EFFECT OF A STRESS RAISER ON THE CONDITIONS GOVERNING THE TRANSITION FROM FATIGUE TO BRITTLE FRACTURE IN 15G2AFDps STEEL AT LOW TEMPERATURES

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It is well known that in both the static and the dynamic loading of metals stress raisers promote a transition from ductile to brittle fracture; this appears, e.g., as a rise in the critical temperature.

It is therefore interesting to estimate the effect of a stress raiser on the temperature corresponding to the transition from fatigue to brittle fracture in the cyclic loading of structural steels, which become brittle with falling temperature. As test object we chose 15G2AFDps steel of the following chemical composition (in %): C 0.16; Mn 1.46; Si 0.09; S 0.034; P 0.11; Cr 0.11; Cu 0.0079; V 0.12. The temperature dependence of the mechanical properties of this type of steel is presented in Fig. 1.

Earlier we used a UKN-1 test machine for applying circular bending to samples of this particular steel with a working part 15 mm in diameter [1], and obtained fatigue curves at +20, −55, −75, −95, and −140°C.

The configuration of the working part of the samples and the shape of the developing fatigue crack which occurred in this case are shown in Fig. 2a, and the corresponding fatigue curves at various test temperatures [2] in Fig. 3.

The temperature of the transition from fatigue to brittle fracture [2] was determined from the form of the fracture surface after the ultimate breakage of the sample (both visually and by electron fractography), from the character of the damage at the instant of the loss of bearing capacity by the sample (the spontaneous, rapid propagation of a crack, accompanied by a sound effect — a slap — or even ductile completion of the fracture), and from the break on the temperature-dependence curves of the quantities \( \frac{F_{fc}}{F_{sam}} \), \( K_{stat} \), \( K_{cycl} \), where \( F_{fc} \) is the area occupied by the fatigue crack at the instant of loss of bearing capacity by the sample; \( F_{sam} \) is the area of the working cross section of the sample; \( K_{stat} \) is the critical value of the stress intensity coefficient determined for static loading by the method of secants [2]; \( K_{cycl} \) is the critical value of the stress intensity coefficient determined from the results of tests based on repeated alternate loading.

Basing our considerations on these earlier results (which were applied to the same batch of metal) we fatigue-tested samples containing an annular notch \((R = 0.5 \text{ mm})\) and an annular scratch 0.25 mm deep with \( r < 0.1 \text{ mm} \) at analogous temperatures. The forms of the stress raisers, scratches, and fatigue fractures of the samples are shown in Fig. 2b and c. The theoretical stress-concentration

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Fig. 2. Configuration of the working part of a smooth sample (a), a sample with an annular notch (b), and a smooth sample with an annular scratch (c), and also the shape of the fatigue crack: 1, 2) regions of accelerated and retarded fatigue-crack development respectively; 3) region of final fracture; 4) annular scratch 0.25 mm in radius.

We have accordingly established that, during the cyclic loading of 15G2AFDps steel samples containing stress raisers, the character of the temperature dependences of $F_{fc}/F_{sam}$ and $\sigma_{netto}$ remains unaltered. We consider that this situation may be explained by the fact that the fatigue crack moves out of the zone of action of the stress raiser and at the instant at which the sample loses bearing capacity the stress raiser has no marked influence on the stressed state of the sample in the final fracture cross section. At the same time, the shape of the fatigue crack, differing as it does for smooth and notched samples, has a considerable influence on the character of the fracture after ultimate (static) breakdown of the sample, when the crack has attained the critical dimensions; it is this which determines the differences in the temperatures at which the transition to a fracture with crystalline structure takes place.

At the same time, for samples containing annular stress raisers or scratches the temperature at which the fatigue crack starts developing spontaneously at a very rapid rate and is accompanied by a sound effect (a slapping noise), while the fracture surface bears a crystalline character, is higher than that obtained for smooth samples. There were no differences between the characteristics under consideration for these samples.

The fracture surfaces of samples containing annular stress raisers (Fig. 2b) show three regions of development of the fatigue crack.

Region 1, some 1.5 mm in depth, has a rough surface, which indicates a high rate of crack development; region 2 contains a smooth surface and relief characteristic of the slow development of a fatigue crack; region 3 represents the ultimate fracture of the sample. In the fracture surfaces of the scratched samples (Fig. 2c) only regions 2 and 3 are encountered, i.e., there is no region of accelerated crack development.

$\sigma_{netto}$ was determined by the "Resistance of Materials" method allowing for the displacement of the center of gravity of the remaining cross section of the sample relative to the center of gravity of the initial crack-free cross section, and also allowing for the area occupied by the fatigue crack.