Effect of Uniaxial Stress on Microstructure Evolution during Isothermal Aging for Ni-Based Superalloy Alloy 80A

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In this study, the effect of uniaxial stress on microstructure evolution during isothermal aging in Alloy 80A. Ni-based superalloy widely used as a high-temperature structural material was investigated. As a result, after stress aging, γ' the alignment phenomenon associated with becoming cuboidal shape of precipitated particles preferentially occurs in the direction of the stress axis. Under stress aging, the introduction of dislocations promotes incoherency of γ' particles, especially when the strain exceeds about 4.5 %, where globular shape becomes apparent. However, stress has not affected on the coarsening rate of γ' particles.

Keywords: *nickel-based superalloy, microstructure, creep, gamma-prime phase*

1. Introduction

Ni-based superalloys are widely used as structural materials for parts exposed to high temperature and high pressure, such as jet engines for aircrafts and gas turbines for thermal power generation(1), because of their excellent high-temperature strength, oxidation resistance, corrosion resistance, etc. Such performance is achieved by precipitation dispersion strengthening of γ' particles.

Ni-based superalloys have been investigated to control the microstructure of γ'-precipitated particles. Alloy 80A used in this study has a medium γ' volume fraction and misfit(2) (3). Yamaguchi et al. reported that the morphology of γ' precipitates changes from spherical to cubic by simple aging treatment. The particles were also observed to be aligned in three <001> directions as they changed to a cuboidal shape(4). However, the morphological process of precipitated particles during stress aging has not been reported. The objectives of this study are: 1) whether the alignment phenomenon occurs in three equivalent directions during stress aging; 2) whether the becoming incoherent occurs in a short period of time due to stress loading; 3) whether the coarsening rate of γ' particles is affected by stress.

2. Experimental

The specimen was a Ni-based superalloy Alloy 80A. The solution treatment was firstly performed on the specimens at 1423 K for 1 h. Stress aging was then performed at 1173 K at 50 MPa and interrupted from 20 h to 500 h. Microstructural observation of the obtained specimens was performed using FE-SEM and TEM.

3. Results and Discussion

3.1 Creep curve

Fig. 1 shows the creep curve at 50 MPa/500 h. It can be seen that the strain increases continuously with increasing creep time. Based on the test results, the stress aging conditions were set at 1173 K/50 MPa for 20 h as the minimum creep rate, 100 h as the initial stage accelerating region, 300 h as the middle stage of accelerating region, and 500 h as the last stage of accelerating region.

3.2 γ' particle alignment phenomenon

Fig. 2 shows the FE-SEM image of the 300 h stress-aged at 1173 K/50 MPa. It can be seen that the γ' precipitates are preferentially aligned in the direction of the stress axis, although the alignment phenomenon can be observed as the γ' precipitates change to a cubic shape. This is because the lattice parameter of the γ phase elastically increases in the stress direction when stress is applied at the γ/γ' interface, and the lattice misfit between the γ phase and the γ' phase becomes small. And the strain energy becomes less emphasized at the γ/γ' interface perpendicular to the stress axis. In contrast, since the lattice parameter does not change at the γ/γ' interface in the direction of the stress axis. The lattice parameter does not affect the alignment in the direction of the stress axis. It is considered that the γ' precipitates are observed to be preferentially aligned in the direction of stress axis.

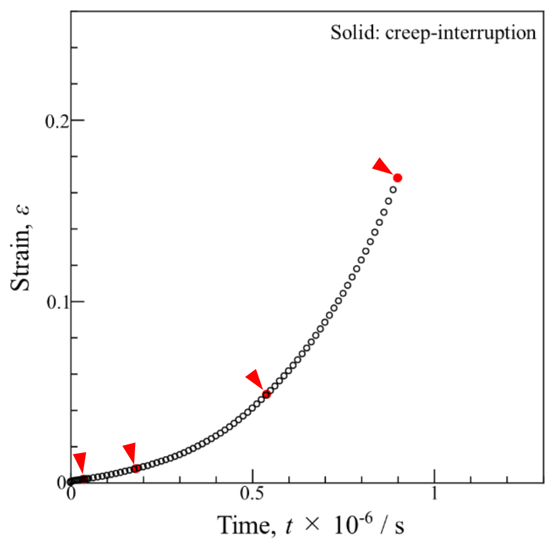

Fig. 1 Creep curve of Alloy 80A at 1173 K under a stress of 50 MPa.

