ULTRASONIC DETECTION AND MEASURING OF ISOLATED OR PITTING CORROSION (IPC)

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Abstract

AS2542.3 (Determination of Thickness – Use of Ultrasonic Testing) states:

"*This standard specifies six methods for determination of thickness of material based on the use of ultrasonic pulse-echo principals where the scanning and reflecting surfaces are substantially parallel".*

In many cases, the principals and procedures used in AS2452.3 are not applicable for the detection and measuring of isolated or pitting corrosion, as the reflecting surfaces are not generally parallel.

1. INTRODUCTION

The ultrasonic methods used to detect general corrosion & erosion are often not suitable for the detection and measurement of isolated pitting and corrosion (IPC). This may be because the reflecting surfaces are not parallel, or the reflector is too small. This paper covers some of the techniques that may be used to improve the accuracy of the detection and measurement of isolated & pitting corrosion (IPC).

2. DETECTION & MEASUREMENT

The factors that affect the sensitivity and reliability of both the detection and measurement of IPC are similar and include:

- Scope of Work
- Discontinuity Factors
- Surface Condition
- Equipment
- Technique

2.1 Scope of Work

In too many cases the end user or client has little or no knowledge of the methodology and limitations of the NDT they have nominated.

It is important for the technician to convey to the client the expected results from a particular method whilst clarifying its limitations.

Remember thickness testing, is exactly that, **THICKNESS TESTING**. If the client wants to know about localized or isolated thinning, more preparation, time and effort will be required.

This is particularly true for IPC.

2.2 Discontinuity Factors

For most Ultrasonic Inspections the size (volume), shape, orientation and depth of the discontinuity are the main variables in its detectability.

2.2.1 Size

The size of the discontinuity in relation to the effective ultrasonic beam is critical in detection and measurement. A small discontinuity within a large beam is easily missed, as many operators rely on the position of the back wall echo (BWE) rather than looking for separate signals. This method is certainly suitable for generalised or large areas of corrosion/erosion, but not for small discontinuities. See figures 1 , 2

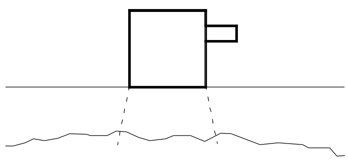

Figure 1
Generalised Loss

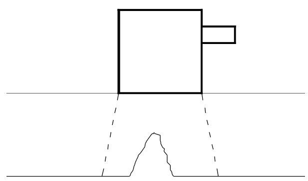

Figure 2
Isolated Loss

Figure 3
Localised Linear Corrosion
Boiler Steam Tube

Figure 4
Pitting Corrosion
Stainless Steel Acid Vessel
Note: Wall Thickness 3mm

2.2.2 Shape / Orientation

The shape / orientation of the pitting and corrosion directly affects the levels of reflection directed back to the probe. The greater the area of discontinuity perpendicular to the beam, the greater the sensitivity. However due to the orientation of most IPC, this is generally minimal.

Often with IPC a discontinuity with many facets will direct more sound to the probe than a smooth discontinuity. See figures 5 & 6.

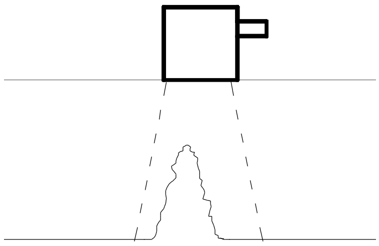

Figure 5
Many Facets

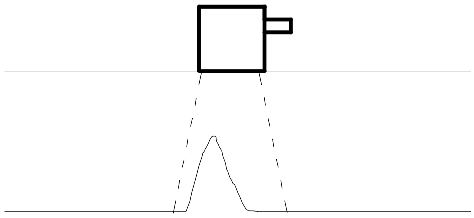

Figure 6
Few Facets

2.2.3 Depth

The detection and measurement of IPC is usually carried out over relatively short ranges (less than 100mm), yet attenuation may need to be considered in some components, particularly cast components and those at elevated temperatures.

2.3 Surface

The ability to detect and measure IPC is significantly affected by the surface of the component under test.

Coatings, Condition and Curvature all play a major role.

