# SOME EFFECTS OF WARM PRESTRESSING (WPS) IN A533BW WELD METAL

P.A.S. Reed* and J.F. Knott*

Warm Prestressing effects have been considered of relevance when calculating possible crack growth in the pressure vessel of a PWR during a loss of coolant accident. Since the most critical regions are associated with welds, a study of WPS has been made in A533BW.

## Comparison of Prestress cycles and transition behaviour

(1) $K_{IC}$ testing of A533BW was undertaken in accordance with BS5447(1) over a range of temperatures (-196°C to -150°C) Weld composition, specimen dimensions and loading configuration are shown in Figure (1). The fracture toughness curve shows a transition temperature of -150°C. Prestress cycles (LCF and LUCF) were carried out at -100°C to K-levels of 61-70 MPa√m (below general yield). These prestressed specimens were then tested over the same temperature range and a comparison of fracture toughness variation with temperature, with and without prestress, is shown in Figure (2).

The LCF cycle increases $K_{IC}$, more than the LUCF cycle. It is possible that the LUCF cycle shows a shift in transition temperature: $K_{IC}$ values for all temperatures are needed to confirm this, but there is no obvious change in the variation of a % fibrous rupture with temperature in LUCF specimens compared with non warm prestressed (NWPS) specimens.

## SEM Fractography

Examination of the NWPS fracture surfaces shows several instances of inclusion initiated fracture (Figure 3) but no single initiation site (c.f. McRobie) possibly because the weld contained many "suitable" microcrack nuclei and so the primary cracking event only slightly preceded many secondary cracking events. The inclusions which initiated failure were ~1µm or more in size.

Both LCF and LUCF fracture surfaces also showed inclusion initiated fracture, but smaller inclusions seemed to initiate cleavage facets and nearby larger inclusions appeared to be blunted (Figure 4).

It is possible that larger inclusions are "taken-out" during prestress, by cracking and forming microcracks which are then blunted out by further flow in the metal matrix. This could effectively change the available inclusion size distribution. Tweed (3) has shown that it is the larger inclusions in weld metals which initiate failure, so this could be a mechanism for the observed beneficial effects of WPS in raising $K_{IC}$ values. Actual failure-initiating inclusion size distribution data are required for both NWPS and WPS specimens.

*Dept. of Materials Science, University of Cambridge, UK

If the postulated "microcrack blunting" mechanism does occur, it may well only be a minor effect as predictive models have been developed by Chell et al and Curry (4,5) for the WPS effect, based on the principle of super-position. Another theory suggested has been that the change in crack-tip profile during prestress could contribute to the WPS effect, as macrocrack blunting would require higher loads to achieve the critical stress distribution for fracture. An investigation was undertaken using the same procedures as in Part (1).

Macrocrack blunting

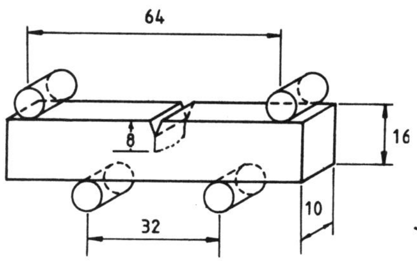
(2) 4 specimens were prestressed to a K-level of 60-68 MPa$\sqrt{m}$ and 4 controls were given a stress-relieving heat treatment of 2 hrs at 650$^{\circ}$C under vacuum followed by slow cooling. They were then tested at -196$^{\circ}$C. See Figure (5), all heat-treated specimens' $K_{IC}$ values lie in the 30-40 MPa$\sqrt{m}$ range, regardless of prior prestress operations and there is no discernible WPS effect. The heat-treatment was designed to relieve all compressive residual stresses about the crack from the prestress operation, but the crack-tip profile change is maintained. Macrocrack blunting therefore has minimal effect on $K_{IC}$. However one would also expect any microcrack blunting effects would remain after the stress relieving heat treatment. Preliminary fractography has found no clear evidence of microcrack blunting but a comparison of failure-initiating inclusion size distributions is needed for WPS and NWPS specimens with and without the stress relieving heat-treatment.

## CONCLUSIONS

There is a beneficial WPS effect in A533BW. The LCF cycle is more effective than the LUCF cycle. Inclusion initiated cleavage failure is observed, and there is some evidence that larger inclusions may be cracked and the microcracks thus formed blunted out in the prestress operation, but the full significance of this with respect to the WPS effect is not clear. Crack-tip blunting is not a cause of the beneficial effect of WPS in A533BW.

## REFERENCES

(1) British Standards Institution, BS5447, 1977
(2) McRobie D.E., "Cleavage Fracture in C-Mn Weld Metals" Ph.D., Univ. of Cambridge (1985)
(3) Tweed J.H., "Microstructure-Toughness Relationships in C-Mn Weld Metals "Ph.D., Univ. of Cambridge (1982)
(4) Chell G.G., Haigh J.R. and Vitek V., Inst.J.Fract., 17, 1981
(5) Curry D.A., CERL Lab. Note RD/L/N78/79 Sept. 1979




A533BW COMPOSITION

| ELEMENT | C | Mn | Si | S | P | Ni |
|---|---|---|---|---|---|---|
| WEIGHT % | 0,04 | 1,26 | 0,65 | 0,002 | 0,007 | 1,66 |
| ELEMENT | Cr | Mo | Cu | Al | S | Ti, V |
| WEIGHT % | 0,08 | 0,35 | 0,025 | <0,02 | 0,03 - | - |

Figure 1 Weld composition and specimen dimensions.

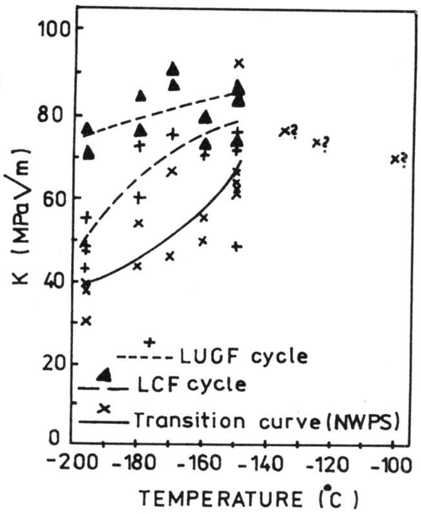



Figure 2 Variation of $K_{IC}$ with Temperature

Figure 3 Large inclusion initiating cleavage (NWPS).

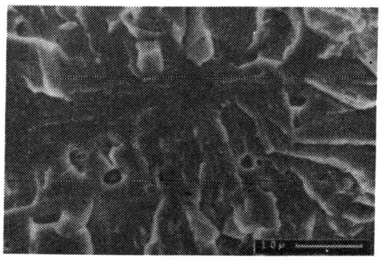


Figure 4 Small inclusion initiating cleavage (WPS).

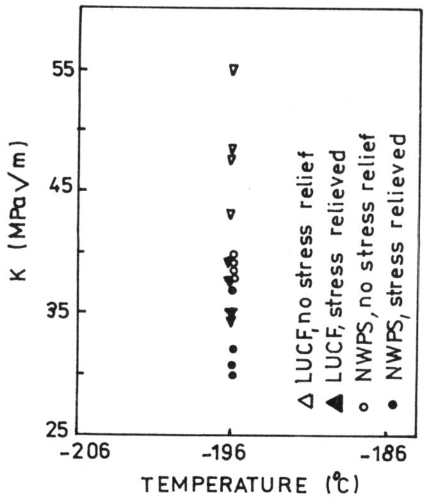



Figure 5 Investigation of macrocrack blunting.