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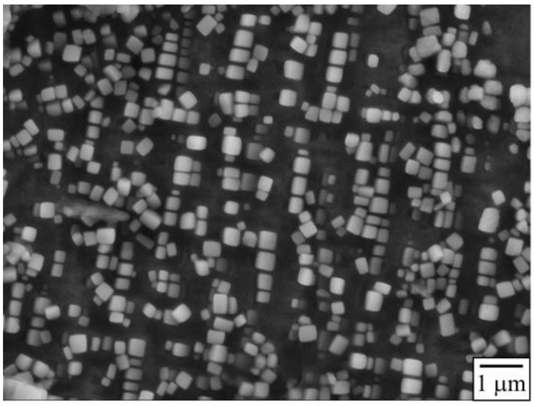

Fig. 2 FE-SEM image of Alloy 80A crept at 1173 K/50 MPa for 300 h. The stress direction corresponds to the vertical direction of the figure.

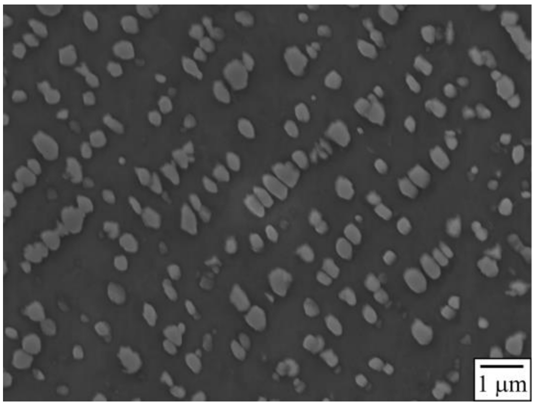

Fig. 3 FE-SEM image of Alloy 80A crept at 1173 K/50 MPa for 300 h. The stress direction corresponds to the vertical direction of the figure.

3.3 Effect of stress on coherency

Fig. 3 shows the FE-SEM image of the 300 h stress-aged at 1173 K/50 MPa. This image shows the area of incoherence γ' precipitates. The results show that stress application promotes the initiation of incoherency in a shorter time than simple aging.

Fig. 4 shows the TEM image of the 300 h stress-aged at 1173 K/50 MPa, where dislocations are observed at the γ and γ' interface. It is deduced that the introduction of dislocations, which is provided by the stress application, promotes the transition of γ' phase from coherent to incoherent. From these results, it can be said that the becoming incoherent of the γ' phase is accelerated by the introduction of stress-induced strain.

3.4 Effect of stress on γ' particle size

Fig. 5 shows the coarsening process in simple aging and stress aging. It shows the relationship between γ' precipitation size and aging time in simple and stress aging. From these results, it can be detected that the coarsening rate of precipitated particles is not affected by stress.

4. Conclusions

In this study, the effect of stress aging on the morphology of γ' precipitates was investigated by observing the

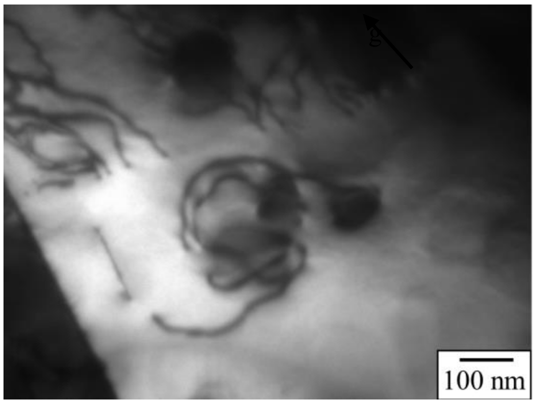

Fig. 4 TEM image of Alloy 80A crept at 1173 K/50 MPa for 300 h, taken with **B** = [110], **g** =111.

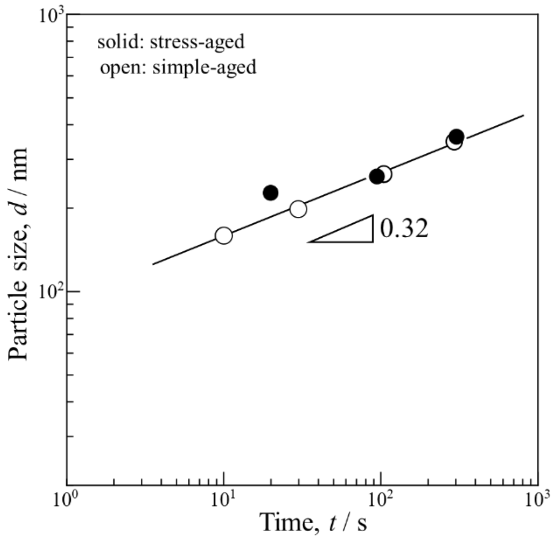

Fig. 5 Plots of particle size vs. aging for Alloy 80A. The stresses in the stress aging are 50 MPa.

microstructure of Alloy 80A at 1173 K/50 MPa for 20 h-500 h at various aging times. The results are summarized as follows: 1) γ' precipitates are preferentially aligned along the stress axis under stress; 2) the incommensurability of the γ' phase is accelerated by the introduction of stress-induced strain; 3) the coarsening rate of the precipitates is not affected by stress.

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