Effect of Ta Content on the Mechanical Properties of 9Cr-WVC Steel

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1. Introduction

Reduced activation ferritic-martensitic (RAFM) steel, austenitic stainless steel, and oxide dispersion strengthened steel are being considered for the structural materials of fusion reactors [1,2]. RAFM steel is being considered as a candidate structural material in a fusion reactor system owing to its good mechanical properties and excellent irradiation resistance at the operating temperatures [3,4]. A RAFM steel design is based on the Cr-Mo alloy of a heat-resistant material. To be suitable for use as structural materials of a fusion reactor, Mo is replaced by W and V to improve the mechanical properties and irradiated damage [5]. In this study, the microstructure and mechanical properties were evaluated by adjusting the content of alloying elements tantalum in the process of developing advanced RAFM steel.

2. Methods and Results

2.1 Experimental Procedure

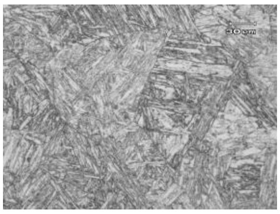
9Cr-WVC steel containing a Ta concentration of 0.02, 0.06 and 0.10 wt.% was prepared by a vacuum induction melting process. The steel ingot was hot-rolled after a preheating at 1150℃ for 2h. The hot-rolled specimen was normalized at 1050℃ for 1h and tempered at 760℃ for 1h.

The microstructures were observed using optical microscopy (OM) and a transmission electron microscope (TEM). In addition, elemental analyses of the particles were made using an energy dispersive spectroscope (EDS) attached to a TEM. The tensile and impact tests were carried out to evaluate the effect of tantalum on the mechanical properties of 9Cr-WVC steel. The tensile properties of the alloys were evaluated by a uniaxial tension test. Tensile tests were carried out at a crosshead speed of 5mm/min at temperatures between 25- 600℃.

2.2 Matrix and Precipitates

Fig. 1 shows the OM and TEM images of the 9Cr-WVC steel. A tempered martensitic structure composed of subgrains and laths was observed. Most of the precipitates observed were $M_{23}C_6$ and V-rich MX. In addition, Ta-rich carbides were observed, in the 0.10Ta alloy.


(a) 0.02Ta alloy


(b) 0.06Ta alloy

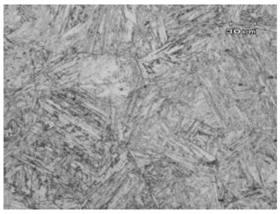
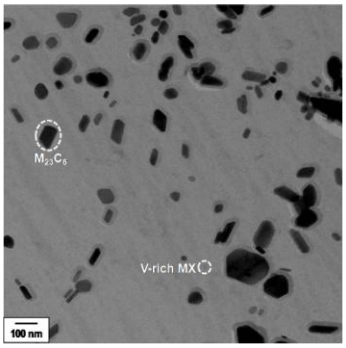
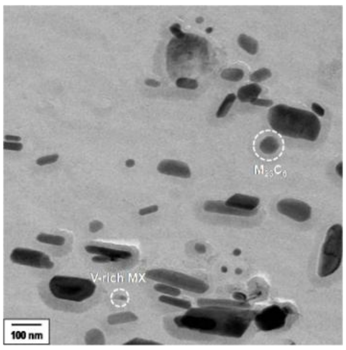

(c) 0.10Ta alloy

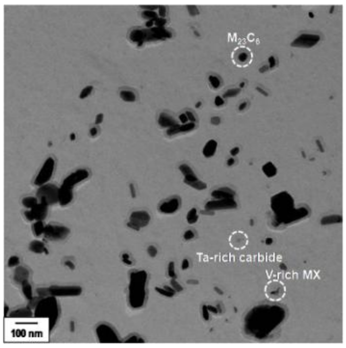
Fig. 1. Optical micrographs of 9Cr-WVC steels



(a) 0.02Ta alloy



(b) 0.06Ta alloy



(c) 0.10Ta alloy

Fig. 2. TEM images of the 9Cr-WVC steels

2.3 Tensile Properties

Fig. 3 shows the tensile properties of the alloys. The tensile strength was found to increase with an increase in Ta content. The yield strength also showed a similar tendency. However elongation showed a different tendency. The 0.10Ta alloy showed good ductility at room temperature. However, the 0.02Ta alloy showed good ductility at temperatures of 300℃ and 600℃, and 0.06Ta alloy showed good ductility at temperatures of 400℃ and 500℃. Increasing the Ta content is beneficial to the yield strength and tensile strength owing to the Ta-rich carbides, but the Ta content was not beneficial to elongation.

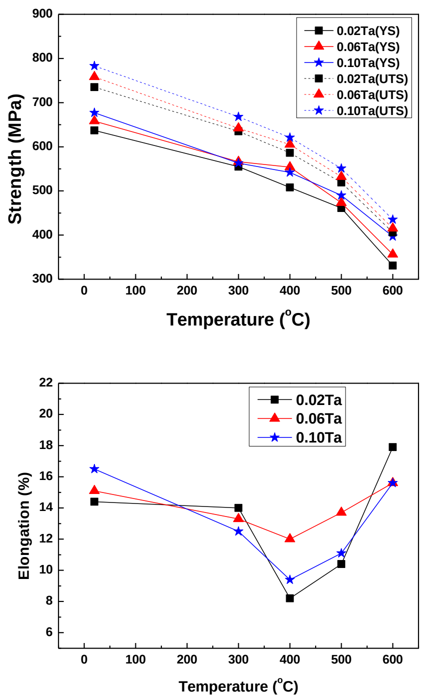


Fig. 3. Tensile properties of 9Cr-WVC steels

2.4 Impact Properties

Fig. 4 shows the impact properties of the alloys. The DBTT and upper shelf energy were improved when the Ta content was increased from 0.02 wt.% to 0.06 wt.%. However, when the Ta content was increased from 0.06 wt.% to 0.10 wt.%, the DBTT and upper shelf energy showed a tendency toward poor. Therefore, the best impact properties were obtained when the Ta content was 0.06 wt.%.

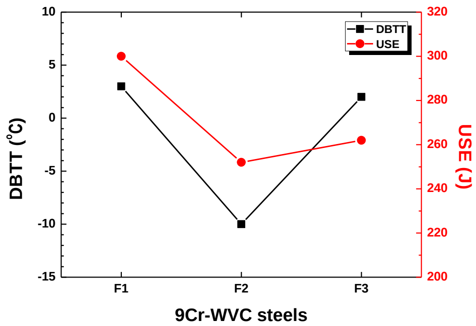


Fig. 4. Impact properties of 9Cr-WVC steels

3. Conclusions

A higher tantalum content in FM steel increases the high temperature strength and degrades toughness. As the tantalum content increased, the tensile and yield strength increased due to the formation of Ta-rich carbides. On the other hand, the best impact properties were obtained when the tantalum content was 0.06 wt.%.

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