Effect of Irradiation fluence on Tensile Properties in High Cr FMS Steel

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1. Introduction

High Cr steels are widely used as high temperature materials in the power plants and chemical industries due to their high strength and thermal conductivity, low thermal expansion, and good resistance to corrosion [1]. Owing to the better irradiation characteristics (e.g. excellent irradiation swelling resistance) of these steels than austenitic alloys, they have been receiving attention for an application to the fuel cladding of Sodium Cooled Fast Reactor in Europe, USA and Japan [2-4].

Irradiation damage caused by high energy particles occurs when the particles displace atoms from their normal lattice position. This irradiation induced microstructural changes lead to lattice hardening, which causes an increase in the yield strength and ultimate tensile strength and a decrease in the elongation. Below 400°C, the interstitials are mobile relative to vacancies, and the interstitials combine to form dislocation loops that increase strength and decrease ductility [5, 6]. The magnitude of the hardening changed with irradiation temperature, irradiation fluence and materials. In the present study, we performed irradiation tests to know the effect of irradiation fluence on tensile properties in high Cr FMS steel.

2. Experimental Procedure

The chemical composition of high Cr FMS steel was 0.15C-10Cr-1.2Mo-0.2V-0.2Nb-0.02N. The steel was laboratory melted in a vacuum by an induction furnace. Heat treatment was carried out in vacuum furnace. The heat treatment consisted of austenitizing at 1050°C for one hour followed by air cooling and tempering at 750°C for two hours also followed by air cooling.

Irradiation tests were performed at CT test hole in HANARO. Irradiation conditions were shown in Table 1. Irradiation fluence increased from 1.1×10^{20} n/cm^2 to 1.0×10^{21} n/cm^2 (E>0.1MeV). High temperature tensile tests for irradiated FMS steels were carried out at hot cell in IMEF. Tensile test was conducted at room temperature - 600°C. The strain rate was 2×10^{-3}/sec.

Table 1. Irradiation conditions

	1st irra. test	2nd irra. test	3rd irra. test
Irradiation Temperature	320±5°C	307±5°C	340±5°C
Irradiation Fluence	1.1×10^{20} n/cm^2	6.4×10^{21} n/cm^2	1.0×10^{21} n/cm^2

3. Results and Discussion

3.1 Change of Strength with Irradiation

Figure 1 shows the change of yield strength with irradiation fluence. Yield strength increased by neutron irradiation. Considerable increase of yield strength occurred for room temperature tensile test and then decreased as tensile test temperature increased. Eventually irradiation hardening effect completely disappeared at elevated temperature tensile test. The yield strength of irradiated FMS steel was nearly recovered at 500°C tensile test. As the irradiation fluence increased, the yield strength also increased. For the room temperature tests, the increase of yield strength by irradiation was about 12% at lower irradiation fluence, but it increased to 34% at higher irradiation fluence. Hardening is greatest for the steel tested at 200°C. For the 200°C tests, the yield strength increased 22%, 31%, and 50% as the irradiation fluence increased. The increase of yield strength with irradiation fluence was not linear but exponential. The yield strength abruptly increased at the early stage of irradiation, and then it increased linearly. It is reported that the hardening saturates with increasing fluence [7]. So the hardening of FMS steel will be saturated at higher fluence.

