LOCALIZED IMMERSION PHASED ARRAY TECHNIQUE FOR THE DETECTION OF WET HYDROGEN DAMAGE (HIC & SWC)

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ABSTRACT
Hydrogen Damage Mechanism (HDM) and its reliable detection is the greatest problem faced in the petrochemical industries. Hydrogen Induced Cracking (HIC), Step Wise Cracking (SWC), Stress Oriented Hydrogen Induced Cracking (SOHIC) are different morphologies of HDM. Failure in Detection, sizing and monitoring of it can lead to catastrophic failures. Ultrasonic inspection is best suited, as HIC forms planer reflectors to normal beam. Conventional UT with normal beam is more time consuming and fails in distinguishing stepping. Here in this article we briefly describe HDM, mainly limited to HIC and SWC. It predominantly describes the optimization of Localized Immersion Phased Array Ultrasonic Technique (LIPAUT) and its test parameters for inspection. A comparative field survey between conventional UT and LIPAUT is prestigiously presented in it. OMNISCAN-MX along with semi automated HydroFORM scanner is used for this study.

A plate of 30mm thick is simulated with defects of flat bottom holes having different diameters and depths resembling bottom corrosion and HIC at mid wall thickness. A LIPAUT with 7.5MHz probe with 1mm pitch mounted on HydroFORM scanner is optimized by selecting one linear 0° and one sectorial with -30° to +30° is applied simultaneously on the defects simulated plate. This technique is greatly succeeded in detection and exact sizing of simulated indications. Comparative field survey results with conventional UT revels that, this technique is more reliable and fast and can cover 60mm at one scan with 1mm resolution data i.e. it covered 12 times than conventional probes by beautifully distinguishing HIC and connected HIC (SWC).

Keywords: Hydrogen Induced Cracking, Stress Oriented Hydrogen Induced Cracking.

INTRODUCTION
Hydrogen Damage Mechanism (HDM) is a mechanical fracture caused by the penetration and diffusion of atomic hydrogen into the internal structure of steel, which changes into molecular hydrogen at internal defects like grain boundaries, inclusions and laminations in the base material. Hydrogen Induced Cracking (HIC) and Stress Oriented Hydrogen Induced Cracking (SOHIC) are the two distinct morphologies of HDM those can be seen in the susceptible steels exposed to aqueous environments containing sour gas (H₂S).

Hydrogen Induced Cracking
It can occur where a little or no applied residual tensile stress exists. It is manifested as Hydrogen Blister oriented parallel to the surface. This Hydrogen blisters nucleate on internal defects or adjacent blisters and cause cracking when the internal pressure exceeds the fracture stress, this is called Step Wise Cracking (SWC). In this stage, a potential dangerous situation occurs which could lead to rupture and leak. Figure 1 is the schematic of HDM.

Stress Oriented Hydrogen Induced Cracking
It is a special form of HIC that may occur when local stress concentration is very high in a sour service pipeline. High stress fields allow the hydrogen to accumulate without the need for inclusions or other interfaces. For example, some types of spiral-welded pipe exhibit highly residual stressed regions adjacent to the seam weld called Heat Affected Zone (HAZ), caused during the edge forming process. This will develop parallel to the weld. SOHIC can have a greater effect on serviceability than HIC because it effectively reduces load carrying capabilities to a much greater degree so that SOHIC is treated as very conservatively in the Fitness For Service (FFS) assessments. Figure1 shows a graphical view of SOHIC.

Presence and extent of Hydrogen Damage like HIC, SWC and SOHIC in the operational equipments in the plant has to be detected, monitored and estimate the extent of damage. Failure
of which, can lead to a catastrophic failure and production loss also. A risk based approach is normally used to prioritize equipment where high probability and consequence of attack is indicated. Areas prone to attack can be identified by review of the process history, geometry, and operating conditions of the equipment.

DETECTION OF HDM

The ideal situation is to carry out the inspection non-intrusively without having shut down the operating plant. The more appropriate selection of NDT techniques is important in ensuring the plant availability is optimized, and defect detection is maximized.

