Material: Ferritic Steel: F82H
Property: Yield stress vs. neutron damage
Condition: Irradiated
Data: Experimental

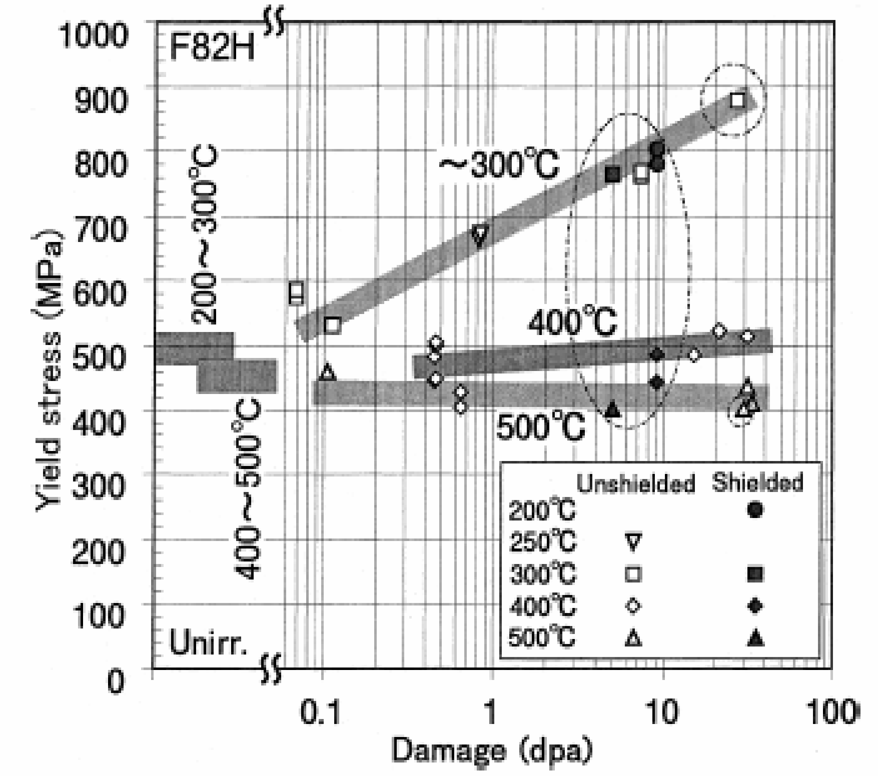


Fig. 3. Dose dependence of yield stress of neutron-irradiated F82H steel.

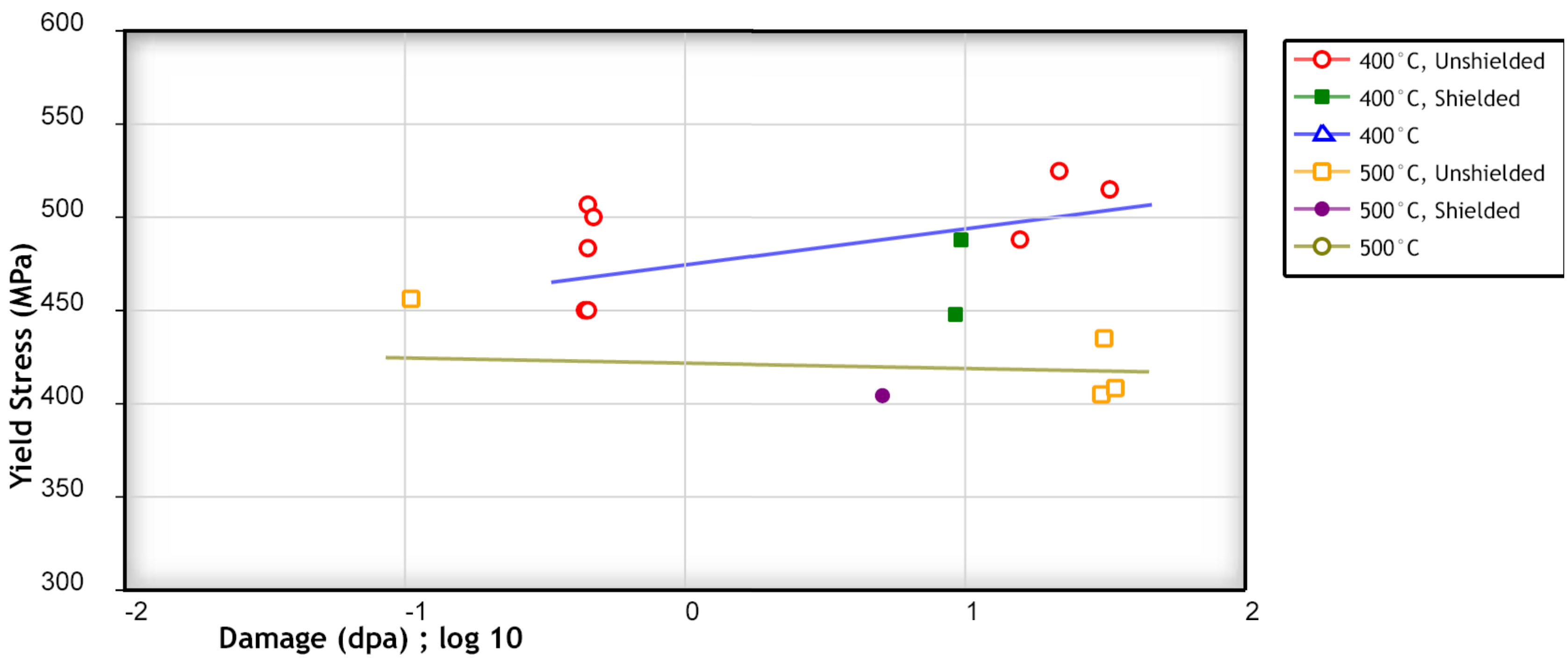
Source:
Journal of Nuclear Materials, 2000, Volume 283-287, Page 358-361

