

I haven't changed anything and now I've got these cracks"...?

By Neville Cornish

Hydrogen cracking is a little understood insidious phenomenon which contributes to more weld failure than perhaps it's credited for.

In an attempt to clarify an understanding of the propensity for hydrogen cracking to occur in materials welded, on what may appear to be an ad hoc basis, the following information is provided.

- Delayed hydrogen under bead cracking, or cold cracking as it may be referred to, is quite common and a well understood phenomenon as a weld defect, occurring in a range of steels including low carbon steels.
- In a weldment where the resultant microstructure in the HAZ is susceptible to cracking as a result of unacceptably high hardness values, (Martensitic structure) delayed cracking may occur, particularly when the weld zone is severely loaded, subject to fatigue, or in fact normal service conditions.

A theory of the mechanism of diffusible hydrogen induced under bead cracking is as follows:

At molten temperature the weldmetal has capacity to readily absorb vast quantities of hydrogen present in the arc environment. However, on cooling to solidification this ability to absorb hydrogen is diminished significantly.

As consequence hydrogen diffuses readily from the weldmetal to atmosphere, and diffuses from the weldmetal into the base material freely as cooling continues. It is considered this free diffusion is occurring to room temperature, however it is more prevalent at 1500C and higher temperatures.

Hydrogen diffuses through the deposit and base material collecting void. This void may be a weld imperfection, ie slag inclusion, lack of fusion, or in fact a grain boundary void of microscopic proportions.

Accumulation of hydrogen in this void or defect eventually leads to cracking. The brittle microstructure will not plastically deform, (brittle fracture), leading to crack growth, and a repeat accumulation of hydrogen and cracking process until wither the crack is arrested by ductile tough material, ie base material or weldmetal, or rapid crack propagation due to an

unfavourable microstructure, and/or stresses on the component.

It is feasible that a microscopic "crack" may remain dormant and undetected for the service life of the component, or conversely, should variables be such that the microstructure has an increased propensity to crack, cracking may be very rapid (see figure 7).

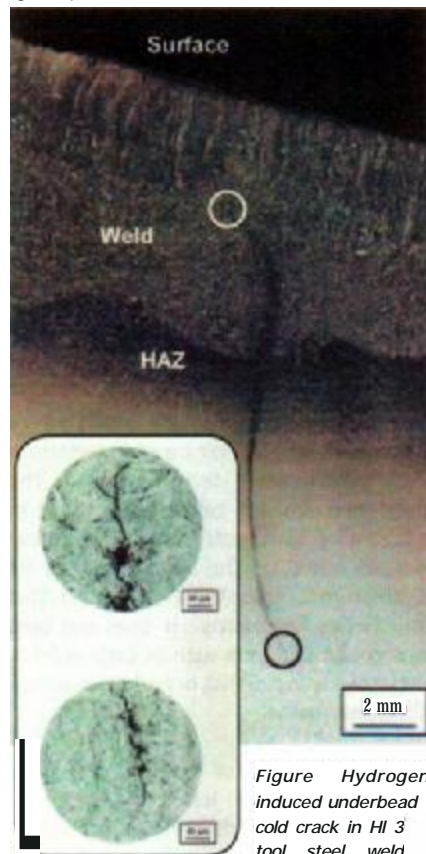


Figure Hydrogen induced underbead cold crack in H13 tool steel weld overlay

The process of crack growth can continue undetected for extended periods, and is normally generated below the bead in the HAZ, therefore the term "Delayed Hydrogen Under Bead Cracking" is appropriate.

Hydrogen presence in the weld zone is affected by numerous factors, some are variables with little control. Variables such as electrical stickout, atmospheric conditions, preheat rate and temperature, interpass temperature, post weld cooling rate or PWHT, base metal chemical specifications, shelf life of the consumable, lubricant residue on the wire, shielding gas moisture content, etc, will all have an effect on the presence of hydrogen.

With modern "clean steels", treatment with calcium has reduced the presence of sulphur, which we recognise as the product

contributing to hot shortness, and porosities in weldments. The clean steel reduces the propensity for these defects. HOWEVER, it is considered that by removing these sulphur sites from the microstructure, there are fewer sinks for hydrogen to be trapped. Therefore the clean steel is more likely to contain free hydrogen, and therefore it is acknowledged hydrogen crack sensitivity of "clean steel" is increased.

The hardness of HAZ is identified as AS1554.1 as a significant factor in determining both preheat and procedure qualification. Where recommended preheat is not adhered to a hardness survey is required of the weld zone, with a peak hardness of not more than 350 FIV10 for conformance with the code pre-qualification requirements.

While it is recognised that some materials, such as TENSILLOY 450, may not conform to the pre-qualified materials covered by AS1554.1 or AS1554.4, it remains sound practice to follow guide lines established by the Australian Standards and the WTIA technical notes. Therefore a welding procedure complete with macro and HAZ hardness survey is essential to be assured the welding practice employed provides a measure of tolerance to HAZ cracking, by offering reasonable ductility in the HAZ, and should therefore be suitable in the service intended. Other expert references may be consulted to establish the parameters of a suitable welding procedure.

The level of hydrogen present in the weld zone should be kept as low as practical to minimise the absorption, and subsequent diffusion of hydrogen. The Australian Standards for consumables, as with Lloyds register, the AWS, and European Norm, all recognise the importance of Hydrogen measurement in deposited weldments. The method adopted by the Australian Standards measures diffused hydrogen in ml per 100gram of deposited weld metal with a gas chromatograph. Each hydrogen controlled consumable is then rated in three categories, ie. less than 5ml per 100 gram of weld metal with a H5, H10 at less than 10ml/100 gram deposited weldment, and H15 over 15ml/100 grams deposited weld metal.

