MICROSTRUCTURE AND PROCESS ZONE IN HSLA STEEL

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Study presents the basic knowledge of influence of HSLA steel microstructure on the temperature dependence of shape and size of stretch or process zone. Methods of fractographic analysis demonstrate the transition character immediately linked up to the defined mechanisms of failure. Defined are two initial transition temperatures of stretch zone development and discussed is the microstructural influence on their values.

INTRODUCTION

Full understanding of quantitative evaluation of individual parameters of fracture toughness requires the more detailed knowledge of influence of microstructure and chemical composition on the development of fracture processes. The most sensible demonstration of their influence is observed at the formation of process and plastic zones in front of the crack tip during the fracture toughness test. Study (1,2) examines in detail the methodic problems of evaluation of the shape and size of stretch or process zone, Fig.1, and the analysis of individual micromechanisms of failure. This contribution presents the first information about the influence of microstructure on the shape and formation of the process zone, taking into consideration the testing temperature influence. These analysis are presented on three states of steels, microalloyed with V,Nb - state A, or Ti - states B,C, with their basic mechanical properties and microstructural parameters shown in Tab. 1.

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TABLE 1 - Basic Mechanical Properties and Microstructural Parameters.

State	σ_{YS} /MPa/	σ_{TS} /MPa/	n	ΔR /MPa/	grain size d /µm/	T_{x_o} /°C/	T_{x_oD} /°C/
A	360	492	0,167	40	5,6	-140	-70
B	559	673	0,120	300	6,6	- 40	+20
C	207	357	0,195	86	45	-120	0

Analysis of results

The shape and size of the stretch zone depends on the temperature of fracture toughness test (3). Changes of its parameters W_{sz}, a_{sz}, θ with the temperature are demonstrated on the state A, Fig.2 (1). Basic parameters indicate a transient character. Given material shows some blunting of failure crack tip of discontinual character (1) already at T=-196 °C. Increasing temperature results in the slight growth (subtransition part) of the stretch zone parameters and in the case when W_{sz} parameter reaches the one-to two-multiple of the ferrite grain size d, intensive growth its value (transition part) is observed up to the certain temperature T_{x_oD}, over which the W_{sz} dimension remains unchanged (above-transition part). Similar behaviour is observed also for the a_{sz} value, which is smaller than W_{sz} over the whole temperature interval. This is reflected in the reverse transition relationship of the vertex angle θ. The raising temperature results in the enlargement of the stretch zone with systematical "sharpening"(tunnel effect) of its front part. Fig.3 shows the basic stretch zone parameters of the state B. States A and B display approximately the same contribution of grain hardening R_z (4), but state B shows significantly higher contribution of embrittlement hardening ΔR. This is unambiguously reflected in different stretch zone temperature parameters of A and B states. As a result of higher ΔR value the first blunting of the failure crack tip of the state B is observed already at -100 °C. Maximal value of W_{sz} and a_{sz} parameters above the T_{x_oD} temperature is substantially lower in the state B, which is related to the different deformational ability expressed by exponent of deformation hardening n. Fig.4 shows the temperature dependence of stretch zone parameters of the state C. Compared to the state A this state has insignificantly higher ΔR value, but as a result of a coarse ferrite grain it has substantially lower R_z value. This results again in the changes of temperature dependence of the stretch zone of these states, Fig.2,4. Stretch zone of the state C is formed at temperature -140 ^oC (state A at -196 ^oC), but on the other hand more intensive development of the stretch zone above the T_{x_oD} temperature is obtained, which is in direct relationship with the n-values. Parallel to the stretch zone parameters we evaluated also the shapeable crack growth, expressed by the length x_o, Fig.2 to 4. The temperature at which the first measurable ductile crack growth had been observed was termed T_{x_o}, see Tab.1. This implies that during the fracture strength test performed below this temperature blunting of the failure crack is followed by the sudden brittle failure of the test specimen, type I (2,3). Comparison of A and B states indicates that the different ΔR values result in T_{x_o} values which are as a matter of fact by 100 ^oC higher in the state B compared to the state A. Negative influence of grain coarsening is manifested at comparison between the A and B states, Fig.2,4.

SYMBOLS USED

W_{sz} = width of stretch zone (μm)

a_{sz} = depth of stretch zone (μm)

x_o = ductile crack growth (μm)

θ = vertex angle (^{o})

T_{x_o} = transition temperature of ductile crack growth start (^oC)

T_{x_oD} = transition temperature over which the ductile fracture is the mechanism of failure (^oC)

ΔR = embrittlement hardening (MPa), (4)

n = exponent of deformation hardening

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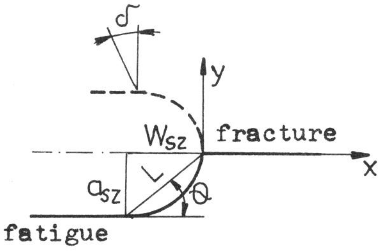

Figure 1 Basic parameters of stretch or process zone

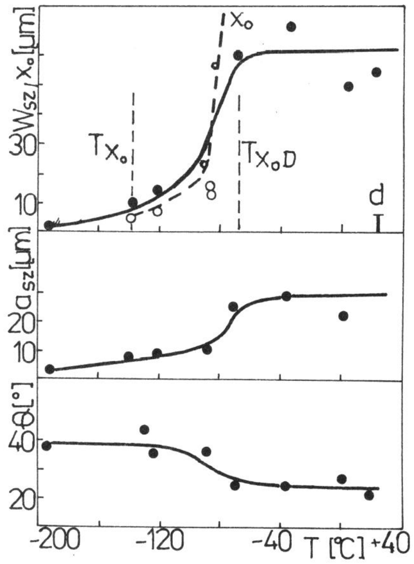

Figure 2 Temperature dependence of W_{sz}, a_{sz}, Θ (state A)

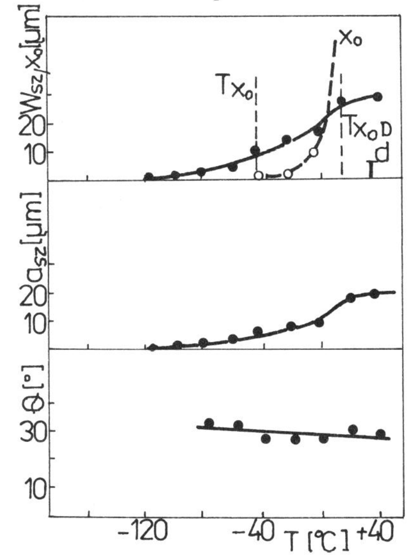

Figure 3 Temperature dependence of W_{sz}, a_{sz}, Θ (state B)

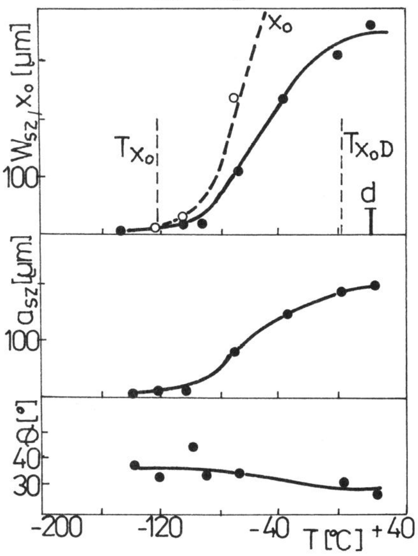

Figure 4 Temperature dependence of W_{sz}, a_{sz}, Θ (state C)