Testing of Cracking Sensitive Materials by the Method of X-ray Fractograph

YU. V. SAPRYKIN
Polytechnic Institute, Frunze, USSR

ABSTRACT

For the first time experimental results shown under maximum reduction of area of plastic deformation microzone hight before fracture $2h_A$ at the crack tip has constant value for structure of steel and not dependent on environment factors. Significance of structure parameter $2h_A$ (microzone hight before fracture) allows to quantitative inspection of fracture and define toughness fracture K_{IC} and K_{ICO}.

KEYWORDS

Microzone before fracture A; structure parameter $2h_A$;toughness fracture K_{IC},K_{ICO}; inspection of fracture, X-ray fractographic.

In this work used chemical resistance method coating with microlayer thickness $h < 10^{-2}$ mm and subsequent radiography at diffractometer analysed fracture of steels (shown table I). Establishing that in plastic zone "C" at the crack tip for - ming microzone before fracture A with maximum level of structural distortion (fig.I.). For above hight range A equal to $2h_A$ under maximum reduction of area of plastic deformation not depending on type of load (cyclik, static), specimen size,

Table I. Significance of mechanical property structural parameter and crack resistance of tested steels.

Steel grade	σ_y MPa	σ_B MPa	ψ %	h_A mm	$K_{IC}^{(h)}$ $MPa \cdot m^{1/2}$	K_{IC} $MPa \cdot m^{1/2}$
Steel 20	264	423	65,6	0,020	75,2	84,5
20 K	256	438	63,8	0,025	77,5	93,5
20ЮЧ	268	470	64,I	0,025	83,2	99,3
XI8HIOT	258	57I	7I,3	0,0I5	78,5	74,2
I8X2H4BA	I000	I095	35,2	0,005	46,9	43,3
40XH2MA	I050	III7	39,I	0,005	48,5	42,6

frequency, loading rate etc. Hypothesis confirms G. Neuber (Neuber, I947) about existence of constant (same) material, together its structures and dimensions of length.

Significance of structural parameter $2h_A$ allows on the basis of analysis (Panasuk et al., I977) to carry out quantitative inspection of with determination K_{IC} (table I) applying analytical relation (Saprykin et al., I986):

$$K_{IC}^{(h)} = \left[4{,}5\, h\, \tau_s E (1-\nu^2)^{-1} \ln(1-\psi)^{-1}\right]^{1/2} \qquad (1)$$

Where $h = 2h_A$ -microzone hight before fracture, $\tau_s = \sigma_y/2$ – shear yield strength according to Treska, E- Modulus of normal elasticity, ν - coefficient of Poisson, ψ – relative contriction after fracture.

In microzone h_A 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 (Sih , I980):

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

Where W_c- specific failure work (Sih, I980; Romvary et al. , I980). From equations (I) and (2) :

$$r_*/h_A = \sigma_y(1-2\nu)\ln(1-\psi)^{-1}/W_c(1-\nu) \qquad (3)$$

Assuming while brittle failure $\sigma_y \cong S_K$ (where S_k real rupture

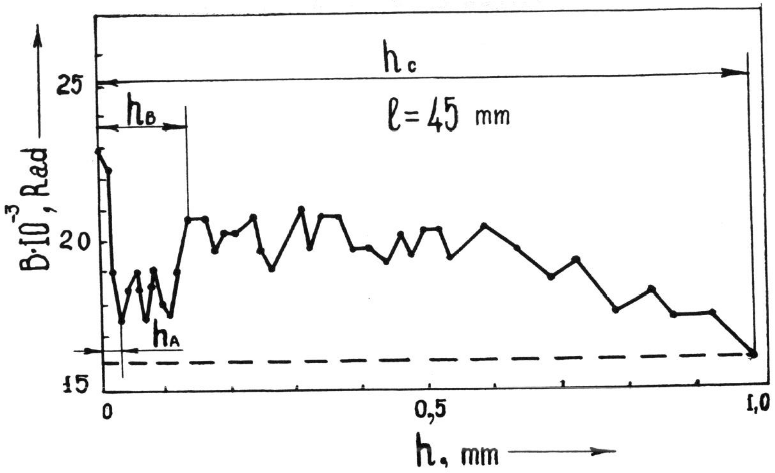

Fig.I. Relationship halfwidth B in diffraction line (220) K_α from distance h undersurface of fatigue fracture of specimen on eccentrictension (thickness 40 mm) steel 20 at crack length ℓ = 45 mm.

stress), $\psi \cong \psi_{min} = 0{,}001$ and accounting (3), we can find r^{min}, and from equation (I) - the minimum value $K_{IC}^{min} = K_{IC0}$, corresponding to 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 (Sih, I980):

$$W_c = (1+\nu)(1-2\nu)\sigma_*^2/2E \qquad (4)$$

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

$$K_{IC} = \sigma_* \sqrt{\pi r_*} \qquad (5)$$

or:

$$K_{IC0} = \sigma_* \sqrt{\pi r_*^{min}} \qquad (6)$$

where σ_* -stress σ at the distance r_* from the crack top.

The calculations based on equations (I....5) with an account of experimental values h_A, S_K, E, ν, ψ and W_c, showed, that for steels value of σ_* varies insignificantly and equals (0,II5...0,I35) E.

The knowledge of K_{IC0} allows to define the minimum critical size of defect (crack) and estimate the value of energy intended for the formation of plastic deformation zone ($K_{I\varepsilon}^{t_H}$) in material in question at given temperature (T_H) :

$$K_{I\varepsilon}^{t_H} = K_{IC}^{t_H} - K_{IC0} \quad (7)$$

or:

$$K_{I\varepsilon}^{max} = K_{IC}^{max} - K_{IC0} \quad (7')$$

The brittle failure giving: $K_{IC0} = K_{IC}^{min} = K_{IC}^{max}$ and $K_{I\varepsilon}^{min} \cong 0$, and quasibrittle and and ductile failure giving:

$$K_{IC0} < K_{IC}^{t_H} \leqslant K_{IC}^{max} \quad \text{and} \quad 0 < K_{I\varepsilon}^{t_H} \leqslant K_{I\varepsilon}^{max}$$

the difference $K_{I\varepsilon}^{max} = K_{IC}^{max} - K_{IC0}$ characterises the maximum plastic deformation energy in material with crack.

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

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