

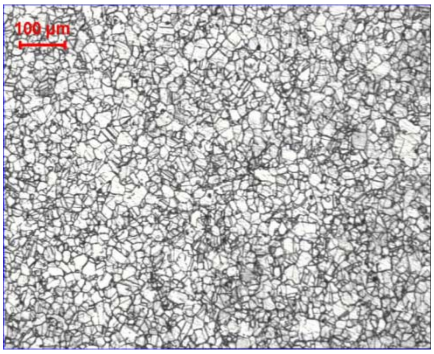
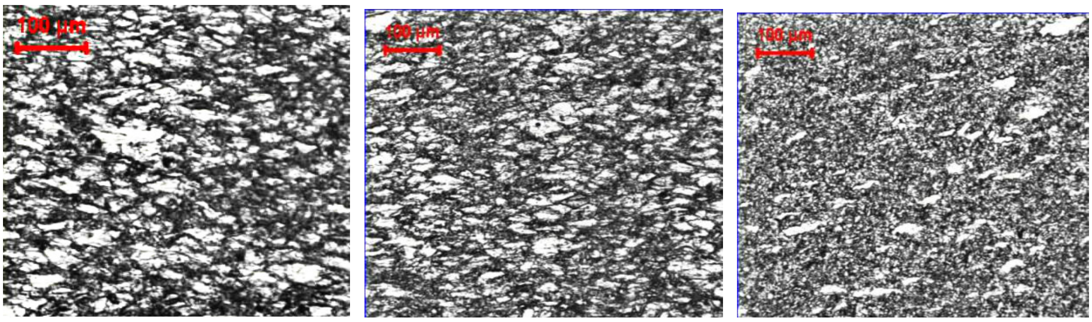


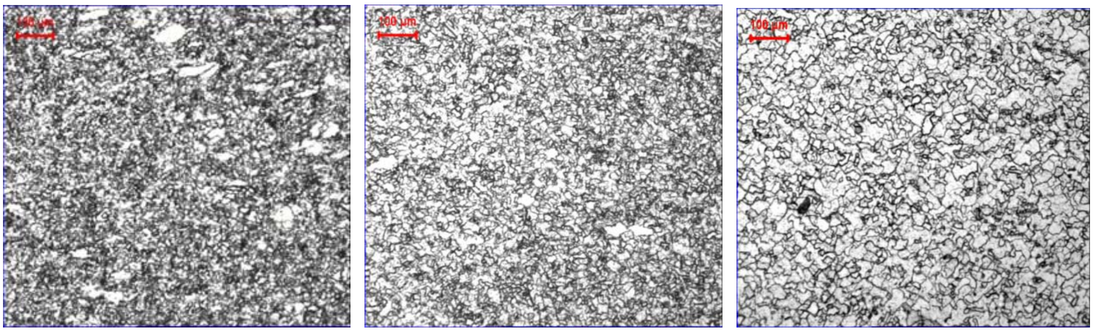
Figure 1. The original organization of GH4169 alloy.

3. Impact of temperature to organization

It was shown as Fig.2 that dynamic recrystallization was found from the organization obtained with strain-rate of $0.01s^{-1}$ and real strain of 0.693 and different temperatures. Mixed grain structure was found when below 940℃, then recrystallization grain grown to equiaxed grain with the temperature growth.The completely dynamic recrystallization appeared with temperature above 1020℃. It proved that higher temperature, more likely to get recrystallization. The degree and grain size of dynamic recrystallization grew with temperature growth. The uniform equiaxed grain structure can be found with strain-rate of $0.01s^{-1}$ and higher than 980℃.



