NITROGEN CONTENTS EFFECT ON CRACK RESISTANCE OF SOME STEELS

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Subject of the present investigation is the study of nitrogen contents effect under dynamic and cyclic loadings on some steel compositions. Nitrogen content increase changes dynamic fracture resistance within the test range. This increase does not substantially influence FCGR and leads to higher strength hardening coefficient of the austenite.

INTRODUCTION

High nitrogen steels are of great interest to the mordern metallurgy. They are particularly applicable in nuclear mechanical engineering, cryogenic equipment, power plants, mining industry, etc. Depending on the casting and heat treatment conditions, nitrogen amount and distribution variations change in different ways the behaviour of such steels when subjected to mechanical loads and this fact has to be considered in practice.

The changes in crack resistance parameters of metal structures are best seen under dynamic and cyclic loadings. Subject of the present investigation is therefore the study of nitrogen contents effect under such loading conditions for some steel compositions.

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EXPERIMENTAL AND DISCUSSION

Dynamic crack resistance has been investigated for three high nitrogen alloys as specified in Table 1.

TABLE 1- Compositions of steels investigated under dynamic load, [%].

Composit.	C	S	Si	Cr	Mn	N
I	0.04	0.009	0.50	17.19	12.7	0.71
II	0.04	0.008	0.99	19.36	12.48	1.01
III	0.03	0.009	0.57	16.90	12.21	1.26

Tests have been carried out in compliance with the techniques and by means of the equipment as described in Reference (1) with a complete registration of the indicator diagram within the temperature range of -60 °C to ambient temperature. Diagram analysis and fractographic studies have shown the following. Steel (composition I) behaviour is purely plastic in the fracture process and the steel shows sufficient resource of ductility. Test temperature decrease to -60 °C does not change below the admissible crack initiation resistance. Indicator diagrams show a tendency of crack arrest regardless of the crack propagation rate. Steel composition II shows a structural state close to ductile-to-brittle transition within the range investigated. Low temperature tests show crack propagation without substantial plastic deformations. Steel composition III shows brittle behaviour at low temperatures and fractographic studies confirm the indicator diagram results. Fig. 1 shows the variation of J^d integral as a function of the test steel temperature. Nitrogen content increase changes fracture resistance within this test range.

Fatigue crack growth resistance has been investigated for the nitrogen steels as specified in Table 2.

TABLE 2-Compositions of steels investigated under cyclic loading, [%].

Composit.	C	S	Si	Cr	Mn	N
I	0.03	-	0.44	18.97	12.04	0.50
II	0.03	0.007	0.50	17.42	12.08	0.88
III	0.04	-	0.32	17.92	12.36	1.13

Fig. 2 shows the variation of fatigue crack growth rate (FCGR) for these metal structures under high-cycle fatigue loading. It can be seen that metal structure ductility decreases with the increase of nitrogen contents but such increase does not substantially influence FCGR. It can be seen that this rate decreases with the inrease of nitrogen contents, i.e. higher nitrogen content is favourable for the fatigue strength. This is also confirmed by the fact that the moment of macrocrack formation is delayed with the increase of nitrogen amount, i.e. the number of cycles to its appearance increases.

Fractographic studies show that fracture surface of crack path becomes rougher with the nitrogen amount increase. In alloys containing 0.5 and 0.88 % nitrogen the primary crack propagates in a single plane. At the beginning the process shows unestablished behaviour and after reaching a certain length the crack demonstrates stable propagation mainly in a single plane. The steel containing 1.13 % nitrogen shows atypical fatigue fracture surface of multiple cleavage meaning that the crack frequently changes its propagation direction. For alloy I the presence has been established of areas of fatigue striation. Persistent slip bands (PSB) in the austenitic grains as well as the beginning of martensitic transformation as a result of deformations under cyclic loads have been established in the fatigue crack path. Strip-shaped groups of nitride precipitations localized along the fatigue striae are observed in steel II and this fact can explain the various FCGR therein. Multiple microcracks are observed in steel composition III which shows that a tendency exists for the crack to propagate not in a single plane only.

