SHEAR PUNCH PROPERTIES OF LOW ACTIVATION FERRITIC STEELS FOLLOWING IRRADIATION IN ORR - R. M. Ermi, M. L. Hamilton, and D. S. Gelles (Pacific Northwest National Laboratory) and A. M. Ermi (COGEMA Engineering Corporation, Richland, WA)

OBJECTIVE

The objective of this effort is to determine the irradiation induced hardening response in low activation ferritic steels following irradiation at temperatures of 400°C and below in order to better understand behavior in this alloy class at low irradiation temperatures.

SUMMARY

Shear punch post-irradiation test results are reported for a series of low activation steels containing Mn following irradiation in the Oak Ridge Reactor at 330 and 400°C to ~10 dpa. Alloy compositions included 2Cr, 9Cr and 12Cr steels with V to 1.5% and W to 1.0%. Comparison of results with tensile test results showed good correlations with previously observed trends except where disks were improperly manufactured because they were too thin or because engraving was faulty.

PROGRESS AND STATUS

<u>Introduction</u>

The post-irradiation tensile test response has been reported for a series of reduced activation alloys containing manganese following irradiation in the Oak Ridge Reactor (ORR) at 60, 200, 330, and 400°C to ~10 dpa.[1] The alloys include 2% Cr alloys with V additions, and 9% and 12% Cr alloys containing Mn with V and W additions (Table 1). Companion transmission electron microscopy (TEM) specimens were included in that irradiation experiment at 330 and 400°C in order to provide microstructural information. Recent improvements in specimen preparation technique now allow preparation of transparent foils from 1 mm diameter disks.[2] Smaller samples reduce magnetic and radioactivity effects allowing, for example, more effective identification of precipitate phases. Therefore, the standard 3 mm diameter TEM disks had to be reduced to 1 mm and it was expedient to obtain shear punch information in the process. This report therefore provides shear punch data for the TEM specimens contained in the ORR test.

<u>Experimental Procedure</u>

Compositions and identification codes for specimens irradiated in the ORR-MFE 6J and 7J tests are provided in Table 1. Table 1 includes identification code information for corresponding tensile specimens. Specimens were of standard TEM geometry, 3 mm in diameter x 0.20 mm. Shear punch tests were performed at room temperature using standard techniques.[3] The 6J test accumulated a midplane fluence of 2.4 x 10^{22} n/cm^2 (total) or 8.8 x 10^{21} n/cm^2 (E>0.1 MeV) and the 7J test accumulated a fluence of 2.7x 10^{22} n/cm^2 (total) or 9.5 x 10^{21} n/cm^2 (E>0.1 MeV).[4,5] This corresponds to damage levels of 6.6 - 6.8 and 7.1 - 7.3 dpa, respectively, variations corresponding to lower or higher chromium levels. Predicted helium levels are 2.1 to 2.3 appm for both tests, with variations due to higher or lower chromium levels, respectively.

Table 1. Identification codes (TEM / Tensile) and compositions for TEM specimens irradiated in the ORR-MFE 6J and 7J tests.[1]

ID code	Heat # or alloy name	Composition (w/o)					
		Cr	V	W	Mo	C	Mn
P3/TE	V02262	2.25	0.5			0.1	
P5/TZ	UC-19	2.25	1.5		0.2	0.1	0.3
RB/TR	V02268	9	0.3	1.0		0.1	2.5
P6/TM	V02264	9	0.5			0.1	
P9/TP	V02266	9	0.5			0.1	2.0
P7/TN	V02265	9	1.3			0.2	1.0
RE/TU	V02269	12	0.3	1.0		0.1	6.5
RA/TL	V02267	12	1.0			0.1	6.5

Results

The shear punch results are given in Table 2 along with corresponding tensile results. These results can be compared by plotting tensile yield strength against effective shear yield stress and ultimate tensile strength against effective shear maximum stress, as shown in Figures 1 and 2. Both plots include a trend line at a slope of 2 and a separation between the 330 and 400 C data points. Figures 1 and 2 indicate that the correlation found previously at a slope of ~2 applies to these data sets, but several data points deviate significantly from the trend line.

