PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

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Phil. Trans. R. Soc. Lond. A 1980 **295**, 295
doi: 10.1098/rsta.1980.0112

Phil. Trans. R. Soc. Lond. A **295**, 295 (1980) [295]
Printed in Great Britain

Creep crack growth in $2\frac{1}{4}$CrMo weld metals: the suppression of trace element embrittlement by creep strength effects*

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It has been shown previously (Gooch *et al.* 1977) that bainitic steels of the $\frac{1}{2}$Cr$\frac{1}{2}$Mo$\frac{1}{4}$V type are severely embrittled in the creep range by the presence of trace amounts of phosphorus, arsenic, tin and antimony. These steels are commonly welded by using $2\frac{1}{4}$Cr1Mo electrodes and problems of weld metal cracking transverse to the welding direction have been experienced both after post-weld heat treatment and during subsequent service. It has been suggested (Bruscato 1970) that trace element embrittlement also may be operative in $2\frac{1}{4}$Cr1Mo weld metal.

In the present work, creep crack growth tests were performed in vacuum at 565 °C on single edge notched tension specimens of four commercial manual metal arc weld metals with varying carbon (0.02–0.06 %), phosphorus (0.012–0.031 %) and arsenic (0.019–0.050 %) levels. Specimens were tested either after tempering at 650 or 700 °C, or after stress relaxation (before notching) at the same temperatures. Complementary creep rupture tests were performed on tempered material.

Results showed that, contrary to $\frac{1}{2}$Cr$\frac{1}{2}$Mo$\frac{1}{4}$V steels, crack growth rates in tempered samples were primarily dependent upon creep strength, i.e. secondary creep rate, and not on trace element levels. The greatest resistance to crack growth was in fact shown by the weld with the highest phosphorus and arsenic levels, this also being the material with the highest secondary creep rates. In all other respects the composition and structure of this weld appeared similar to that with the least resistance to crack propagation and with the lowest secondary creep rates.

However, metallographic examination revealed that, when crack growth was tested after stress relaxation at 650 °C, the high phosphorus and arsenic material showed the most extensive columnar boundary cavitation and micro-cracking remote from the major crack. Conversely, this weld showed the best resistance to crack propagation after stress relaxation at 700 °C, this being due to strain softening during the relaxation treatment.

This suggests that the major embrittling effect of high phosphorus and arsenic levels occurs during post-weld heat treatment before the matrix softens, particularly if the maximum temperature reached is nearer 650 than 700 °C. Subsequent crack propagation at operating temperatures will depend upon the damage introduced during heat treatment. However, if this damage is slight, for example if the weld contains a substantial proportion of fine grained material, crack propagation may be more dependent upon creep strength than upon trace element level.

References (Gooch)

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* Extended abstract; the full paper appears in *Proc. 5th Bolton Landing Conference* August 1978, p. 393.