TENSILE RESULTS OF LOW-ACTIVATION MARTENSITIC STEEL IRRADIATED IN HFIR RB-11J AND RB-12J SPECTRALLY TAILORED CAPSULES, K. Shiba (Japan Atomic Energy Research Institute), R. L. Klueh (Oak Ridge National Laboratory), Y. Miwa, N. Igawa (Japan Atomic Energy Research Institute) and J. P. Robertson (Oak Ridge National Laboratory)

Objective

The objective of this investigation is to examine post-irradiation tensile behavior of low-activation martensitic steel F82H IEA heat base metal and weldments irradiated at 300 and 500°C in HFIR. Additionally, strain rate effects on the tensile properties of F82H IEA base metal were examined.

Summary

Post-irradiation tensile test results for F82H IEA heat base metal (BM) and TIG weldments are reported. Tensile specimens were irradiated to about 5 dpa at 300 and 500°C. Irradiation caused significant hardening at 300°C. The TIG weld metal (WM) exhibited almost the same amount of irradiation hardening as the BM, but the TIG weld joint (WJ) showed less hardening than BM and WM. Increasing the strain rate caused a slight increase in yield strength, while a decreasing strain rate caused a sharper stress drop after yielding for BM specimens irradiated at 300°C. No difference in strength was observed for the BM, WM, and WJ specimens irradiated at 500°C. However, a decrease in strain rate caused a reduction in elongation.

Progress and status

Introduction

Investigation of irradiation behavior of low activation martensitic steel has been conducted using the HFIR. Previous irradiation experiments dealt with mainly base metal (BM). Irradiation behavior of weldment joints, such as TIG welded joints, is also important for a fusion reactor design. Tensile, Charpy and other specimens have been irradiated in US/JAERI phase 3 experiment. Post-irradiation tensile test results of F82H IEA heat BM and TIG weldments are presented in this report.

Experimental Procedure

F82H IEA heat (F82H IEA) BM and its TIG weldments were used for the irradiation. F82H IEA was hot-rolled at 1200°C and then normalized at 1040°C for 0.63 h and tempered at 750°C for 1 h. TIG weldments were annealed at 720°C 1 h after welding. The chemical compositions of the F82H IEA heat and TIG wire are shown in Table 1, and TIG welding conditions have been previously reported [1]. Microstructure and Vickers' hardness of a TIG welded joint are shown in Figure 1. Weld joint (WJ), weld metal (WM) and heat affected zone (HAZ) type specimens were fabricated as shown in Figure 2. SS-3 sheet tensile specimens with gauge section of 7.62 mm x 0.76 mm x 1.5 mm were irradiated. Tensile tests on the BM, WM, and HAZ were carried out at a strain rate of 1×10^{-3} s^{-1} at room temperature and the nominal irradiation temperature. Some F82H IEA BM specimens were

also tested at strain rates of $1x10^{-2}$ s^{-1} and $1x10^{-4}$ s^{-1} at room temperature to examine strain rate effects. The irradiation was performed in the HFIR RB-11J and -12J capsules, which had Europium thermal neutron shields for neutron spectrum tailoring. Irradiation conditions of these capsules are summarized in Table 2, and further information on the capsules can be found elsewhere [2-5].

Table 1 Chemical composition of the steels (wt.%).

	Fe	Cr	W	V	Ta	C	B
F82H IEA heat	Bal.	7.71	1.95	0.16	0.02	0.090	0.0002
TIG wire	Bal.	7.34	2.04	0.22	0.026	0.08	< 0.0002

	Si	Mn	P	S	Al	N
F82H IEA heat	0.11	0.16	0.002	0.002	0.003	0.006
TIG wire	0.10	0.49	0.004	0.004	< 0.002	0.0064

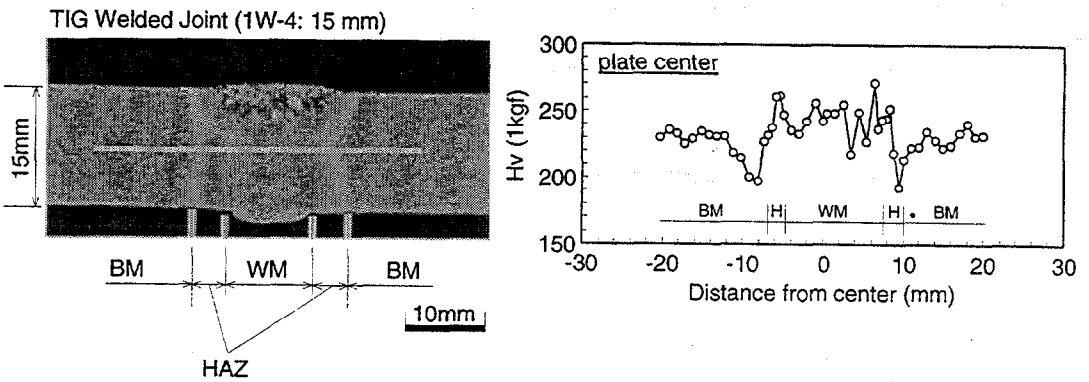

Figure 1 Microstructure and Vickers' hardness of F82H IEA TIG welded joint.

