INFLUENCE OF POST WELD HEAT TREATMENT ON THE HAZ TOUGHNESS OF A C-Mn MICROALLOYED STEEL

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HAZ toughness of a ASTM A537 C1steel thick plate is evaluated in the as welded condition and after PWHT at 650°C for 5 hours. Charpy impact test was carried out for both conditions and temperature × absorbed energy and temperature × % ductile fracture curves were drawn. Micrographs were taken from CGHAZ and impact test results are discussed on the basis of the microstructure found.

INTRODUCTION

The heterogeneous microstructure of the heat affected zone (HAZ) of welds makes difficult toughness evaluation of this region. Points in HAZ at different distances from the fusion line undergo different thermal cycles which produce varied microstructures from this line to the unaffected base metal. The HAZ microstructure of a single pass weld is composed of some microstructural areas such as: coarse grained HAZ (CGHAZ), grain refined HAZ (GRHAZ), intercritically reheated HAZ (IRHAZ) and subcritically reheated HAZ (SRHAZ).

CGHAZ is known as the area of lower toughness, pointed out by the literature as a site where there is great probability of one to find M-A microphase (1) (retained austenite in high carbon martensite). This microphase can be found in the IRHAZ and SRHAZ. The literature (2) also states that upper bainite and ferrite side plates usually combine both large fracture facet size and the presence of M-A constituent between lath boundaries, resulting low toughness from this microstructure. In multipass welds, CGHAZ can be subdivided in IRCGHAZ (intercritically reheated CGHAZ) and SRCGHAZ (subcritically

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reheated CGHAZ).

Toughness in CGHAZ may decrease because of the excessive hardening that usually occurs in this region. In multipass weldments, reheating of this region can refine the grains but patches of coarse grain may be left if the heat is not enough for recristallization. Some ways are indicated by Varga (3) to improve impact strength in CGHAZ, which include the use of steels with alloying elements as Ti, V and Nb (to form precipitates) and the post-weld heat treatment (PWHT).

As has been shown, toughness results from tests will depend on the region of HAZ through which crack went. When fracture mechanics assessment is used, like CTOD test, the pre-crack must be placed at the region to be taken into consideration. But fracture mechanics assessment is worth applying only in expensive or of high damage potential welded structures (3).

Charpy impact test applied to HAZ gives largely scattered results because of the impossibility of stablishing the exact place of crack initiation from the V notch. To reduce scatter, it's usual to use some specific groove geometries when preparing welded joints to HAZ toughness study based on Charpy impact test. Groove geometries like those used by Loureiro and Fernandes (4) and Xavier and Azambuja (5) allow the obtainance of a straight HAZ, which permits more precision in notch location.

MATERIALS AND METHODS

Welding characteristics

The welding process used was the SAW process, multipass welding, using the following parameters: current = 540 A, voltage = 28,5 V and travel speed = 60 cm/s. These parameters have given a heat input of 15,39 kJ/cm. The electrode/flux classification (AWS) was F7P8 - EH 12K.

Plate characteristics

The steel tested was ASTM A537 C1, which has the following chemical composition (% in weight): 0.16% C, 1,317% Mn, 0.0148% Al, 0.1879% Si, 0.0140% P, 0.0084% Ti, 0.0029% V, 0.0202% Cr, 0.1439% Ni, 0.0079% Cu, 0.0192% Nb, 0.005% S, 0.0037% N and % Mo<0.008. Its required yield strength (ASTM Standard Specification) is 345 MPa. The plate was 38.1 mm thick and had groove geometry as shown in figure 5.

Post-weld heat treatment

The plate was cut in two and PWHT was carried out in one half of the plate at 650°C for 5 hours.

Metallography

From each condition (as welded and after PWHT) one specimen was taken for metallographic examination in light microscope. These specimens were polished to 1μm diamond paste and etched with Nital 2%. Micrographs were taken from unreheated HAZ, associated with the final pass of the weld. This is the HAZ region expected to have lower toughness.

Charpy impact test

Charpy impact test was carried out and test temperatures were chosen during the test, in order to select appropriate temperatures to assess upper and lower shelves of the transition curve of each condition (21 specimens were taken from each condition).

Specimens were machined acccordingly to ASTM standards, 0.5 mm below plate surface, notch lines parallel to thickness plane. The specimens were extracted near the plate surface in order to comprehend the region of the final passes. Each specimen had one surface prepared and etched to reveal HAZ position.

It was expected to obtain straight HAZ at one side of the groove but, after etching, it was observed that it wasn't straight near the plate surface, where Charpy specimens were taken. In the as welded condition, most of the specimens had notches comprising 90% HAZ and 10% weld metal. In the condition of PWHT, most of them had notches comprising 50% HAZ and 50% weld metal.

RESULTS

The temperature × absorbed energy and temperature × % ductile fracture curves are showed in figures 1 - 4. In the PWHT condition, 50°C temperature test results were highly scattered, reason why 5 specimens were tested at this temperature. Five specimens were tested at -80°C and -60°C as well, discarding the lower and the higher energy results. It's possible to observe that in PWHT curve upper shelf temperature was lowered and lower shelf temperature was elevated. It also can be seen that transition from ductile to brittle fracture became more drastic.

HAZ micrographs are shown in figures 6 - 8. The microstructure found was similar to those found by Sparkes (6) when studying a similar steel after PWHT. In the as welded condition ferrite with aligned second phase (FS(A)) and martensite were found (figure 6). In PWHT condition, one can observe that intragranular microstructure is less defined and colony boundaries are more pronounced (figure 7). At a higher magnification of the same region (figure 8), the presence of precipitates can be observed.