Title of paper (or report) this figure appeared in:
Tensile Behavior of F82H with and without Spectral Tailoring

Author of paper or graph:
K. Shiba, R.L. Klueh, Y. Miwa, J.P. Robertson, A. Hishinuma

Caption:

Dose dependence of yield stress of neutron-irradiated F82H steel (Figure 2 of 2).



Dose dependence of yield stress of neutron-irradiated F82H steel (Figure 2 of 2).

Reference:

Author: *K. Shiba, R.L. Klueh, Y. Miwa, J.P. Robertson, A. Hishinuma*
Title: *Tensile Behavior of F82H with and without Spectral Tailoring*
Source: *Journal of Nuclear Materials 283-287 (2000) 358-361, 2000, Volume 283-287, Page 358-361*, [PDF]

View Data
Author Comments

Plot Format:

Y-Scale: ◉ linear ○ log ○ ln
X-Scale: ○ linear ◉ log ○ ln

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Tensile behavior of F82H with and without spectral tailoring

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Abstract

The effects of neutron spectrum on tensile properties of the low-activation martensitic steel F82H (8Cr–2WVTa) was examined using a thermal neutron shield to tailor the neutron spectrum for steels irradiated in the high flux isotope reactor (HFIR). The yield stresses of spectrally tailored specimens irradiated in HFIR to 5 dpa at 300°C and 500°C are on trend lines obtained from unshielded irradiation in HFIR. No significant effect of the neutron spectrum on tensile properties could be detected.

1. Introduction

Low-activation ferritic/martensitic steels have been developed for structural applications for fusion reactors by several research groups, and numerous irradiation experiments have been carried out on such steels [1–8]. The neutron irradiation experiments are conducted in fission reactors; but it is difficult to apply such fission reactor data to fusion reactor conditions, because the neutron spectra of these reactors are quite different. In particular, the high concentration of helium and hydrogen generated from nuclear transmutation by the high-energy neutrons in a fusion neutron spectrum may affect the microstructure and mechanical properties of fusion reactor structural materials differently than in a fission spectrum.

Additionally, alloy composition may also be changed by nuclear transmutation reactions. Such nuclear transmutations occur differently in fission reactor irradiation, and they could affect test results. For example, in the mixed-neutron spectrum of the high flux isotope reactor (HFIR), W in F82H transmutes to Re then to Os by nuclear reactions with thermal neutrons at higher doses. Greenwood et al. [9] calculated the transmutation of W as a function of irradiation damage at the HFIR target position. The results of that calculation applied on F82H are shown in Fig. 1. Such a change in the chemical composition might additionally affect the microstructure and mechanical properties of F82H. For example, a decrease in the amount of W in F82H might change the Laves phase precipitation behavior and high-temperature strength. Therefore, a hard neutron spectrum, such as that of a fast breeder reactor (FBR), might provide a better comparison to fusion for the irradiation of materials containing W. A thermal neutron shield, such as that employed in the present experiment, is also useful to prevent such nuclear transmutation reactions.

