Non – Intrusive Inspection for process pressure vessels by Advanced and Common NDT techniques save cost whilst enhance safety and reliability

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Abstract

In – service Pressure vessels and pressure system components are essential to carry out periodic inspection to confirm continued safe and reliable operation. The inspection requirements include possible external and internal degradation of pressure vessels and pressure systems. It may achieve by external and internal visual inspection [IVI] link with other surface flaw detection methods which are very high cost because of shutting down, isolating and preparing entries for process pressure vessels. Every owner is expected to operate the pressure vessels and pressure systems safely and reliably without shutting down the equipment because of the present oil price drop.

If the inspections are executed from external side of the vessel without destroying the object, i.e. non-invasively, the owners can expect significant cost reduction from the non-invasive inspection. This paper explains the Non – Intrusive Inspection process involved with Non-destructive quantitative techniques such as phased array ultrasonic, computed radiography, manual ultrasonic thickness gauging and direct visual inspection to satisfy the present expectations. Direct visual inspection was used to inspect external degradations quantitatively such as general corrosion, pitting corrosion. PAUT HydroFORM corrosion mapping test has used to examine internal degradation for bigger areas of pressure vessel. Manual ultrasonic thickness gauging inspection has used to check internal degradation for smaller areas of pressure vessel. Computed radiography has used to examine internal degradation of small diameter nozzles of pressure vessel. The direct visual, PAUT ultrasonic corrosion mapping, manual ultrasonic thickness gauging and computed radiography NDT techniques quantitative results are helpful to assess the pressure vessels and pressure systems fit – to – service as per API – 579 or BS 7910. Therefore, the owners can save the cost whilst enhance safety and reliability through the Non – Intrusive inspection by advanced and common NDT techniques.

Keywords: Non-intrusive inspection [NII], Phased array ultrasonic testing [PAUT], Fitness – for – service [FFS], Computed radiography [CR], Risk based inspection [RBI]

1. Introduction

Pressure vessels and pressure systems are required to undergo periodic review to ensure internal and external degradation for continued safe and reliable operation which achieved by inner and outer visual inspection linked with surface NDT [Non-destructive testing] methods. However, shutting down the in-service vessel, isolating it and preparing it for entry leads to very high cost impact compare than the
inspection cost. Therefore, there is a need to inspect the in-service vessels from outside without affecting the service that is non-invasively. The NII [non-intrusive inspection] is a new approach for cost reduction, to eliminate internal inspection and to avoid shutting down the plant. The suitability of Non-intrusive inspection depends on vessel geometry, materials, potential corrosion, process, historic inspection records, location of defects, assurance in inspection and control cost. This paper provide Non-intrusive inspection combine with quantitative nondestructive methods such as direct visual, manual ultrasonic, phased array ultrasonic corrosion mapping and computed radiography. Development of the Non-intrusive inspection coupled with conventional and advanced NDT methods can save cost while enhancing safety and reliability.

2. Internal visual inspection

For internal inspection, the degree of surface preparation needed to ensure the type of deterioration and location. The used cleaning methods are: washing with hot water, steaming, solvents, power wire brushing, abrasive – grit blasting, grinding, high – pressure water blasting and scraping. All internal areas of the vessel to be inspected for wall thinning, pitting, cracking, erosion, blistering, lamination, deformation and mechanical damage. The internal inspection scope covers, trays, baffles, grids, screens, piping, stiffeners, nozzles and linings. The direct cost involved in an internal inspection of vessels depends on planning, project management, shutting down the vessel, vessel entry, cleaning, inspection and closing the vessel. The cost of internal investigation summarized in table [1] and the statistics plotted in figure [1]. The total cost involved in the internal investigation is 1, 50,000 $.

<table>
<thead>
<tr>
<th>Planning management</th>
<th>Project management</th>
<th>Shutting down the vessel</th>
<th>Vessel entry</th>
<th>Vessel cleaning</th>
<th>Vessel internal inspection</th>
<th>Vessel closing</th>
<th>Total cost for internal inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 1500</td>
<td>$ 3000</td>
<td>$ 90,000</td>
<td>$ 1500</td>
<td>$ 2500</td>
<td>$ 50,000</td>
<td>$ 1500</td>
<td>$ 1,50,000</td>
</tr>
</tbody>
</table>

Table 1: Vessel Internal Inspection Cost Break – Up

Figure 1. Statistics for Vessel Internal Inspection Cost Break-Up
3. Non-intrusive inspection

Non-intrusive inspection of in-service pressure vessels and pressure systems are fast becoming the preferred method for fitness – for – service assessment due to the substantial cost saving and not shutting down for internal inspection. Potential benefits of non-intrusive inspection are; avoid man entry into the vessel which can be a potential hazard, minimize disturbances to the vessel which can be a cause of deterioration, turnaround complexity and duration significantly reduced because the inspection can often carry out outside of the vessel. Non-intrusive inspection is most useful when the inspection scope link with RBI assessment. Screening assessment is used to determine whether the vessel is suitable to perform non-intrusive inspection before preparing the work scope. The screening assessment includes gathering data, identifying credible deterioration mechanisms and analyzing risk. The non-intrusive inspection has undergone after the screening assessment.