(a) 900℃ (b) 940℃ (c) 980℃

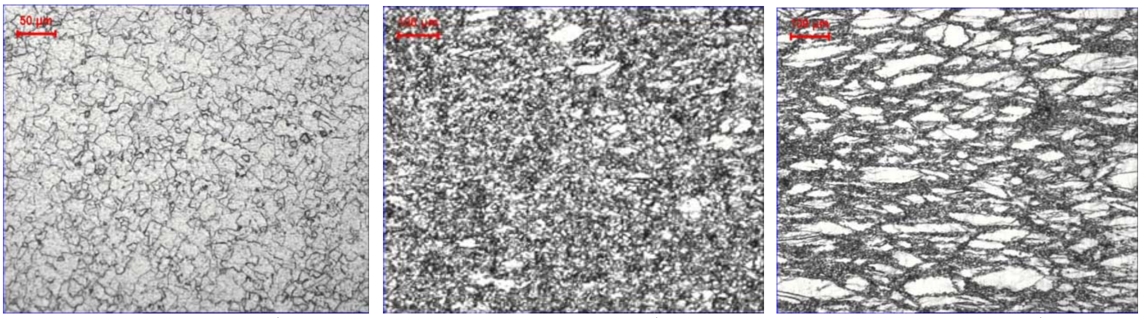


(d) 1020℃ (e) 1060℃ (f) 1100℃

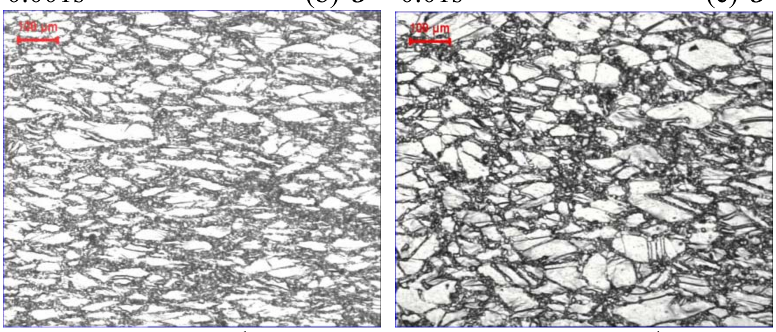
Figure 2. The microstructures with different temperatures ($\dot{\varepsilon} = 0.01\text{s}^{-1}$, $\varepsilon = 0.693$).

4. Impact of strain-rate to organization

It was shown as Fig.3 that dynamic recrystallization was found from the organization gained with temperature of 1020℃ and real strain of 0.693 and different strain-rates.The scope of dynamic recrystallization expanded and grains grew smaller as strain-rates became lower.The larger degree may be due to the higher deformation temperature caused by the accumulation of deformation heat. The completely dynamic recrystallization appeared with strain-rate below 0.01s^{-1}.



(a) $\dot{\varepsilon} = 0.001\text{s}^{-1}$ (b) $\dot{\varepsilon} = 0.01\text{s}^{-1}$ (c) $\dot{\varepsilon} = 0.1\text{s}^{-1}$