In this study, the effects of neutron spectrum on tensile properties of F28H martensitic steel were studied using a thermal neutron shield for the HFIR irradiation.

2. Experimental procedure

Two heats of F82H were irradiated, and they are distinguished as F82H original and F82H IEA. The chemical composition and heat treatment condition of these steels are listed in Table 1. These steels were hot-rolled at 1200°C, and then F82H original was normalized at 1040°C for 0.7 h and tempered at 740°C for 2 h. F82H IEA heat was normalized at 1040°C for 0.6 h and tempered at 750°C for 1 h. Minature SS-3 type sheet tensile specimen, 7.62 mm in gage length, 1.52 mm in gage width and 0.76 mm in gage thickness were used for

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PII: S0022-3115(00)00362-7

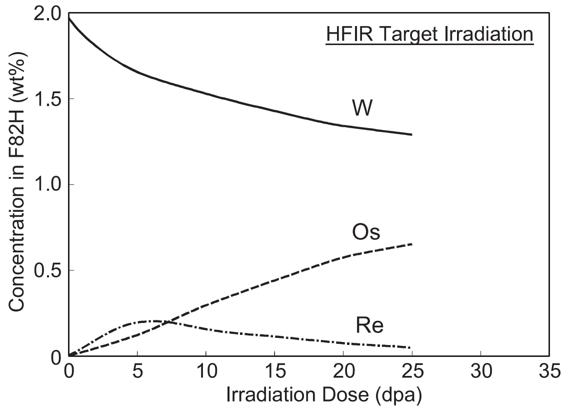

Fig. 1. Calculated change of W content in F82H due to nuclear transmutation during HFIR target irradiation taken from Garner and Greenwood [9].

irradiation. Specimens were fabricated from a F82H plate ($320 \times 400 \times 15$ mm^3) along the rolling direction. Additionally three alloys (1B, 1J and 1K in Table 1) with different W content were used to estimate the effect of W on tensile properties. They were normalized and tempered in the same condition as F82H original and tested with round-bar tensile specimens (6 mm diameter and 30 mm length in gage section).

The irradiation was performed in several different HFIR irradiation capsules (Table 2). Irradiation experiments were separated into thermal neutron shielded and unshielded irradiation. The shielded irradiation were performed in 200J, 400J, 11J and 12J capsules at the HFIR RB position. The 200J and 400J capsules used a Hf shield, and the 11J and 12J capsules used a europium oxide shield. Unshielded irradiation were performed in JP-20 and JP-22 capsules at the HFIR target position. Irradiation conditions of these capsules are summarized in Table 2, and further information on individual capsules can be found elsewhere [10–13]. JP-14 data is used for the comparison, and detailed information of JP-14 irradiation experiment can be found in Ref. [4].

Tensile tests were carried out using an Instron universal test machine at the irradiation temperature at a strain rate of 1×10^{-3} s^{-1}. The 0.2% yield stress,

Table 1
Chemical composition of used steels (wt%)

	Fe	Cr	W	V	Ta	C	B
F82H original	Bal.	7.46	2.1	0.18	0.03	0.097	0.0004
F82H IEA heat	Bal.	7.71	1.95	0.16	0.02	0.090	0.0002
1J	Bal.	7.41	1.4	0.20	0.043	0.097	–
1B	Bal.	7.59	2.0	0.19	0.047	0.097	–
1K	Bal.	7.44	2.5	0.20	0.046	0.098	–
	Si	Mn	P	S	Al	N	
F82H original	0.09	0.07	0.002	0.003	0.025	0.002	
F82H IEA heat	0.11	0.16	0.002	0.002	0.003	0.006	
1J	0.13	0.10	<0.002	0.001	–	0.002	
1B	0.12	0.10	0.003	<0.001	–	0.002	
1K	0.13	0.10	<0.002	0.001	–	0.002	