2.3.1 Coatings

For parallel surfaces where a coating is present this apparent change in metal thickness can be eliminated by using the multiple back wall method.
Nevertheless in many situations two or more clearly resolved back walls are difficult to achieve.

If the coating is sufficiently adhered, to provide adequate coupling, detection can be carried out using suitable scanning methods, yet the coating will most likely require removal where accurate measurement is required.

2.3.2 Condition

The surface condition will directly affect detection, measurement and productivity.
As the surface condition degrades, coupling decreases, & scattering increases resulting in loss of expected response and sensitivity.

Other than mechanically modifying the surface, the preferred method for detection is to reduce probe diameter to provide better coupling efficiency.

2.3.3 Curvature

In too many cases the curvature of the component in relation to the crystal diameter is not taken into account.

It is important to match the curvature with the probe diameter to maximize coupling efficiency and to reduce the possibility of spurious indications caused by scatter and mode conversion.

2.4 Equipment

Equipment can be broken down into the following categories.

- Flaw Detector
- Twin Crystal Probes
- Single Crystal Probes
- Probe Size / Diameter
- Probe Frequency / Dampening

In many cases shear wave inspections can be used to aid the technician in detection, measurement and classification of discontinuities. Due to the advanced nature of these inspections, they have not been covered in this paper.

2.4.1 Flaw Detector

We are looking for flaws - isolated corrosion and pitting.

We require a flaw detector not a thickness meter.

In most cases where the detection and measurement of IPC is required, the use of digital or digital with A-Scan devices is not suitable.

The rationale being that these units rely on the use of gates, which is suitable where parallel surfaces are involved, but not with IPC.

For IPC, the use of gates may result in missed signals due to the incorrect operation of the gates.

2.4.2 Twin Crystal Probes

Depending on the probe design, twin crystal probes generally offer the best solution for inspections between 3mm to 25mm. They offer the following:

- Advantages

  No Effective Dead Zone

  Focusing of Beam
  (Increased Resolution and Sensitivity)

- Disadvantages
  There is a blind zone just beneath the probe at very short beam paths.

  There is an effective focusing of the beam due to the inclination of the transmitting and receiving crystals. (Decrease in effective ranges.)

The "W" Effect
In thin materials (less than focal length of the probe) the beam path may take a "W" path , rather than the focused "V" path. This can result in the 1st BWE not being displayed and the second back wall assumed to be the 1st BWE. This will result in the thickness measured being twice the actual thickness.

The "V" Effect
Since the sound travels in a "V" path, the beam path length is longer than the actual thickness.
As the thickness reduces, the ratio of the sound path versus actual increases. For this reason it is critical that calibrations be carried out on material thickness that closely matches the actual area under test. Step wedges have steps to enable calibration over a wide range usually 2.5 – 25mm). Recommended variation of calibration thickness to actual thickness is ±25%. (See Figures 7, 8 and 12)

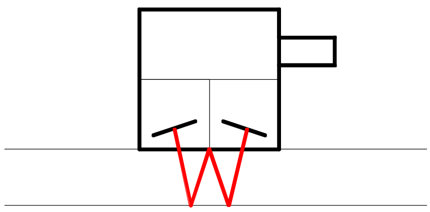

Figure 7
The "W" Effect

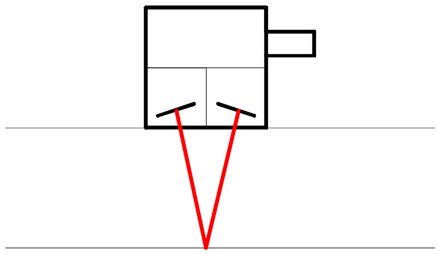

Figure 8
The "V" Effect

2.4.3 Single Crystal probes

Single crystal probes are not often used for the detection and measurement of IPC, however at high frequency and with the use of delay blocks, their major limitations can be compensated for.

- Advantages:

  The beam does not go in a V-path and therefore does not require correction for thin materials.

  Contact testing probes are generally not focused and so are favored for testing a wider range of thicknesses.

- Disadvantages:

  Single crystal probes have a dead zone that makes measurement of thin materials difficult if the BWE occurs in the dead zone.

Delay Lines
The use of delay lines or standoffs with single crystal probes can be used to improve near surface resolution, as the dead zone is contained within the delay line material.

