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Effect of aging on tensile properties of ODS steel

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1. Introduction

Oxide dispersion strengthened (ODS) martensitic steel is a candidate material for fuel cladding of sodium cooled fast breeder reactor (SFR). ODS steel shows high strength at high temperature because of the dispersion of oxide particle in matrix and high thermal conductivity. ODS steel has low thermal expansion and low swelling during operation at SFR. The operating temperature of SFR was 550°C and precipitates, such as $M_{23}C_6$, MX, Laves phase, were observed after long exposure at the operating temperature of SFR for martensitic Cr-Mo steel. To design SFR, the effect of aging on mechanical properties should be evaluated as a function of temperature because these precipitates affect mechanical properties. In this study, tensile properties of martensitic ODS steel were investigated after aging at high temperature.

2. Experimental procedure

Martensitic ODS steel was fabricated by mechanical alloying (MA) and hot isostatic pressing (HIP). Metallic powders and Y_2O_3 were mechanical alloyed by horizontal ball mill machine (Model CM-08) in high purity Ar (purity of 99.999%) environment. Mechanical alloying was performed at 300 rpm for 40 h. Ball to powder weight ratio (BPWR) was 10:1. MA powder was charged in a stainless steel capsule and sealed. The sealed capsule was degassed at 500°C in $5x10^{-3}$ torr for 1h. HIP was conducted at 1150°C for 4h at a heating rate of 5°C/min, cooled in furnace, and hot rolled. Annealing temperature was 1050°C and tempering temperature was 800°C. Chemical composition of ODS steel is shown in Table 1.

Table 1. Chemical composition of ODS steel (wt%)

C	Cr	Mo	Ti	Zr	Y_2O_3
0.15	10	1	0.1	0.15	0.35

ODS steel was aged at 475°C and 650°C for 1000h in vacuum. Sheet type specimen with 25.4 mm gage length, 3.7 mm width, and 1 mm thickness was machined for tensile test. Tensile test was carried out under displacement control at temperature range from RT to 700°C. Strain rate was $2x10^{-3}$/s. Microstructure of ODS steel is shown in Fig. 1.

3. Results

Tensile properties are shown as a function of temperature for unaged and aged steels in Fig. 2. Yield stress and UTS decreased gradually with increasing temperature to 500°C and decreased considerably with increasing temperature after 600°C. Elongation did not change greatly to 500°C and increased abruptly after 600°C. The effect of aging on tensile properties was little observed. Stress-displacement curves are shown as a function of temperature for unaged and aged steels in Fig. 3. Work hardening was a little observed at temperature range from RT to 400°C for unaged and aged steels. Softening was observed after 500°C for unaged and aged steels. Serration was not observed at all temperature range for unaged and aged steels.

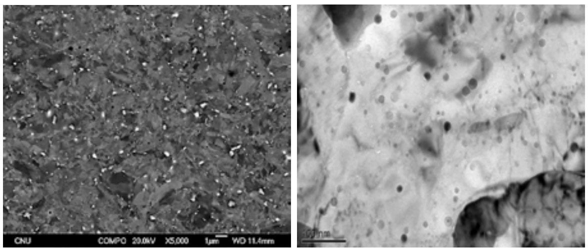


Fig. 1. Microstructure after annealing and tempering.

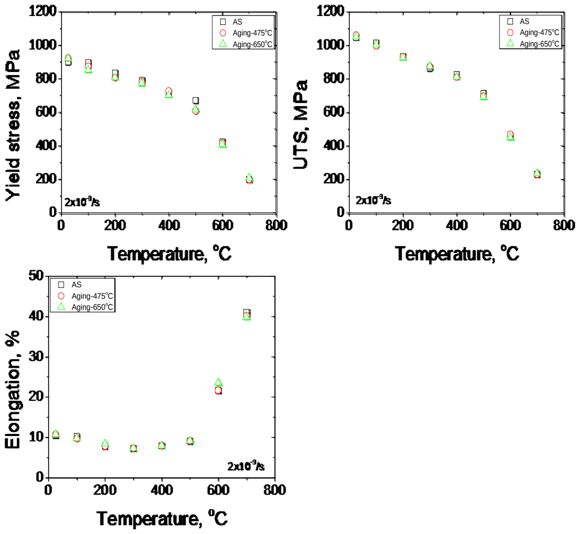


Fig. 2. Tensile properties as a function of temperature for unaged and aged steels.

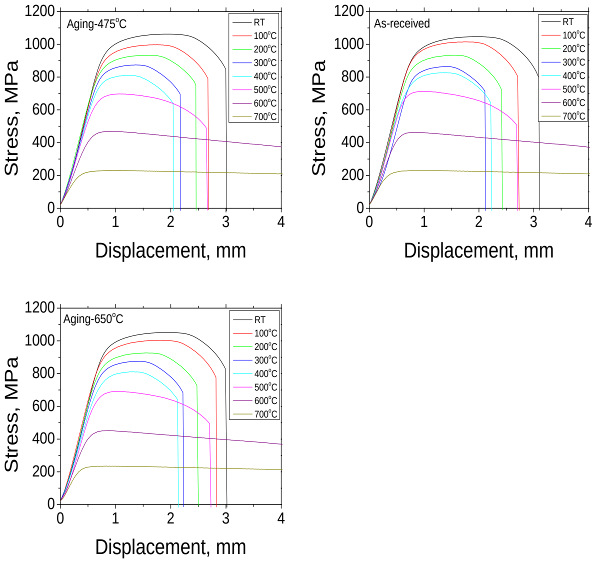


Fig. 3. Stress-displacement curves as a function of temperature for unaged and aged steels.

Fracture surfaces are shown after tensile test at RT, 400°C, and 700°C for unaged and aged steels in Fig. 4. Dimple was observed at all testing temperature range on fracture surface of unaged and aged steels.

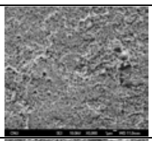
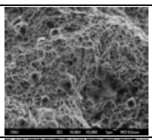
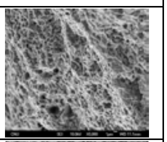
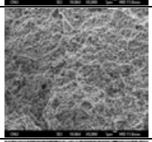
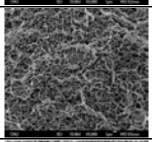
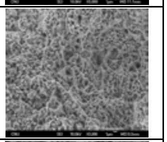
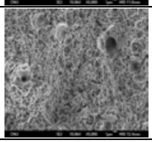
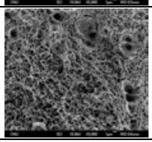
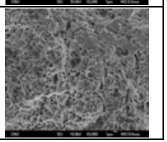
	RT	400°C	700°C
AS			
475°C			
650°C			

Fig. 4. Fracture surface after tensile test at RT, 400°C, and 700°C for unaged and aged steels.

4. Conclusions

ODS steel shows high strength but exhibits low elongation at temperature range from RT to 500°C. Tensile properties are little changed by aging. Dynamic strain aging is not observed at temperature range from RT to 700°C for unaged and aged steels.