INFLUENCE OF WATER ENVIRONMENTS ON FRACTURE TOUGHNESS OF AN A508 CLASS 3 FORGING

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INTRODUCTION

In the design of pressurised water reactors, use has been made of J integral-crack growth resistance curves (J-R curves) largely conducted in air at loading rates faster than anticipated in service. In this study the effect of water environments and loading rate on the J-R of a pressure vessel steel is determined.

EXPERIMENTAL DETAILS

J-R curves were determined using DC potential drop on 50 mm thick sidegrooved compact specimen at 288 °C and at one of four loading rates 5×10^{-1}, 5×10^{-2}, 5×10^{-3} and 5×10^{-4} mm/min. Tested were in air or one of three low flow rate (20l/hr) water environments; simulated PWR primary circuit water ($O_2 < 5$ ppb); simulated PWR water plus 2 ppm sulphate; and Oxygenated (100 ppb) and Sulphated (1 ppm) water. The final crack extensions were predicted to within 8 %, except in PWR water at the slowest loading rate where the technique was not successful probably due to the formation of corrosion products. Further details are given in Bigson and Druce (1).

RESULTS AND DISCUSSION

Figure 1 shows the effect of loading rate on the J-R curves determined in air and the J- Δa points determined in PWR water at the slowest loading rate.There is little effect of loading rate except at the slowest rate. Examination of the load-deflection curves revealed that this latter effect was not due to a change of yield properties, suggesting there is no effect of dynamic strain aging. Examination of the fracture surfaces revealed no effect of loading rate, with the average dimple size the same at the fastest and slowest loading rates (280 ± 20 and 270 ± 20 μm^2 respectively). However, the Vickers hardness near the crack surface and thus the fracture strain was higher for the slowest compared to the fastest loading rate (238 and 223 VPN respectively).

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The effect of loading rate could be due to thermally activated plastic flow reducing the crack tip constraint at the slowest loading rate and thus increasing the strain for void growth.

Figure 2 shows the J-R curves determined in air and various water environments at a loading rate of $5x10^{-2}$ mm/min. It can be seen from figures 1 and 2, that there is little effect on toughness of PWR water environments, with or without additions of sulphate. Examinations of the fracture surfaces revealed that fracture was by microvoid coalesence in all cases. The effect of Oxygenated and Sulphated water was to lower the J-R curve, see figure 2. Examination of the fracture surfaces revealed that the crack growth occurred by a combination of quasi-cleavage and microvoid coalesence. The occurrence of quasi-cleavage explains the audible clicks and associated rapid changes in load and PD during these tests. The quasi-cleavage is probably due to hydrogen embrittlement.

CONCLUSIONS

Fracture toughness of an ASTM A508 class 3 steel at 288 °C was unaffected by the presence of simulated PWR primary circuit water, with or without additions of 2 ppm sulphate. However, in Oxygenated (100 ppb) and Sulphated (1 ppm) water the toughness was lowered and there were bursts of quasi-cleavage fracture augmenting microvoid coalescence. Loading rates over the range $5x10^{-1}$ to $5x10^{-3}$ mm/min had little effect on fracture toughness, but he toughness was higher at a loading rate of $5x10^{-4}$ mm/min.

ACKNOWLEDGEMENT

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REFERENCE

(1) Gibson, G.P. and Druce, S.G., "The effects of water environments and loading rate on ductile crack growth resistance of an A508 class 3 forging at 288 °C", report no R12259, Harwell, Oxon, UK, 1986.

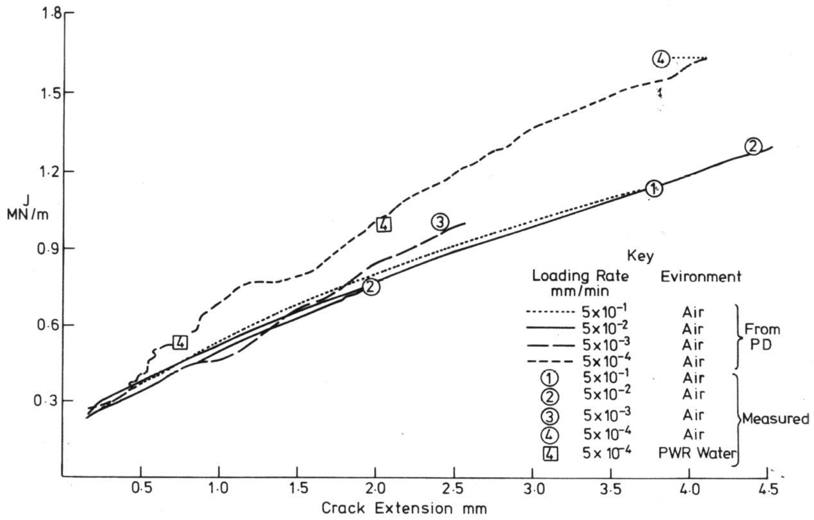

Figure 1 Effect of loading rate on J-R curves

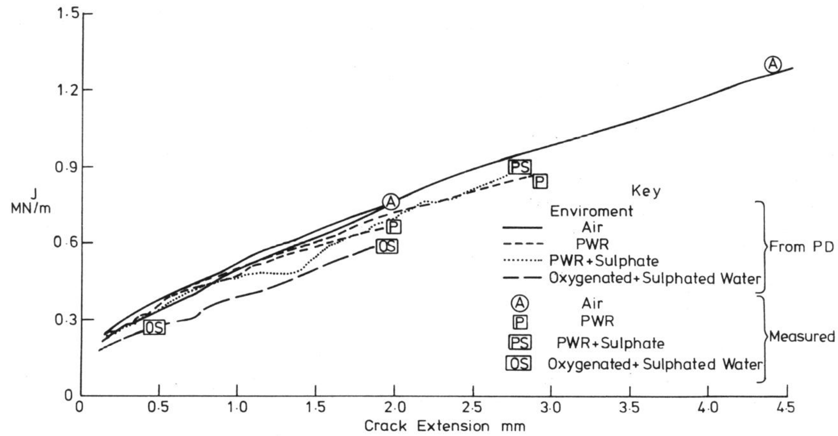

Figure 2 J-R curves determined at a loading rate of $5x10^{-2}$ mm/min