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Lessons Learnt from Fitness-for-Purpose Assessments of Defects Detected by Smart Pigs

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Abstract

Smart pigs are used extensively for inspecting pipelines. Their use will increase rapidly due to their proven benefits, expanding capabilities, and legislative requirements.

The result of a smart pig inspection is an inspection report with a list of defects. Therefore, these pigs are of little use unless the pipeline operator understands the reliability and accuracy of the report, and has methods for assessing the significance of the defects detected.

There are a number of recognised defect-acceptance (or ‘fitness-for-purpose’) methods available for assessing these defects (for example ASME B31G, and API 579), but these methods are simply calculation methodologies; there are many issues related to the input data and the engineering assessment that also need to be resolved. These include tolerances on pig data, variability in pipeline operational data, and differing defect types.

Consequently, it is good practice to approach fitness-for-purpose assessments holistically. This means that all aspects of the pipeline's integrity are taken into account, and it is not viewed simply as an exercise of inputting smart pig data into an equation and simply obtaining a predicted failure pressure for the defect.

This paper covers some lessons learnt by the authors in dealing with both smart pig data and associated fitness-for-purpose assessments. It covers a number of case studies and ends with a list of recommendations.

1. Introduction

The safety of pipelines is our main focus, both as an industry and as engineers. Consequently, pipeline integrity is ensuring a pipeline is safe and secure. It involves all aspects of a pipeline's design, inspection, management and maintenance. This presents an operator with a complex 'jigsaw' to solve if they are to maintain high integrity (Figure 1). Pipeline integrity management is the management of all the elements of this complex jigsaw; the management brings all these pieces of the jigsaw together. Therefore, to appreciate and ensure pipeline integrity, a 'holistic' approach is needed, requiring a number of skills. These skills will need to be continually updated, and therefore training is a key input into pipeline integrity [1,2].

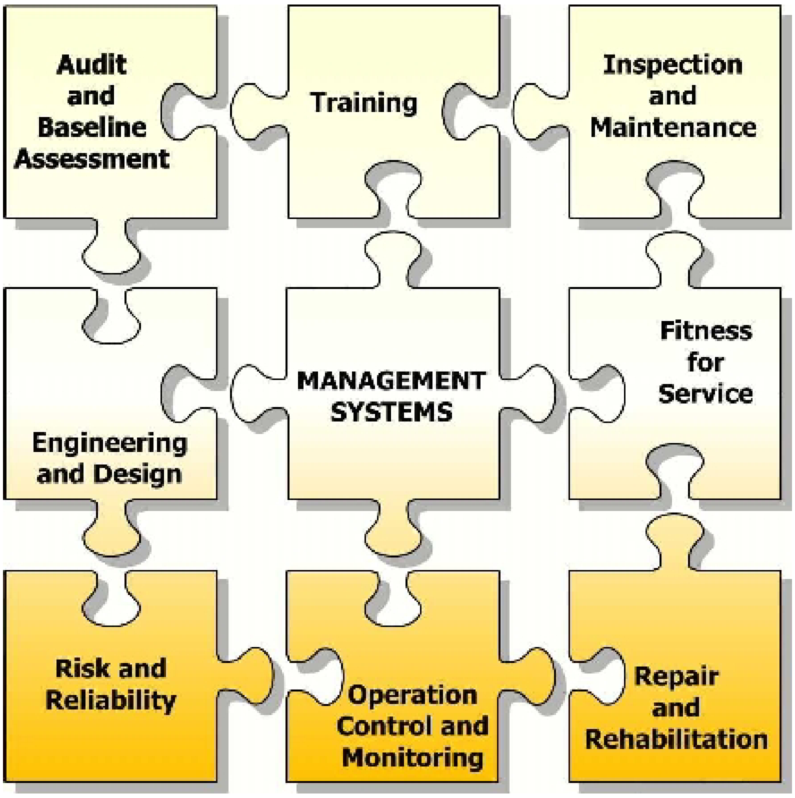

Figure 1: **Pipeline Integrity**

We have recently seen major change in the USA in how pipeline integrity is regulated and standardized, as a result of a number of high profile and tragic failures in gas and liquid lines (Figure 2). API 1160 [3] is a new pipeline integrity management standard for liquid lines, and ASME is to publish [4] an integrity appendix for B31.8 (gas lines).

Figure 2: Pipeline Failures in the USA (Courtesy of Office of Pipeline Safety, www.ops.com)

Consequently, we now have formalized pipeline integrity management with the intention of[5]:

- Accelerating the integrity assessment of pipelines in areas where failures would have a high consequence,
- Improving operator integrity management systems,
- Improving government's role in reviewing the adequacy of integrity programs and plans, and, and
- Providing increased public assurance in pipeline safety.

A key input into our pipeline integrity management program can be smart pigging. This paper presents some lessons learnt by the authors in dealing with smart pig runs and their reported data.

