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

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The study of failure toughness (K_{IC}) and evalution of plastic deformation zones in the fractures of structural steels of different strength levels ($\sigma_{0,2}$ = 256... ... 1050 MPa) allowed to establish the correlation between K_{IC} and the size of prefailure microzone h_A [1].:

$$K_{Ic} = [\pi(2h_A)\,\sigma_{0,2}\,E\,(1-\nu^2)^{-1}\,\ln(1-\psi)^{-1}]^{1/2} \tag{1}$$

where: $\sigma_{0,2}$ - yield strength; E - Young's modulus; ν - Poisson's ratio; ψ - sample cross-sectional area contraction ratio.

In microzone h_A the microzone of failure (the nuclews of the crack with radius r_* with deformation energy critical density W_c) being formed, K_{IC} and r_* can be correlated as follows:

$$K_{Ic} = [r_* W_c\, 2\pi E/(1+\nu)(1-2\nu)]^{1/2} \tag{2}$$

where W_c is for specific failure work [2].
From the equations (1) and (2):

$$r_*/h_A = \sigma_{0,2}\,(1-2\nu)\,\ln(1-\psi)^{-1}/W_c\,(1-\nu) \tag{3}$$

Assuming that brittle failure $\sigma_{0,2} \cong S_k$ (where S_k is the real rupture stress), $\psi_{min} \cong 0.001$ and accounting (3) we can find r_*^{min}, and from equation (1) - the minimum value $K_{Ic}^{min} = K_{ICO}$, 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:

$$W_c = (1+\nu)(1-2\nu)\,\sigma_{y*}^2/2E \tag{4}$$

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

$$K_{Ic} = \sigma_{y*}\sqrt{\pi r_*} \tag{5}$$

or:

$$K_{Ic} = \sigma_{y*}\sqrt{\pi r_*^{min}} \tag{6}$$

where: σ_{y*} - stress σ_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_A, S_K, E, ν and W_c showed that for steels the value of σ_{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 ($K_{I\varepsilon}^{ti}$) in material in question at given temperature (t_i).

$$K_{I\varepsilon}^{ti} = K_{Ic}^{ti} - K_{Ico}$$
$$K_{I\varepsilon}^{max} = K_{Ic}^{max} - K_{Ico} \tag{7}$$

The brittle failure giving: $K_{ICO} = K_{IC}^{min} = K_{IC}^{max}$ and $K_{I\varepsilon}^{min} \cong 0$, and quasibrittle and ductile failure giving: $K_{ICO} < K_{IC}^{ti} \leq K_{IC}^{max}$ and $0 < K_{I\varepsilon}^{ti} \leq K_{I\varepsilon}^{max}$ the difference $K_{I\varepsilon}^{max} = K_{IC}^{max} - K_{ICO}$ characterises the maximum plastic deformation energy in material with crack.

Nondimensional value of $k_{\varepsilon}^{ti} = K_{I\varepsilon}^{ti} / K_{I\varepsilon}^{max}$ can be taken as failure toughness safety factor at a given temperature t_i. In the tough-brittle transition temperature interval k_{ε}^{ti} can vary within the range: $0 \leqslant k_{\varepsilon} \leqslant 1$.

REFERENCES

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