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論 文 要 旨

THESIS SUMMARY

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要旨（英文800語程度）
Thesis Summary（approx.800 English Words ）

The present thesis of "Precipitation Kinetics and Microstructure Control of Fe_2Nb Laves Phase on Grain Boundaries in Fe-Cr-Ni-Nb Quaternary Austenitic Heat Resistant Steels" is constructed by 7 chapters:

In chapter 1 of "Generation Introduction", the current state of the power generation in Japan since the Great East Earthquake is firstly described, pointing out the elevation of the efficiency of thermal power plants urgently requires the development of the austenitic heat resistant steels with a 10^5 h creep rupture strength of over 100 MPa at 973 K. Then the excellent creep rupture strength of novel austenitic heat resistant steel Fe-20Cr-30Ni-2Nb (at.%, base steel) strengthened by intermetallic phases of Fe_2Nb and Ni_3Nb at 973 K, as well as the "*Grain-boundary precipitation strengthening* (GBPS)" mechanism by the Fe_2Nb phase, is explained, emphasizing the further application of the steel at 1073 K largely relies on the precipitation control of Fe_2Nb phase on the grain boundaries under the situation where both Fe_2Nb and Ni_3Nb phases need Nb atoms for their formation. Finally the significance and objective of the thesis are raised.

In chapter 2 of "Evaluation of Nb Supersaturation for the Precipitation of Grain-boundary Fe_2Nb Laves Phase", based on the study of γ+Fe_2Nb+Ni_3Nb three-phase co-existing region in Fe-Cr-Ni-Nb quaternary phase diagram, a model steel of Fe-20Cr-35Ni-2Nb (at.%) is proposed at 1073 K by maintaining the same molar volume fractions of both phases to that of the base steel at 973 K. Along with the construction of TTP diagram, it's clarified that the microstructure of the model steel nearly reaches to the equilibrium state after 3600 h aging at 1073 K, where the Fe_2Nb phase precipitates on grain boundaries and within grain interiors and reaches to an area fraction of 60%, while the Ni_3Nb phase only precipitates within grain interiors. A method is proposed to evaluate the Nb supersaturation for the precipitation of grain-boundary Fe_2Nb phase, which is 0.35 at.% in the model steel, out of the total Nb supersaturation of 1.5 at.%.

In chapter 3 of "Change in Nb Supersaturation for the Area Fraction of Grain-boundary Fe_2Nb Laves Phase", the dependence of the Nb supersaturation for grain-boundary Fe_2Nb phase on the concentrations of Nb and Ni is investigated with a Nb+ steel Fe-20Cr-35Ni-3Nb and a Ni+ steel Fe-20Cr-36Ni-2.5Nb (at.%), using the same method proposed in chapter 2. The results reveal that a 0.5 at.% Nb addition to the model steel increases the Nb supersaturation for grain-boundary Fe_2Nb phase by 0.2 at.% and raises the area fraction to 80%, while higher Ni content mainly increases volume fraction of the Ni_3Nb phase and shows little effect on the area fraction. Based on these results, it's proposed that at least 0.85 at.% Nb supersaturation for grain-boundary Fe_2Nb phase is required to approach to an ideal 100% area fraction.

In chapter 4 of "Effect of Nb Supersaturation on the Precipitation Kinetics of

Grain-boundary Fe_2Nb Laves Phase", the nucleation and growth behavior of both Fe_2Nb and Ni_3Nb phases as well as the effect of Nb supersaturation is investigated. The results show that Fe_2Nb phase precipitates first on grain boundaries in the model steel at 1073 K, followed by its precipitation within grain interiors, then the Ni_3Nb phase precipitates as meta-stable γ'', and transforms to stable δ at long-term aging. Nb addition accelerates the nucleation of grain-boundary Fe_2Nb phase, while Ni addition shows little effect, mainly enhancing the nucleation and growth of Ni_3Nb phase. Based on these results, a composition of Fe-20Cr-36Ni-3Nb (at.%) is proposed to enhance the grain boundary precipitation of Fe_2Nb phase.

In chapter 5 of "Nucleation and Growth Kinetics of Grain-boundary Fe_2Nb Laves Phase through 3D Analysis", the different nucleation and growth behaviors of Fe_2Nb phase on grain boundaries is investigated using a 3D observation & analysis method based on slice & view of FIB-SEM system. The results show that the nucleation kinetics of Fe_2Nb Laves phase is delayed on low-angle boundaries and twin boundaries, on high angle boundaries, however, the nucleation kinetics is enhanced, showing two different types of behaviors: 1. fine granular particles with a size of about 100 nm and high density, and holds for certain time; 2. larger granular particles with a size of several 100 nm and low density, and grow along preferential growth direction. It's also revealed that the growth kinetics of Fe_2Nb phase tends to be faster when the grain boundary plane is close to the 111 plane of neighboring grains. The dependence of the morphology of Fe_2Nb phase on the grain boundary characters becomes weaker at long-term aging.

In chapter 6 of "Precipitation Control of Grain-boundary Fe_2Nb Laves Phase", a concept to control the precipitation of grain-boundary Fe_2Nb Laves phase is proposed based on the results of the former chapters. Ideally, an equilibrium microstructure should consist Fe_2Nb phase on grain boundaries with a 100% area fraction and only Ni_3Nb phase within grain interiors. In terms of precipitation kinetics, the precipitation sequence should be grain-boundary Fe_2Nb phase first, followed by the Ni_3Nb phase. Based on the effect of Nb supersaturation on the equilibrium microstructure and the precipitation kinetics, a composition of Fe-20Cr-37Ni-3.5Nb (at.%) is proposed.

In chapter 7 of "General Conclusion", the results and conclusions obtained in this thesis are summarized.