Welding issues: Hydrogen cracking - Cold Cracks (Hydrogen embrittlement)

A ship is not a static object. It flexes through the high seas, it vibrates from the engine, and receives sudden impacts from moving cargo.

Welds onboard of a ship take tremendous punishment and must be of superb quality. If welds have hydrogen porosity, all that is needed to make them fail, is sufficient mechanical stress and a hydrogen crack will form.

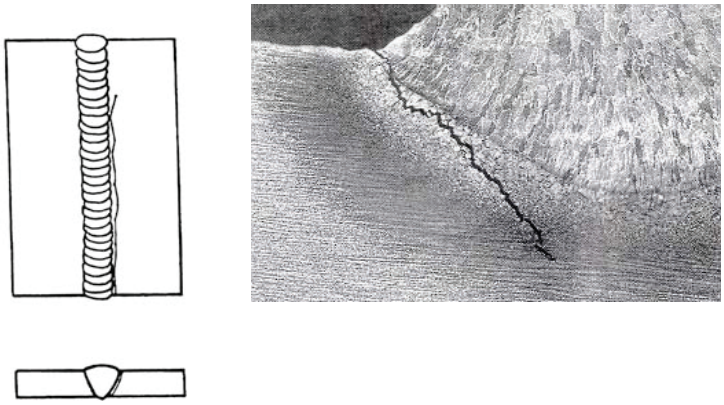
Hydrogen cracking is also known as cold cracking or delayed cracking.
The main feature of this type of crack is that it occurs in ferritic weld able steels, and generally occurs immediately on welding or a short time after welding, usually within 48hrs.

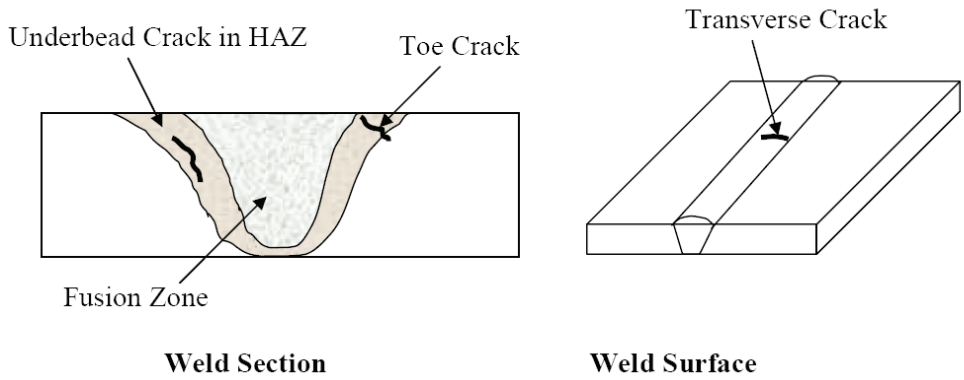
Moisture in the consumable and/or material will change to hydrogen gas (H_2) in the arc because of the high temperature (7000 °C)
The hydrogen ends up as hydrogen porosity in the weld material or diffundates to the heat affected zone (HAZ=Heat affected Zone).

Detection
As hydrogen cracks are often very fine and may be sub-surface, they can be difficult to detect.
Surface-breaking cracks can be readily detected using visual examination, liquid dye penetrant (LDP) or magnetic particle (MPE) testing techniques.
Internal cracks require ultrasonic or radiographic examination techniques. Ultrasonic examination is preferred, as radiography is restricted to detecting

relatively wide cracks that are parallel to the beam. As the formation of cracks may be delayed for many hours after completion of welding, the delay time before inspection, according to the relevant fabrication code, should be observed.

Example of visual appearance of Hydrogen Cracking:





HAZ= Heat Affected Zone

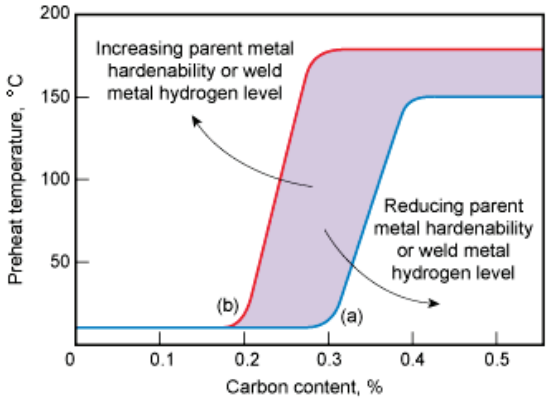
Possible Causes

Cracking is caused by the diffusion of hydrogen to the highly stressed, hardened part of the weld (weld material or Heat Affected Zone). Controlling the source of hydrogen and the microstructure of the weld are important. There are three factors which contribute to cracking:

- hydrogen formed during the welding process
- a hard brittle structure which is susceptible to cracking
- tensile stresses acting on the welded joint

Cracking usually occurs at temperatures at or near normal ambient.

