FRACTURE MECHANISMS SELFORGANIZATION AND FRACTURE THRESHOLD PARAMETERS OF LOW-ALLOYED STEELS UNDER LOW TESTING TEMPERATURES

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For conditions of fracture selfimilarity of investigated steels two versions of fracture micromechanisms selforganisation are distinguished. In first case the selforganisation leads to stable realization of similar fracture mechanisms in some temperature intervals. The main ones are interval below nil-ductility transition (brittle transcristallyne fracture) and over intensive plasticity transition (mainly ductile fracture micromechanisms). In second case the selforganisation is determined by the sequentional changes of dissipative structures developing under complicate defect metal structures. The two parameters criterion is used for comparative estimation of steel efficiency in conditions of similar local fracture mechanisms.

INTRODUCTION

In accordance with a synergetical fracture toughness concept the physical character of rupture process is caused by formation (on the corresponding damaging stages evolution) of specific dissipative structures that provide the most effective remove of energy supplyed from without. On the stage of crack growth this circumstance is reflected in the realization of suitable materials fracture micromechanisms (microrelief of fracture surface) controlling the materials failure. From a synergetics position the threshold parameters of stage-to-stage transition boundaries can be considered as a bifrucation points and materials properties determined in these point are the fundamentals properties. Testing conditions influence significantly the fracture mechanisms and on the boundaries of their realization.

In this paper the results are presented of investigations of fracture toughness and fracture micromechanisms of low-alloyed steels under static- and cyclic loading in temperature interval -196 ÷ +20°C.

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Material

The material investigated were two low-alloyed steels (symbols 1A and 2A). There were chemical composition (wt-%): 1A (C-0.22, Mn-1.20, Ni-1.85, Cr-1.0, Cu-0.45, Si-0.21, S-0.010, P-0.015, microdope Nb, V, Mo), 2A (C-0.14, Mn-0.75, Ni-0.69, Cr-0.80, Cu-0.27, Si-0.94, S-0.025, P-0.022). Steels microstructure were bainite (1A) and ferrite+pearlite (2A).

Fracture mechanisms and threshold parameters. One of the important behaviour of synergetical systems is the ability of fracture self-similarity realization. This permits as it is shown in the works of Ivanova and Shanjavskii (1), Kunavin (2) to realize different versions of fracture micromechanisms selforganisation, to decrease the number of constitutive parameters, to suggest the easy and effective working multiparameters criteria. One of them (for mode I fracture) taking into account the cooperation of two mechanisms of energy dissipation by plastic deformation and by creation of divided surfaces in generaly may be represented as:

$$T_q = \sigma_{TO} \cdot K_q \tag{1}$$

where parameters σ_{TO} and K_{Iq}- characterize plastic deformation and fracture resistance of material, respectively. The values of these parameters are depended on loading conditions (static, cyclic, dynamic taking into consideration environmental factors: media, temperature).

Two versions of fracture micromechanisms selforganisation for investigated steels are distinguished that are depended on test temperature and number of loading cycles. In first case the selforganisation leads to stable realization of similar fracture mechanisms in some temperature intervals. As an approximate upper temperature limitof one of them(to which mainly brittle fracture mechanisms - transcristallyne cleavage and quasi-cleavage - are realized for both investigated steels) controlled by value K_{Iq}^m, there may be used a nil-ductility temperature TND. Within this temperature interval $K_{Iq} = K_{IC}$, $\sigma_{TO} = \sigma_T$. As an approximate lower temperature limit of the other one (above which mainly ductile fracture mechanisms are realized: microvoid formation and coalescence) there may be used a intensive plastic temperature transition. Here $K_{Iq} = K_{IR}$ or K_{Ifc},$\sigma_{TO} = \sigma_T^c$. In the second case selforganization is determined change (hierarhyc sequence) of dissipative structures under achieving of threshold crack growth rates V_q^N. Crack instability corresponds to V_q^N. This instability is connected with the change of leading fracture micromechanism and it is reflected in corresponding change of microfractographic features. The realisation of concrete microfractographic features sequence depends on original metallurgical microstructure and temperature of tests. So (under room temperature), for steel 2A this sequence is band relief - quasi-striations - real striations

