NITROGEN INFLUENCE ON MECHANICAL PROPERTIES OF STEEL FOR THREADED CONNECTION ELEMENTS

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Nitrogen influence as an alloying element in 38HN3MAFA steel on its behaviour during static, cyclic and dynamic loading has been investigated. 38HN3MAFA demonstrates better behaviour under dynamic load compared to 38HN3MFA and having in mind that the presence of nitrogen has no significant influence on its static and cyclic behaviour, this steel is more appropriate for threaded connection elements, intended for water-cooled nuclear reactor bodies (VVER-type).

INTRODUCTION

At present in East European countries 38HN3MFA steel (similar to 4337+V, AISI) is used for threaded connection elements for water-cooled nuclear reactor bodies (VVER-type). In the Institute for Metal Science&Technology 38HN3MAFA steel, (St.1) of optimized chemical composition and alloyed with super-equilibrium nitrogen content has been developed, USSR Pat.(1). It has been manufactured by counter-pressure casting and after a heat treatment a bainite structure has been obtained. The chemical contents of the newly developed steel and 38HN3MFA, (St.2) are given in Table 1. The main purpose of this work is to establish some mechanical properties of this new material.

EXPERIMENTAL

Results of the tensile tests are presented in Table 2. High-cycle fatigue investigations have been carried out (Fig.1). Fatigue strengths for 10^7 cycles have been determined by means of Dixon-Mood's method. Low-

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cycle fatigue behaviour has been established based on 10^4 cycles, Table 3. Fracture toughness estimation has been made by Charpy test in the temperature region within -196°C to +20°C (Fig.4).

DISCUSSION

The mechanical properties obtained from the tensile tests for both materials do not differ significantly - nitrogen alloying and the heat treatment applied lead to negligible decreasing of these properties values. At 20°C both steels meet the requirements for yield strength limitations according to GOST 23304-78 (more than 1000 MPa), whereas at 350°C some results for 38HN3MAFA are slighly under the minimum value of yield strength (more than 900 MPa) required by the same standard. In the high-cycle fatigue region the presence of nitrogen in 38HN3MAFA does not affect significantly the fatigue characteristics compared to 38HN3MFA. Nevertheless a minimal increasing of the fatigue strength based on 10^7 cycles could be seen - fatigue strength mean value for 38HN3MAFA is $\bar{\sigma}_{-1}$ = 434.6 MPa (the variation is $S_{\sigma_{-1}}$ = 24.7 MPa) and for 38HN3MFA - $\bar{\sigma}_{-1}$=427.2 MPa ($S_{\sigma_{-1}}$ =27.8 MPa), respectively. Clear dependence of load amplitude on number of cycles to failure is missing (Fig.1). A slight tendency could be seen in that the results for 38HN3MAFA lie on the right side compared to

TABLE 1 - Compositions of the steels investigated, in [%].

Steel	C	Si	Cr	Ni	Mn	S	Mo	N	V
St.1	0.22	0.09	2.31	2.6	0.32	0.014	0.42	0.107	0.20
St.2	0.31	0.13	1.24	3.2	0.36	0.011	0.38	0.012	0.16

TABLE 2 - Mechanical properties of the steels.

Steel	σ_{YS},[MPa]		σ_{TS},[MPa]		δ_5 ,[%]		ψ ,[%]	
T[°C]	20	350	20	350	20	350	20	350
St.1	1009	891	1102	979	12.2	9.8	66.0	65.7
St.2	1066	912	1148	1005	12.3	8.2	63.6	62.1

TABLE 3 - Fatigue characteristics of the steels.

Steel	ε'_f,[%]	σ'_f/E,[%]	b	c	C_2x10^{-7}	m_2
St.1	1.03	0.94	-0.027	-0.04	8.08	2.28
St.2	1.07	0.9	-0.026	-0.044	8.26	2.19

these for 38HN3MFA and it is an evidence for the positive influence, even minor one, of the nitrogen as an alloying element on the fatigue strength.

