Avoidance of Hydrogen Assisted Cold Cracking in Multi-pass Weld Metal

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Introduction

Many challenges still remain regarding the mechanism of hydrogen assisted cold cracking (HACC). Historically, heat affected zone (HAZ) HACC has been the predominant failure mode, its causes and mitigation have been studied extensively and are generally well understood. However, with the development of lean composition steels a shift from HAZ cracking to weld metal (WM) cracking may also commonly occur. Therefore, a need has arisen to define the cracking mechanism and techniques for the avoidance of WM HACC.

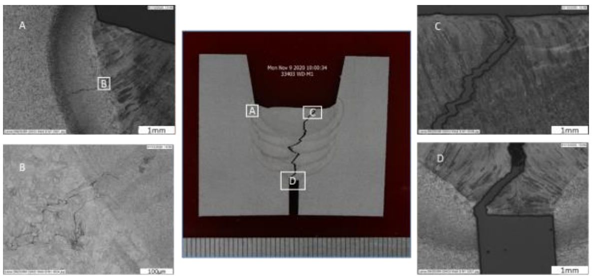


***Figure 1** Photomicrograph showing a transverse cross section of a FCA welded U-groove sample made between S690QL parent material AWS A5.29 E111T1 weld metal*

In this study a condition that results in both WM and HAZ HACC has been developed on U-groove S690QL grade steel samples, welded with a multi-pass technique and flux-cored welding wire. In-depth microstructural investigation was undertaken to characterise HACC morphology in both WM and HAZ, and the bulk diffusible hydrogen of the deposited WM was quantified. Following this, HACC avoidance techniques will be applied to the cracking condition in order to understand the effectiveness of different procedural techniques for avoidance of WM HACC.

Approach

Literature Review – Determine current knowledge state and identify future challenges. Determine experimental approach.

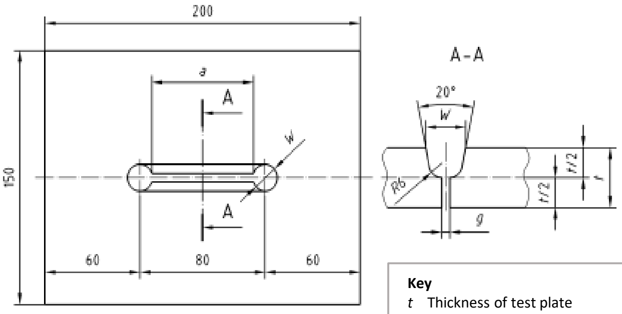
Define the Cracking Condition – U-Groove restraint testing and weld metal hydrogen determination to establish the cracking condition.

Effect of Procedural Controls – Adjust the variables that control hydrogen cracking susceptibility to determine the crack/no crack boundary for each variable and combination of variables. Variables include preheat, heat input and post weld hydrogen release treatment.

Modelling – Finite element analysis (FEA) model to predict the evolution of residual stresses, hydrogen diffusion, and cracking in the test specimens and interpolate the crack/no-crack boundary for a selection of conditions.

Experimental Methods

The self-restraint U-groove test as shown in Figure 2 is the recommended self-restraint test to assess weld metal cracking susceptibility *(1).*

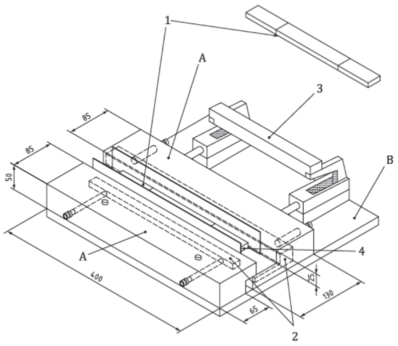


Key
t Thickness of test plate
g Root gap 2.0mm ± 0.2mm
W Diameter of drilled hole/groove width

***Figure 2** U-groove restraint schematic (1)*

The test consists of depositing a weld bead on to a machined grooved test sample using pre-defined conditions followed by examination of transverse sections of the weld with a view to detect cracks using microscopy. Cracking may be micro or macro as shown in Figure 1.

The diffusible hydrogen test in Figure 3 is used to determine the amount of diffusible hydrogen contained in deposited weld metal. The welding consumable to be tested is used to deposit a single weld bead, which is rapidly quenched and subsequently stored at −78 °C.



Key	
1	Test piece assembly
2	Water cooling jacket
3	Lever clamp
4	Copper foil insert
A	Copper
B	Carbon Steel

***Figure 3** Diffusible hydrogen test fixture schematic (2)*

The sample is then heated to 400˚C and the hydrogen is collected using a gas carrier method and measured using a thermal conductivity detector (TCD). The hydrogen evolved via diffusion, together with the test piece weight, are used to calculate the volume of diffusible hydrogen (ml/100g).

Research Aims

- Define the crack/no-crack boundary condition for weld metal hydrogen cracking, relating to the levels of combined controls required to sufficiently reduce the concentration of diffusible hydrogen and avoid cracking;
- Define robust and economical techniques for the avoidance of weld metal hydrogen cracking and provide sound underpinning through empirical research.

References

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2) BSI. 2018. BS EN ISO 3690:2018 Welding and allied processes - Determination of hydrogen content in arc weld metal. British Standards Institute.

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