Discussion

A review of experimental details showed that all points that deviated significantly from the trend lines in Figures 1 and 2 corresponded to defective TEM disks. Either they were thinner than 0.006" (0.15 mm) [P3LH and P9LH] whereas TEM disks were intended to be 0.008" (0.20 mm) thick, or engraving codes were not located properly [P5LB was engraved at the center and P7LH was engraved on both sides]. Disks are oriented with engraving codes up and away from the punch to avoid stress risers in regions under tension. Engraving problems consistently raised shear strength values about 100 MPa from the trend line whereas disks with reduced thickness gave inconsistent behavior, sometimes higher and sometimes lower than the trend line. Standard procedures require die tolerances be related to specimen thickness, but a fixed die tolerance was used for this work. However, a recent study has shown that the mechanical properties obtained from the shear punch test are relatively insensitive to specimen thickness over the range of thicknesses covered in the present study.[6] Therefore, the inconsistent mechanical properties obtained from thin specimens is not understood. But it can be concluded that shear punch tests on irradiated low activation alloys can be expected to give consistent estimates of strength provided disks are not undersized in thickness and engraving codes do not interfere with testing.

Conclusions

A series of low activation alloys that were irradiated as TEM disks in the ORR have been tested by shear punching and the values obtained have been compared with tensile tests on companion specimens irradiated under identical conditions.

Comparison of shear punch and tensile behavior is found to be consistent with previous trends except when specimens are too thin or when engraving codes are improperly positioned. Therefore, it should be possible to assess strength increases due to irradiation of low activation alloys using shear punch procedures providing disks are carefully manufactured.

Table 2. Shear punch and uniaxial tensile test results on low activation steel specimens following irradiation in ORR.

ID TEM/Tensile	Dose (dpa)	Irr Temp (°C)	Test Temp (°C)	Effect.Yield Shear (MPa)	Effect.Max. Shear (MPa)	YS (MPa)	UTS (MPa)	UE (%)	TE (%)
P3LB/TE11	7.1	330	22	680	888	1367	1412	0.8	5.8
P3LH/TE13	7.1	400	22	320	462	1198	1230	0.8	6.9
P4LB/	7.1	330	22	580	694				
P4LH/	7.1	400	22	405	506				
P5LB/TZ11	7.1	340	22	650	717	1014	1014	0	0
P5LH/TZ15	7.1	400	22	305	423	661	700	1.4	8.6
RBLB/TR11	7.2	330	22	480	567	885	893	0.4	8.4
RBLH/TR15	7.2	400	22	260	458	576	673	6.2	16.6
P6LB/TM11	7.2	330	22	480	620	879	883	0.3	9.6
P7LB/TN11	7.2	330	22	500	613	917	933	0.6	8.9
P7LH/TN13	7.2	400	22	410	555	504	618	7.4	20.1
P9LB/TP11	7.2	330	22	430	537	960	971	0.5	8.1
P9LH/TP13	7.2	400	22	400	546	565	643	5.1	17.8
RELB/TU11	7.3	330	22	530	650	1009	1066	1.4	7.8
RELH/TU15	7.3	400	22	420	581	755	888	5	10.2
RALB/TL11	7.2	330	22	480	587	970	1004	3	10.8
RALH/TL13	7.3	400	22	400	553	719	846	7.1	15.3