Table 2
Summary of irradiation conditions

Capsule	Material	Irradiation temperature (°C)	Neutron fluence (n/cm^2) Thermal ($E < 0.5$eV)	Fast ($E > 0.1$MeV)	Damage (dpa)	He (appm)
200J shielded	F82H original	200	4×10^{21}	2×10^{22}	9	6
400J shielded	F82H original	400	4×10^{21}	2×10^{22}	9	6
11J shielded	F82H IEA	300	1×10^{21}	1×10^{22}	5	3
12J shielded	F82H IEA	500	1×10^{21}	1×10^{22}	5	3
JP-14	F82H original	400	4×10^{22}	3×10^{22}	21	13
			6×10^{22}	4×10^{22}	31	17
		500	6×10^{22}	4×10^{22}	31	17
JP-20	F82H original	300	1×10^{22}	1×10^{22}	7	5
JP-22	F82H original	300	6×10^{22}	4×10^{22}	27	15
		400	3×10^{22}	2×10^{22}	15	10
		500	6×10^{22}	4×10^{22}	30	17

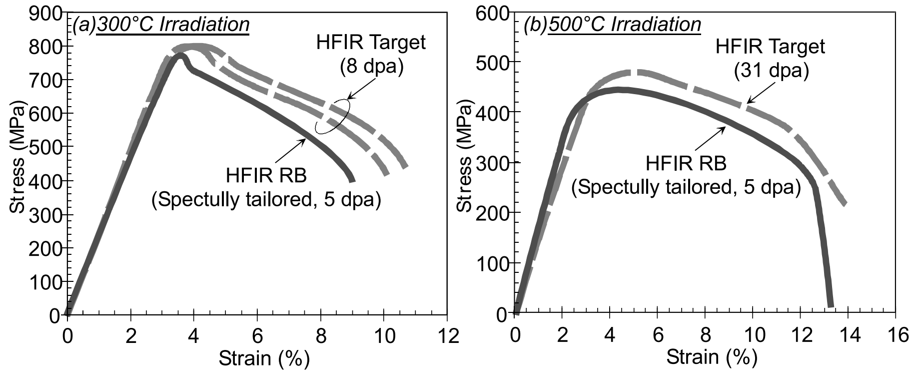

Fig. 2. Comparison of tensile stress–strain curves of specimens irradiated in the HFIR with and without a thermal neutron shield at: (a) 300°C; (b) 500°C.

ultimate tensile stress, uniform elongation and total elongation were estimated from load-cross head displacement charts.

3. Results and discussion

In Fig. 2, stress–strain curves of neutron shielded tensile specimens irradiated at 300°C and 500°C up to 5 dpa are compared with those from specimens irradiated in the HFIR target position to 8–31 dpa at the same temperatures. As shown, shielded (spectrally tailored) specimens and unshielded specimens had similar characteristic stress–strain curves. The spectrally tailored sample irradiated at 300°C (5 dpa) exhibited slightly less total elongation and a lower ultimate tensile stress than the HFIR target samples (8 dpa) and had a sharper drop in stress after yielding. Yield stresses of the spectrally tailored specimens are plotted in Fig. 3 as a function of irradiation dose, and they are compared with unshielded results obtained previously [14,15].

At 300°C, yield stress increases with irradiation damage (Fig. 3). For irradiation at ~300°C, ($T_{irr} = T_{test}$) resulted for shielded and unshielded irradiation are on a trend line described by the following equation; yield stress (MPa) = 665 + 59 ln (dpa), where 30 > dpa > 0.1. Since tensile data of F82H or similar low-activation ferritic steels at high fluence level are quite limited, the saturation level in yield strength cannot currently be determined. The present spectrally tailored results at 200°C (200J) and 300°C (11J) are also on this trend line. Irradiation at 400°C and 500°C does not indicate significant irradiation hardening (Fig. 3) and yield stresses are almost the same (±50 MPa) as those of unirradiated material. Yield stresses of spectrally tailored specimens irradiated at 200°C and 400°C in 200 J and 400 J (9 dpa) are also shown on the trend line. Total elongation of specimen irradiated at 200°C in 200J and at 400°C in 400J10 was 8% and 10%, respectively, which are in reasonable agreement with other irradiation results.