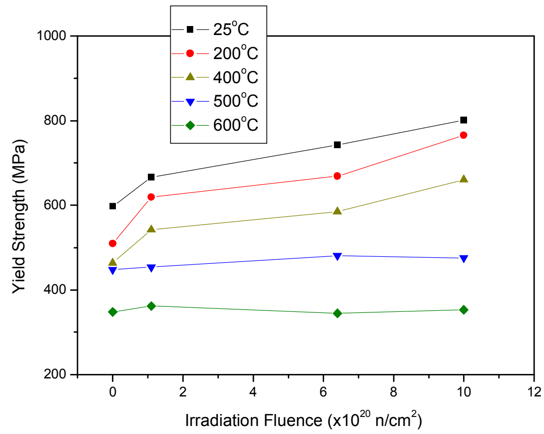

Fig. 1. Change of yield strength with irradiation fluence in 10Cr-1.2Mo steel

Figure 2 shows the change of tensile strength with irradiation fluence. The change of tensile strength was similar to the change of yield strength. But the increase of tensile strength with irradiation was low compared with the increase of yield strength. That is, the increase of tensile strength with irradiation was lower than that of yield strength. As the irradiation fluence increased, the tensile strength also increased linearly. The tensile strength increased up to 24% at higher irradiation fluence. It is the half of yield strength increase. As tensile test temperature is above 500°C, the increase of tensile strength by the irradiation is not occurred. The complete recovery of tensile strength was also occurred at 500°C.

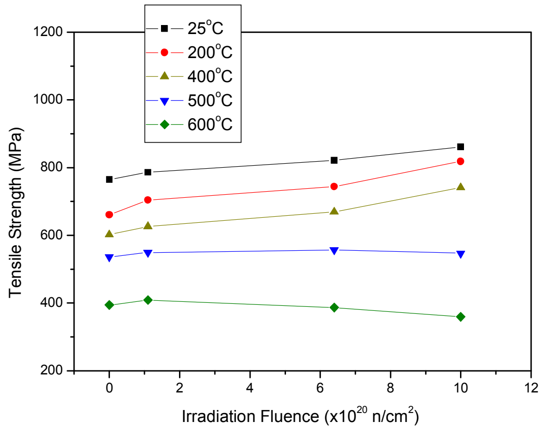

Fig. 2. Change of tensile strength with irradiation fluence in 10Cr-1.2Mo steel

The decrease of irradiation hardening at high temperature tensile test comes from the recovery of irradiation damage by thermal activation process. That is, interstitial and vacancy which formed by neutron irradiation, become unstable at high temperature, so these faults easily move and combine with each other, and eventually disappear. As a result, the number density of faults decreases to the level before irradiation and then irradiation hardening will be disappeared.

3.2 *Change of Elongation with Irradiation*

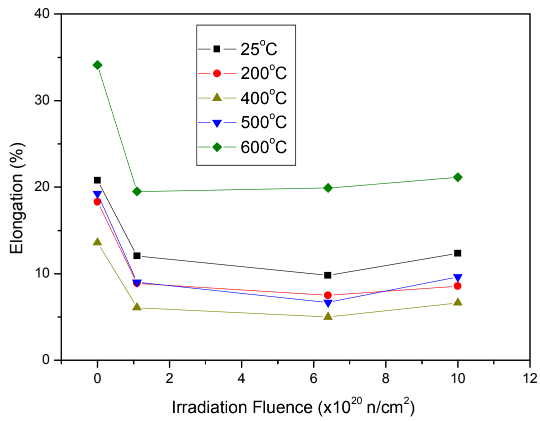

Fig. 3. Change of elongation with irradiation fluence in 10Cr-1.2Mo steel

Figure 3 shows the change of elongation with irradiation. The change of elongation showed different behavior with change of strength. Elongation was not recovered even though tensile test was carried out at 600°C. The decrease of elongation by irradiation was 40- 65%. The change of elongation with irradiation fluence was not appeared. That is, though the irradiation fluence increased, the elongation was not decreased.

4. Conclusion

The tensile properties of high Cr FMS steel which were irradiated in HANARO have been studied. The following conclusions were obtained:

The yield and tensile strength of high Cr FMS steel increased, and the elongation decreased by neutron irradiation. The increase of yield strength by irradiation was higher than that of tensile strength. As the tensile test temperature increased, the increase of strength by irradiation was diminished. But elongation was not completely recovered at elevated temperature tensile test. The increase of yield strength with irradiation fluence was not linear but exponential. The yield strength abruptly increased at the early stage of irradiation, after that it increased linearly. For the 200°C tests, the yield strength increased from 22% to 50% as the irradiation fluence increased ten times.

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