Effect of Tantalum on the Creep Properties of SFR Fuel Cladding Tube Materials

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1. Introduction

Ferritic/martensitic steels are being considered as an candidate material for a SFR fuel cladding tube because of the excellent irradiation swelling resistance.[1,2] When FM steels are applied to a SFR fuel cladding tube, the temperature of SFR are expected to above 650°C, and fission gases which were released from the SFR fuel become the source of an internal stress on the cladding tube. Thus the cladding tube should have excellent creep resistance at high temperature. The purpose of this research is to develop cladding tube materials having higher creep strength.

2. Methods and Results

2.1 Experimental Procedure

3 alloys were designed to investigate the effect of tantalum on the mechanical properties of FM steels. The chemical composition of the steels is shown in Table 1. The Ta content changed from 0.02wt% to 0.10wt%. These steels were laboratory melted in a vacuum by an induction furnace. Heat treatment was carried out in a vacuum furnace. The heat treatment consisted of an austenitizing at 1050°C for one hour followed by an air cooling and tempering at 750°C for two hours also followed by an air cooling.

Table I: Chemical composition of FM steels

	C	Cr	Mo	W	V	N
0.02Ta	0.070	9.10	0.52	2.00	0.200	0.083
0.05Ta	0.069	8.97	0.50	2.07	0.203	0.084
0.10Ta	0.069	8.96	0.50	2.01	0.205	0.086

The tensile and creep tests were carried out to evaluate the effect of tantalum on mechanical properties of FM steels. The microstructures were observed by using a transmission electron microscope (TEM), and the elemental analyses on the particles were made by using an energy dispersive spectroscope (EDS) attached to a TEM.

2.2 Phase equilibrium

The phase equilibrium diagrams of alloys were calculated using thermocalc. Fig. 1 shows the phase equilibrium of the 0.05Ta steel. The A_{e1} and A_{e3} temperature of the 0.05Ta steel were 780°C and 860°C, respectively. The mass fraction of MX particles was about 5×10^{-3} at 300°C. The 0.02Ta and 0.10Ta steels showed the same A_{e1} and A_{e3} temperature and the mass fraction of MX particles with the 0.05Ta steel. But the mass fraction of MX particles in the Ta bearing steels was higher than that in Gr.92 steel. This is due to the high nitrogen content in the Ta bearing steels.

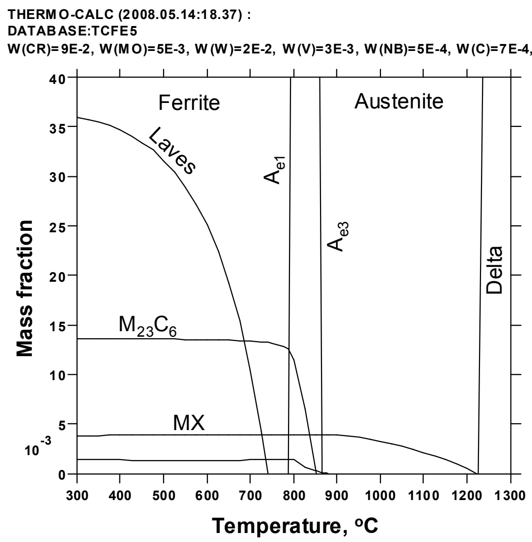
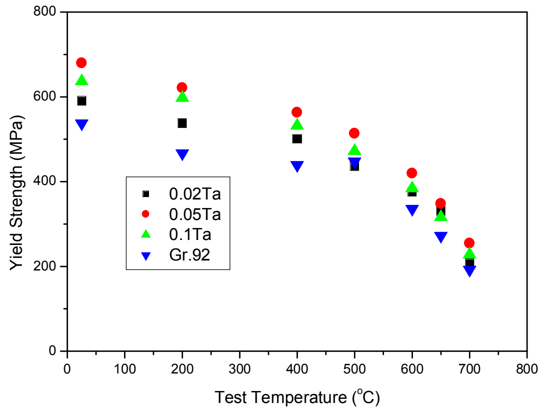