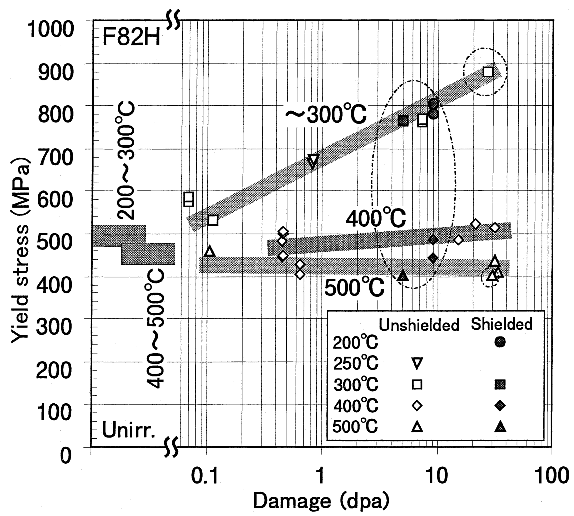

Fig. 3. Dose dependence of yield stress of neutron-irradiated F82H steel.

As shown in Fig. 1, HFIR target irradiation to 5–10 dpa reduces W content in F82H from 2 to about 1.6 wt%. To determine the effect of W on tensile properties, heats 1B, 1J and 1K (Table 1) containing ≈1.4%, 2.0% and 2.5% W, respectively, were tested in the normalized and tempered condition at room temperature. The results are shown as the dependence of yield stress and total elongation on W content in Fig. 4. From these results, it appears that the reduction of W caused by nuclear transmutation might decrease the yield stress and increase the total elongation. In the case of 300°C irradiation, the thermal neutron fluence of the spectrally tailored irradiation to 5 dpa was about 1/10 of target irradiation to 8 dpa so that the W content in the spectrally tailored specimen is estimated to be about 1.9 wt%

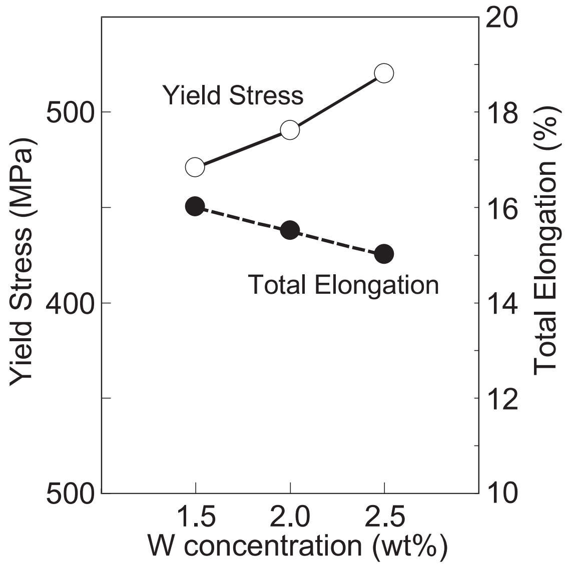

Fig. 4. Yield stress and total elongation dependence on W content of normalized and tempered 8Cr–(1.5–2.5)WVTa martensitic steel at room temperature.

from Fig. 1. Furthermore, the target irradiation to 31 dpa at 500°C reduces W content more strongly to about 1.3 wt%. However, tensile results of spectrally tailored specimen were almost the same as unshielded target result (Fig. 2). A helium effect could also be expected in a spectral-tailoring irradiation, but the calculated helium amount of 3–17 appm He generated during irradiation is small in all the specimen (Table 2). Therefore, the helium effect on both strength and ductility can be neglected. These irradiation test results indicate that the neutron spectrum do not influence tensile properties at the damage level of 5–9 dpa investigated in this study.

4. Summary

Spectral tailored irradiation of low-activation martensitic steel F82H was carried out in the HFIR RB position to investigate the neutron spectrum effects on tensile properties. While tungsten reduction by the neutron transmutation was expected, no such significant spectrum effects on tensile strength and total elongation were observed for irradiation up to 5 dpa at 300–500°C.

Acknowledgements

The authors wish to express their thanks to Drs E.E. Bloom, and A.F. Rowcliffe for administering the US/Japan collaborative experiments and all the people at the ORNL M&C Division Hot Laboratory for their service to complete the testing in this research. We also thank Dr S. Jitsukawa for his useful discussions on this research.

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