THRESHOLDS, ACCURACIES AND RESOLUTION: QUANTITATIVE MEASUREMENT AND ITS ADVANTAGES FOR METAL LOSS INSPECTION
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Abstract

Today pipeline inspection through the use of in-line inspection tools is a standard procedure. These inspection tools collect data regarding the geometry of flaws and defects in the pipe wall. In turn this data is used for fitness-for-purpose investigations, the final goal of the operator being an understanding of the true state of integrity for a given pipeline.

Different physical principles are applied during the non-destructive testing of pipelines, each with its own set of advantages and disadvantages. Choosing the most suitable non-destructive testing technology and therefore in-line inspection tool for a given inspection task requires an understanding of these different techniques and their system-specific measurement thresholds, accuracies and resolutions. All of the latter are critical parameters relating to the suitability of inspection data as input for assessment codes such as ASME B31G, RSTRENG or DNV RP-F101. This paper will discuss major issues regarding the quality of data with respect to their use for integrity assessment and fitness-for-purpose applications.

Case examples will be used to explain and show the advantages of improved resolution. The influence of accuracy, resolution and confidence levels and their effect on integrity assessment results will be discussed.

1 Introduction

With an aging pipeline infrastructure worldwide and increasing economical and regulatory constraints for pipeline operators, pipeline integrity issues are an area of increasing relevance. In many countries of the world pipeline regulations not only demand inspections or monitoring of structural integrity in certain intervals, but a continuous process of verification of pipeline integrity and fitness-for-purpose. In-line inspections complemented by other inspection techniques applied externally are today the method of choice for these inspection requirements. Many regulations recommend or even demand the use of intelligent pigs [1, 2].

The purpose of an in-line inspection is the detection, sizing and location of flaws and defects within the pipe wall. In other words, the determination of geometric
dimensions, which in turn are used as input for the codes applied for integrity assessment.

There is a huge choice of inline inspection (ILI) tools on the market today. ILI tools for geometry inspection and metal loss have been introduced in the mid-sixties of the last century. Initially available metal loss and corrosion inspection tools were based on axial magnetic flux leakage technologies. Later in the eighties ultrasound technologies were also applied, offering the possibility for true quantitative wall thickness measurement. Crack detection and sizing followed in the late eighties, early nineties. More recently – late nineties – the range of technologies was complemented with circumferentially orientated magnetic flux leakage tools, inertia tools for mapping and the development of combo tools, combining various applications in a single tool. Table 1 provides an overview of the in-line inspection tools available on the market today. Further information can be found in the literature [3, 4] and is regularly published in the industry journals.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Mission</th>
<th>Physical Principle Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caliper Tools</td>
<td>detecting, sizing, locating geometric anomalies</td>
<td>mechanical, eddy current</td>
</tr>
<tr>
<td>Metal Loss or Corrosion Detection Tools</td>
<td>detecting, sizing, locating metal loss features</td>
<td>magnetic flux leakage (axial and transverse), ultrasound, eddy current</td>
</tr>
<tr>
<td>Crack Detection Tools</td>
<td>detecting, locating cracks, where possible also sizing.</td>
<td>ultrasound</td>
</tr>
<tr>
<td>Inertia Tools</td>
<td>mapping, pipeline displacement</td>
<td>gyroscopes</td>
</tr>
<tr>
<td>Leak Detection Tools</td>
<td>detecting and locating leaks in pipelines (limited to liquid lines)</td>
<td>ultrasound, pressure difference</td>
</tr>
</tbody>
</table>

The information provided by ILI tools consists of geometric data regarding a flaw or anomaly found, namely:

- length (how long is a flaw from beginning to end, extent in the direction of the pipe?)
- depth (how deep is a flaw, deepest point?)
- width (how wide is a flaw, circumferential extent?)
- circumferential position (orientation, o’clock position of a flaw?)
- longitudinal position (where along the line is the flaw?)
- pipeline route (where is the pipeline and was there any change in position?)
This data is then used to analyze the integrity of a line. Integrity assessment and fitness-for-purpose investigations in turn play an important role in defining and optimizing maintenance and possible rehabilitation procedures. Two extremely important issues within this context are the defect specifications (probability of detection, probability of identification) achieved and the question of measurement accuracy (confidence level). As more and more refined assessment methods are available, probabilities of detection and confidence levels for sizing have to be taken into account.

