Study on Fracture Toughness of Welded Joints for 15MnMoVNRE Steel

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ABSTRACT

The low temperature fracture toughness in various zones of welded joints for 15MnMoVNRE with defferent strength levels, obtain with different heat treatments, has been studied. The results are as follows: 1. The fusion zone and coarse-grained zone are the most brittle zones in the welded joints. 2.The δi and Ji values of the fusion zone remain quite high at low temperatures. No significant difference has been found in δi or Ji values for specimens with difference strength levels, while the Ji value of high strength specimens decreases with decreasing temperature because of the change of m value.

INTRODUCTION

Fracture toughness tests have been used in selection of materials, design, check of products and evaluation of safety. It is of great importance to quality assurance, and huge economical benefit has been achieved through its use. The IIW, Japan, Britain and some other countries have put forward proposals and standards for using the fracture toughness method to assess defects in welded joints. The pressure vessel industry in China has conducted research on this subject for many years, and has drawn up the CVDA standard for assessment of defects. Most research conducted in China has been on the toughness of parent metals; less on welded joints. However, the failures of welded structures often start and propagate in welded joints, so that the determination and study of fracture toughness of welded joints is more important than that of parent metal.

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DISTRIBUTION OF FRACTURE TOUGHNESS IN WELDED JOINTS

The distribution of microzone fracture toughness is very unhomogeneous. Fig. 1 shows a typical distribution of δc and the corresponding compositions and properties.[5] A scanning electron microscope was used to take pictures for every 0.5 mm interval and to measure the stretch zone depth (SZD).[1] In Fig. 1 we can see that the most brittle zone (with the lowest δc) is coarse-grained. In the softened zone δc is slightly lower than that in parent metal, but still much higher than that in coarse-grained zone. One dose not need to worry about the fracture toughness in the softened zone, but should pay particular attentioin to the fracture toughness in the fusion zone and the coarse-grained zone, because those zones are brittle, easy to crack, and with the highest welding residual stress and stress concentrations. The fracture toughness of weld metal is also important, of course, but it can be easily improved with the proper matach of welding materials.

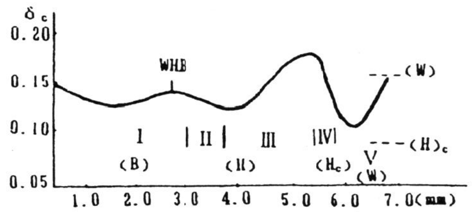

Fig. 1. Distrubtion of δc.

W-Weld metal, H-HAZ, B-Base metal. Hc-Coarse-grained zone

LOW TEMPERATURE FRACTURE TOUGHNESS OF QJ70, QJ60 AND QJ50 STEEL

Many welded structures are used at low temperatures. Even for those alloys that are not used at low temperatures, one shold examine the trend of brittle transition with temperature using fracture toughness tests. We have carried out low temperature fracture toughness tests on the fusion zone with edge-notched sepecimens of 15MnMoVNRE steels with varying yield strengths (in kg/mm^2), QJ50, QJ60 and QJ70. The experimental results are shown in Table 1.

Fig. 2 was drawn using the data in Table 1. From Fig. 2 it can be seen that QJ50 has higher fracture toughness for the fusion zone than QJ60, and that below -20℃ Ji and δc QJ60 are very close to those of QJ70. The exent of decrease in δi and Ji as temperature is decreased can be expressed as δ_{LT}/δ_{RT} (LT-low tempreature, RT-room temperature) and J_{LT}/J_{RT}.

J_{LT}/J_{RT}: $QJ50=0.783$, $QJ60=0.403$, $QJ70=0.374$
δ_{LT}/δ_{RT}: $QJ50=0.720$, $QJ60=0.560$, $QJ70=0.740$

Table 1. Experimental Results of Low Temperature Fracture Toughness.

QJ50					QJ60					QJ70				
NO	T(°C)	J_i (N/mm)	δ_i (mm)	m	NO	T(°C)	J_i (N/mm)	δ_i (mm)	m	NO	T(°C)	J_i (N/mm)	δ_i (mm)	m
501	24	88.55	0.0820	1.95	601	24	106.04	0.0804	2.14	701	24	99.40	0.069	2.41
503	24	95.26	0.0886	1.94	607	24	107.24	0.0881	1.97	702	24	81.65	0.066	2.12
505	-15	83.03	0.0759	1.98	608	-15	74.61	0.0615	1.97	705	-15	69.34	0.062	1.87
506	-29	76.10	0.0620	2.22	610	-25	54.38	0.0610	1.45	706	-25	60.70	0.056	1.80
507	-34	76.97	0.0640	2.11	609	-31	54.25	0.0570	1.54	707	-32	75.35	0.062	2.03
510	-45	69.34	0.0590	2.12	612	-40	67.10	0.0550	1.98	710	-40	56.71	0.061	1.55
					613	-50	42.94	0.0450	1.54	711	-52	37.62	0.052	1.07

Composition (wt.%) and properties of 15MnMoVNE steel														
σ_b (N/mm^2)	σ_s (N/MM^2)	δ (%)	a_k - 40°C (J)	C_v - 40°C (J)	σ_b (N/mm^2)	σ_s (N/MM^2)	δ (%)	C_v - 40°C (J)	a_k - 40°C (J)	σ_b (N/mm^2)	σ_s (N/MM^2)	δ (%)	a_k - 40°C (J)	C_v - 40°C (J)
778	554	21.9	33	9.8	809	598	18.5	58	53	859	616	20.4	66	32
QJ50					QJ60					QJ70				
0.15C, 0.51Si, 1.54Mn, 0.19P, 0.015S, 0.53Mo, 0.65V, 0.025N, 0.535R (added)														
Welding Conditions, SAW. Ho8MnMoA electrod 1431 flux, heat input, 21.3 KJ/cm														

