THE EFFECT OF J-INTEGRAL ESTIMATION PROCEDURE AND SIDE-GROOVING ON J-RESISTANCE CURVES FOR A533 B STEEL.

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R-curves determined for A533 B steel showed a strong variation with metallurgical structure. Reduction of crack growth resistance saturated at 25% side grooves in one structure, but continued to 40% in another. Crack growth beyond 3mm in these specimens requires the use of Jmodified.

INTRODUCTION.

This investigation explores factors which strongly influence J-resistance curves, that is the increase in resistance to cracking as a crack grows, for the pressure vessel steel A533 B. Those factors are : the structure of the steel, the method of estimating the value of the J-integral itself, the degree of constraint on yielding at the crack tip, simulated by degrees of side grooving the test pieces.

The investigation was carried out at 100C ,in order to represent conditions of ductile crack growth, and this work is part of a larger investigation into the accuracy of prediction of cracking instabilities using R-curve methods.

EXPERIMENTAL METHODS AND MATERIALS.

The steel , conforming to the A533 B composition, was tested in two conditions; the M1 condition was as-rolled (a ferrite/ pearlite structure and an extreme variant on the service condition), the M2 condition was a bainitic structure produced by heat treating at 910C, water quenching and tempering at 670C for one hour. This simulates the pressure vessel service condition.

Compact tension test pieces, 45mm thick, conforming to the ASTM E813-81 design, were tested at 100C,heated by hot air blowers. Continuous recording of the load, load-point -displacement ,allowed estimation of the J-integral value. Crack length was continuously monitored using a probe potential calibrated to the crack length by break-open experiments. The probe voltage arose from a direct current of 25 amps. passed through the testpiece. Multiple testing was at least at the triplicate level, though in some cases five similar tests gave rise to an average J-r curve.Side grooves were either not present , reduced the net thickness by 25% or reduced the net thickness by 40% of its original value.

Pre-fatigue cracking was carried out using peak loads of upto 40% of the limit load, and fatigue cracks were grown,typically, 15mm long to give a/W greater than 0.6. Side grooves were machined after fatigue cracking.

Fracture tests were carried out at a constant displacement rate of 0.2mm/min., and to separate the elastic and plastic components of the J integral, derived from the load/load-point-displacement curve, testing was periodically interupted and

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load reduced by 10%. Thus the elastic area could be subtracted from the total area. An alternative is using a theoretical elastic load-point-displacement, EPRI NP-1931 (1).

ANALYSIS.

J is derived from the load versus load-point-displacement curve using the Merkle -Corten corrections given in ASTM E813-81:

$J_r = n \text{ Area} / B_{net} b_o$ (b_o the initial ligament, n, the eta factor)

The crack growth correction used is:

$J_{cc} = J_r\ (1 - (0.75n-1))da / b_o$

Modification of the J_{cc}, Ernst (2), is based on numerically integrating the variation of J_{cc} with da and eliminating this variation. In this case:

$$J_{mod} = J_{cc} + \int_{a_o}^{a} (1 + (0.76b / W))(J_{plastic} / b)da \quad (b = \text{current ligament})$$

EXPERIMENTAL DATA.

Figure 1 shows examples of tests with no side grooves on each steel. The J derived directly from the load/load-point-displacement curve is plotted.The bainitic structure has a markedly higher J-r curve. In each case the crack corrected, Jcc, J-r curve is lower than the J curve, and the Jmod curve is higher.

Figure 2 shows average J_{mod} and da for structure M1 with no-side grooves, 25% side grooves and 40% side grooves. Figure 3 is similar for steel M2.

DISCUSSION.

The data shown here demonstrates a large variation in resistance to ductile crack growth arising from structural control of ductile micromechanisms. Though the effect of increased yielding constraint saturates at about 25% side grooving in the M1 structure, there is still a significant reduction in crack growth resistance between 25% and 40% side grooving for the M2 structure.

During the first 3mm growth of cracks in our specimens there is no significant difference between J_r, J_{cc} or J_{mod}.This is, of course, the region for J_{IC} determination. Beyond this region the difference indicates J_{mod} is necessary. This is important for prediction of instabilities based on small specimen tests.

REFERENCES.

1. EPRI-NP1931, July 1981, Elastic -Plastic Fracture Analysis.
2. Ernst H.A.,ASTM STP 803, Elastic Plastic Fracture I, pp.191-213.

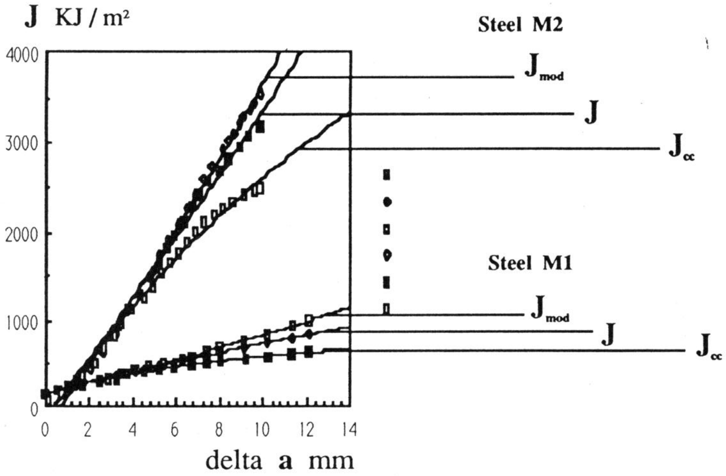

Figure 1. J-resistance curves. 45mm 2T compact, 100C.
Steels M1 & M2. No side grooves.

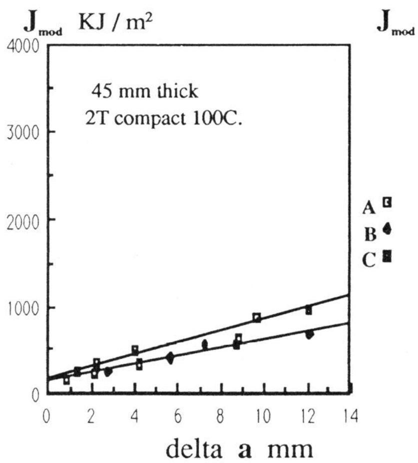

Figure 2. J-r curves steel M1: A, no side grooves B, 25% side grooves, C, 40% side grooves.

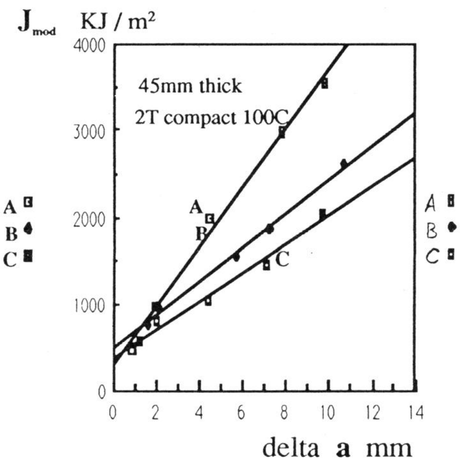

Figure 3. J-r curves steel M 2: A,no side g, B, 25% side grooves, C, 40% side grooves.