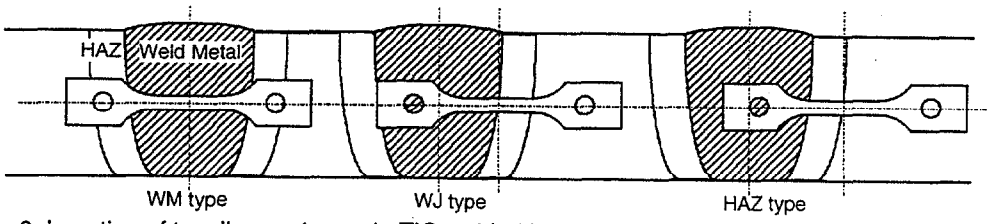

Figure 2 Location of tensile specimens in TIG welded joint.

Table 2 Summary of irradiation conditions. (*: Estimation)

Capsule		Nominal Irradiation Temperature (°C)	Neutron fluence (n/cm^2)*		Damage* (dpa)	He* (appm)
			Thermal (E<0.5eV)	Fast (E>0.1MeV)		
11J	Shielded	300	$1x10^{21}$	$1x10^{22}$	5	3
12J	Shielded	500	$1x10^{21}$	$1x10^{22}$	5	3

Results and Discussion

Tensile test results are summarized in Table 3. Increases in yield stresses of F82H IEA BM and weldments are plotted in Figure 3. Significant hardening occurred by irradiation at 300°C for tests at both room temperature and 300°C. In contrast, irradiation at 500°C did not cause apparent hardening. Stress-strain curves of F82H IEA and weldments irradiated at 300°C and tested at room temperature are shown in Figure 4. BM and WM have almost the same character of stress-strain curves; however, the stress-strain curves of the WJ and HAZ are apparently different. As shown in Figure 3, TIG weld metal exhibited a higher yield strength than base metal before and after irradiation. The increase in yield stress of WM is almost the same as that of BM. On the other hand, the increase in yield stress in WJ is less than half of that of the BM and WM. Yield strength and elongation of the TIG weld joint were lower than those of base metal, because it contains heat affected zone with lower strength.

Table 3 Tensile test results from RB-11J and -12J capsules.

Material	Specimen ID	dpa	Irrad. Temp. (°C)	Test Temp. (°C)	Strain Rate (s^{-1})	Yield Stress YS (MPa)	Ultimate Tensile Stress UTS (MPa)	Uniform Elongation Eu (%)	Total Elongation Et (%)
F82H IEA std	A025	4.9	307	28	$1x10^{-2}$	960	968	0.47	7.62
	A023	4.9	307	25	$1x10^{-3}$	898	911	0.45	7.76
	A026	4.9	307	25	$1x10^{-4}$	889	896	0.38	8.23
	A024	4.9	307	300	$1x10^{-3}$	762	770	0.32	7.31
	A038	4.8	497	25	$1x10^{-2}$	510	630	6.66	18.22
	A033	4.8	497	25	$1x10^{-3}$	527	637	7.54	18.31
	A039	4.8	497	25	$1x10^{-4}$	535	620	4.30	14.51
	A035	4.9	497	500	$1x10^{-3}$	401	444	1.92	11.16
F82H IEA std TIG WM	TW01	4.7	307	25	$1x10^{-3}$	963	1011	0.55	8.54
	TW02	4.7	307	300	$1x10^{-3}$	821	867	0.67	7.83
	TW05	4.5	497	25	$1x10^{-3}$	605	714	4.90	13.61
	TW06	4.5	497	500	$1x10^{-3}$	460	515	1.96	10.71
F82H IEA std TIG WJ	TJ01	4.7	307	25	$1x10^{-3}$	665	685	0.96	8.92
	TJ02	4.7	307	300	$1x10^{-3}$	532	552	1.00	8.08
	TJ08	4.7	497	25	$1x10^{-3}$	528	597	2.85	12.30
	TJ06	4.7	497	500	$1x10^{-3}$	347	373	1.57	9.37
F82H IEA std TIG HAZ	TH02	4.8	307	25	$1x10^{-3}$	652	670	1.15	9.32
	TH03	4.8	307	300	$1x10^{-3}$	550	568	1.03	8.62
	TH08	4.3	478	25	$1x10^{-3}$	422	569	5.30	13.96
	TH09	4.3	478	500	$1x10^{-3}$	320	370	2.10	11.65

