PART A: EVALUATION OF CURVE FIT

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Four types of curves fit to J-Δa data obtained using the EGF Procedure P1-90 multiple specimen technique were compared in terms of fracture parameters such as $J_{0.2}$. These plus four other models were also compared from a 'goodness of fit' point of view. A power law curve was found to be the most suitable.

INTRODUCTION

The validation of the EGF Procedure P1-90 was based on the testing of three materials with different fracture resistance behaviour. The materials used were a C-Mn pressure vessel steel (BS1501-224-490), a C-Mn structural steel (BS4360 Grade 50E) and an Al-Mg-Mn alloy (5083-0). The participating laboratories were supplied with sets of either compact specimens or single edge notch bend specimens of thickness 25mm. They produced crack growth resistance curves, R-curves, using the multiple specimen technique given in the Procedure. In addition, many of the laboratories returned R-curves determined by single specimen techniques covered in the Appendices to P1-90.

The Procedure calls for an offset power law ($J = A(\Delta a+C)^D$) to be fitted to the crack growth - toughness data obtained. This offset power law is then taken to describe the crack growth resistance behaviour of the material. There has been considerable debate over the suitability of this model and the work outlined here was carried out to evaluate a series of different curve fits.

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CURVE FIT

Comparison of the offset power law with other fits was made firstly on the basis of the fracture parameters determined from the different curves. These fracture parameters are defined schematically in Fig.1. The blunting line used is determined from the tensile properties of the material. It should be noted that the parameter J_{iBL} is not included in the current version of the Procedure.

In order to obtain sufficient data for valid comparisons, simulation techniques were used. These involved pooling the results obtained from all laboratories for each material and randomly selecting a number of points to which a curve was fitted. From every simulated R-curve, the different fracture parameters were determined. Simulations were carried out using 4, 5, 6, 7, 10 and 20 points for each curve, ensuring that the data point spacing requirements were always met.

Four different types of curve fit were studied: the offset power law, the ordinary power law, a linear fit and a fit of the type $J = A\sqrt{\Delta a}$. The results shown in Table 1 illustrate the general findings. The power laws tended to give lower values than the linear fit although in the region of maximum valid crack growth all four models gave similar results. The scatter in the fracture parameters was lowest for the square root fit but other factors discussed later do not make this fit the most suitable.

TABLE 1 - Values of $J_{0.2}$(N/mm) obtained from 500 simulated R-curves based on 6 points for BS4360 Grade 50E

	$J=A(\Delta a+C)^D$	$J=A(\Delta a)^D$	$J=A\Delta a+D$	$J=A\sqrt{\Delta a}$
Min	128.6	119.3	137.3	133.8
Max	203.1	187.7	212.5	153.9
Mean	154.4	147.7	163.4	144.0
St. dev	13.2	12.5	18.5	4.4

The simulation work also showed that scatter in J_{iBL} was so high as to make the parameter meaningless for the power law fits. For the parameters other than J_{iBL}, there was little difference between fits using 4, 5 and 6 points so the minimum of 4 points required by the Procedure would seem reasonable.

To make a more critical assessment of possible curves, eight different regression equations were fitted to the pooled data for each material. These equations were:

1. $J = D + A\Delta a$
2. $J = D + A_1\Delta a + A_2(\Delta a)^2$
3. $J = D + A_1\Delta a + A_2(\Delta a)^2 + A_3(\Delta a)^3$
4. $J = D + A_1\Delta a + A_3(\Delta a)^3$
5. $J = A(\Delta a + C)^D$
6. $J = A(\Delta a)^D$
7. $J = A + C(\Delta a)^D$
8. $J = A\sqrt{\Delta a}$

Where appropriate, the fits were made using non-linear methods. Study of the residual sums of squares obtained showed the linear and the square root fits to be the poorest. The polynominal fit without the $(\Delta a)^2$ term was very sensitive to individual points. The ordinary power law and the two offset power laws (equations 5 and 7) were very similar in their 'goodness of fit' and for small data sets, such as normally encountered in multiple specimen R-curve determination, there was no distinguishable difference.

CONCLUSIONS

The outcome of this study was to select the ordinary power law as the most appropriate fit to the R-curve data. The power law fit to the pooled data for the three materials studied is shown in figures 1, 2 and 3. This choice of fit has the advantage of simplicity over the offset power law currently indicated in the Procedure. In fact for most of the R-curves generated in this validation round robin, the offset was zero or close to it. Furthermore the work described in Part C of this combined paper indicates that the ordinary power law more accurately models the real behaviour of materials in the region of small crack extension.

Acknowledgement

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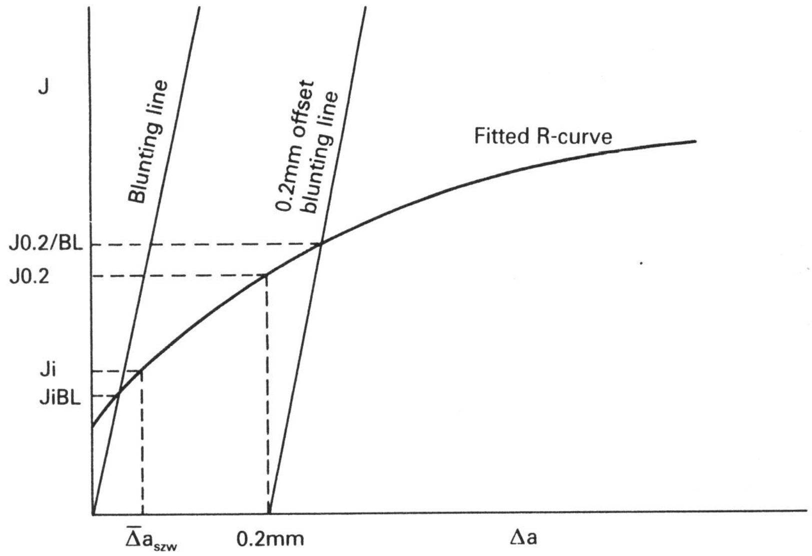