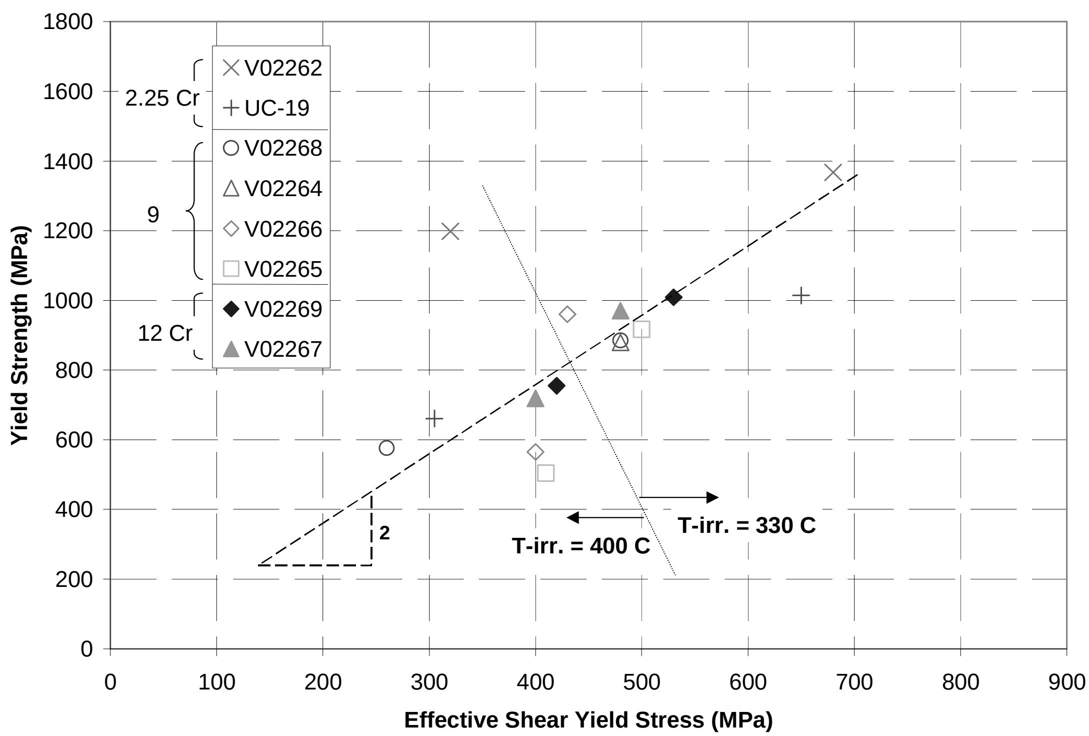

Figure 1. Comparison of tensile yield strength and effective shear yield stress.

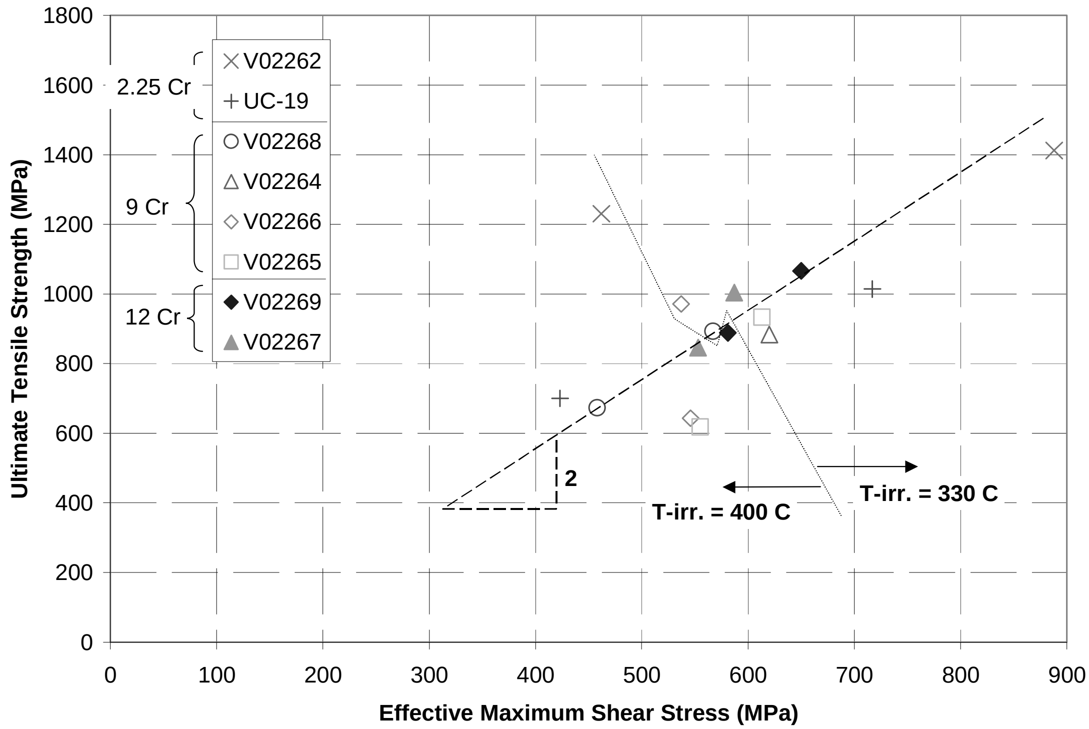

Figure 2. Comparison of ultimate tensile strength and effective maximum shear stress.

FUTURE WORK

TEM specimens 1 mm in diameter will be thinned and examined. The effort is then expected to shift to acquisition and testing of the ORR specimens further irradiated in HFIR.

REFERENCES

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