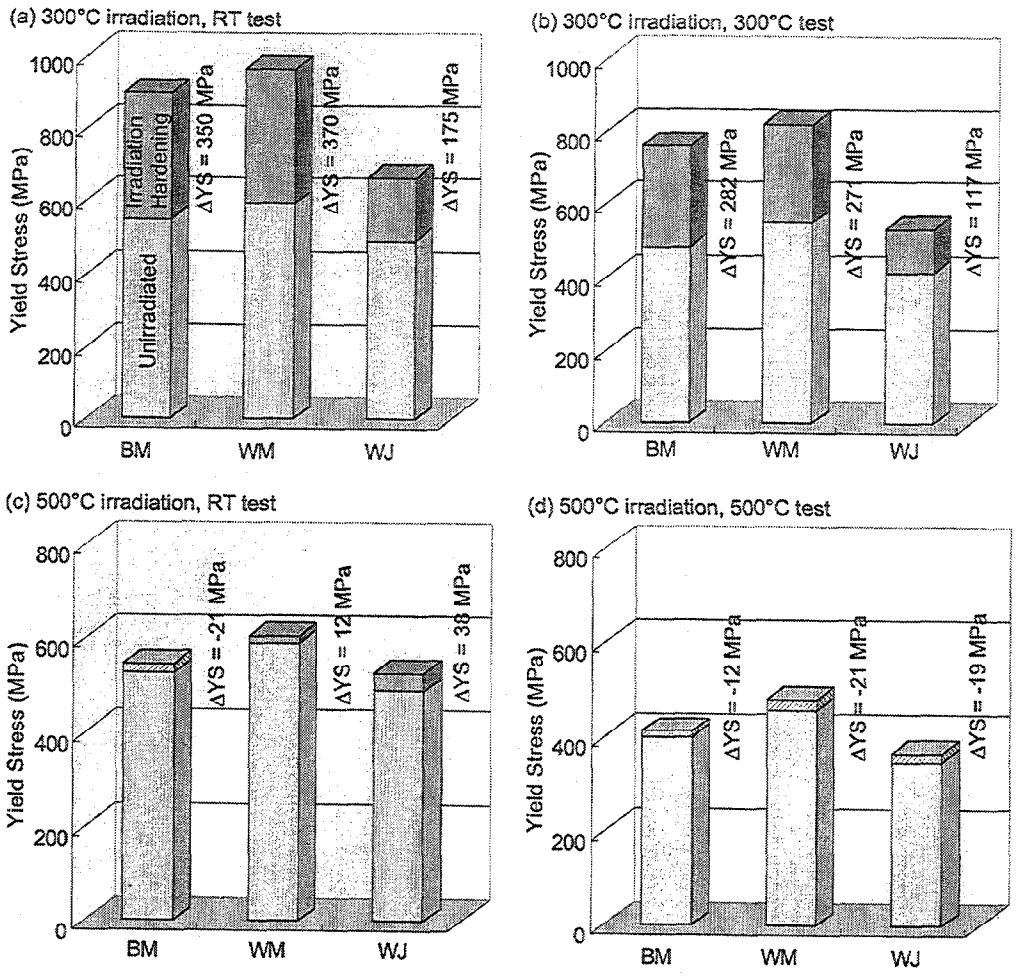

Figure 3 Irradiation hardening in F82H IEA and TIG weldments (HFIR RB-11J and 12J).