Considering the choice of tools on the market, it is by no means a trivial task to choose the right tool and technology. Each pipeline and each inspection is different. It is therefore of great importance to carefully plan an inspection and base the preference for a tool on the major aim of the inspection. The choice of tool or tools will then have to be made on a variety of factors and issues governing the inspection requirements and the operational boundaries of the project. The capabilities and suitability of a tool should be based on its quality in detecting, sizing, discriminating and locating flaws and features.

The most widely performed inspection relates to the detection and sizing of metal loss and corrosion. The issues of thresholds, accuracies and resolution will therefore be discussed for this application.

Within the scope of this paper, operational constraints cannot be considered. The focus will be placed on the data provided by metal loss in-line inspection tools for integrity assessment purposes.

2 Technologies Applied for Metal Loss and Corrosion Inspection

The two most widely applied technologies for metal loss and corrosion inspections are magnetic flux leakage (MFL) and ultrasound (UT). Both technologies are based on different physical principles, both with their individual characteristics. Each physical principle has advantages and disadvantages whereby in general non-destructive testing techniques cannot be differentiated in good or bad, but have to be chosen based on the inspection requirements for a specific task. This paper will not add to the published comparisons of magnetic flux leakage versus ultrasound technologies, but will address different configurations of ultrasound tools available today.

Figure 1: Ultrasound principle for wall thickness measurement
Figure 1 depicts the ultrasound principle used for metal loss inspection and quantitative wall thickness measurement. A sufficient number of ultrasound probes must be used to ensure full circumferential coverage of the pipe. Here piezoelectric transducers are sketched. They send out a short pulse of ultrasonic energy which is initially reflected from the internal surface of the pipe wall. It is important to understand that ultrasonic waves are not laser beams. The ultrasonic signal is not an individual arrow, but a wave front of acoustic energy. Part of this signal will be reflected; the remainder will enter the wall and be reflected from the outer surface of the pipe, the back wall. The electronics of the tool will precisely measure the time of flight. As the speed of sound of the medium in the pipe and also the pipe wall are known and constant, the time of flight will provide quantitative values for the stand-off distance between sensor and internal wall, as well as the wall thickness. Any changes in stand-off and wall thickness readings will clearly identify internal metal loss; any changes in wall thickness only will identify external metal loss. In addition, ultrasound can detect and size mid wall features such as laminations and inclusions.

A reflection coming back to the transducer which acts as emitter and receiver must have a certain energy level in order to be received "properly". If the area of metal loss is so small that only a portion of the acoustic energy reaches the bottom of the flaw (figure 2a), then detection and sizing will be impaired. The latter was one reason why in the past ultrasonic in-line inspection tools were limited in their capability for detecting and sizing small areas of metal loss, such as pitting corrosion. Use of new, focused US probes however, allows for the detection of pitting (figure 2b, ref. also to chapter 5 of this paper).
Figure 2a, b: (a) Pitting corrosion – not all acoustic energy reaches the deepest point, (b) US probe with focused ultrasound can measure small areas of metal loss

3 Typical Thresholds

Table 2 shows typical thresholds regarding the depth sizing of metal loss for different in-line inspection tools. This means any feature or flaw in the pipe wall must have a minimum depth in order to be picked up by the inspection tool utilized. Typical values regarding the minimum defect diameters a feature must have in order to be detected and sized by a magnetic flux leakage tool are between 1 and 3 x t (MFL-tools usually relate defect specifications to the wall thickness (t) of the line being inspected). For a 10 mm wall thickness this would mean 30 mm. A typical industry specification for high resolution ultrasound tools is a minimum depth of 0.5 mm, with a minimum surface diameter of 20 mm. Detection only can usually be achieved for smaller surface diameters. Some magnetic flux leakage tools state 1 x t, and ultrasonic tools 10 mm.
Table 2: Typical minimum defect specification for different tool types

<table>
<thead>
<tr>
<th>Tool Type</th>
<th>MFL high resolution</th>
<th>MFL extra high resolution</th>
<th>UT high resolution</th>
<th>UT pitting configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Metal Loss</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum depth of feature to ensure detection</td>
<td>&gt; 10 % t</td>
<td>&gt; 5 % t usually valid for internal metal loss.</td>
<td>0.5 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td><strong>Pitting Corrosion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum depth of feature to ensure detection</td>
<td>&gt; 20 % t</td>
<td>&gt; 10 % t usually valid for internal metal loss.</td>
<td>1.5 mm for minimum feature diameter of 10 mm</td>
<td>1.5 mm for minimum feature diameter of 5 mm</td>
</tr>
</tbody>
</table>

where \( t \) = wall thickness.