2. Smart Pig Technology and Data

Smart pigs are used to provide information about the condition of a pipeline and can be used to locate problem areas. Smart pigs are either ‘free flowing’ pigs, that are propelled by the fluid and are totally self-contained (onboard power, data collection, etc.), or they are tethered (or cable) pigs, that are connected to a power supply or data acquisition box via a cable. These latter pigs can either be driven by motors, or pumped through the pipeline and are particularly useful for ‘unpiggable’ lines such as loading lines.

There are several types of smart pig that can perform different tasks. These tasks include:

- geometry measurement
- metal loss detection
- leak detection
- pipeline profiling
- temperature and pressure recording
- mapping
- bend measurement
- curvature monitoring
- product sampling
- photographic inspection
- wax deposit measurement
- crack detection

The most common smart pigs used for 'integrity' monitoring are for geometry measurement and metal-loss detection, with an increasing use of pigs that can detect cracks, and pigs that can map pipeline co-ordinates

2.1 Inspection Framework, Type, Level and Frequency

A smart pigging run should form part of a pipeline integrity management program[3, 4], and the type of pig, level of inspection, frequency of inspections and how to deal with the reported data should be based on the risk review contained within the integrity management program.

2.2 Geometry

Geometry pigs usually utilize a calliper arrangement to measure the cross-section of the pipeline. This type of pig can be used to prove the bore of a pipeline and to measure deformations (dents for example) in the pipeline.

2.3 Metal-loss

Metal-loss inspection pigs are used to detect defects that have resulted in wall thinning in the pipeline. Metal-loss detection pigs can discriminate to some extent between manufacturing defects and corrosion defects. There are two main types of metal-loss pigs: magnetic-flux leakage (MFL) and ultrasonic (UT).

2.4 Pig Selection

Before hiring a smart pig, it is important to decide: Why you are pigging (to revalidate a line, detect defects, replace a hydrotest, etc.); what you want to detect (various pigs can detect corrosion, dents, cracks, weld defects, etc., but no pig can detect all defects (Table 1[3]), when you want to detect the defects, to what level and accuracy and reliability you require (do you need very high resolution results?); how you are going to assess the reported data (do you need the pig company to assess the reported defects and give you a repair report?); and what you are going to do with any defect that is unacceptable.

The above will require a strategy BEFORE hiring the pig.

Any invitation to tender sent to a smart pig supplier must have a clear scope of work, with pipeline design and operational details, maps, product and environment details, pig trap and site details, pipeline cleaning requirements, demarcation responsibilities before and during pigging, liabilities for a 'stuck' pig, types of defect to be detected, timetable for the inspection, etc.. Usually the pig company will give the defect location and sizing accuracy for the pig that is to be used.

There is no 'best' pig on the market. The pig you select for your pipeline depends on the above considerations, price, availability, etc.. Always check with other local operators who have used a pig supplier you propose to hire, and ask about quality, value, reliability, logistical support, and delivery of pigs and data.

DEFECT	METAL LOSS TOOLS			CRACK TOOLS		GEOMETRY TOOLS	MAPPING TOOLS
	MFL - SR	MFL HR	UT	UT	MFL		
CORROSION	D&S[1]	D&S	D&S	D&S	D&S	NO	NO
CRACKS - axial	NO	NO	NO	D&S	D&S	NO	NO
CRACKS - circ	NO	D&S	NO	D&S[2]	NO	NO	NO
DENTS	d[3]	D&s[4]	D&s	D&s	D&s	D&S	D&s
LAMINATIONS	NO	NO	D&S	D&S	NO	NO	NO
MILL DEFECTS	NO	NO	D	D		NO	NO
OVALITY	NO	NO	NO	NO	NO	D&S	D&S[5]

Notes:
D = detect S = size
MFL – magnetic flux leakage tool UT – ultrasonic tool HR – high resolution MFL SR – standard resolution MFL
1 – NO ID/OD DISCRIMINATION 2 – MODIFICATION NEEDED (SENSORS NEED ROTATING 90 deg)
3 – LOWER CASE d MEANS UNRELIABLE DETECTION 4 – LOWER CASE 's' MEANS UNRELIABLE SIZING
5 – IF TOOL IS EQUIPPED WITH OVALITY MEASURING GEAR

Table 1 Ability of Pigs to Detect differing Defects (from API 1160 (1))

2.5 Pipeline Cleanliness

If a smart pig is going be used in a pipeline it must be very clean. 'Standard' cleaning pigs may not be sufficient to clean a pipeline prior to smart pigging. This is because smart pigs such as MFL pigs have powerful brushes/magnets that remove residual wax, etc., left behind by the cleaning tools. These residues can foul or destroy sensors. Pigs using ultrasonic technology have problems as residual substances such as wax can attenuate their signals. Therefore, pre-pigging cleaning is often a special programme (e.g. it may require a magnetic cleaning pig to remove ferrous debris) increasingly carried out by the smart pigging company itself.

2.6 Pig Data Interpretation

It is important to remember that smart pigs record data – they do not interpret data. For example, MFL pigs measure magnetic flux leakage not defect depth and length. To interpret the readings made by the pig, the data is processed by software and viewed by human analysts who will attempt to discriminate between corrosion, metal-loss and manufacturing defects, etc. by looking at the signal characteristics (i.e. shape, amplitude, length, etc.).