4. Direct visual inspection

Direct visual inspection is an oldest nondestructive testing method used to evaluate an item by observation. This method is used to determine the surface condition of an object, position of coupling surfaces, corrosion, pitting, dissimilar metals, dimensions etc. Usually, visual inspection is the first method used to locate suspected surface defects at all stages. The direct visual examination recommendation is enough to place the eye within 610 mm of the surface to be inspected and at an angle not less than 30 degree to the surface to be observed. The minimum light intensity at the examination surface/site shall be 100 foot-candles [1000 lux]. The direct visual inspection conducted on the vessel when the above conditions met. The scope of the non-intrusive inspection for direct visual inspection is 100 %. The total cost spent for direct visual inspection with abseil and non-abseil is around 1500$. The figure [2] shows the direct visual inspection result.

Figure 2. Active Corrosion on Nuts with metal loss
5. Manual ultrasonic inspection

Manual ultrasonic testing is a non-destructive testing method used to detect internal flaws such as internal corrosion, erosion, lamination and remaining thickness. The scope of manual ultrasonic inspection for non-intrusive inspection is: [1] Condition monitoring locations 1, 2, 3 & 4 – Shell and Head area 4” x 4” band for scan and split the circumference into eight quadrants. [2] Condition monitoring position 5 [A, B, C & D – 4” bands each quadrant] on top dish-end, from circular seam to center of the top dish end with 6” inch band width. [Grid UT at 1” intervals]. [3] Nozzles - 8 points at all quadrants of pipe diameter and record minimum wall thickness in each quadrant. Olympus 38DL Plus equipment has used to measure the thickness of the process vessel. The equipment used to detect internal corrosion/erosion of process vessels with single/dual element probes to deliver very accurate thickness measurements. The most important features are: [1] Measuring thickness range: 0.08 mm to 635 mm. [2] Thickness measurement on painted and coated surface with through – coat and echo-echo selections. [3] High-Resolution option to measure low thickness of 0.001 mm. The below tables [2 and 3] are showing nozzle and condition monitoring location manual ultrasonic thickness gauge readings. The total cost spent for manual ultrasonic inspection is around 25,000$.

<table>
<thead>
<tr>
<th>Location</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>19.0</td>
<td>19.2</td>
<td>19.0</td>
<td>19.2</td>
<td>18.9</td>
<td>19.0</td>
<td>19.3</td>
<td>19.2</td>
</tr>
</tbody>
</table>

Table 2: Manual Ultrasonic Thickness Reading on Nozzle

<table>
<thead>
<tr>
<th>Location</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>CML 1</td>
<td>19.3</td>
<td>19.6</td>
<td>19.0</td>
<td>19.0</td>
<td>19.7</td>
<td>19.2</td>
<td>19.2</td>
<td>19.3</td>
</tr>
</tbody>
</table>

Table 3: Manual Ultrasonic thickness Reading on Head

6. PAUT corrosion mapping

PAUT Corrosion mapping is used to identify the condition of components affecting with internal flaws and identify remaining wall thickness for maintenance needs. The HydroFORM scanner is designed to detect wall thickness reductions due to corrosion, abrasion and erosion of process pressure vessels for fitness-for-service. Also, HydroFORM detects mid-wall destruction such as hydrogen induced blistering or manufacturing induced laminations and it quickly separates these anomalies from loss of wall thickness through A, B, C scan presentation. The main advantage of corrosion mapping is 100 percent coverage of the area which undergone for inspection. Another real advantages is corrosion mapping can produce a permanent record for corrosion measurements like radiography. C Scan display of phased array ultrasonic testing equipment allows easy to interpret corrosion mapping. Olympus Omniscan MX2 phased array flaw detector used with HydroFORM scanner for high-performance corrosion mapping. The scope of the phased array ultrasonic inspection is condition monitoring location
6 [A, B, C & D – 4” bands each quadrant] on top dish-end, from circular seam to center of the top dish end with 6” inch band width. The below figure [3] and table [4] shows the phased array ultrasonic corrosion mapping image and corresponding thickness readings. The total cost spent for phased array ultrasonic testing is 15,000$.