Only recently have ultrasonic tools entered the market which offer full depth sizing capabilities starting from a depth of 0.4 mm with a surface diameter of 10 mm, and detection without depth sizing starting from a surface diameter of 5 mm.

4  The Three Dimensions of Resolution

The term resolution is most widely used in relation to depth measurement in the context of metal loss surveys, i.e. relating to the question of how precisely a given tool can resolve the depth of a flaw. Another critical issue is the ability of a tool to reliably detect the actual deepest point of a metal loss.

However, it has to be noted that resolution is an issue of all three dimensions, e.g. depth, axial size (length of feature along the pipe) and width (circumferential extent of feature).

- **Axial Resolution and Circumferential Resolution**

Measurements taken by an in-line inspection tool basically supply a grid of measurement points taken, i.e. measurements taken along the axis of the pipe inspected and measurements taken across the circumference of the pipe. Figure 3 shows such a typical grid, each black circle depicting the location of an ultrasonic transducer, not its coverage. The actual area that a sensor covers will ensure that there is overlap from sensor to sensor, thus ensuring full coverage of the pipe wall.

A standard value in the industry regarding axial resolution is approximately 3 mm, i.e. taking a reading every 3 mm along the axial direction of the pipe. For an average
speed of 1 m/s during the inspection this value relates to a pulse repetition frequency of 300 Hz. The term “pulse repetition frequency” relates to the number of times the ultrasound transducer switches from emitting to receiving a signal per second. If the pulse repetition frequency is set as a constant, the number of measurements taken is influenced by the speed at which the tool travels. This is referred to as “time-triggering”. Modern tools often utilize speed triggering thus retaining the axial resolution also at higher speeds.

The number of samples taken can be raised, for example by increasing the pulse repetition frequency, whilst retaining the same inspection speed (e.g. 600 Hz at a speed of 1 m/s would result in an axial sampling of 1.67 mm or 3.3 mm at 2 m/s). Today, a second generation of ultrasonic tools is available which can offer a 0.75 mm sampling (i.e. one measurement taken every 0.75 mm or 0.03 inches). Advanced electronics also allow for survey speeds to be increased to approximately 2.5 m/s. Today, most ultrasonic tools on the market relate to the resolution depicted in the figure below, 3 mm in the axial direction and approximately 8 mm in the circumferential direction, as shown. This configuration is often referred to as “high resolution”, making use of the same term also used for magnetic flux leakage tools. It should be noted, however, that comparing the resolution of ultrasonic and magnetic flux leakage tools is not that easy.

Figure 3: High resolution (industry standard) for an ultrasonic in-line inspection tool

➢ Depth Resolution vs. Accuracy
The depth resolution of an inspection tool indicates which precision the depth measurement can achieve. It is not to be mistaken with the depth sizing accuracy, which is a value defined by the operator of the tool and which is usually stated in the defect specification sheet. An important aspect in depth sizing accuracy is to consider whether a measurement technique provides quantitative depth measurement characteristics or qualitative ones. Ultrasound is an example of a quantitative wall thickness measurement technique. Wall thickness, and in the case of metal loss, remaining wall thickness, can be measured directly in mm. The accuracy is determined by the hardware capabilities of the tool, e.g. sensor design, electronics.

Resolution relates to the quality of the measurement. Simplified it can be said that this relates to the number of readings taken in an effective time interval. The better the resolution an inspection tool can achieve the greater its ability to precisely measure the depth contour of a given flaw or defect. A good example is the river bottom profile of a corrosion as shown in figure 4.

**Figure 4: Effect of improving depth resolution**

![Figure 4: Effect of improving depth resolution](image)

Figure 4 shows the contour of a metal loss flaw and the difference for a 0.2 mm and a 0.06 mm resolution. Increased depth resolution helps to identify deepest points. In the left figure it is not possible to define whether the deepest signal is indeed the deepest point or possibly an outlier, i.e. a spurious signal. The right picture clearly depicts the contour of the corrosion feature and shows that the deepest signal does refer to the deepest point of the metal loss feature. The actual deepest point will have significant influence on the results of any integrity assessment.