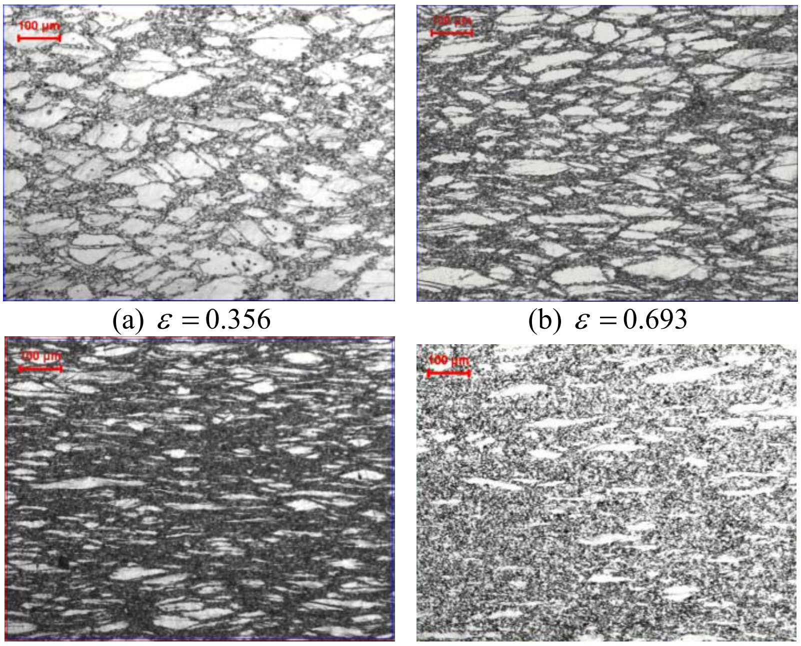


(d) $\dot{\varepsilon} = 1\text{s}^{-1}$ (e) $\dot{\varepsilon} = 10\text{s}^{-1}$

Figure 3. The microstructures with different strain-rates (T=1020℃, $\varepsilon = 0.693$).

5. Impact of deformation to organization

The microstructure gained with temperature of 1020℃ and real strain-rate of $1\text{s}^{-1}$was shown as Fig.4. Along with deformation, original grains were elongated and replaced by new dynamic recrystallization grains.The volume fraction of dynamic recrystallization grains grew as deformation increased, but not the grain size. It showed that the affection of deformation to recrystallization volume is great, but not obvious to the grain size.



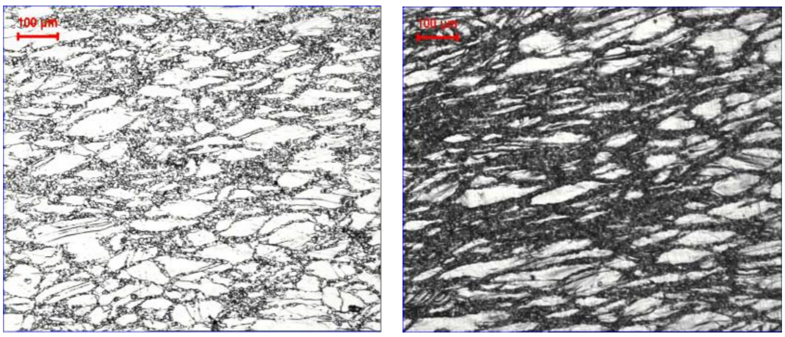
(a) $\varepsilon = 0.356$ (b) $\varepsilon = 0.693$

(c) $\varepsilon = 0.896$ (d) $\varepsilon = 1.2$

Figure 4. The microstructures with different strains (T=1020℃, $\dot{\varepsilon} = 1s^{-1}$).

6. Impact of original grain size to organization

The microstructure gained with temperature of 1060℃ and real strain-rate of $1s^{-1}$was shown as Fig.5. It showed that dynamic recrystallization volume decreased with the increase of original grain size.There were huge energy barriers in crystallization process and disorganization at grain boundary where serious lattice distortion and high distortion energy appeared.So,dynamic recrystallization appeared firstly in the grain boundary.The larger original grain size due to the shorter grain boundary, less potential of distortion, more narrow recrystallization nucleation area and less amount of dynamic recrystallization.



(a) 32.56μm (b) 63.06μm

Figure 5. The microstructures with different original grain sizes (T=1060℃, $\dot{\varepsilon} = 1s^{-1}$).

7. Conclusion

(1) Mixed grain structure was found when below 940℃, then recrystallization grain grew to equiaxed grain as the temperature grown.The completely dynamic recrystallization appeared with temperature above 1020℃.

(2) The uniform equiaxed grain structure can be found with strain-rate of $0.01s^{-1}$ and temperatures between 980 to 1020℃.

(3) The dynamic recrystallization grain size increased with the increase of deformation temperature and the decrease of strain-rate, the lower the strain-rate, the more the degree of grain growth.

(4) The volume of dynamic recrystallization increased with the increase of temperature and the deformation degree, decreased with the increase of original grain size.

Acknowledgments

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