In the low-cycle fatigue region both materials show similar behaviour. Here also a slight tendency could be observed for the fatigue-ductility coefficient to decrease and fatigue-ductility exponent **c** to increase (Table 3). Figure 2 shows that both materials demonstrate permanent cyclic softening to the final fracture. Fatigue crack growth rate versus ΔJ (da/dN - ΔJ) curves for both materials are similar (Fig.3). 38HN3MAFA steel demonstrates better behaviour under dynamic load in the whole temperature range of investigation compared to 38HN3MFA (Fig.4). Therefore the nitrogen presence in the first material leads to its fracture toughness increasing. Figure 4 also shows that the ductile-brittle transition temperature is -75°C for 38HN3MFA and -95°C for the newly developed material.

CONCLUSION

38HN3MAFA demonstrates better behaviour under dynamic load compared to 38HN3MFA and having in mind that the presence of nitrogen has no significant influence on its static and cyclic behaviour, this steel is more appropriate for threaded connection elements, intended for water-cooled nuclear reactor bodies (VVER-type).

SYMBOLS USED

ε_f' - fatigue-ductility coefficient
σ_f' - fatigue-strength coefficient
b - fatigue-strength exponent
c - fatigue-ductility exponent
C_2, m_2 - empirical coefficients from eqn. $da/dN = C_2 (\Delta J)^{m_2}$

REFERENCE

(1) USSR Pat. N 1627584/ 30 Nov. 1988.

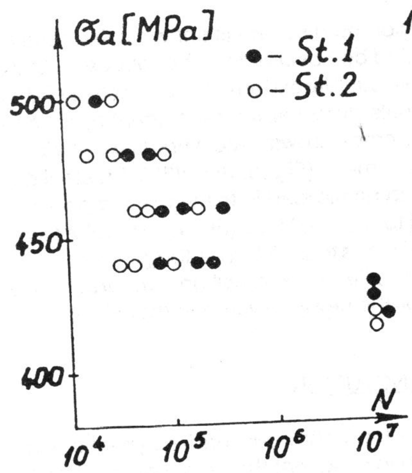

Figure 1 Stress amplitude versus cycles to failure (high-cycle).

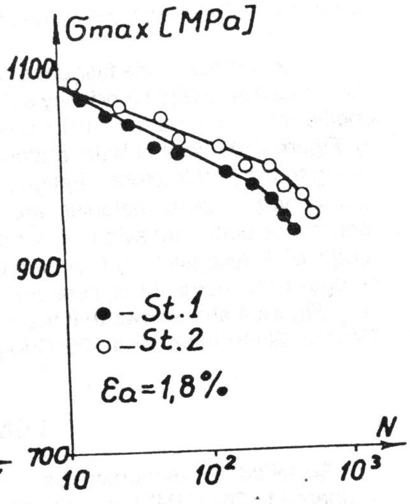

Figure 2 Maximum stress versus cycles to failure in low-cycle region.

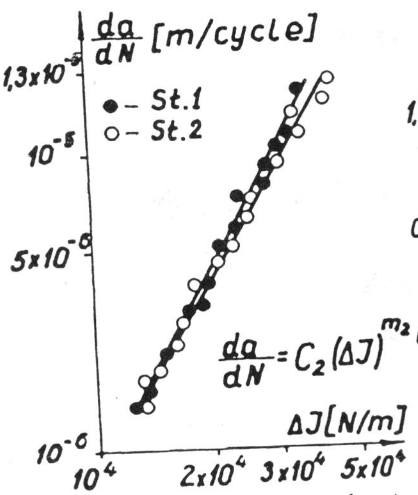

Figure 3 Fatigue crack growth rate versus cyclic J-integral (low-cycle).

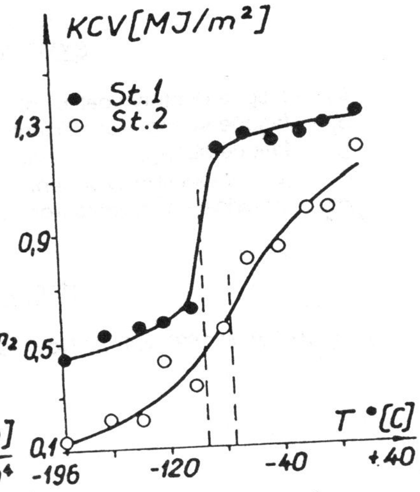

Figure 4 Fracture toughness dependence on the temperature.