5 A Word on Localized Metal Loss and Pitting Corrosion

Regarding the depth sizing accuracy of ultrasound tools, it is also important to understand that an average value of wall thickness is determined regarding the time of flight (i.e. time taken until an emitted ultrasonic signal returns to the transducer) for all reflections received for a given sensor covering a specific area. A transducer with
an emitting diameter of 10 mm will cover a greater area than, say, a 6 mm sensor. The true actual area covered will further depend on whether the transducers used are focused or not, see figure 5.

**Figure 5: Unfocused vs. focused ultrasonic transducer**

![Unfocused vs. focused ultrasonic transducer](image)

The upper figure shows how the cylindrical beam of acoustic energy covers a much wider area of the pipe wall than the focused probe in the lower figure. The geometries and specifications of the ultrasonic transducers used in the industry determine the minimum defect specifications attainable. Typical industry values are the detection of metal loss features starting from a feature diameter of 10 mm and depth sizing capabilities starting from feature diameters of 20 mm. These values were the reason why ultrasonic tools were considered less suitable for pitting inspection compared to magnetic flux leakage tools for a long time.

Today, modern configurations of ultrasonic in-line inspection tools are available which can achieve detection thresholds for metal loss starting from a surface diameter of 5 mm, with full depth sizing capabilities starting from 10 mm surface diameter. Experience in the field has shown that now even features with a surface diameter as small as 2.5 mm can be detected. The advantage over magnetic flux leakage is that these new configurations of tools provide quantitative sizing for the depth of pitting corrosion and the remaining wall.

These configurations make use of a closer sensor spacing in the circumferential direction of the pipe and higher pulse repetition frequencies enhancing the axial resolution, resulting in a more highly resolving grid, schematically shown in figure 6.
Due to the optimized sensor carrier design used for pitting inspection, the circumferential spacing of the sensors was decreased to 3.7 mm for the tool considered here. The axial sampling can be increased from 3 mm to 1.5 mm (i.e. one reading taken every 1.5 mm along the pipe axis) or even to 0.75 mm. These increased axial resolutions are shown as light grey and darker grey regions in figure 6. The ability to configure the tool for specific inspection requirements means that the resolution, or in other words the refinement of the measurement grid can be varied. Figure 7 shows as an example the various UT sensor plate layouts for standard resolution, enhanced resolution and pitting resolution for the tool considered here.
Figure 7 schematically shows how more closely packed sensors (decreased sensor spacing) increase the number of readings that can be taken for a given area covered.

Figure 8: (a) High Resolution coverage, (b) pitting resolution

The left picture in figure 8 shows how the standard high resolution configuration would cover the area of a corrosion feature, the right picture shows how the larger number of (smaller) sensors provides more readings for that given area.

In general it can be said that the more readings a tool can take for a given area inspected, the better. If only a relatively small number of readings (i.e. samples) can be taken for a given area, the effect of any spurious signal will be much larger than if a higher number of readings can be obtained.

Increasing the resolution will of course result in a higher total number of sensors used and therefore number of electronic channels the in-line inspection tool needs to provide, in order to secure full circumferential coverage of the pipe surface. The great
advantage is that such a "pitting"-resolution tool provides reliable detection and sizing of local metal loss, such as pitting corrosion, with the precision and confidence level of an ultrasound tool and the ability for quantitative wall thickness measurement.

The market also offers a range of tools combining magnetic flux leakage technology and ultrasound. But here it has to be understood, that the ultrasound transducers used are "standard" transducers and not optimized for pitting detection and sizing. The magnetic flux leakage technology portion of these tools is used for the detection of pitting, not allowing for any exact sizing, the ultrasonic technology part of the tool for the detection and sizing of general corrosion and quantitative wall thickness measurement.

Table 3 provides a rough guide regarding the capabilities of different tool types available regarding the detection and sizing of localized metal loss and pitting corrosion.

### Table 3: Detection and sizing capabilities regarding localized metal loss (pitting) for different in-line inspection tool types.