DISCUSSION

At 50°C test temperature the most largely scattered results could be found and 2 of the 5 specimens tested couldn't be totally fractured. In this case, the result adopted was 80% of the test machine scale (240 J). This scatter may indicate that this temperature was around the transition temperature, region where scatter is usually greater (3).

The enhancement in toughness showed in the upper shelf may be associated with a drop in yield strength like observed in (6). Tension tests will be necessary to check this hypothesis.

It is known (7) that PWHT promotes break up of the second phases, and leads to spheroidization of the packets of cementite formed when temperature and time are increased. The low angle between laths disappear as well, lowering the interfacial energy that is usually associated with elongated microstructures. This may be an explanation for the difference between the toughness results of the conditions analysed. It also must be taken into consideration that the Charpy specimens of the PWHT condition had 50% of weld metal at notch and the results were more affected by weld metal than the as welded ones.

CONCLUSION

In spite of the problems in notch location one can conclude that PWHT at 650°C for 5 hours must have increased toughness around -40°C and higher because weld metal probably wouldn't affect transition curves to the point observed. Other tests will be carried out with specimen notches comprising 100% HAZ to check these results.

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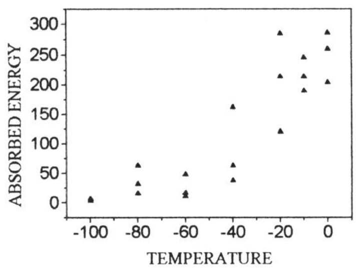


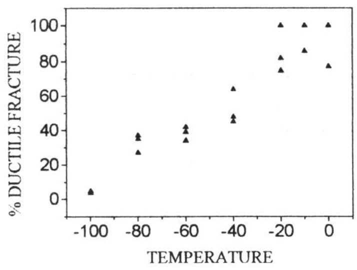
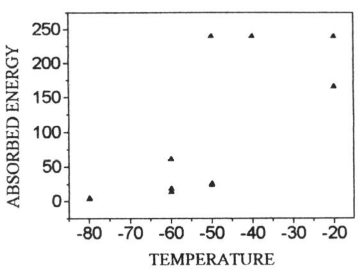


Figure 1: Absorbed energy for the as welded condition

Figure 2: % ductile fracture for the as welded condition



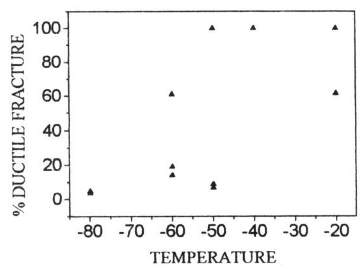


Figure 3: Absorbed energy for PWHT condition

Figure 4: % ductile fracture for PWHT condition

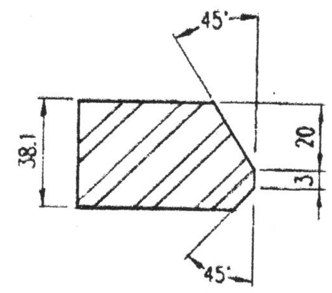


Figure 5: Groove geometry. The other side of the groove is straight.

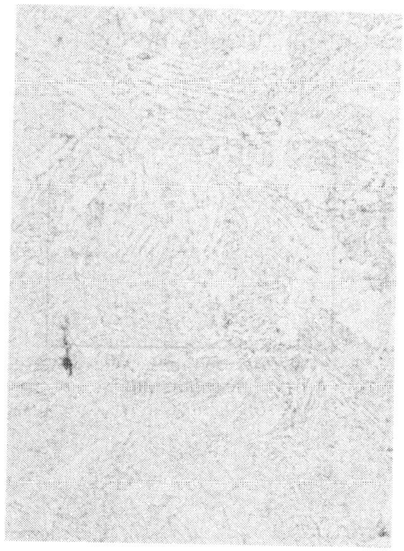


Figure 6: Unreheated CGHAZ, as welded condition. Magnification: 300×

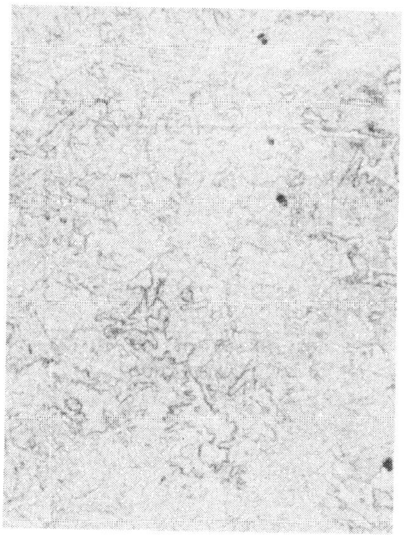


Figure 7: Unreheated CGHAZ, PWHT condition. Magnification: 300×

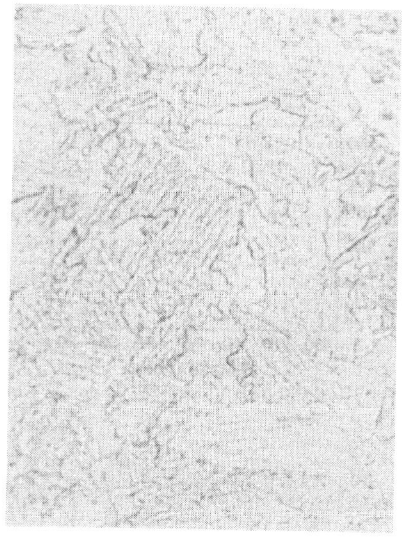


Figure 8: Unreheated CGHAZ, PWHT condition. Magnification: 700×