Investigations carried out show that austenitic steels become more strengthened with nitrogen amount increase. This can be explained both by the fact that the nitrogen atoms additionally deform the austenitic lattice and the fact that they locate to some extent over the dislocations. High velocity of dislocation density increase has been established during cold deformation. Deformation strengthening of nitrogen austenite favours the formation of fine twin substructure and increases the efficiency of Suzuki's barriers on split dislocations. More detailed explanation of this effect has to be found in the fact that nitrogen concentration increase leads to stacking fault energy decrease which favours the formation of deformation twins. This decreases the energy of plane slip initiation and results in greater deformation strengthening compared to cellular deformation structure.

REFERENCE

(1) - Vodenicharov, St., Razvitie na metodite za opredeliane na dinamichnata puknatinoustichvost s izpolzuvane na malki probni tela, Teoretichna i prilogna mechanica, N 3, 1989, p.p. 16-23

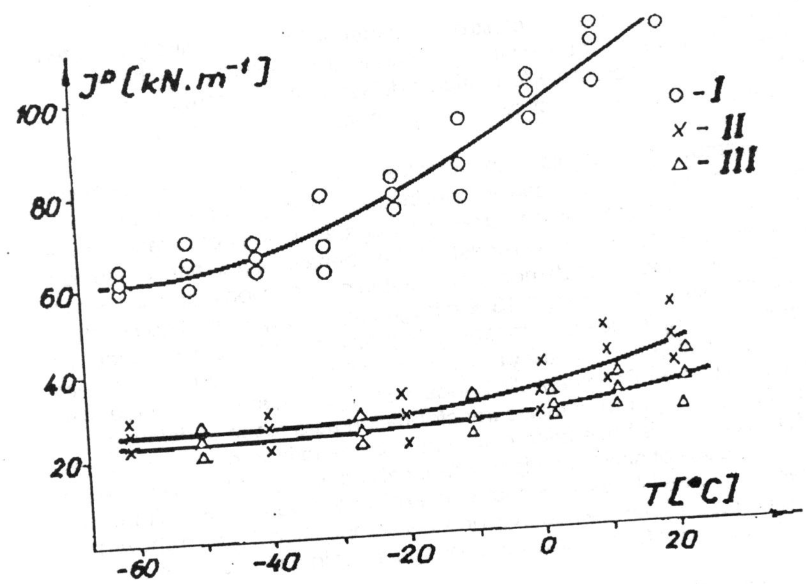

Fig.1. Dynamic J-integral versus temperature.

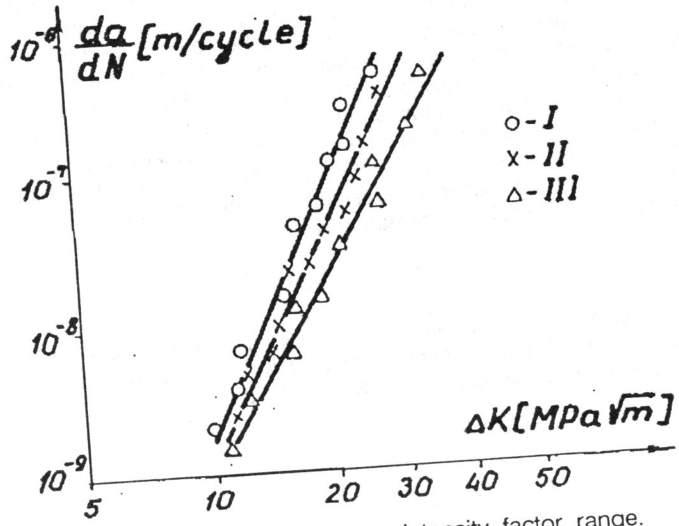

Fig.2. FCGR versus stress intensity factor range.