<table>
<thead>
<tr>
<th></th>
<th>High Resolution MFL&lt;sup&gt;1&lt;/sup&gt;</th>
<th>MFL &amp; UT combination tools&lt;sup&gt;2&lt;/sup&gt;</th>
<th>High Resolution UT&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Pitting Configuration UT&lt;sup&gt;4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feature surface dimension:</strong> 10 mm by 10 mm; wall thickness (t): 10 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>detection only</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>depth sizing</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>quantitative wall thickness measurement</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
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<td></td>
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</tr>
<tr>
<td><strong>Feature surface dimension:</strong> 10 mm by 10 mm, wall thickness (t): 20 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>detection only</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>depth sizing</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

<sup>1</sup> Typical minimum defect specification reported in industry for magnetic flux tools is t x t, detection only; depth sizing starting from 2t x 2t.

<sup>2</sup> combines high resolution MFL and UT.

<sup>3</sup> Typical minimum defect specification reported in industry for ultrasonic high resolution is 20 mm x 20 mm for depth sizing and 10 x 10 mm for detection only.

<sup>4</sup> Typical minimum defect specification reported in industry for ultrasonic pitting corrosion tools is 10 mm x 10 mm for depth sizing and 5 mm x 5 mm for detection only.
According to the POF Standard [5], the geometrical parameters of anomalies are length "L", width "W", depth "d" and reference wall thickness "t". The parameter A is used for the geometrical classification of the anomalies detected by a tool. This parameter is needed for pipes with t<10 mm. The geometrical parameter A is linked to the NDE methods in the following manner:

- If t < 10 mm then A = 10 mm
- If t ≥ 10 mm then A = t

Pitting is defined in said document as a feature having a surface area of less than 2A x 2A. A feature as small as 0.5A x 0.5A is termed "pin hole" type feature. Using these defect specifications means that the new generation of ultrasound tools with pitting configuration can offer detection and sizing capabilities for pitting and pin hole type features.

6 Key Success Factors

The ability to reliably detect features and flaws of a specific size, the measurement accuracy, the confidence of identifying and discriminating flaws and features as well as the accuracy of location are the key success factors regarding an effective inspection. One important characteristic often quoted is the confidence level.

According to the POF specifications [5] this value is set at 80% with regard to the sizing accuracy for magnetic flux leakage tools. This means that 8 out of 10 features detected must be sized to within the specified defect specifications. For most ultrasonic in-line inspection tools this value is in the 90 to 95 % band. However, it must be noted that these confidence levels only relate to features as small as 20 mm surface diameter. Special pitting configurations of ultrasonic tools extend the quantitative measurement capabilities and associated confidence levels of ultrasonic tools to 10 mm and below, see figure 9.

Figure 9: Ultrasonic accuracy and confidence levels for detection and sizing of localized metal loss and pitting corrosion
7 Case Studies

7.1 Local Corrosion: Detecting and Identifying The Deepest Point

Figure 10a shows a screenshot of a localized corrosion feature (surface diameter less than 20 mm) detected with a specially configured ultrasonic tool using a 5.5 mm circumferential sensor spacing. The metal loss was clearly detected and sized. The B-Scan of the ultrasonic data shows a corrosion feature with a maximum depth of 9 mm. Figure 10b shows the same feature detected and sized with a tool using a standard industry configuration. The depth sizing delivered a value of 4.6 mm. Both configurations have performed to within their specifications, but show the effect of sensor spacing with regard to the detection and sizing of small area metal loss. Even smaller features will be detected and sized reliably with a tool using a pitting configuration and a 3.7 mm circumferential spacing.

Figure 10a, b: Improved depth sizing capability for localized metal loss and pitting corrosion with a surface area of less than 20 mm by 20 mm
This screenshot nicely shows the importance of resolution with the regard to the sizing of localized metal loss, such as pitting corrosion.

### 7.2 Localized Corrosion in Girth Weld

Figures 11 shows the screenshot of the data obtained for a 12" product pipeline with a wall thickness range from approximately 6 to 8 mm. The inspection identified a localized metal loss feature within the girth weld zone. The detection and sizing of this type of flaw requires a pitting resolution or at least an enhanced resolution above the normal industry standard. For this inspection the axial resolution of the tool was set to 1.5 mm (i.e. 1 reading taken by each sensor every 1.5 mm in the axial direction) and approximately 4 mm for the circumferential resolution. Figure 12 shows a photograph of the feature, after the feature had been verified and the pipe had been excavated. The dimensions of the feature found were 15 x 56 mm.

