THE INFLUENCE OF STEP-COOLING HEAT TREATMENT ON THE FRACTURE BEHAVIOUR OF 2.25Cr-1Mo STEEL

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INTRODUCTION

The steel 2.25Cr-1Mo used for producing various components in power generation and chemical plants can be embrittled during operation in the temperature interval 350°C - 550°C. Extensive investigation of the embrittlement of this type of steel has been performed (e.g. Viswanathan and Jaffe (1), Doig et al. (1)). The degree of embrittlement has been shown to be a function of chemical composition, microstructure and strength level. Either long-term tmperature ageing (LTTA) or accelerated heat treatment procedure known as step-cooling treatment (SCT) are applied for studying this embrittlement. The shift of transition temperature FATT is most often used for an assessment of the embrittlement stage. Only few papers deal with the influence of LTTA or SCT on the fracture toughness, its transition behaviour and the relation to the notch toughness (Iwadate et al. (3)).

RESULTS AND DISCUSSION

The experimental data concerning of the influence of SCT (type Socal, Grosse-Woerdermann and Dittrich (4)) of the fracture behaviour were obtained on the commercially produced 2.25Cr-1Mo steel with the chemical composition (in weight %) 0.14C, 0.55Mn, 0.25Si, 0.018P, 0.009S, 2.38Cr, 0.95Mo, 0.33Ni, 0.008Sn, 0.009Sb, 0.012As, 0.015 Al (Watanabe's factor J = 200). The as-received plate in normalized and tempered condition (bainitic microstructure) was 80 mm thick. The specimens were cut out from the middle part of the plate. From the broadly based research programme only notch toughness and fracture toughness results for as-received and SCT states are presented. Fig. 1 shows the Charpy V-notch absorbed energy as a function of temperature. A large scatter of the notch toughness values can be seen in the transition region. Therefore, to assess the transition behaviour besides FATT, the propagation t_p and the initiation transition temperature t_i are marked (Holzmann et al. (5)). After SCT the t_p and FATT shift was about 30°C and that of t_i was 20 °C.

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In Figs. 2 and 3, the dependence of the fracture toughness (SEN three-point specimen, thickness 25 mm) on the temperature is shown. The transition temperatures t_{DBU} and t_{DBL} (Milne and Curry (6)) are marked. The cleavage fracture after some ductile crack growth occurred in the temperature interval $t_{DBU} - t_{DBL}$. Further, the transition temperatute t_C is marked at which the cleavage unstable fracture occurred directly at the original pre-crack tip. Due to the scatter in the transition behaviour, t_C need not be identical to t_{DBL}, as presented by Milne and Curry (6). It results from Figs. 2 and 3 that the shift of t_C is much smaller than that of FATT. Therefore, the transition fracture behaviour prediction by FATT after SCT is more pessimistic than that by t_C. The same results has been found for the same steel with bainitic-ferritic microstructure.

There is no difference in the upper shelf fracture toughness values for the as-received and SCT states. To compare the fracture toughness temperature dependence below t_C the equation

$$K_{IC}, K_{JC} = K_o + A \exp(BT)$$

was used. The constants A and B can be calculated by the linear regression method after choosing $K_o = 25 \text{ MPam}^{1/2}$. Assuming the normal distribution , the fracture toughness curves for various probability limits P can be drawn (Fig. 4). It can be seen that after SCT, fracture toughness temperature curves for P 0.5 and 0.95 are clearly below that of the as-received state.

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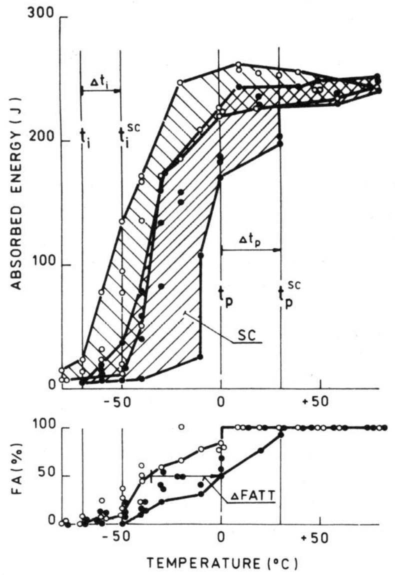

Figure 1 Absorbed energy vs temperature

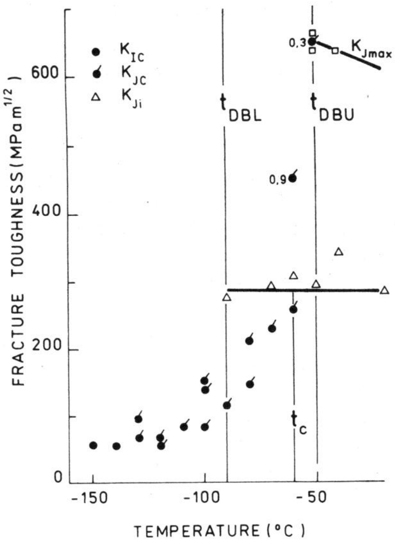

Figure 2 Fracture toughness vs temperature, as-received

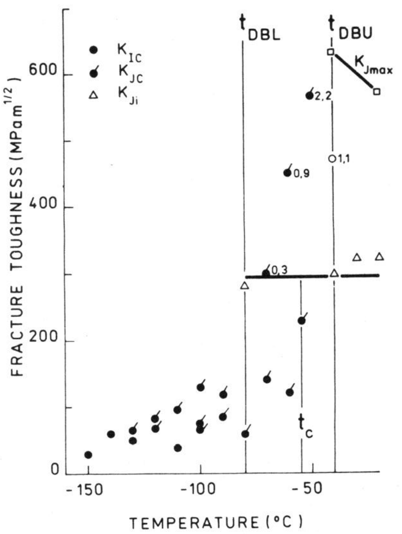

Figure 3 Fracture toughness vs temperature - SCT

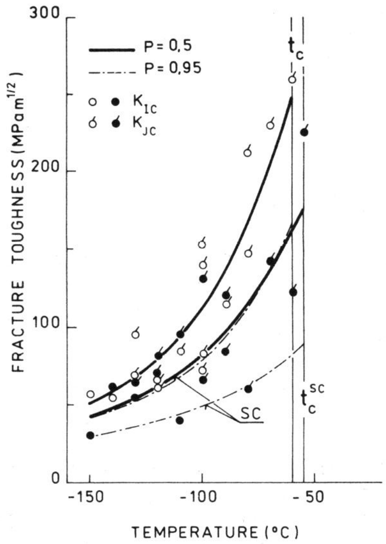

Figure 4 Comparison of fracture toughness curves