INVESTIGATION ON THE INFLUENCE OF LOADING RATE ON FRACTURE TOUGHNESS OF STEEL USED IN GAS PIPE LINE

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This paper describes the results of an investigation on the influence of loading stress intensity rates on fracture properties of steel used in gas pipe line within the range of $1x10^{-5}$ to $1x10^{7}$ MPa.$m^{1/2}$.s^{-1}. The experiments with precracked rectangular specimens have been carried out by three-point-bend test. From the critical load for onset of crack propagation the fracture toughness values K_{Ic} have been measured for this range.

INTRODUCTION

The knowledge of the fracture toughness K_{Ic}, of steels at different loading rate is important from the point of view of fundamental research as well as for a practical safety analysis especially of gas pipe line. The Bulgarian steel A and its modifications used for gas pipe lines require an investigation of their mechanical properties within a wide range of load rates and temperatures.

The object of the present work is to study the behaviour of the newly created A-steel modifications (Table 1) within a range of load rates $\dot{K}_I$ from $1x10^{-5}$ to $1x10^{7}$ MPa.$m^{1/2}$.s^{-1} within the temperature range from - 60 °C to + 20 °C.

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EXPERIMENTAL AND DISCUSSION

The object of the study is the fracture toughness K_{Ic} (critical value of stress intensity coefficient, K_{Is}, K_{Id}) of A steel and its modifications within the above rate and temperature ranges. Charpy fatigue precracked specimens have been used for determining K_{Ic}, within the $\dot{K}_I$ rate range from $1x10^{-5}$ to $3x10^5$ $MPa.m^{1/2}.s^{-1}$. These tests have been carried out by means of MTS hydraulic machine and Charpy pendulum according to the methods suggested by Kalthoff et al (1,2). Modified Hopkinson bar and the method as described by Stroppe et al (3) have been used for determining K_{Ic} within the load rate range $\dot{K}_I$ from $1x10^6$ to $1x10^7$ $MPa.m^{1/2}.s^{-1}$.

Based on the test results diagram of the test parameter variation has been plotted within the indicated temperature range (Fig.1) for all rate ranges (Fig.2) and have been compared with the basic steel type.

TABLE 1 - Chemical content of the steels investigated.

	C	Mn	Si	P	S	V	Ti	Nb	Mo
A	0.12	1.59	0.53	0.14	0.006	0.08	-	-	-
1	0.11	1.58	0.56	0.13	0.007	0.08	0.03	0.04	-
2	0.09	1.62	0.49	0.14	0.005	0.08	-	0.043	0.05
3	0.09	1.62	0.47	0.16	0.006	0.08	-	0.043	-

CONCLUSIONS

The analysis of test results has shown the following :

1. The test results have shown possitive loading rate sensitivity over the low loading rate region, i.e. K_{Ic} increases with log $\dot{K}_I$. The lower shelf behavior is characteristic for the decrease of K_{Ic} when log $\dot{K}_I$ increases. At the loading rate $\dot{K}_I$ = $1x10^4$ $MPa.m^{1/2}s^{-1}$ minima of K_{Ic} are obsered for all steels. When the loading rate exceeds the value of $\dot{K}_I$ $1x10^4$ $MPa.m^{1/2}.s^{-1}$ fracture toughness rises again at $\dot{K}_I$ $1x10^7$ $MPa.m^{1/2}.s^{-1}$ and reaches the maximum values.

2. Type 1 modification has shown the highest fracture toughness which is also higher than that of the basic material. Brittle-to-ductile fracture transition temperature is about -40° C and the steel modification has had higher strength characteristics as compared to the basic steel type.

3. Type 2 modification has had approximatately the same strength characteristics but has shown lower fracture toughness and its brittle-to-ductile fracture transition temperature is shifted at about -20° C.

4. Type 3 modification has had higher strength characteristics but has shown lower fracture toughness as compared to the basic material and its brittle-to-ductile transition temperature is shifted at about +20° C.

SYMBOLS USED

K_{Ic} = critical value of fracture toughness ($MPa.m^{1/2}$)

$\dot{K}_I$ = loading rate ($MPa.m^{1/2}.s^{-1}$)

°T = test temperature (° C)

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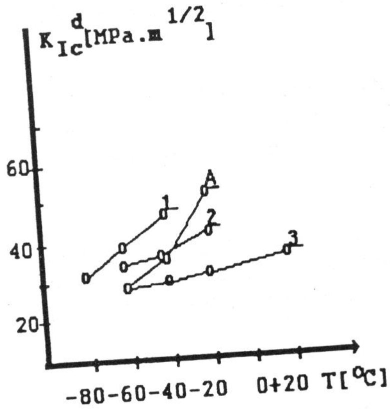

Figure 1 Temperature dependence of K_{Ic}^{d} for all steels

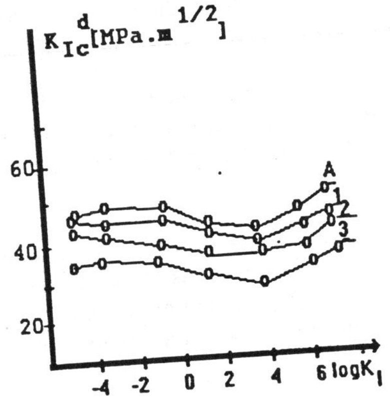

Figure 2 Loading rate dependence of K_{Ic} for all steels