Inspection Technologies

The inspection requires characterization of the suspected areas and to differentiate between inclusions, laminations and different stages of HIC. An optimized Ultrasonic inspection best suited for this type of inspection which reliably detect non-destructively and size hydrogen damage. HIC can easily detect by longitudinal ultrasonic normal beam because, HIC forms laminar reflectors parallel to the surface. But SWC and SOHIC which will be inclined to the surface, a normal beam cannot effectively detect the stepping and size it accurately. The objective in this case is to reliably determine if stepping is there between the HIC or not. For this purpose an angle beam is necessary for satisfactory detection as well as determining the stepping and its height measurements.

Advanced Ultrasonic Inspection

Manual UT is good for planar defects but slow and operator dependent. Automated Ultrasonic Testing (AUT) typically involved focusing beam, multiple A-scans display, combination of multiple views like S, B, C and D scan displays. This allows the operator flexibility in locating, characterizing, and sizing the indications with much faster and easier inspection. And moreover, it is less operator dependent. AUT scanner using conventional single or dual element ultrasonic probes needs higher raster scanning and poor ultrasonic data quality.

A phased Array Ultrasonic inspection is one of the advanced ultrasonic inspection techniques for HDM inspection where two or more piezoelectric elements are triggered in a desired phase which allows electronically steering the beams in multiple angles, focusing the beam in the desired area of interest. This helps one to optimize the inspection parameters for one’s desired inspection needs and gives best resolution.

LOCALISED IMMERSION PHASED ARRAY TECHNIQUE

The contact ultrasonic techniques are limited by the test surface irregularities and near zone effects. Immersion techniques can overcome these limitations but the total part has to be immersions in the suitable liquid. This is most difficult when applying for heavier parts and in field conditions. A localized immersion ultrasonic phased array technique (LIPAUT) perfectly suits this purpose.
The part is locally isolated and a water column is established between the test part and the probe. This can be obtained by a special arrangement of the scanner. A Olympus make HydroFORM scanner can develop this. It can cover 60mm of part in a single scan by giving 1.6mm near surface resolution, 1mm X 1mm data point quality. The near surface resolution helps in detecting the corrosion at the testing surface very nicely which is difficult by conventional UT. Moreover, it results in much increased production rate with 100mm/s speed of inspection. So it can give 12 times more production than conventional UT.

TEST SAMPLE PREPARATION

A 35mm X 150mm plate of 30mm thickness is simulated with defects of Flat Bottom Holes (FBH) which resembles the bottom corrosion, laminations and mid-wall imperfections like HIC. The FBH diameters ranges from 3mm to 12mm (3mm, 5mm, 7mm, 10mm & 12mm) and depths from top surface are 3mm, 15mm & 26mm. the separation between them is 38mm X 20mm. Figure 2 shows the drawing and the photograph of the test sample.

EXPERIMENTAL TECHNIQUE AND RESULTS

The experiment is done with Omniscan-Mx and HydroFORM scanner. The test angles are optimized in such a way that all the imperfections are effectively detected. A scan plan of 0° linear and +30° to -30° is developed with 7.5MHz phased array probe and generated on the test sample.

A single scan is enough to cover all these defects in very short time and the indications observed by this are presented in different varieties of views. Finally all the indications are sized. The figure 4 and Figure 5 shows the experimental results. The setup is tested in real site conditions. These results are compared with manual UT. This technique, in the real field conditions has given 12 times more production than the manual UT. The results by LIPAUT are in good agreement with manual UT with much increased data quality and production rates. Figure 5 shows the real field indications.
These experimental demonstrations showed that this localized immersion technique can satisfactorily be used and leads to much faster inspection by giving best production and data point quality than manual UT and other automated inspections using single or dual crystal ultrasonic probes.

CONCLUSIONS
A brief introduction of HDM is given. A LIPAUT inspection is proved that it is an advantageous method than other contact conventional techniques. The demonstration of the test results on the prepared sample with FBH resembling the HIC and corrosion at the bottom are satisfactory. The comparison of this results with conventional UT stats that this technique is much faster and gives good data point quality and could give 12 times greater production than conventional UT.

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