Fig. 1. Phase equilibrium of 0.05Ta steel

2.3 Tensile Properties

The tensile properties of the alloys were evaluated by the uniaxial tension test. Tensile test was carried out at a crosshead speed of 3mm/min from room temperature to 700°C. Fig. 2 shows the tensile properties of the alloys. The Ta bearing steels showed higher yield strength than the reference (Gr.92) steel. The 0.05Ta steel showed higher yield strength among the Ta bearing steels regardless of the tensile test temperature. Tensile strength also showed a similar tendency to the yield strength. But the elongation of the 0.05Ta steel was a little lower than that of the other steels. The optimum Ta content for yield and tensile strength was 0.05wt. %.



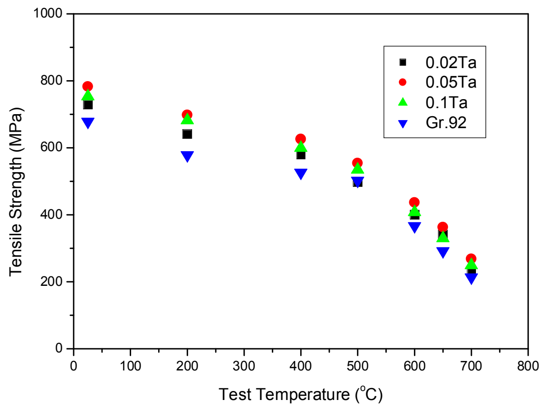


Fig. 2. Tensile properties of FM steels

2.4 Creep Properties

The creep test was performed at 650°C under constant load conditions. Applied load was 140MPa. Fig. 4 shows the time to rupture of the Ta bearing steels and reference (HT 9 and Gr.92) steels. The Ta bearing steels showed higher time to rupture than the reference steels. The time to rupture of the 0.05Ta steel was a little longer among the Ta bearing steels. But the difference was not high.

Ta is substitute for the Nb in Nb-rich MX particles. The addition of Ta had a good effect on creep rupture elongation of FM steel.[3] Though the Ta content changed, the mass fraction of MX particles did not changed. And the mass fraction of $M_{23}C_6$ particles also did not changed with the Ta content. These mean that precipitation hardening effect by the addition of Ta was immaterial. The 0.05Ta steel showed higher yield, tensile and creep strength among the Ta bearing steels. But the change of these properties with Ta content was not high. Further investigation will be continued to confirm the effect of Ta on the creep rupture strength.

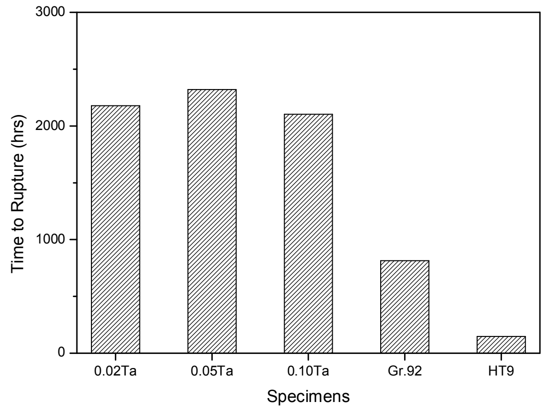


Fig. 3. Creep rupture strength of FM steels at 650°

3. Conclusions

Tantalum content was changed to study the optimum content for the creep rupture strength of FM steels. The A_{e1} and A_{e3} temperature and the mass fraction of MX did not change with the Ta content. The 0.05Ta steel showed higher yield and tensile strength and longer time to rupture among the Ta bearing steels. But the difference of these properties with Ta content was not high. Further studies are going on to investigate the optimum tantalum contents for the creep properties of the FM steels.

ACKNOWLEDGEMENT

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