FRACTURE TOUGHNESS OF LOW-TEMPERATURE 10N2 AND 10N3 STEELS

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INTRODUCTION

The fracture toughness and mechanical properties of two nickel steels selected for low-temperature application were investigated. The highest toughness and mechanical properties were observed between 203-223 K for 2.5% Ni and between 173-200 K for 3.5% Ni steels, respectively.

MATERIAL AND METHODS

Application of the low-temperature nickel steels should be based on the well elaborated fracture toughness results for comparison with the rutine tensile and impact energy measurements. Analysis of the main chemical elements and tensile properties are listed in Table 1.

Table 1. Comparison of carbon and nickel contents, Re, Rm and application temperature for 10N2 and 10N3 steels.

Steel	Content, wt %		Re - yield strength [MPa]	Rm-ultimate strength [MPa]	Application temperature down to [K]
	C	Ni			
10N2	0.10	2.24	390	500	213
10N3	0.09	3.69	495	615	183

The thickness of steel sheets was too small to satisfy the plane strain conditions during fracture toughness tests. In spite of it the critical mixed-mode stress intensity factor (Kc) can be treated as a measure of fracture toughness properties, valid for the plates of the thickness up to 14 mm for 10N2 steel and 16 mm for 10N3 steel.

The COD tests were performed according to (1) using three point bend specimens of 15x30x140 mm for 10N3 and 10x20x100 mm for 10N2 steel. All the tests were performed at the temperature range between 293 and 153 K. In addition, to find out the nil

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ductility temperature , the DWT tests according to the ASTM requirements (2), using P-3 type of specimens, were done.

RESULTS AND CONCLUSIONS

The results of Charpy-V impact tests are presented in Figure 1. The ratios between the specific impact energies measured at 200 K for 10N2 and 10N3 steels on transverse and longitudinal specimens are 58/94 and 168/205, respectively. It means that the 10N3 steel is less susceptible to the drop of impact properties tested in transverse direction. A graph in Figure 2 shows that Kc for the 10N3 steel is much higher than for 10N2 within the whole range of test temperatures. The Kc value was calculated with the use of the following equation:

$$Kc = \sqrt{\delta c \quad Re \quad E}$$

All the above results lead to the conclusion that the toughness decreases rapidly between 203-183 K for 10N2 and between 193-173 K for 10N3 steels, respectively. For the selection of the best combination of the highest toughness (Kc) and mechanical properties (Re) the Hornbogen's method (3) has been applied. The maximum of the product of Re and Kc lies between 203-223 K for 10N2 and between 173-200 K for 10N3 steel (see Figures 3 and 4). Both temperature ranges belong to safety region from the toughness point of view, and obtained NDT values are 158 and 133 K for 10N2 and 10N3 steels, respectively.

SYMBOLS USED

E - Young modulus (MPa),
Kc - critical stress intensity factor (MPa .mm^1/2),
Re - yield tensile strength (MPa),
Rm - ultimate tensile strength (MPa),
δc - critical crack opening displacement (mm),

REFERENCES

(1) BS 5762:1979 Methods for Crack Opening Displacement (COD) Testing.
(2) ASTM E208-78T Standard Method for Conducting Drop-Weight Test...
(3) E. Hornbogen - Seminar of the Phys. Met. and Heat Treatment Dpt., Academy of Mining and Metallurgy, Cracow, 1981.

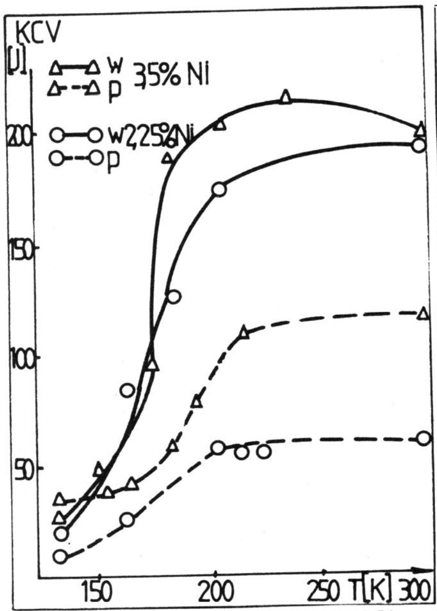

Figure 1. Graph of the specific impact energy vs temperature.

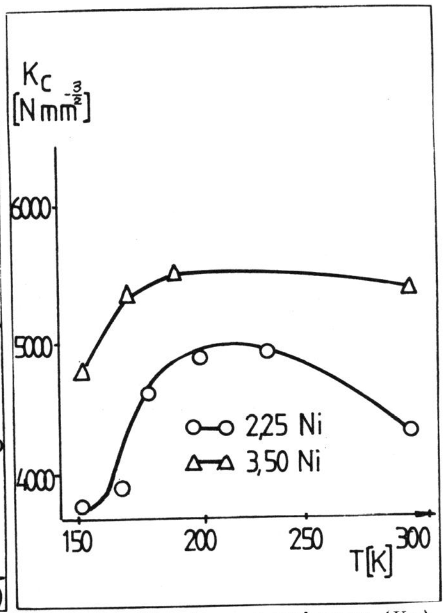

Figure 2. Fracture toughness (Kc) versus temperature.

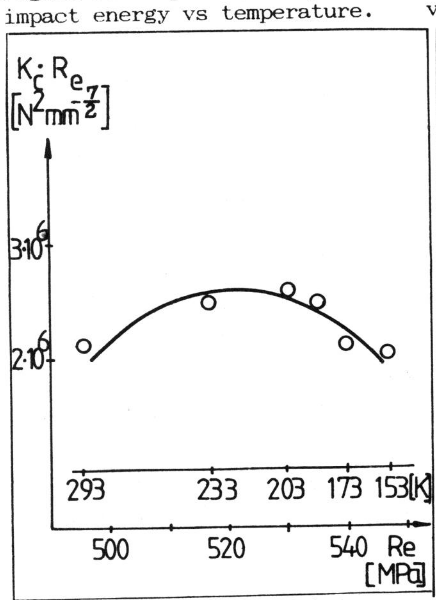

Figure 3. The Hornbogen's curve for 10N2 steel.

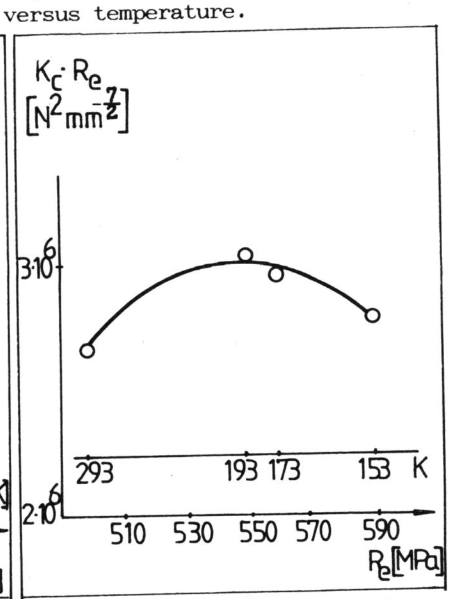

Figure 3. The Hornbogens curve for 10N3 steel.