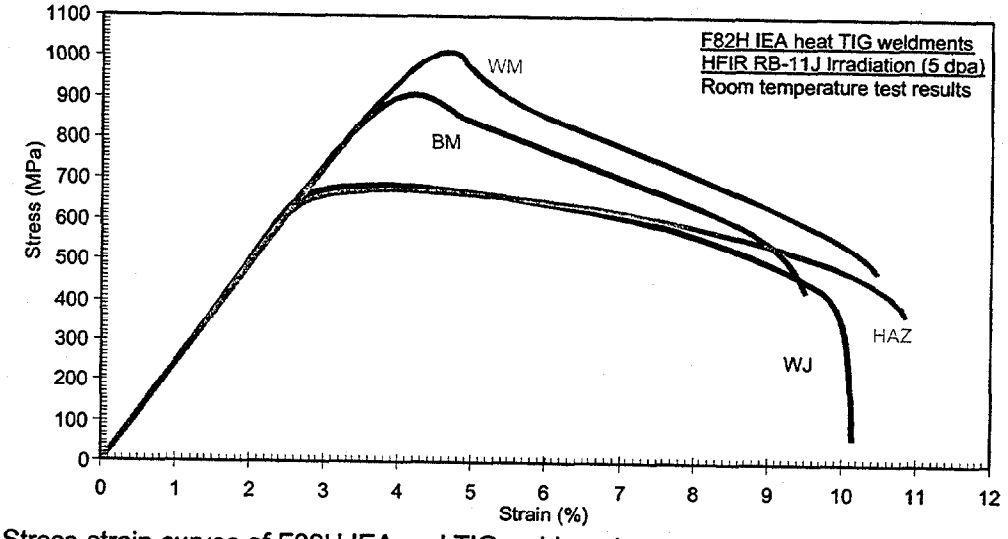

Figure 4 Stress-strain curves of F82H IEA and TIG weldments.

Stress-strain curves of F82H IEA BM specimens tested with different strain rates are shown in Figure 5. Stress levels for the specimens irradiated at 300°C were affected by strain rate, when the strain rates were changed from 1 x 10^{-3} s^{-3} used for the tests discussed above. A higher strain rate (1 x 10^{-2} s^{-1}) caused some increase in yield strength, and a slower strain rate (1 x 10^{-4} s^{-1}) caused a sharper stress drop after yielding for the specimens irradiated at 300°C. The specimens irradiated at 500°C did not exhibit any difference in strength due to strain rate, but the slowest strain rate caused less elongation.

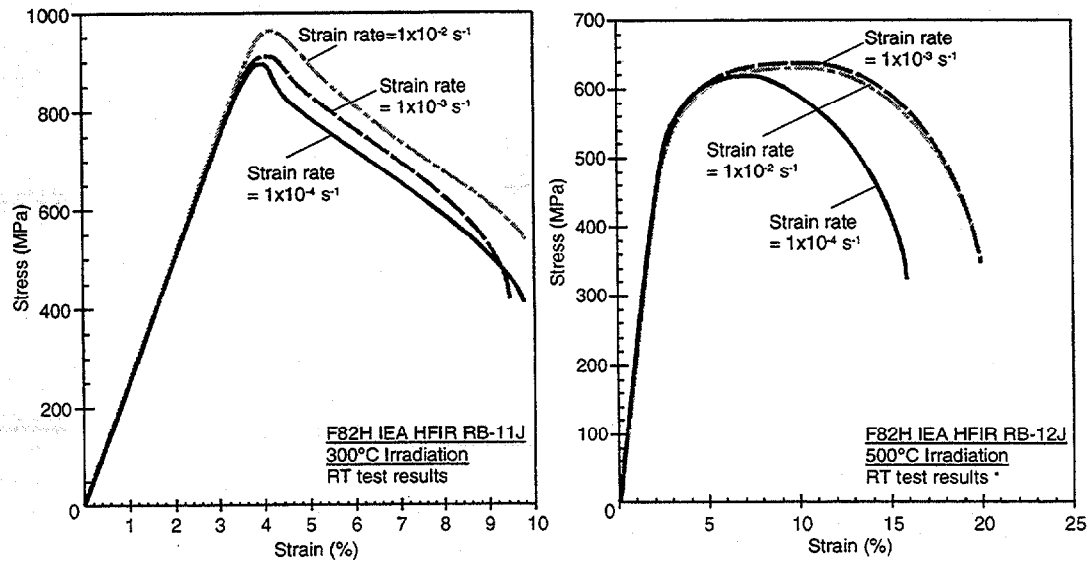

Figure 5 Stress-strain curves of F82H IEA tested at different strain rates.

Future Work

TEM observation of the HAZ region of the weldment is needed to understand the reason for the low irradiation hardening in this material irradiated in the 11J capsule. Ion irradiation experiments on TIG weldments using the TIARA facility (JAERI, Takasaki) is scheduled to examine the changes in microstructure and hardness due to ion irradiation. Some more tensile tests to determine the strain rate effect using F82H IEA specimens irradiated in 11J and 12H are planned at JAERI.

References

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[2] J.E. Pawel, et al., DOE/ER-0313/19 Fusion Materials (Sep. 30 1995), p312.

[3] J.E. Pawel, et al., DOE/ER-0313/21 Fusion Materials (Dec. 31 1996), p249.

[4] M.L. Grossbeck, et al., DOE/ER-0313/22 Fusion Materials (June 30 1997), p254.

[5] L.E. Lenox and M.L. Grossbeck, DOE/ER-0313/25 Fusion Materials (Dec. 31 1998), p307.