CORRELATION OF STATIC AND DYNAMIC CHARACTERISTICS FOR TOUGHNESS ESTIMATION OF THERMORESISTANT STEEL

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The paper presents some correlations between the static and dynamic characteristics of a thermoresistant steel, taken from a service steam pipe. The study of toughness was based on CTOD at temperatures of 20°C and between 500°C and 600°C.

It presents also the variation of the crack length in tests with repeated shocks.

INTRODUCTION

The working safety of service steam pipes requires a systematic control of reserve in toughness of the material after certain operating time period. The control of the state of the pipe is done by determining the mechanical characteristics of for characterization of the brittleness of the material.

Accepting that in service conditions cracks may appear due to thermic shocks, the authors tried to make a study of the strength of the pipe material, at starting of propagation of some cracks at ambient temperature and at high temperatures.

The testing was performed with a thermoresistant steel cut out from the pipe which showed a high capacity in plastic straining.

Determination of the resistance at the beginning of crack propagation was based on determination of crack-tip opening displacement (CTOD).

The test for determining CTOD was performed using 10×10×55 mm specimens with 2 mm deep notch, ended by root radius δ_o = 0.2 mm.

A crack of 1 mm was developed in notch root, directed to inside and outside wall in order to test through-thickness material homogeneity.

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THE PROGRAMME AND TESTING METHODOLOGY

In the first stage, the notched samples were submitted to fatigue by repeated bending load on the side opposite to the notch, in order to initiate crack from the notch root and to propagate it up to breaking (2),(3).

Figure 1 shows the dependence of crack length corresponding to impacts of low energy on the number of impacts, N. Each point represents the average value of three specimens tests.

This first stage allowed to analyze the fatigue crack propagation at the notch root up to breaking and at the same time to choose the best precracking regime of the samples submitted to CTOD tests.

No significant difference was found in crack initiation and propagation behaviour of two tested specimen groups.

In the second stage, the two specimen series were submitted to repeated impacts until they reached 1 mm long crack.

The CTOD tests were performed by dynamic bending, applied sequentially with raising loading, using precracked samples, that have cracks 1 mm deep, with a Charpy hammer of 50 J energy capacity.

The CTOD, δ, was determined from rotation of notch flank, optically measuring the distances b and c after each applied impact (Fig.2) (1). By the notation from Fig.2, the CTOD was calculated using the relation:

$$\delta = (b - \delta_o) - \frac{a}{p}(b - c)$$

Crack opening is considered as critical (δ_c) when the propagated crack becomes visible on the specimens' flank.

RESULT ANALYSIS

The critical CTOD, δ_c, determined by extrapolation, was checked by critical values, obtained using previously unstrained specimens.

It was found that previous strain generally does not influence the critical CTOD at high temperatures. In the case of repeated impact fatigue tests no significant differences were found between critical values of the CTOD for specimens with notches directed inside and outside (2),(3).

In Fig.3 temperature dependence of mechanical properties and critical CTOD, δ_c, is presented.

General decrease of static mechanical characteristics ($R_{p0,2}$, R_m) and also of the dynamic properties (CTOD, KV) is obvious in Fig.3, but KCU_2 has a tendency of slow increase with temperature.

For the analyzed temperature range, it was possible to correlate impact fracture Charpy V energy (KV) and critical CTOD, δ_c, in the form:

$$\delta_c = - 2.78 + 0.033 \, KV \quad [mm]$$

A similar dependence was found for other thermoresistant steels, in the same temperature interval.

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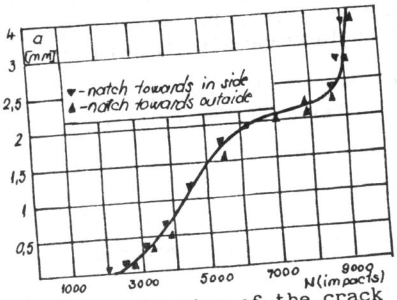

Figure 1 Variation of the crack length depending on the impacts number N.

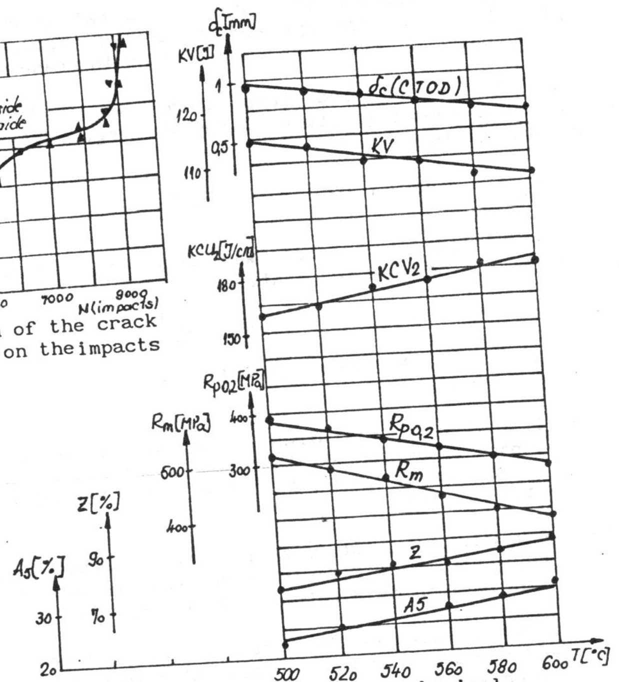

Figure 3 Variation of the mechanical characteristics with the temperature.

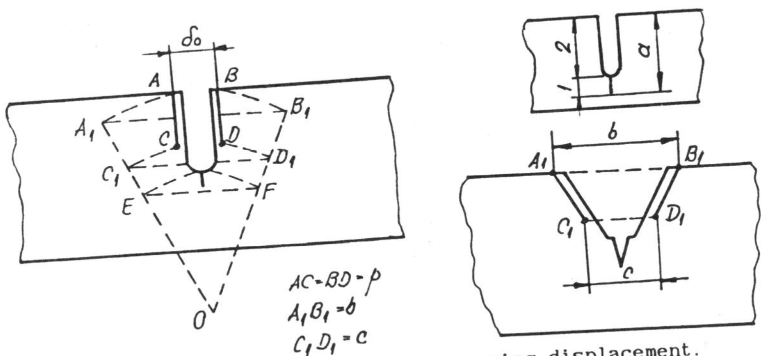

Figure 2 The measuring of the crack opening displacement.