- Advantages:

  Increased resolution.
  (Decrease in dead zone)

  Ability to focus beam.
  (Increased sensitivity and resolution)

- Disadvantages:

  Limited ranges of thickness can be inspected depending on length of delay line.

  Many materials used in construction of delay lines have high attenuation coefficients, which may affect the sensitivity of the inspection (particularly at high frequency – i.e 10MHz and higher).

2.4.4 Size

The size of a given probe will have numerous effects upon the inspection process, and in many cases different sized probes will be required for the detection and measurement processes.

Large Diameter (> 10mm)

- Advantages:

  More scanning coverage.

  Generally easier to manipulate and scan with because they fit the hand better).

- Disadvantages:

  Generally less sensitivity and resolution than smaller probes at short ranges (depending on damping and design).

  Coupling issues on rough surfaces or curved surfaces may arise.

Small Diameter (< 10mm)

- Advantages:

  Generally better sensitivity and resolution than large probes at short ranges (depending on damping and design).

  Increases coupling efficiency on curved or rough surfaces.

- Disadvantages:

  Slow scanning rates.

  May be difficult to manually scan, due to ergonomic fit to hand.

2.4.5 Frequency

Since most detection and measurement for IPC takes place over relatively short ranges, attenuation of higher frequencies is not generally a governing factor.

The use of higher frequencies increases both sensitivity and resolution, which assists significantly in the measurement process.

Note: AS2452.3 was updated in 2005, with the upper frequency range increased from 10MHz to 15MHz.

Probe Dampening (Bandwidth)

In this application, the use of highly damped (broad frequency bandwidth, short pulse) probes is encouraged, as this results in significant increases in resolution, with only a minimal decrease in penetration and sensitivity.

2.5 Technique

The techniques used in these inspections, may vary widely between the detection and measurement phases. Differing methodologies and more importantly different equipment may be required to increase reliability and accuracy.

2.5.1 Scanning

If the inspection is over a large area, break down the scans into smaller clearly identified areas.

One method to use is the application of Liquid Penetrant Developer prior to inspection. This gives the inspector an idea of the areas that have been inspected.

Scanning patterns will generally be determined by the area to be inspected.

In some situations a preliminary scan may be carried out using a large diameter crystal to locate areas of thinning and a smaller probe used for precise measurement of thinning.

Typically, scanning will be carried out over a closed grid with overlapping scans (up to 50%).
The scanning speed will be dependant upon discontinuity size/reflectivity, surface condition and the refresh rate of the ultrasonic set.

The human eye is particularly sensitive to movement, so a rapid scanning rate can be beneficial in many cases. However if the ultrasonic set cannot match the scan rate, or the surface condition gives significant noise then the scanning rate will need to be reduced.

Wherever possible a calibration plate with a discontinuity similar to those being scanned for should be used to confirm all settings and techniques.

2.5.2 Detection

The location of thinning may be detected through a variety of methods.

These include:

- Loss of Expected Response (LER) from back wall indications.
- Movement of the back wall along the base line.
- Indications appearing before the Back wall.

The 3/6/9 method of scanning, where a back wall placed at approx 30%, 60% and 90% across the base line is monitored for movement is an excellent method for the detection of generalised corrosion and erosion.

However in many cases the size of the corrosion/pitting may be small when compared to the beam spread. In this case there may only be minimal LER from the back wall and only a minor indication from the corrosion/pitting itself (Sometimes more than 12-20db less than the BWE).

For this reason it is important to monitor the baseline in front of the back wall as well as the back wall. Subsequently for this application, the use of gates is discouraged when scanning.

2.5.3.1 Non-Relevant Indications

It is extremely important that the operator is able to distinguish between different types of discontinuities, in particular, the difference between corrosion or pitting and laminations or inclusions. This primarily comes down to the experience of the operator.

One method is to monitor the echo dynamics of the signal when scanning over the discontinuity. Typically the signal from a lamination will appear to jump up in front of the back wall. That is, as the probe is scanned over the discontinuity the signal appears at a set beam path and the amplitude increases, with the signal remaining at the same beam path. Corrosion however typically "Walks" across the screen towards the left and then back as the probe is scanned over. A high amount of gain may be required to view the "Walking" corrosion signal.