Where no hydrogen testing is conducted under the Lloyds Register system a default H15 is nominated by Lloyds for hydrogen controlled consumables. These ratings appear in the electrode classification systems as a suffix. ie ETP-W503A.CM1 H10.

It is important to note that this hydrogen level has no bearing on the pre-qualification status of the consumables in accordance with the AS 1554.1 to 5 series of codes.

An awareness of the hydrogen level needs to be factored into economics of the project and risk management criteria when considering the consequences of a weld failure.

The basic slag type fluxcore filler metals have significantly lower hydrogen status (ie. 1-2 ml/100 grams) than rutile and micro-alloyed rutile slag type wires. However, as we know only too well, the globular droplet transfer arc characteristics and spatter levels do not make basic wires a favourite with welders.

Operator appeal has been improved with CDT Pulse transfer and mixed gas. Where the use of basic wire types is imperative, CDT Pulse transfer has proven to be a productive option.

When considering the economics and integrity of a total project, the welding time associated with manufacture is minuscule. The propensity for hydrogen cracking in the HAZ should be considered before dispensing with the basic wire option.

The rutile and micro-alloyed rutile fluxcored wires manufactured from fat strip, commonly known as fabricated wires, are typically H10 and H5 hydrogen status.

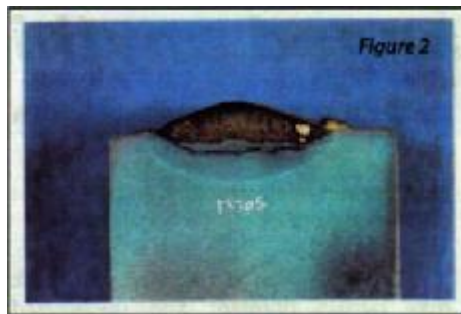
The manufacturing process for fabricated wires, although very productive in producing cost effective wires, does not lend itself to minimising hydrogen generated in the arc of these wires.

The formed tube can retain drawing lubricants in the folded closing seam, and may also absorb moisture through this seam.

The tubular wire however, is annealed at 7000C during the manufacturing process, which disassociates moisture present with the hydrogen diffusing out through the tube at this time.

The sealed tube prevents re-absorption of moisture and lubricants, as does occur with the fabricated wire.

This explains why the rutile and micro-alloyed rutile tubular wires do not achieve less than the H5 status where frequently the fabricated rutile and micro-alloyed rutile wires are typically H10 and H15 hydrogen status.



Preheat calculation, or more correctly, preheat prediction has many facets.

Please consider:

- Base material specifications
- Thickness to be welded
- Joint configuration
- Level of joint restraint within the component within the total fabrication
- Residual stresses
- PWHT
- Hydrogen level of filler metal
- How preheat is applied
- When preheat is applied
- Cooling rates
- Shrinkage
- Distortion

A number of formulae are available to predict preheat temperature and martensite transformation start temperatures. The widely used Preheat calculation guides in the Australian Standards and WTIA technical notes are based on the IISW formulae for CEQ. $C-FMn16 (Cr+Mo+V/5)+(Ni+Cu/15)$. This formulae has limitations. It does not take into account elements such as carbon Boro, crack intensity factor (Ks), or hydrogen status of the consumable.

The carbon content of the base materials considered must be less than 0.25% C. Increased design loads can be applied to modern thermo mechanically rolled steels, FISLA steels, & HSLZ Q&T steels due to increased material strength. These enhanced material stresses combined with shrinkage induced stresses increase residual stresses in the weldment to as much material yield strength.

The desire to reduce preheat for productivity improvements, hence increased cooling rating, "clean steels; and high residual stresses, have the potential to increase hydrogen crack susceptibility.

It is for these reasons the level of hydrogen in consumable is most significant in reducing the level of preheat required, the level of free hydrogen in "clean steel; and the propensity to cold crack.

The Pcm formulae for predicting preheat in low alloy steels takes into account hydrogen

status of the consumable. Lower the status, lower the preheat required for a given material, lower the risk of hydrogen cracking. $P_{cm} = C + \{Mn+Cr+Cu/20\} + V/10 + Mo/15 + Ni/60 + 5B$.

Estimated welding conditions need to be tested in practice, hence the welding procedure qualification formats in various welding codes, which endeavour to assess the susceptibility of a material to hydrogen cracking by physical testing. Welding procedure qualification remains an empirical task.

It remains very much an informed decision as to which consumable product is fit for the purpose intended.

For the TENSILLOY 450 material specified a basic slag type fluxcored wire is probably the best option, followed by the tubular type rutile wire, and the fabricated wire as the least favoured, based on the high propensity for hydrogen embrittlement of the HAZ.

Appreciating the operator appeal and past success of fabricated wires, it is possibly just a matter of maintaining close control over the entire welding process, including an elevated preheat of some 200-2500C, uniformly applied to the opposite side of the joint, preheat and interpass throughout the welding process, maintain a preheat of 1500C for some two hours after welding to permit hydrogen to dissipate, control cooling rate to touch.

A welding procedure in accordance with AS1554.4, with a subsequent macro and HAZ hardness survey may provide the welders a benchmark to maintain consistent quality weldments in the production environment.

For more information:

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