![Figure 3. PAUT corrosion mapping](image)

<table>
<thead>
<tr>
<th>Datum mm</th>
<th>0 -300mm Min/Max</th>
<th>300 - 600mm Min/Max</th>
<th>600 - 900mm Min/Max</th>
<th>900 - 1200mm Min/Max</th>
<th>1200 - 1500mm Min/Max</th>
<th>1500 - 1800mm Min/Max</th>
<th>1800 - 1930mm Min/Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100</td>
<td>A1 18.0/18.4</td>
<td>B1 18.4/19.4</td>
<td>C1 18.8/19.4</td>
<td>D1 18.2/18.6</td>
<td>E1 17.4/18.0</td>
<td>F1 17.6/18.2</td>
<td>G1 17.6/18.4</td>
</tr>
<tr>
<td>100-180</td>
<td>A2 18.0/18.4</td>
<td>B2 18.6/19.2</td>
<td>C2 18.6/19.4</td>
<td>D2 18.2/18.6</td>
<td>E2 17.6/18.0</td>
<td>F2 17.4/18.0</td>
<td>G2 17.6/18.2</td>
</tr>
</tbody>
</table>

Means not scanned due to external pitting and rough surface

Table 4: PAUT Corrosion Mapping Reading

**7. Computed radiography**

Computed Radiography (CR) is used to produce digital image by using a Phosphor Imaging Plate (IP) instead of conventional film. Imaging plates are reusable but traditional films are not reusable. The CR radiography works in 3 steps. (1) When X-ray or gamma rays are passing through the imaging plate, the image of the object stored in the phosphor layer of the plate which can produce digital image. (2) A focused laser releases the stored image in the form of visible light photons when the image plate undertake for scanning. (3) These photons are collected and amplified by the scanner and converted into a digital image then transported to a computer for display and interpretation. The scope of the computed radiography recommended wherever the ultrasonic manual thickness testing not possible to take nozzles diameter 2” and below 2”. Minimum two exposures are recommended to shot at 0 degrees and 90-degree locations. The below figure (4) shows computed radiography image with 8.3mm minimum wall thickness. The total cost of computed radiography is around 4000$.
8. Summary of non-intrusive inspection cost

The below table [5] and statistics figure [5] are showing the total cost spent for non-intrusive inspection.

<table>
<thead>
<tr>
<th>Direct Visual Inspection</th>
<th>Manual Ultrasonic Inspection</th>
<th>Phased Array Ultrasonic Inspection</th>
<th>Computed Radiography Inspection</th>
<th>Total Cost for Non-Intrusive Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1500</td>
<td>$25,000</td>
<td>$15,000</td>
<td>$4,000</td>
<td>$45,500</td>
</tr>
</tbody>
</table>

Table 5: Summary of Non-Intrusive Inspection

Figure 5. Statistics of Non-Intrusive Inspection Cost
9. **Fit-for-service**

Fitness–For-Service (FFS) calculations are quantifiable engineering assessments to validate the reliability of an in-service component that may contain a defect or destruction or that may be operating under a particular condition that might cause a failure. Pitting is defined as localized regions of metal loss written off as by a pit diameter and depth on the order of the plate thickness or less. Surface metal loss quantified by the pitted area and pit depth then compared to standard pit charts to determine fit-for-service. If the depth of all the pits is less than the stated corrosion allowance, then a pitting assessment is not required for fit-for-service. From the above non-intrusive inspection results, concluded that there is no reading indicated less than the corrosion allowance. It is stating that the vessel is fit to service.

10. **Safety and reliability**

The safety and reliability of pressure vessels have been a community concern since the beginning of the industrial era. Failures of old condensation boilers became widely reported as boiler bursts killed thousands of people per year and inflicted great loss to assets. It is necessary to identify the potential failure mechanisms and failure modes to evaluate the integrity of process vessel fit-for-service. From the non-intrusive inspection results and fit-to-service assessment, concluded that it has fitted to continue the process safely and reliably.

11. **Comparison of internal and non-intrusive inspection costs**

The below statistics figure (6) shows the comparison of internal and non-intrusive inspection costs and concluded from the statistics that the internal inspection cost most high compared to non-intrusive inspection.

![Figure 6. Comparison of Internal Inspection and Non-intrusive Inspection Costs](image-url)
10. Conclusion

The application of Non – intrusive inspection with appropriate nondestructive testing methods such as direct visual inspection, manual ultrasonic testing, phased array ultrasonic testing and computed radiography can support the Asset integrity Management process. The research experience has shown in this paper that developing a Non – Intrusive Inspection for process pressure vessels by Advanced and Common NDT techniques discussed is less costly than internal and enhances safety and reliability of process pressure vessels. However, to get the process to be effective for long-term, it is necessary to implement RBI assessments. Integration with the non-intrusive inspection and risk based inspection introduces further benefits, ensuring changes in the operating conditions and continuous monitoring to operate the process pressure vessels safely and reliably. The conventional and advanced nondestructive testing methods optimize the ability to carry out the inspections non-intrusively to reduce the downtime and to know better conditions of process vessels. Finally, whereas Non-intrusive inspection has applied to the process pressure systems, significant benefits can be generated by using similar methods in other critical areas such as Piping and piping components, Tanks, Risers, and Structures.

References


