



Corrosion Testing of Pipelines

By Dr Chris Fowler, Exova

Corrosion of pipelines has always been a hot topic in the oil and gas industry and will continue to be but unfortunately it isn't a straightforward subject. There are a number of variables that we have to take into consideration in the testing process such as environments, age of pipeline, materials used, coatings – the list is endless. Furthermore, there are of course the types of corrosion too, namely sweet corrosion, which is wet Carbon Dioxide (CO₂) and sour Corrosion, that is wet Hydrogen Sulphide (H₂S), and these conditions exist inside a pipeline.

There are many examples of failures of pipelines from each of the conditions cited above, therefore to give a pipeline a good chance of a long lifetime the base materials and welds are tested in severe conditions to establish the suitability of the material. This is of course in addition to evaluating the coating of the pipeline.

So where do we need to start in qualification testing for a pipeline? The essential parameters which must be determined prior to any testing are; what is the pipeline designed for, what is the environment inside, what is the environment on the outside? Typically we need to know is the product sweet or sour? What are the temperature ranges, is the pipeline sub-sea or on land? Regardless of the range of variables, the pipeline will probably be welded and therefore weld qualification testing is also automatically required.

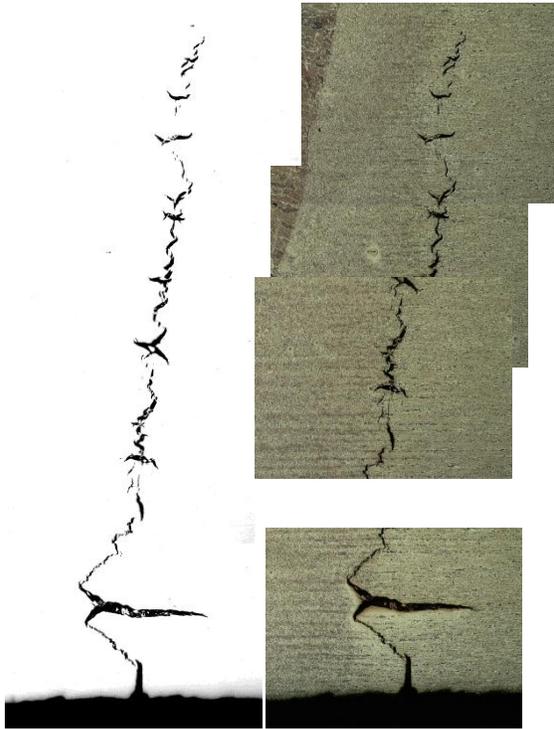
Once these questions are answered, a test and qualification programme can be mapped out. For most pipelines NACE MR0175/ISO 15156 is the Materials Recommendation Standard. This document provides the environmental limits for a wide range of materials, if the operating and design conditions fall within the documented ranges, then qualification tests of the base material are not required, apart from the weld which would be tested and qualified.

The Materials Recommendation Standard covers all forms of cracking associated with hydrogen sulphide, Sulphide Stress Cracking (SSC), Hydrogen Induced Cracking (HIC) Stress Orientated Hydrogen Induced Cracking (SOHIC) and so on. Most areas are adequately covered by providing environmental limits, hardness limits, test conditions, load levels and so on.

However, one crack mechanism, although cited and described in the Standard, is incomplete and as a dedicated test method was not available. This is SOHIC! This is an issue which has to be addressed immediately because in the Standard's guidelines, there is a section which details under "test" methods. There are numerous and a wide variety of tests listed but the section, rather alarmingly then finishes with "and others under development".

This Standard was first published in 2003 after nine years hard work between ISO work group 7 members and the industry itself. Now, for the first time, there is a dedicated test method which is available.

FIG1: Stress Orientated Hydrogen Induced Cracking (SOHIC) Adjacent to a Girth Weld



SOHIC is a cracking mechanism which only affects Carbon and Low alloy steels in wet sour service. At least nine pipelines (over the past 20 years) have failed by using this mechanism, and SOHIC has been evident in numerous Pressure Vessels. In addition this type of crack has been generally found adjacent to a weld, but not exclusively. One reported failure was in a seamless pipe and residual stress is thought to have played a key role in the crack's initiation.

FIG2: Failure of spirally welded pipeline from Stress Orientated Hydrogen Induced Cracking.