The analysts will use their experience, in-house software and decision algorithms to decide on the type and size of defect recorded by the pig. Unfortunately, these interpretations and analyses are not standardised, and we rely on the pig company to deliver an accurate and reliable defect location, type and size.

3. ‘Fitness-for-purpose’[1] assessments

Pipelines can experience many forms of damage during their life, ranging from damage introduced at the time of manufacturing and construction, through to in-service damage due to corrosion or external interference.

During the fabrication of a pipeline, recognised and proven quality control (or workmanship) limits will ensure that only innocuous defects remain in the pipeline at the start of its life. These control limits are somewhat arbitrary, but they have been proven over time. However, a pipeline will invariably contain larger defects at some stage during its life, and they will require an engineering assessment to determine whether or not to repair the pipeline.

This is usually achieved by performing a ‘fitness for purpose’ calculation’ (better described as an ‘engineering critical assessment’ [6,7]), where a calculated failure stress of a structural defect is compared with the operating stress of the structure. It should be noted that fitness-for-purpose is not intended as a single substitute for good engineering judgement; it is an aid. The fitness for purpose of a pipeline containing a defect may be estimated by a variety of methods ranging from previous relevant experience, to model testing, to engineering critical assessments, where a defect is appraised analytically. These latter assessments can be by:

- Generic methods [8,9],
- Traditional pipeline industry methods [10-12],
- Recognised pipeline codes developed using the traditional methods [6,7],
- Publications from pipeline research groups [12-15],
- ‘Best practice’ publications emerging from Joint Industry Projects [16-19].

These methods are not covered in this paper – the reader is directed to the literature quoted above. However, the information required for an assessment is detailed below since this shows the information that can be gathered using a smart pig, and the additional information that is required to make an assessment.

3.1 Key Considerations

Any operator conducting a fitness for purpose calculation should consider the following:

- FITNESS FOR PURPOSE FRAMEWORK - A smart pig inspection, and a fitness for purpose assessment of any reported defect, should be conducted within the framework of a Pipeline Integrity Management System[3, 4].
- SAFETY FIRST - The prime consideration of a fitness-for-purpose calculation is ALWAYS safety. It is the assessor’s responsibility to ensure that any fitness-for-purpose assessment is correct and it is important to understand the origin of the defect to be assessed.
- UNDERSTAND THE DEFECT - Understand the origin of the defect being assessed (this will affect the assessment methods and remnant life calculation).
- THE ENGINEER –
  - The assessor must always be qualified[2] and experienced in these type of calculations,

[1] We use ‘fitness for purpose’ in the pipeline integrity business as ‘a failure condition will not be reached during the operation life of the pipeline’. Note that fitness for purpose also has a different legal meaning, particularly in the construction business, with differing liability.
[2] There are now special courses on defect assessment and pipeline integrity.

  - Recommendations following an assessment (e.g. remedial action, or further inspections) may result in significant expenditure, and therefore an assessor should be independent,
  - Use all available information including pig data, operations records, maps, etc.?
  - Always apply a safety margin to your calculation,
  - Review the whole life of the defect in the pipeline – will it grow by further corrosion, fatigue, etc.,
  - Check inputs, assumptions and calculations for validity, accuracy and reliability,
  - Finally, always have the calculations checked for correctness, and approved by knowledgeable senior staff.
- ASSESSMENT METHODS - Use the best possible practices available
- THE CONSEQUENCES - Always consider the consequences of an assessment.

The quality of your data and confidence in your assessment method will influence the safety margin you use in your calculation, but the last point – considering the consequences of failure – will be the major factor in assessing a suitable safety margin. Hence, it is useful to ask the following questions:

- What if I have made an error?
- What if the defect measurement is incorrect?
- What will happen if the pipeline fails?
- What are the consequences?

It can be seen that it is not enough to just review one element of information, such as a smart pig run, when assessing pipeline integrity. Therefore, defect-acceptance calculations form just one element of the pipeline integrity jigsaw, Figure 1.

3.2 Input Data

We cannot cover all the defect, operational, design, and pipeline data required for a defect assessment – it varies with pipeline, defect type, product type, defect assessment methodology, defect assessment deliverable (e.g. failure stress or remnant life), etc.. Therefore, we will focus on the generic questions that need to be posed, to allow the necessary data to be gathered. Remember that the defect data that will be available to an assessment will be dependent on the tools used to gather data – smart pigs can provide only one element of the information required to perform a fitness-for-purpose assessment.

The type and level of detail of information that is required in any assessment depends on the depth and scope of the assessment, but the issues that typically should be considered include:

1. THE PIPELINE –
   a. What is the pipeline geometry (diameter, wall thickness), grade, age, type (DSAW, ERW, seamless, etc.), specified material properties (yield and tensile strength, toughness)[3], pipeline design code?
   b. What are the pipeline operational characteristics (operating pressure and temperature, temperature and pressure cycles)?
   c. What are the pipeline products and environments (internal and external)?