DISCUSSION ABOUT m VALUE

The relation between the J integral and δ is a very important subject in the study and application of elastic-plastic fracture toughness. The value m ($m = J/\sigma_s\delta = 1$) was deduced from the D-M moldel, which is obviously unsuitable for low and medium strength steels. According to the elastic-plastic finite element analysis, m equals 2 for outer notch specimens, and 1.7 for inner notch specimens.[4] In this analysis, the properties of materials were not considered. Chen, et al, have studied the relation between J and δ.[6] From the analysis of an elastic-plastic body, the formula was obtained:

$$J = G + \sigma\delta/(1+n)$$

In the linear elastic range, $\sigma\delta_p \ll G$ therefore, J=G. In the elastic-plastic range, $\delta = \delta_p$, therefore, $J \approx \sigma \cdot \delta/(1+n)$; the critical value, Jc $(\delta F/\sigma s)/(1+n)$, where n is the hardening index, which decreases as the yield limit increases. The definitions of the parameters are:

$\sigma F/\sigma\delta$ =ratio of fracture stress to yield limit, which decreases as yield limit increase;

J =J integral

G =energy release rate during crack propagation;

=crack opening displacement.

p and c represent plasticty and critical value respectively.

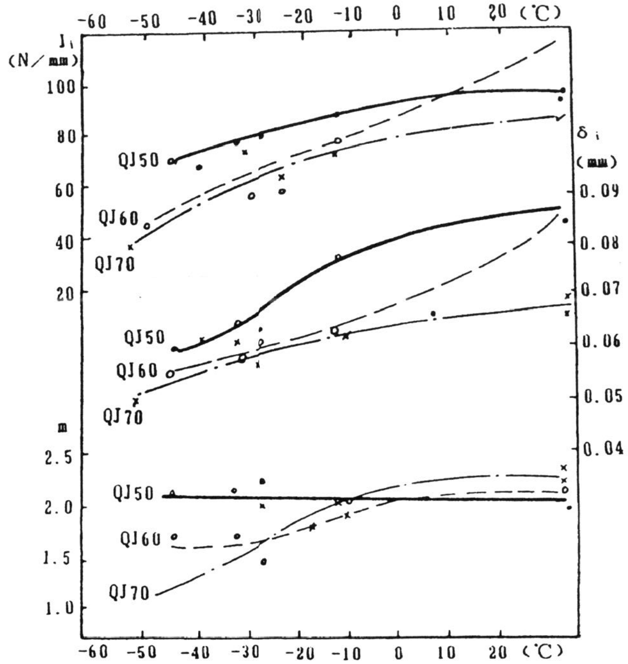

Fig. 2. The relationship of fracture toughness and temperature

In these formulae, only the harding index and ratio of fracture strength to yield limit are considered. All experimental phenomena cannot be completely interpreted. Our previous experimental results did not support this trend. A series of low temperature expermental results of 15MnMoVNRE has shown that the m value of QJ70 was larger than that of QJ50. Temperature basically has no effect on m for QJ70 steel, has significant effect for QJ60 steel, and has the greatest effect for QJ60 steel. The ratios of m_{LT}/m_{RT} equal 1.1 for QJ50, 0.72 for QJ60 and 0.44 for QJ70. According to the analysis based on our previous experimental results, there are many factors affecting the m value, such as difference zone in welded joints, type of specimen, direction of specimen, and, especially, temperature. The factors affecting the m value are not only n and σ_F/σ_s.

SUMMMARY

1. The most brittle zones in welded joints of 15MnMoVNRE steel are the fusion zone and the coarse-grained zone. The δ_c of the softer zone is lower than that of the fusion zone and the coarse-grained zone.
2. The low temperature fracture toughness tests showed that at room temperature δ_i and J_i for three steels (QJ70, QJ60, and QJ50) do not have significant difference. The J_i of the highest strength steel decreases significantly because temperature affects m value greatly. There are many factors affecting the m value, and further research is necessary on this subject.

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Fatigue Crack Growth Behaviour of HSLA Steel at Low Temperature

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ABSTRACT

Fatigue crack growth rate and fatigue fracture toughness of HSLA steel were studied from room temperature to -90 °C. It has been found that the fatigue crack propagation rate decreases with decreasing temperature down to a certain temperatue, then the crack propagation rate increases at lower temperature in the range of medium and high ΔK. There is a fatigue ductile-brittle transition temperature (FDBTT) while the fatigue fracture toughness transition (FTT) was observed. FDBTT and FTT close to the vTrs, which is the fracture-surface-appearance transition temperature of the Charpy-V impact. Fatigure fracture surface were quantitatively and semi-quantitatively analysed with scanning electron microscope. Fatigue crack propagation mechanism map of the steel at low temperature was drawn

KEYWORDS

Fatigue cracking behavior; low temperature; transition temperature; fracture mechanism.

INTRODUCTION

It is generally accepted that fatigue strength of steel increases with decreasing temperature, so fatigue behaviour at low temperature has been paid much less attention than that at room temperature and elevated temperature, that is apparently due to the test results obtained from unnotched specimen and constant amplitude cycle loads at low temperature. Unfortunately, a series of accidents of engineering constructions subjected cyclic loads at low temperature have taken place, so the beneficial effects of low temperature on fatigue behaviour are not always possible. It is necessary to study fatigue properties of notched specimen and crack growth rates at low temperature. The authors have published research results on the impact fatigue life of high strength steels at low temperature (Yan et al, 1981), the results indicated that, at first, the impact fatigue life of steels used gradually increasing with decreasing temperature down to a certain temperature. Then the impact fatigue life changes abruptly, it decreases with a drop in temperature, the fatigue life transition appears at certain temperature, below the