Figure 1 Definition of fracture parameters

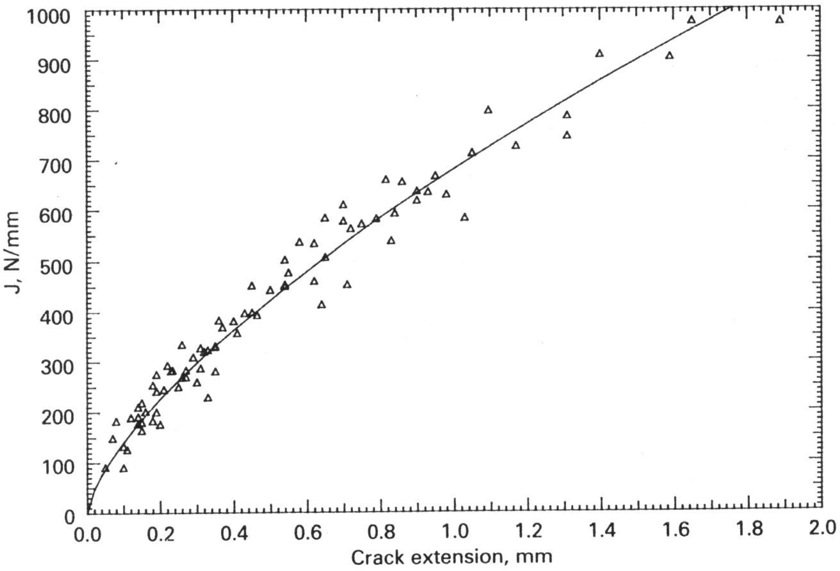

Figure 2 Power law fit to BS1501 steel results

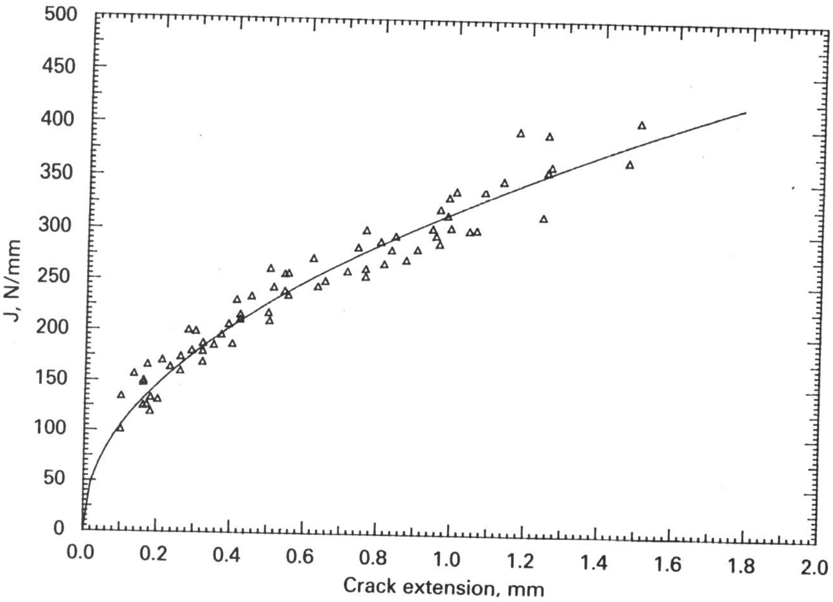

Figure 3 Power law fit to BS4360 to steel results

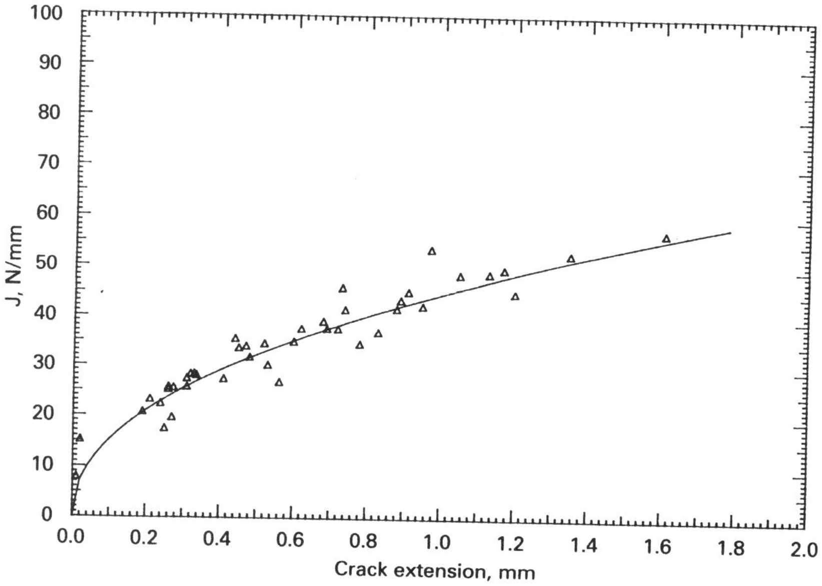

Figure 4 Power law fit to 5083 Al alloy results