[3] Actual material properties should be used with caution unless it can be established with confidence that the material properties are directly relevant to the length of pipe containing the defect(s).

d. What is the history of the pipeline, from manufacturing and construction through to operation? (What is the pipeline's history (failures, repairs, hydrotests, previous inspection results)?).
e. What are the intended future operating conditions?

2. STRESSES –
   a. What are the loads acting on the length of the pipeline containing a defect?
   b. Will these loads change in future?
   c. Are there any circumstances that may result in overpressure (e.g. surge), and what would the overpressure be?
   d. Are there any cyclic loads on the pipeline?
3. INSPECTION METHOD –
   a. What are the capabilities of the inspection methods used, e.g.. what types of defect can the intelligent pig detect?
   b. What is the minimum sizing threshold and what are the sizing tolerances and accuracies of the inspection methods?
4. DEFECT –
   a. What is the cause, or causes, of the defect(s) (corrosion, bacterial, transport, storage, etc.)?
   b. What are the dimensions of the defects reported (length, width, depth, acuity, profile)?
   c. What are the types of defect (metal-loss, dent, gouge, girth weld defect, crack, laminations, blister)?
   d. Where is the defect located? (see next section)
   e. What is the potential for defect growth?
5. CONSEQUENCES -
   a. What is the failure mode expected (running fracture, leak, rupture)?
   b. What are the consequences of failure (blast, fire, pollution)?

3.3 Considerations when Using Smart Pig Data.

The following points should be considered when using smart pig data to aid a fitness-for-purpose assessment:

1. PIGS CANNOT DETECT ALL DEFECTS ALL THE TIME – See Table 1.
2. PIGS ARE NOT PERFECT - Always check with the pigging company regarding reliability, tolerances (depth, length), etc.. Add quoted tolerances onto the reported defect size: if a defect is reported at 20% wall thickness and the pig depth measuring tolerance is 10% wall thickness, then use a defect depth of 30% in your preliminary calculations.
3. PIGS CANNOT DISCRIMINATE BETWEEN ALL DEFECTS - There will be confusion with some defects. This may require excavation/uncovering for visual inspection of defective areas.
   - Work with the pigging company when interpreting data. They understand the data the best. Ensure you understand all reported features and ask for further interpretation if there are problems.
   - When pigging companies are confused over a defect , it is your responsibility to determine the most likely defect. For example, if a report says 'manufacturing or mechanical defect' you should be clear which one it is. If in doubt – investigate.
   - Has the pipe a history of manufacturing defects (e.g. has the pig reported many of these defects)?
   - Is the reported defect in an area where mechanical damage is likely to occur, e.g. heavily populated area, shared corridor, pipeline crossing, etc..
4. PROVISION OF SIMPLE DEFECT ASSESSMENTS - Pigging companies may provide you with a very simple defect assessment listing. This will help you rank the

defects' severity. Check that the pig company has taken into account all loadings on the pipeline (e.g. pressure stresses, external loading, cyclic stresses, over pressures, thermal stresses), material properties (e.g. your pipeline may be low toughness) defect interactions, and any future defect growth.

5. USE ALL AVAILABLE INSPECTION DATA – Use all pipeline inspection data when considering a smart pig defect report. For example, previous inspections by other pigs may help current interpretations.
6. USE ALL OPERATIONAL DATA – Operational data may help identify the cause of defects; for example if inhibitor injection was unavailable for periods of operation.
7. ENGINEERING OVERVIEW - Compare your pig report with your pipeline map and superimpose pig defect locations. For example:
    - Do defects coincide with heavily populated areas (this would mean high consequence of failures, and possible third party interference defects), at low points (could be corrosion due to water settling), etc.?
    - Are reported features near recent excavations (could be gouges), at top of pipe (could be denting due to impacts), in field bends (could be wrinkles), along longitudinal seam weld (could be SCC)?
    - Be certain of the type and origin of the reported defects.
8. LOCATION OVERVIEW - Location accuracies of pigs vary – check the pig company's specification. A pig run one year may report a defect at a one location, but in later years another pig may report the same defect at another location – but it's the same defect.
    - Location accuracies are typically 1-2% from a fixed reference point (but always check with your pig supplier). This means that if you have a pipeline feature that the pig can easily identify (e.g. a valve or a 900 bend), it will be within ± 1-2% from this point. For example, if a defect is 200 metres from a valve reference point, the pig should be able to locate the defect to ± 4m (for 2% accuracy). However, if the only reference point is a Tee that is 2km from the reported defect, the accuracy is ± 40m.
9. DIRECT ASSESSMENT - Excavate/visually inspect features that are potentially serious – for example, if you have a report of a part wall defect at the top of the pipe, and a previous caliper run has found denting in that vicinity, you may have a combined dent and gouge.

