DYNAMIC TOUGHNESS OF ELECTRON BEAM WELDS ON C-Mn STEELS

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Charpy-V testing of electron beam welds of C-Mn microalloyed steels for low temperature service led to some uncertainties due to fracture path deviations, to the specimen heterogeneity and to absorbed energy values only just above the requirements. Then dynamic toughness tests were carried out. That reduced the tendency to fracture deviation and confirmed that the higher the welding cooling rates the higher the toughness. Contrary to the Charpy-V results, similar low dynamic toughness values were obtained for three different steels when cooling times are about 15 seconds.

INTRODUCTION

The electron beam (EB) welding process of C-Mn microalloyed steels generally results in a significant deterioration of the base material toughness. With reference to offshore structures, Festa et al (1) found that, if the same commonly used base materials (BM) are EB welded, the Charpy-V (CV) specifications at - 40°C can hardly be fulfilled: only in very few conditions energy values were just above the requirements (typically 36-54 J). Then, for better insight into the weld metal (WM) toughness, precracked Charpy-V (PCV) specimens were tested by an instrumented pendulum and the dynamic toughness K_{Id} was evaluated.

Apart from the well known limits of the Charpy-V test, some doubts may arise concernig the significance of the absorbed energy data due to the specimen heterogeneity. Under certain conditions, namely a narrow weld, a weld metal considerably harder than the

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base material, and above a certain temperature, fracture path deviation towards the base material may occur. Should this be the case, the failure mechanism is plastic collapse in the base material and, as a consequence, the absorbed energy is quite high.

Althought it may be supposed that non propagation of the crack in the weld shows that this zone is very tough, Kaplan and Devillers (2) demonstrated that, as long as the test result does not characterize the weld metal, the exact value of its toughness is not known. Additional testing then has to be performed until a non deviated fracture is obtained. Moreover, even if no deviation occurs, the absorbed energy depends not only on the properties of the weld metal itself where the notch is located, but also on the properties of the material next to it (2).

Charpy-V test results are reported in detail in (1) and showed that the higher the welding cooling rate, the slightly higher the absorbed energy, up to fracture deviations at the highest cooling rates. On the other hand, high cooling rates are associated with narrow, hard welds for which heterogeneity effects are far more important. All that considered, dynamic toughness tests were carried out in order to confirm the correlation between CV energy and the cooling rate.

RESULTS

The influence of the weld width on the dynamic toughness for the material "70" is shown in Fig.1. It is clear that the narrower weld , 1.8 mm wide, is not only tougher than the 3.5 mm one, but is also comparable to the base material toughness. As the cooling time from 800°C to 500°C is estimated to be 2.9 and 11.5 seconds for the 1.8 mm and the 3.5 mm wide welds respectively (1), it is then confirmed that within our experimental conditions, the higher the cooling rate, the higher the toughness.

All data reported in Fig. 1 are obtained from non deviated fractures, however for the 1.8 mm wide weld, one specimen at -20 °C and all at temperatures above -20°C did not break on the crack plane. This means that plastic collapse was the preferred failure mode despite the specimens being fatigue precracked and having a sharp crack starter and a shorter ligament.

Much worse was the situation for the CV test: 3 out of 3 specimens had deviated fractures at 0°C, -20°C and also at -40°C. All in all we can say that, for this weld, PCV specimens allowed a shift in the temperature at which a deviation starts of at least +20°C with respect to CV specimens. The improvement is not extraordinary but is appreciable and helpful in this case.

The influence of the base material on CV testing and on dynamic toughness is shown respectively in Fig.2 and 3. The welding speed and the estimated cooling time (about 16 seconds) are the same for the three materials: "40", "50" and "70B". As the weld width is about 4 mm for all welds, there is not any risk of fracture deviation.

As fas as the CV test is concerned, Fig.2 shows that the 70B welded metal performs better than the others, whereas dynamic toughness tests in Fig.3 do not show significant differences between the 70B weld metal and the others.

Nevertheless, average weld metal hardness is: 280, 260, and 255 HV5 for the "40", the "50" and the "70B" materials respectively. If we assume a proportionality between hardness and σ_{ys}, and if we take into account the ratio K_{Id}/σ_{ys}, again it appears that the 70B material is slightly better than the others.

Note also that the 70B weld does not meet the CV specifications but it is not far off. On the other hand, the transition temperature from the dynamic toughness test is considerably higher than -10°C, the design temperature.

REFERENCES

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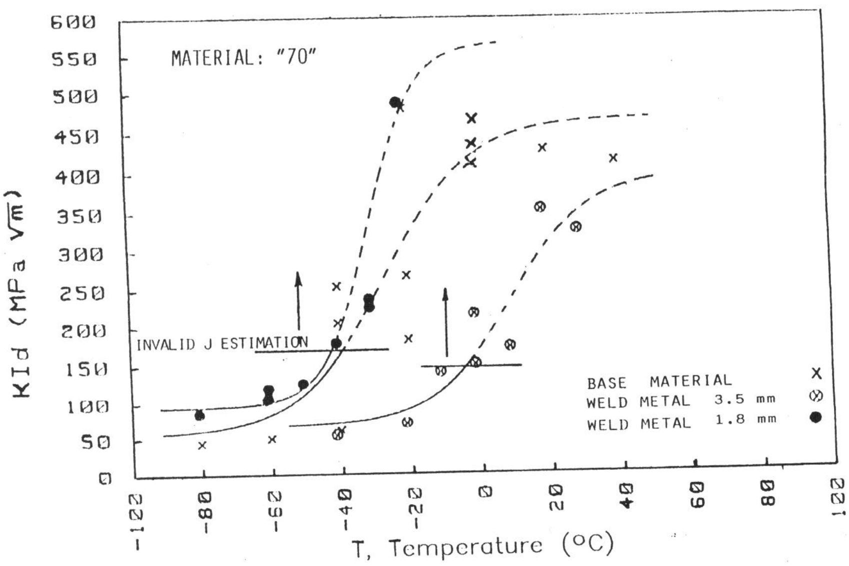

Figure 1 Influence of weld width on dynamic toughness

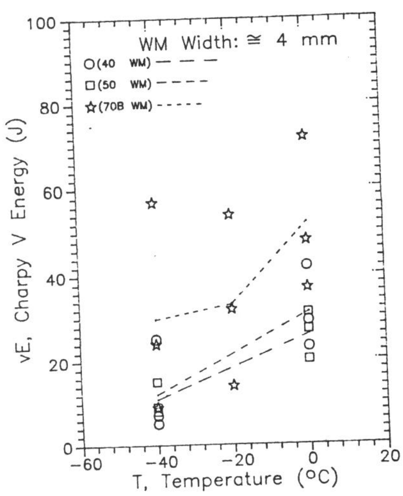

Figure 2 CV energy for different materials

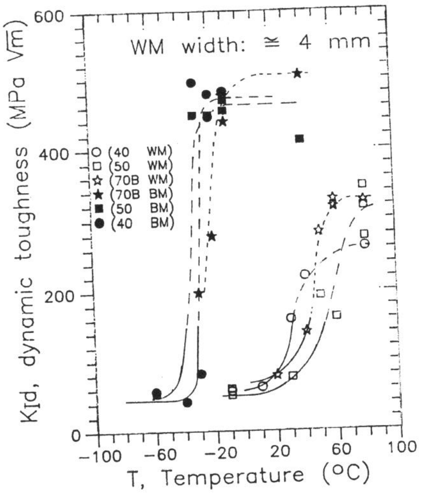

Figure 3 Dynamic tougness for different materials