In C-Mn steels, there is a greater risk of forming a brittle microstructure in the HAZ, and thus most of the hydrogen cracks are likely to be found in the parent metal. Using the correct choice of electrodes, the weld metal will have a lower carbon content than the parent metal and, hence, a lower carbon equivalent (CE).



However, transverse weld metal cracks can occur especially when welding thick sections. In low alloy steels, as the weld metal structure is more susceptible than the HAZ, cracking may be found in the weld bead.

The effects of specific factors on the risk of cracking are:

- Parent material composition
- Parent material thickness
- Stresses acting on the weld
- Heat input
- Weld metal hydrogen content

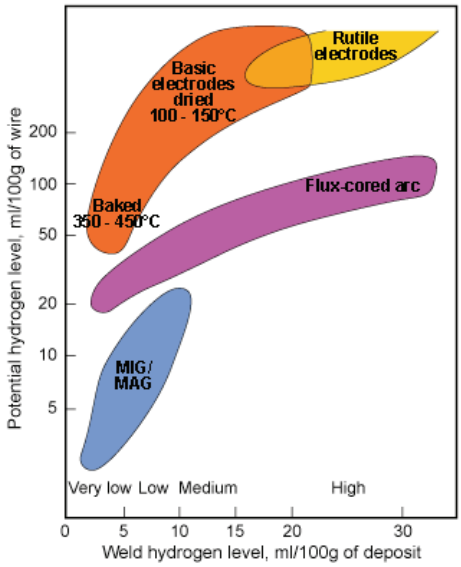
One of the principal sources of hydrogen is the moisture contained in the flux i.e. the coating of MMA electrodes, the flux in cored wires and the flux used in submerged arc welding. Mainly the electrode type determines the amount of hydrogen generated. Basic electrodes normally generate less hydrogen than rutile and cellulosic electrodes.

It is important to note that there can be other significant sources of hydrogen e.g. moisture from the atmosphere or from the material where processing or service history has left the steel with a significant level of hydrogen. Hydrogen may also be derived from the surface of the material such as oil, grease and dirt, rust, paint and coatings or cleaning fluids.

Avoiding hydrogen cracking:
The following practical techniques are recommended to avoid hydrogen cracking:

- clean the joint faces and remove contaminants such as paint, cutting oils or grease

- use a low hydrogen process, if possible
- bake the electrodes (MMA) or the flux (submerged arc) and then either store them warm or restrict the duration of exposure to ambient conditions, all in accordance with the manufacturer's recommendations.
- reduce stresses on the weld by avoiding large root gaps and high restraint
- if preheating is specified in the welding procedure, it should also be applied when tacking or using temporary attachments
- preheat the joint to a distance of at least 75mm from the joint line, ensuring uniform heating through the thickness of the material
- measure the preheat temperature on the face opposite that being heated Where this is impractical, allow time for the equalisation of temperature after removing the preheating before the temperature is measured
- adhere to the preheat and minimum interpass temperature, and heat input requirements
- maintain heat for approximately two to four hours after welding, depending on crack sensitivity
- In situations where adequate preheating is impracticable, or cracking cannot be avoided, austenitic electrodes can be considered



Repair

Most codes will specify that all cracks should be removed. A cracked component should be repaired by removing the cracks with a safety margin of approximately 5mm beyond the visible ends of the crack. The excavation is then re-welded.

To make sure that cracking does not re-occur, welding should be carried out

To make sure that cracking does not re-occur, welding should be carried out with the correct procedure, i.e. preheat and an adequate heat input level for the material type and thickness. However, as the level of restraint will be greater and the interpass time shorter when welding within an excavation compared to welding the original joint, it is recommended that a higher level of preheat is used (typically by 50°C) to minimise welding stresses.

General guidelines

The following general guidelines are recommended for the various types of steel, but requirements for specific steels should be checked according to EN 1011-2: 2001

Mild steel (CE <0.4)

- readily weldable, preheat generally not required if low hydrogen processes or electrodes are used
- preheat may be required when welding thick section material, high restraint and with higher levels of hydrogen being generated

C-Mn, medium carbon, low alloy steels (CE 0.4 to 0.5)

- thin sections can be welded without preheat, but thicker sections will require low preheat levels, and low hydrogen processes or electrodes should be used

Higher carbon and alloyed steels (CE >0.5)

- preheat, low hydrogen processes or electrodes, post-weld heating and slow cooling required

More detailed guidance on the avoidance of hydrogen cracking is described in EN 1011-2: 2001.

Sources: Defects - hydrogen cracks in steels - prevention and best practice published by TWI Jan 2000/March 2000

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