4. Some Recent Issues with Assessing Smart Pig Data

4.1 Shallow defects (less than 10% of the pipe wall)

Both old and new pipelines will inevitably contain some defects. This is reflected in the codes, i.e. the API pipe specification allows some defects and ASME B31 allows defect up to 10% below nominal wall thickness. The manufacturing wall thickness tolerances in API 5L are given in Table 2 below (note that size designation refers to the nominal diameter of the pipe in inches)[20].

These defects may have escaped detection at the pipe mill or may have been introduced during transportation, storage or construction, or be due to a corrosion mechanism.

Size Designation	Type of Pipe	Tolerance (percent of specified wall thickness)	
		Grade B or Lower	Grade X42 or Higher
> 2.875 and < 20	All	+15.0, –12.5	+15.0, –12.5
≥ 20	Welded	+17.5, –12.5	+19.5, –8.0
≥ 20	Seamless	+15.0, –12.5	+15.0, –10.0

Table 2: **Manufacturing wall thickness tolerances from API 5L [20]**

The new generation of smart pigs will detect some of these defects since the new pigs can now detect defects of depth below 10% wall thickness, whereas the older generation of pigs could not. In a thin-walled pipeline (<10mm) this means that defects less than 1mm deep will be detected. This can cause problems:

a. FINGERPRINT RUNS. Smart pigs are increasingly being used to 'fingerprint' new pipelines. A fingerprint run is a pig run shortly (e.g. within one year) after commissioning, to check the quality of the new build. There has been a recent case of a new pipeline that has been superficially corroded during storage and transportation, and contained many thousands of small internal corrosion pits (all below 1mm). Following a fingerprint run it was 'condemned' because the smart pig reported all these corrosion defects. However, this pipeline had passed the pre-service hydrotest, the corrosion was not active or growing, and it did not affect the pipeline's fitness for purpose. The defects detected may not have been desirable but they are likely to be 'custom and practice' storage and/or construction defects, mostly within ASME tolerances. The operator only became aware of them because of the new and very smart pigs.
b. REPEAT RUNS. The above has also been found to cause problems when comparing old pig runs with new pig runs:
    i. older generation pigs would only detect defects greater than 30% wall thickness;
    ii. later generations of pigs could detect defects that where 20% of wall-thickness;
    iii. the current generation are capable of detecting defects less than 10% of wall thickness.

Therefore a pipeline that was fingerprinted using old technology and passed as 'defect free' (i.e. no defect above 20% wall thickness), may (on a new run today) have 10,000 defects reported, all under 20% wall thickness but nevertheless reportable, using the new technology.

Clearly there is a need to quantify the 'workmanship' level of defects on a fingerprint run, otherwise perfectly acceptable new constructions containing 'custom and practice' defects, will be the subject of lengthy arguments between operator and constructor [21].

Therefore, it is necessary to consider the following factors when dealing with inspection data that is reported to the level that is now possible with modern smart pigs:

i. Defect Cause - It is necessary to determine the cause of the reported defects. This helps us to understand the nature of the defects and to determine their likely development over time. Are the reported defects due to storage and transportation or are they caused by in-service corrosion?
ii. Defect Size - Account needs to be taken of the reported defect size. A smart pig that can detect defects that are less than 10% wall thickness is likely to report many

thousands of defects, many of which are likely to be shallow. It is important to decide which of the reported defects are significant and need to be assessed.

iii. Defect Location - The location of the reported defects within the pipeline gives a good indication of the nature of the defects. For example, internal defects consistently located at low-points in the pipeline in the 6 o'clock position are likely to be due to corrosion. Therefore, the location of the defects can help us to interpret the cause of reported defects.

4.2 Defect Sizing

Problems can arise when defects are grouped together or 'clustered' by pigs. Clustering is a method some smart pig inspection contractors use for simplifying the inspection data. Individual defects are recoded as 'boxes', with the box length, width and depth equal to the maximum length, width and depth of the defect. For defects that are close together, the boxes that define that defect are 'clustered' together according to in-house defect interaction rules. Consequently, they are treated as a single defect with the length equal to the distance from the start of the first 'box' to the end of the last 'box', and the depth is equal to the depth of the deepest 'box' within the cluster (Figure 3).

This method is well proven; however, in the past only defects that were deeper than 10% or 20% of the wall thickness would have been reported and then clustered. Now very shallow defects are also being included. This can lead to extremely conservative defect sizing. An example is shown in Figure 4: the defect depth is that of the deepest of the three boxes. However, the overall length of the three boxes is used for the defect length, meaning that a long deep defect is assessed, where in fact there is only a short defect. If the predicted failure mode is a leak (the corrosion continues to grow until it goes through the pipe wall) then this may not matter. However, if a rupture is predicted, which is possible for a long defect in a high pressure system, then the assessment may be excessively conservative.