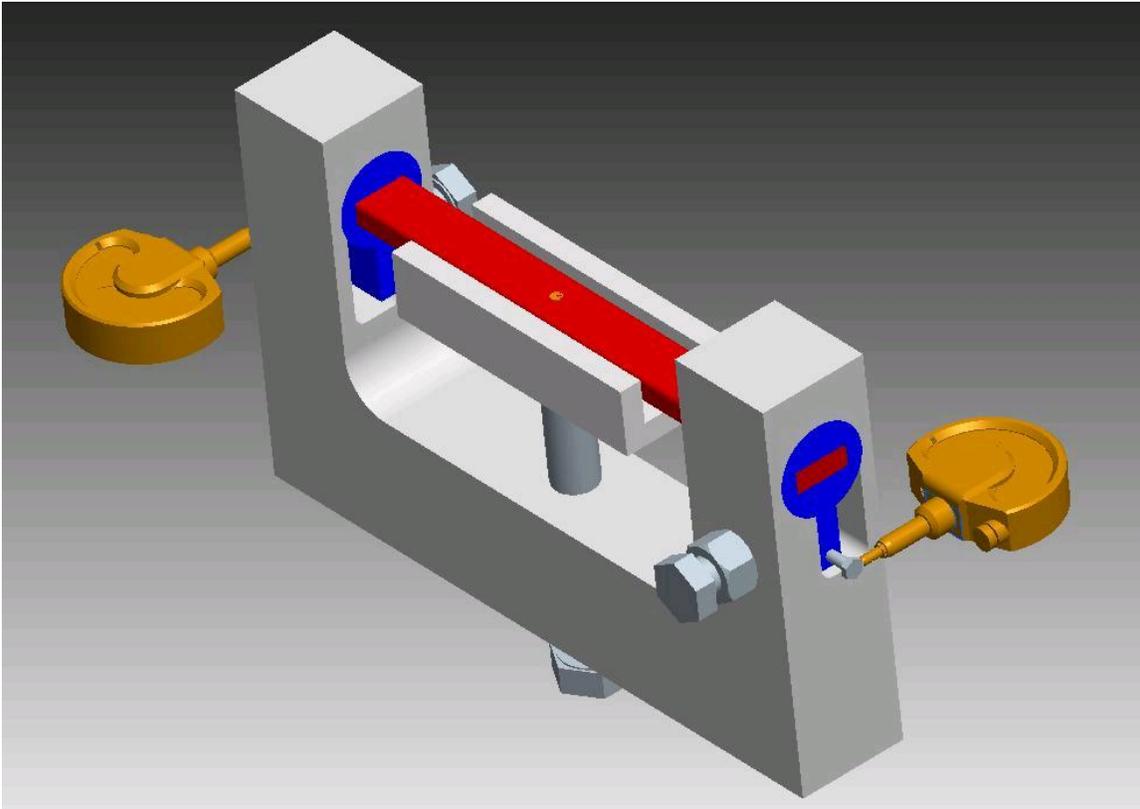
Failure of spirally-welded pipeline from Stress Orientated Hydrogen Induced Cracking.
(Courtesy M Hay Shell Canada)

This form of cracking is characterised by a through wall stacked array, visually resembling a ladder, which is why its early name was ladder cracking. First seen in the early 1980's it is only fairly recently that a test method has been defined that can effectively determine a material's susceptibility to this type of mechanism.

Now that a dedicated test method is available, the work to determine what variables are important can begin! Over many years the thought has been that SOHIC testing required a new method and sample configuration.

Exova has now completed a project which began eight years ago, which objective was to find a solution to this problem. In essence a pipeline sample has to be bent and twisted to simulate the residual stress adjacent to a weld. The control and level of the loading has also finally been solved meaning that we can reproduce a 'live' environment producing test results that are even more robust.

FIG3: The “new” test rig which can impart controlled bending and twist.



It has been shown that materials susceptible to SOHIC do indeed crack in this method, and materials that are resistant to SOHIC do not crack, ultimately resulting in a go/no go test being developed.

So, what are the variables that now need to be considered? The obvious starting point is microstructure. We can probably point to a number of microstructures that are more susceptible than others but which ones? Next to consider is steel chemistry. Do additions of microalloying elements help or hinder? And one variable that should never be missed is hardness. For example, is there a ceiling or even a lower limit of hardness where SOHIC does not occur?

These are questions that can now be addressed and ones which my team is now working on to provide the oil and gas industry with much needed answers. In terms of knowing which answers are more important to us, then It looks like we are probably 18 months away from finding out. However, some of the initial results will be published and shared at the NACE Conference in Orlando in March 2013 at the Oil and Gas symposium.

Once further research work has been undertaken, it could be possible to have a set of acceptance criteria such that many of the oil and gas industry's future pipelines can be designed to be resistant to SSC, SOHIC and HIC, but their welds would still require additional qualification to ensure pipeline integrity.

Other developments also include the evolvement of Girth Welding over the years. The primary driver being costs. The faster the welding, the less time and thus a more economical weld is produced. But with speed comes the possibility of increased hardness and possible susceptibility to cracking. In addition there could also be more likeliness of weld defects which of course leads to an increased susceptibility to cracking.

The majority of girth welds are qualified using the “Four Point Bend Technique”, interestingly there is no universally published and accepted test method. This is an issue which is being addressed by NACE International and EFC. Both organisations have working parties currently devising, developing and writing a consensus standard to which the oil and gas industry can subscribe to. EXOVA is very much part of both work groups, and is wholly committed to producing a workable test method. This is now in first draft form and it is envisaged that the document will be finally published by the end of 2014.

In conclusion even though the oil and gas pipeline industry has been operating for many years, the understanding of pipeline material properties is still a high priority, and with the advent of new test methods the understanding can continue. The industry objective of building safer pipelines with greater longevity and integrity can become reality.

About the author:

Dr Chris Fowler holds a BSc, MSc and completed his PhD in metallurgy at the University of Manchester Institute of Science and Technology (UMIST). He is a postdoctoral Fellow of the Corrosion and Protection Centre.

Dr Fowler joined Corrosion Industrial Services in 1980 and established what is now the Exova European Corrosion Centre in 1998 in which he was group technical director for corrosion and protection.

He has been a Member of the IOM (Institute of Materials) since 1977, adding CEng to his list of qualifications the same year. Now a Fellow of the IOM, Dr Fowler joined NACE International in 1989. He spent four years as its European director before becoming vice president (2009-2010), and president (2010- 2011). He took up his current position as president of the NACE Institute in 2012.