2.5.4 Measurement

The techniques used for measurement will depend upon the required accuracy of the inspection, and therefore time allocated accordingly.

Correct calibration is critical. Remembering that twin crystal probes should be calibrated at a thickness within 25% of the part under test.

Typically with IPC, the multiple back wall method for measurement will be unsuitable due to lack of response and noise. Therefore a direct reading along the baseline is required. Gates can be used for this function, however it is advised that utmost care be taken as this can lead to errors if not calibrated accurately.

The use of high frequency/highly damped probes is encouraged to increase sensitivity and more importantly resolution. In thin components less than 3mm, a specialised twin crystal probe designed for these ranges will generally be required due to the "W" effect. Conversely a high frequency single crystal probe with a delay block can be used.
(The author's probe of choice below 3mm is a 20MHz, 0.125", Broadband Probe with a focused delay block.)

Ultrasonics relies on confidence, wherever possible, the technician should get confirmation of their results to reinforce their confidence in both the technique and themselves.
This may include coupons, other NDT methods, getting a second opinion or something as simple as un-calibrating, recalibrating and confirming a reproducible result.

3.0 CONCLUSION

The ultrasonic methods for "thickness testing" are generally not suitable for the Detection and Measurement of Isolated Pitting and Corrosion.

The main elements for reliable detection and measurement are:

- Both technician and client, have the same realistic expectations of the result.
- Preparation of the surface may be required.
- Use an A-Scan Flaw Detector
- Overlapping Scans monitoring the Baseline
- Detection and Measurement may require different approaches. (probe diameter, frequency, type, dampening)

The reliable and accurate detection and measurement of isolated pitting and corrosion is a skill that takes many years to develop and one that is rarely mastered. However with experience, both competence and more importantly confidence will develop.

Figure 9 - 5MHz Twin 12mm

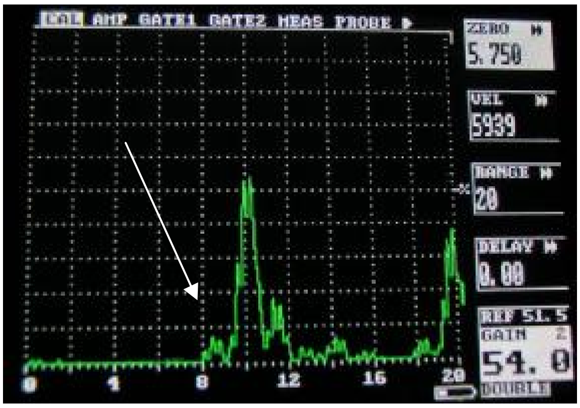

Figure 10 - 5MHz Twin 12mm

Figure 11 - 5MHz Twin 6mm

Figure 12 - 5MHz Twin 6mm

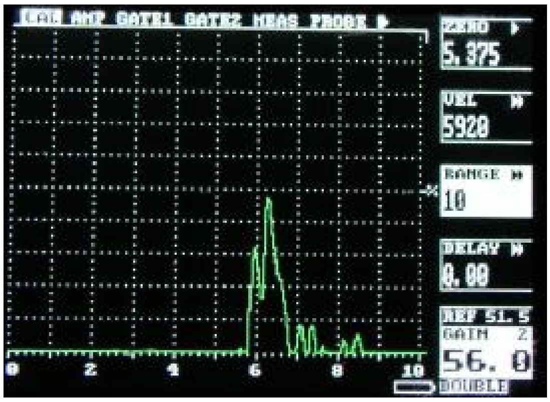

Figure 13 - 5MHz Twin 12mm

Guide to Figures:

Figures 9 to 12 show the difference in signals between probes of different diameters only.

Figure 9
Discontinuity Free Area

Figure 10
Over isolated pitting.
No positional change in back wall only minor change in amplitude.
Small amplitude discontinuity signal.

Figure 11
Discontinuity Free Area

Figure 12
Over isolated pitting.
No positional change in back wall, significant change in amplitude.
Larger amplitude discontinuity signal.

Figure 13
The “V” Effect
Twin Calibrated on 25mm Step
Measurement Taken on 5mm Step
Indicated thickness 5.75mm