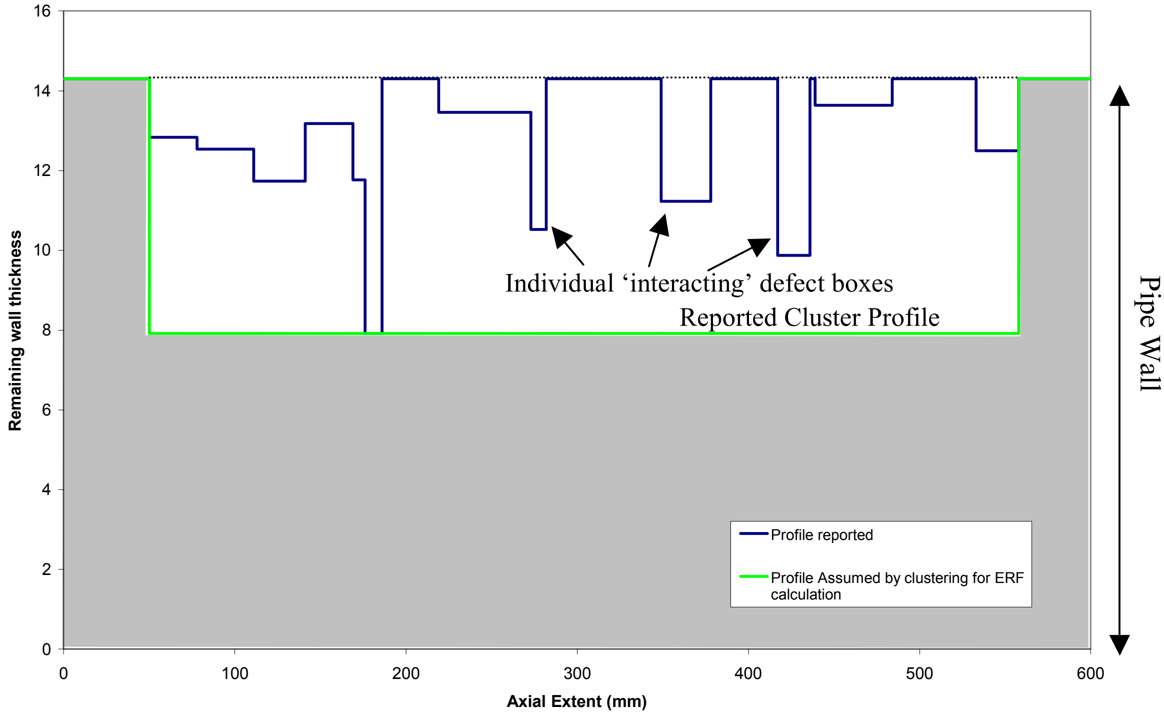

Figure 3 Reported profile of defect boxes, and cluster profile generated by interaction rules used by smart pig.

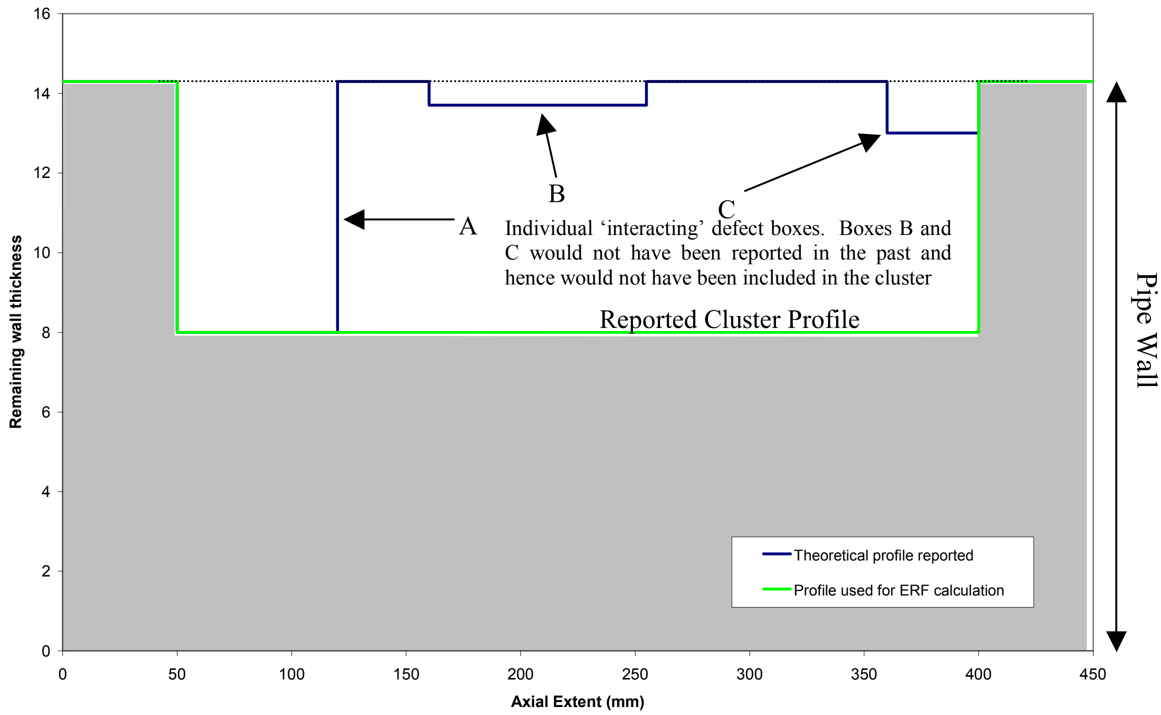

Figure 4 Theoretical profile of defect boxes, and cluster profile generated by interaction rules used by smart pig.

