SOLUTION OF FRACTURE MECHANICS PROBLEMS USING COMPLETE STRESS-STRAIN DIAGRAMS OF MATERIALS

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Beginning with the works by Stepanov A.V., Puttick K. and Bluhm J.I. numerous references were made in the literature to the fact that fracture should be considered as a result of the loss of the deformation process stability and the feasibility of studying this phenomenon using loading systems with maximum stiffness was pointed out.

Such a system has been developed at the Institute for Problems of Strength, as well as the technique for static tests of structural materials using the system with the recording of complete stress-strain diagrams including both ascending and descending branches associated with the initiation and growth of microcracks in the material.

Phenomenological and metallophysical analysis of the specific features of deformation of steels St3, 40Kh, 22K, 15Kh2MFA, 15Kh2NMFA and other materials (technical copper, nickel alloy single crystals, aluminium alloys), which differ essentially in fracture toughness parameters, revealed complete qualitative analogy of the processes of damage accumulation and microcrack nucleation in the materials (Lebedev et al (1)). Macrofracture occurs by ductile tearing which is accompanied by the coalescence of micropores formed during deformation mainly near the inclusions and on the grain boundaries. A macrocrack is nucleated at the moment (point K in the Figure) when the stresses in the material reach the level corresponding to the tearing strength.

Basing on the convincing experimental data on the continuous character of the damage accumulation process (BK on the diagram, see the Figure) and on the macrocrack nucleation and growth (KR on the diagram, see the Figure) during deformation of plastic materials, we proposed an express-method for the material fracture toughness evaluation from the parameters of the descending branches of the stress-strain diagrams when testing small-size specimens (Lebedev and Chausov (2)). Specific work of the crack propagation has been taken as the main characteristic:

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$$\lambda = \frac{P_K \cdot \Delta \ell_p}{2 F_K}$$

where F_K -is the specimen cross-section at the moment of the crack growth onset in the material, the meaning of parameters P_K and $\Delta \ell_p$ is illustrated in the Figure.

If we use the concept of the critical specimen length $\ell_{p(\kappa p)}$ at which the elastic energy stored in the specimen at the moment of the macro-crack growth onset is equal to the work of fracture $(A_{frac.} = P_K \cdot \Delta \ell_p / 2)$, the situation arises when the specimen material completely unloaded from the point K (see the Figure) can be considered to be macroelastic during the repeated active loading. In this case the averaged elasticity modulus of the material, which is determined by the method of unloading on the basis of the measurement of the whole specimen critical length at the moment of the macrocrack growth onset, does not practically differ from the Young's modulus of the material.

Specific work of fracture can be treated as the rate of the elastic energy release during the crack propagation across the cross-section F_K i.e. as the analogue of the well-known relationship

$$\lambda = \frac{P_K \cdot \Delta \ell_p}{2 F_K} = \frac{(1 - \nu^2) \cdot K_\lambda^2}{E}$$

Reducing the parameter $\Delta \ell_p$ to a single fracture area, we get

$$K_\lambda = \alpha \cdot \sqrt{\frac{P_K \cdot \Delta \ell_p \cdot E}{F_K \cdot (1 - \psi_K)}}$$

where K_λ - is the fracture toughness parameter for a plastic material, E - is the Young's modulus, ψ_K - is the thinning of the specimen cross-section at the moment of the macrocrack growth onset.

One can judge about the stability of the correlation between the parameter K_λ and the critical stress intensity factor K_{Ic} from the scatter of the average values of the coefficient α determined from the condition $K_\lambda = K_{Ic}$ for different materials. For steels of different grade and structural state the mean value of the parameter α is equal to 0.23. The values of the parameter K_λ determined by the above formula are listed in Table 1 for some steels.

TABLE 1 - The Values of K_λ for the Steels Studied.

Grade of steel	40Kh	St3	15Kh2MFA	15Kh2NMFA	22K
K_λ, MPa$\sqrt{m}$	63.75	80.9	171.1	163.3	78.4

REFERENCES

(1) Lebedev, A.A. et al, Problemy Prochnosti (in Russian), No.1, 1982, pp.12-18.

(2) Lebedev, A.A. and Chausov, N.G., Probl. Prochn., No.2, 1983, pp.6-10.

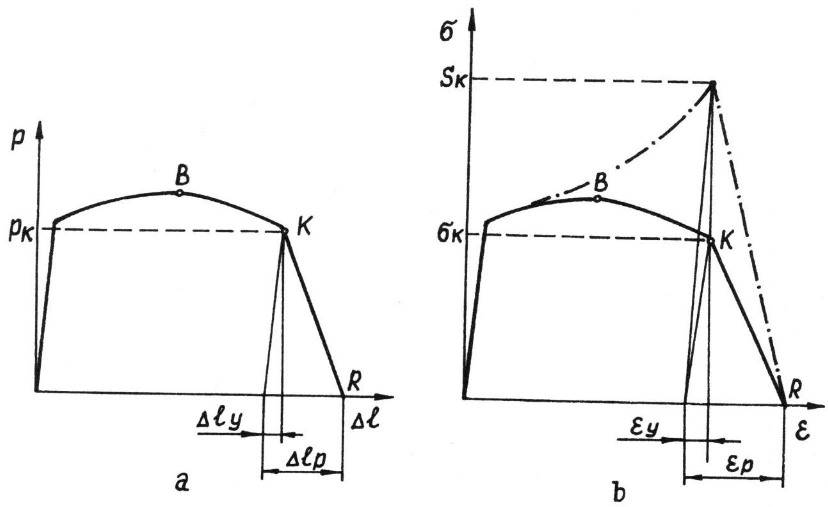

Figure Complete stress-strain diagrams for plastic material: (a) machine diagram; (b) in the conventional (solid line) and true (dot-and-dash line) coordinates.