A GENERALIZED CRACK GROWTH CRITERION - SIMPLIFIED J_R--TESTING

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A model for JT_J-controlled stable crack growth is presented leading to nonlinear J_R-curves and simplifying their experimental evaluation.

Among the modern fracture criteria the J-integral and its modifications (see Michel and Will (1)) have proved to be of great importance in fracture testing. It seems relevant to point out that the process of crack growth is accompanied by energy dissipation which can occur in different forms during stable crack growth supplementary to those used up in the formation of free surface. Suppose that a process zone at the crack tip has undergone plastic deformation then a fraction of the stored energy vill be dissipated and not be available for virtual crack advance. Estimation of J is based upon its meaning as the difference in the potential work done between two crack lengths. Confusion can arise when the same symbol J is used to denote the variation with crack advance of the total work.

The energy balance for a crack has been the subject of previous papers (e.g. Will and Michel (2)). Assuming quasistatic or steady crack growth and neglecting the kinetic energy the energy release per unit thickness reads as:

$$dG = Jda + e_o dA_o \qquad (1)$$

A characteristic internal energy density e_o is appropriately utilized to define the shape of the finite process region A_o. The irrecoverable energy per unit area and unit crack growth dissipated due to the expansion of the process region is given by $e_o dA/da$. On condition that the material in front of the crack should obey a power law stress-strain behaviour the second term in the energy balance reads an (Will et al (3)):

$$e_o \, dA_o/da = c_1 J T_J, \qquad T_J = n/(n+1) e_o^{-1} \, dJ/da \qquad (2)$$

Thickness effects and strain hardening or softening (exponent n) are taken into account by the dimension less factor c_1. T_J then is a modified tearing modulus.

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In contradiction to the generalization of the Griffith-Orowan concept the proper resistance of materials controlling stable crack growth above the pseudo crack advance during blunting is assumed to be a material-specific absorbed energy per unit crack extension, compensating for any excess energy (Will et al (4)). The latter concept yields an instability criterion:

$$J dJ/da \geq C_R/2 \tag{3}$$

The parameter J is characterized as the net energy rate available to create new material surface. Equation (3) associated with stable crack growth implies the non-linearity of J-resistance curves for a wide range of crack extension beyond initiation ($J > J_c$) of virtual crack growth.

$$J^2 = J_c + R_R\,(a-a_c) \qquad a \geq a_c \tag{4}$$

Note that the applicability of equation (4) is bound to the validity of the J-concept. Usually, J is determined from the area under load-deflection curves according to:

$$J = \int_0^u \frac{2}{W-a_o} P\, du' - \int_{a_o}^{a_1} \frac{J}{W-a'}\, da' \tag{5}$$

P and W-a are the current load per unit thickness and the remaining ligament respectively. The combination of the nonlinear R-curve (4) and a linearized equation (5) yields a linear regression model concerning the unknown parameter C_R.

$$\int_0^u \frac{2}{W-a_o} P\, du' = J_c + \left[J_c/(W-a_c) + 0.5\, C_R/J_c\right](a-a_c) \tag{6}$$

Relationship (6) is valid for small, virtual crack extensions beyond blunting. Its use simplifies the task of determining J-resistance curves. Figures 1 and 2 depicting experimental data (Hesse et al (5), Will et el (3)) confirm the predicted, nonlinear variation of fracture toughness with crack advance.

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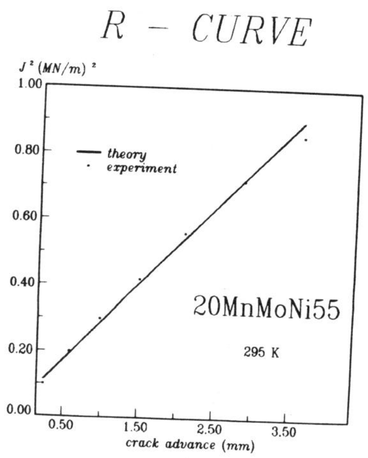

Figure 1 Variation of J^2 with crack growth

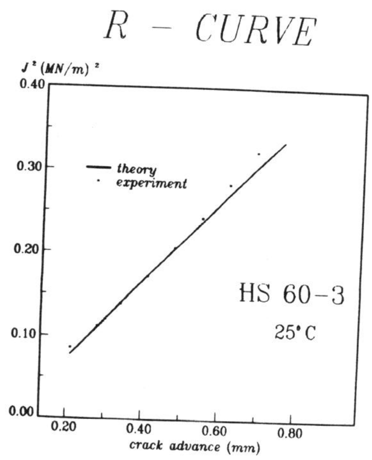

Figure 2 Variation of J^2 with crack growth