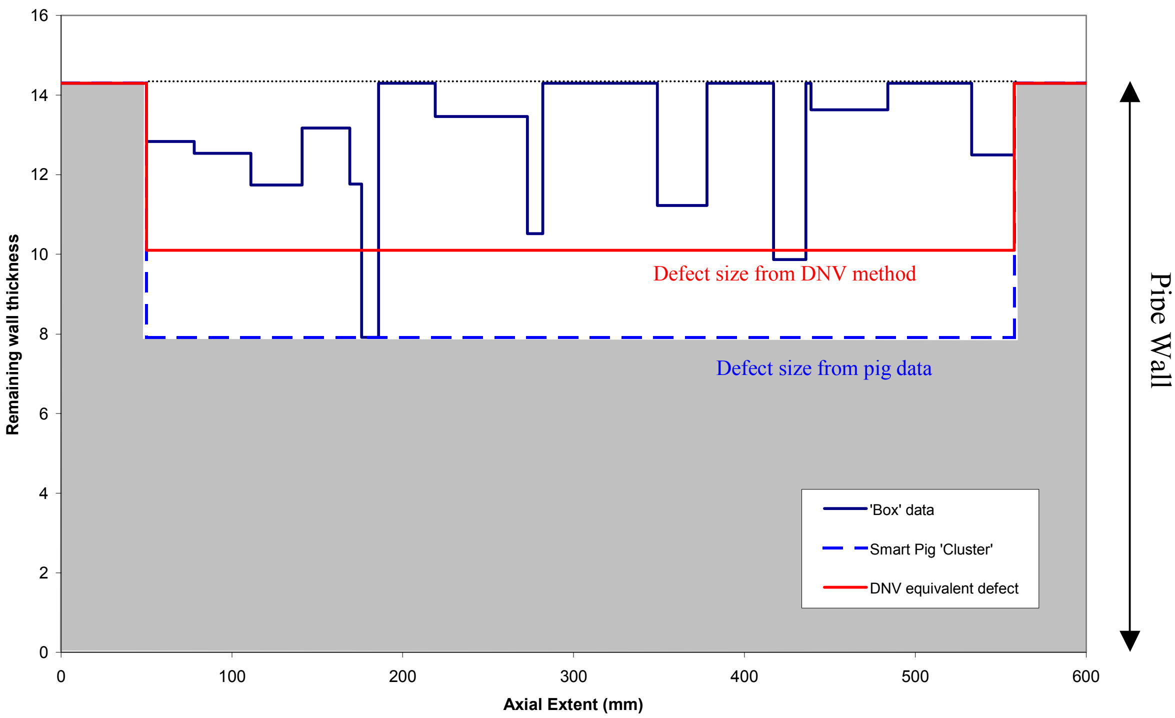

Figure 5 Comparison of DNV equivalent defect and 'cluster' profile used by smart pig vendor for assessing its significance.

A fitness for purpose calculation on a reported defect will be very conservative if maximum depths and lengths of corrosion defects are used in the calculations – the actual defect profile can now be used, minimising conservatism.

Using simple grouping and assessment tools on detailed defect data may result in a very conservative assessment, and lead to unnecessary repairs or reductions in operating pressure. To avoid this, and to obtain the best value from an inspection, an appropriate level of assessment should be carried out. If detailed data is collected (usually at great expense) then it is sensible to look closely at it and analyse it carefully. This is demonstrated in Figure 5 where the equivalent defect size based on the DNV RP-F101 methodology[7] is overlaid on the cluster profile and the defect shape used for calculating the ERF[4] value. The DNV equivalent defect size includes the quoted inspection tolerances, but is still significantly smaller than the clustered defect shape used for calculating the ERF value.

Consequently, in assessing inspection data it is important to understand how the inspection company has processed it so that the assessment is not overly conservative [21].

4.3 Contract Inspection Accuracy and Significant Figures in Reporting

Inspection tolerances agreed and quoted in an inspection contract can affect the way that inspection companies report detected defects.

[4] The 'ERF' or 'Estimated Repair Factor' is a popular method for assessing the significance of a defect. The ERF calculation is another way of expressing an ASME B31G assessment [6]. If the ERF is less than one the defect is acceptable to ASME B31G. If the ERF is greater than one the defect is not acceptable to ASME B31G.