- dimpled relief; for steel 1A - striation-like cleavage - - combined transcristallyne fracture with brittle and ductile elements - dimpled relief. Decrease in a test temperature influences the foregoing sequences under $T < T_{ND}$ when the number of transcristallyne cleavage facets are sufficiently increasing (especially for steel 2A). Fatigue fracture diagrams (log da/dN - - log ΔK) for steels at T = 20 and -60°C are shown in Fig.1. The comparison of steels according to criterion (1) has showed (Fig.2) that steel 1A has much higher efficiency in the whole temperature range.

SYMBOLS USED

σ_{TO} = total yield stress (MPa)

K_{Iq} = threshold stress intensity factor are determined in condition of similar local fracture mechanisms ($MPa \cdot m^{1/2}$).

K_{Iq}^{m} = threshold stress intensity factor controlling the realization level of maximum plastic deformation constrainting where state is connected with the fracture instability ($MPa \cdot m^{1/2}$).

K_{IR} = threshold stress intensity factor controlling fatigue crack growth quasielastic-to-elastic-plastic transition ($MPa \cdot m^{1/2}$).

K_{Ifc} = cyclic fracture toughness ($MPa \cdot m^{1/2}$).

σ_{T}^{c} = cyclic yield stress (MPa)

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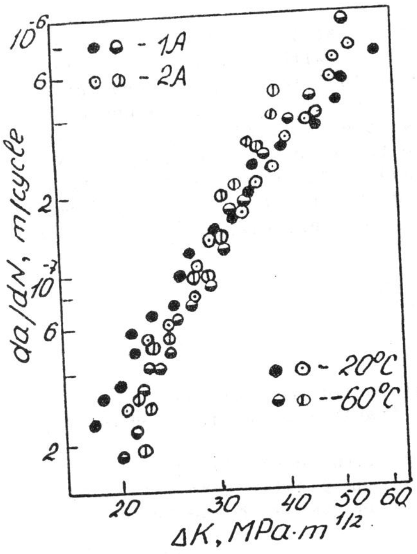

Figure 1 Fatigue fracture diagrams for steels 1A and 2A

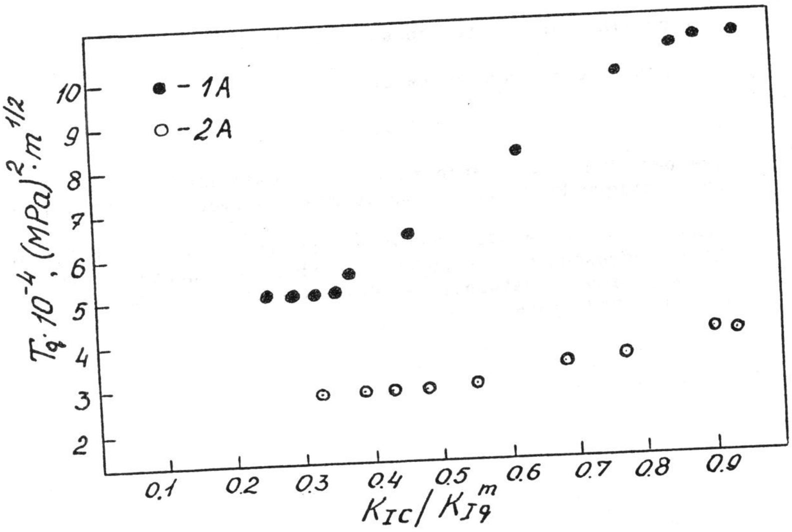

Figure 2 T_q versus K_{IC}/K_{Iq}^m