Evaluation of the Relationship between Microstructure and Hardness in Neutron Irradiated Reactor Pressure Vessel Model Alloys following Thermal Ageing

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The relationship between microstructures and mechanical properties is important issue for the embrittlement correlation method for Japanese reactor pressure vessel steels. In this work, the characteristics of solute clusters are studied by atom probe tomography in neutron irradiated model alloys following thermal ageing to peak hardness. Also, the relationship between solute clusters and Vickers hardness change is investigated.

Keywords: reactor pressure vessel, embrittlement, solute clusters, atom probe tomography

1. Introduction

The irradiation embrittlement of nuclear reactor pressure vessel (RPV) steels is of increasingly crucial concern for the safe and economical long-term operation of nuclear reactors. Previous studies show that the characteristics of solute clusters formed in RPV materials are influenced by the material composition [1] and the environment [2]. The effect of thermal ageing and that of high-flux neutron irradiation on the solute clusters and hardening need to be distinguished considering the long-term operation of nuclear reactors. For this purpose, the alloys with different solute contents are neutron irradiated following thermal ageing in the work. The evolution and characteristics of solute clusters are studied in detail, and the relationship between solute clusters and hardening is evaluated.

2. Experimental

The chemical composition of the studied alloys is provided in table 1. These alloys were thermally aged at temperature 450 ^{o}C in vacuum to peak Vickers hardness. Then this was followed by neutron irradiation to 5.8×10^{18} n/cm^2 at 290 ^{o}C. Vickers hardness tests and Atom probe tomography (APT) are applied for the evaluations of mechanical properties and microstructures of these alloys, respectively.

Table 1. Alloy chemical composition

Series	Concentration (wt.%)			
	Cu	Ni	Mn	Si
Fe-Cu	0.5	-	-	-
Fe-Cu-Si	0.5	-	-	0.1
	0.5	-	-	0.2
Fe-Cu-Ni	0.5	0.6	-	-
	0.5	0.8	-	-
Fe-Cu-Ni-Mn	0.5	0.6	1.4	-
	0.5	0.8	1.4	-

3. Results and conclusion

No linear relationship between the square root of the volume fraction of solute clusters and the hardness change is observed in the irradiated alloys following thermal ageing. In the Fe-Cu-Ni-Mn alloys, the formation of Cu, Ni and Mn-rich clusters was detected and two groups could be distinguished. One group is enriched in Cu, while the other contains Ni-Mn dominant clusters. These two groups of clusters may have different contribution to the hardening. More results are expected after examining the alloys aged to peak hardness.

References

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