TESTING OF CRACKING SENSITIVE MATERIALS BY THE METHOD OF X-RAY FRACOGRAPHIC

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The study of failure toughness (KIC) and evolution of plastic deformation zones in the fractures of structural steels of different strength levels (σ0.2 = 256...1050 MPa) allowed to establish the correlation between KIC and the size of prefailure microzone h_A [1].

\[ K_{IC} = \left[ \pi (2h_A) \sigma_{0.2} E (1-\nu^2)^{-1} \ln (1-\psi)^{-1} \right]^{1/2} \]  

(1)

where: \( \sigma_{0.2} \) - yield strength; \( E \) - Young's modulus; \( \nu \) - Poisson's ratio; \( \psi \) - sample cross-sectional area contraction ratio.

In microzone h_A the microzone of failure (the nucleation of crack with radius \( r_* \) with deformation energy critical density \( W_C \) ) being formed, KIC and \( r_* \) can be correlated as follows:

\[ K_{IC} = \left[ r_* W_C 2\pi E (1+\nu)(1-2\nu) \right]^{1/2} \]  

(2)

where \( W_C \) is for specific failure work [2].

From the equations (1) and (2):

\[ \frac{r_*}{h_A} = \frac{\sigma_{0.2} (1-2\nu) \ln (1-\psi)^{-1}}{W_C (1-\nu)} \]  

(3)

Assuming that brittle failure \( \sigma_{0.2} = S_k \) (where \( S_k \) is the real rupture stress), \( \psi_{min} = 0.001 \) and accounting (3) we can find \( r_*^{min} \), and from equation (1) - the minimum value \( K_{IC}^{min} = K_{IC0} \) corresponding to the limit embrittlement of the material, when the plastic deformation energy in zone h_A, comparable with the value of structural parameter - can be neglected.

As:

\[ W_C = \frac{(1+\nu)(1-2\nu) \sigma_{y*}^2}{2E} \]  

(4)

jointly solving equations (2) and (4), we get:

\[ K_{IC} = \sigma_{y*} \sqrt{\frac{\pi r_*}{2}} \]  

(5)

or:

\[ K_{IC} = \sigma_{y*} \sqrt{\frac{\pi r_*^{min}}{2}} \]  

(6)

where: \( \sigma_{y*} \) - stress \( \sigma_y \) at the distance \( r_* \) from the crack tip.

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The calculations based on equations (1 ... 5) with an account of experimental values H_{Al}, S_{K}, E, Y and W_{G} showed that for steels the value of G_{Y} varies insignificantly and equals (0.115 ... 0.135) E.

The knowledge of K_{ICO} allows to define the minimum critical size of defect (crack) and to estimate the value of energy intended for the formation of plastic deformation zone (K_{Ic}) in material in question at given temperature (t_i).

\[ K_{Ic}^{tie} = K_{Ic}^{tie} - K_{Ico} \]
\[ K_{Ic}^{max} = K_{Ic}^{max} - K_{Ico}^{min} \]  

(7)

The brittle failure giving: K_{Ico} = K_{IC} = K_{Ic} and K_{Ic} = 0, and quasi-brittle and ductile failure giving: K_{Ico} < K_{IC} < K_{Ic}^{max} and 0 < K_{Ic} < K_{Ic}^{max} the difference K_{Ic}^{max} - K_{Ico} characterises the maximum plastic deformation energy in material with crack.

Nondimensional value of \( k_{Ic}^{tie} = \frac{K_{Ic}^{tie}}{K_{Ic}^{max}} \) can be taken as failure toughness safety factor at a given temperature \( t_i \). In the tough-brittle transition temperature interval \( k_{Ic}^{tie} \) can vary within the range: 0 \( \leq k_{Ic}^{tie} \leq 1 \).

REFERENCES