**Figure 11: Screenshot of inspection data for localized metal loss feature in girth weld**
7.3 Pitting Corrosion

Figure 13 shows the screenshot of a pitting feature found in a 10" crude oil line. The wall thickness lay in a range of approximately 7.5 to 14.5 mm. The localized feature identified was located in a section of a pipe that had been operational for less than three years at the time of inspection. This again was a feature geometry which required the use of a pitting configuration for the ultrasonic tool. The dimensions of the feature were found to be 4 x 32 mm.
8 Effect On Integrity Assessment

As more refined integrity assessment codes are being used, the resolution and accuracy of tools play an ever increasing role. High resolution magnetic flux leakage tools usually report metal loss features found with an accuracy of ± 10% of wall thickness and a confidence level of 80%. The industry standard for ultrasound tools is approximately ± 0.5 mm with a confidence level of 90%, and latest generation ultrasonic pitting detection tools offer the same accuracy and confidence level for localized metal loss.

Accuracies also strongly influence the results obtained regarding the estimation of corrosion growth based on consecutive in-line inspection runs. Anticipated corrosion growth and the definition of safe inspection intervals will be influenced by the accuracy of the inspection measurements. It can be stated that a larger error in measurement will result in a more conservative assessment of a given metal loss feature and its associated maximum allowable operating pressure (MAOP). More features will be identified to be outside the safe region of the failure assessment curve. Resulting verification costs, e.g. potential costs for excavating the line and performing external inspections may be significantly higher.

Larger measurement errors will also lead to the need for more inspections and shorter inspection intervals. The additional costs that this conservatism may cause should be taken into account when the direct inspection costs of different tool technologies are evaluated.

Figure 14 shows the effect the error band (accuracy) has on integrity assessment investigations.
Figure 14: Effect of accuracy on integrity assessment

The figure gives an indication of how long a pipeline can be operated in the presence of a corrosion flaw that is growing. The anticipated corrosion rate is calculated based on consecutive in-line inspection measurement assumed to be taken in 2005 and 2010 in this example. The y-axis shows the measured depth of the metal loss, the time axis being shown in the x-direction. In 2005 this depth was 3 mm.

A second measurement in 2010 in this example provides a depth reading by the tool used of 4 mm. In order to use these results for a corrosion growth assessment, the error bands of the tool technologies used have to be taken into account, and a worst case scenario has to be considered. This means the greatest likely corrosion growth must be assumed. This scenario would imply that the corrosion depth measured first takes on a least value, i.e. the depth is oversized by the tool. The second depth measurement taken after 5 years however underestimates the real corrosion depth.

An ultrasonic tool has a measurement error (or reporting accuracy) of ± 0.5 mm, a MFL tool of 10% of wall thickness, i.e. ± 1 mm for the 10 mm wall considered here. Taking these accuracies and applying the worst case scenario provides the blue and magenta lines. These show how the calculated corrosion growth can be projected into the future. The blue line - representing the MFL tool - intercepts the 80% wall loss failure criterion of B31G in the year 2015, the magenta line - representing the UT tool - roughly 4 years later in 2019.

This schematically shows the conservatism in the MFL results, due to the higher error band. Re-inspection intervals based on this assessment would therefore have to be shorter for MFL tools than for UT tools. The green line shows the "life" of the
pipeline based on the B31G failure criterion (metal loss must not exceed 80% of wall thickness) if no measurement errors are taken into account.

9 Conclusions

In-line inspection tools provide important data regarding the flaws and anomalies detected in a pipeline wall. These data, comprising of geometric information regarding the length, width, depth and location of flaws and anomalies are critical input for integrity assessment and subsequent effective planning of repair and rehabilitation measures.

Modern integrity assessment codes benefit from higher levels of inspection data quality, especially with regard to accuracy and resolution. Ultrasonic in-line inspection tools provide these accuracies and confidence levels as well as quantitative measurement capabilities, allowing for a less conservative assessment.

In the past ultrasonic tools were not considered suitable for the detection and depth sizing of localized metal loss features such as pitting corrosion.

Latest generation ultrasonic tools with special pitting configurations widen the scope of inspection of ultrasonic tools and provide detection and accurate sizing capabilities for these small metal loss and corrosion features.

Ultrasonic tools with enhanced resolutions beyond the current high resolution standard are ideally suited for the future requirements regarding integrity assessment, fitness-for-purpose and corrosion growth studies.

10 References