In a recent assessment of smart pig data, the accuracy quoted for the axial position of a feature was within 1% of the distance from the nearest reference weld. As most pipe spools in this pipeline were 12m long the position of the features was typically given to the nearest 0.1m. This kept the positional accuracy within the quoted accuracy and did not give the appearance of a better accuracy. For excavation and repair this level of accuracy is sufficient. However, in this particular case, where there were numerous very short defects (less than 0.05m long), the 'rounding' of the axial position to the nearest 0.1m led to many defects being reported at the same position (see Figure 6). In addition, and more serious, there were external defects reported exactly coincident with the internal defects, with a combined depth greater than 100% of the pipe wall thickness (see Figure 6). Based on this information, the pipeline should have been leaking. This was queried with the inspection company and they supplied data giving the axial positions of the defects to the nearest millimetre. Obviously, the inspection vehicle cannot locate the feature with this level of accuracy relative to a reference weld up to 12m away; however, the relative positional accuracy from one defect to the next is very good and it is reasonable to use measurements that give the position to the nearest millimetre. This higher resolution data showed that the features were not coincident and allowed a reasonable assessment to be made.

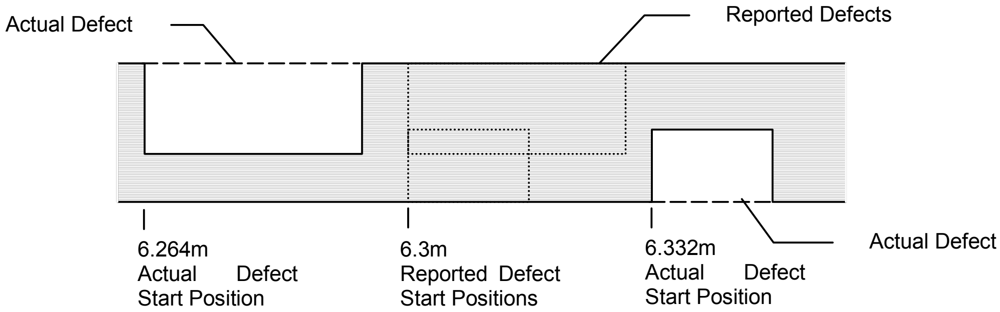

Figure 6: Example of defects reported as coincident due to reporting tolerances

4.4 Dents

Some smart pigs can detect dents. Both MFL and UT pigs may give an indication of the length and width of a dent; they may also give an indication of the presence of associated metal loss (a gouge or corrosion). However, they cannot give the depth of the dent, which is a critical parameter in a fitness for purpose assessment. At present only calliper pigs will give a measurement of dent depth. So how should we assess dents picked up be MFL or UT pigs?

Firstly, any dent with associated metal loss damage due to impact should be investigated by excavation, and repaired, as the combined dent and gouge is a very severe defect. However, if there is no metal loss then it may be acceptable to leave the dent. A first indication of the dent depth may be gained from any gauging pigs runs that may have been made of the pipeline. For example if a 95% gauge plate has been run with no damage, then the maximum dent depth can be estimated to be 5% of the pipe diameter. The axial and circumferential extents of the defect can also be used to decide whether this is reasonable. The orientation of the dent can also be used to give an indication of the likely source and severity of the dent. Dents on the top of the pipe line are most likely to have been caused by external interference; on the bottom of the pipeline they are more likely to be the result of rocks in the bottom of the trench the pipe was laid in, and will have been there since the pipeline was built.

4.5 Defects at Girth Welds

At girth welds MFL pigs are affected by the change in metallurgy and the sensor may lose contact with the pipe surface due to the root penetration of the weld. This can prevent the detection of defects. In a recent case a smart pig inspection of an oil pipeline in an environmentally sensitive area identified a number of internal corrosion defects all in the pipe body. Soon after the inspection the pipeline leaked at a girth weld [22]. Severe localised pitting at a girth weld had not been detected by the smart pig inspection. Subsequent external inspection of 30% of the girth welds on the pipeline provided data that allowed the smart pig vendor to review the inspection data and identify defects in some of the remaining welds.

So what does this tell us about how to assess inspection data? It tells us that all defects may not be detected and it tells us the importance of working with the smart pig supplier before the inspection to warn him/her of all possible defects. It reinforces the requirement to identify the corrosion mechanism, and tells us to consider the potential for preferential weld corrosion.

4.6 'False Positive'

Debris and other features in a pipeline can lead to the inspection tools reporting defects where there are none – 'false positives'. This misinterpretation can lead to pipeline derating, or even shutdown and repair, which can be very costly particularly for trunk lines and offshore pipelines.

In a recent case in the UK North Sea the need to remove a defect to allow a pipeline to be used at its original design pressure required the temporary shutdown of a major trunk line and a very costly subsea pipeline section replacement exercise [23]. This defect, which had been reported as slowly growing by repeat smart pig inspections, did not exist. It seems that the pig had been confused by some scale containing iron grit at the location where the metal loss had been reported. The pipeline in question carried dry gas and had always been operated responsibly.

This again emphasizes the importance of identifying the root cause of a defect, and using more inputs that just the smart pig data when undertaking an assessment.

4.7 Growth Rate Analysis

The estimation of corrosion growth rates based on smart pig data is increasingly common. Corrosion defects reported by two pig runs can be compared and a corrosion rate estimated. This is done using processed data, comparing reported defect sizes[24] or using the sensor signal data , and comparing signals to derive a change in signal and hence a change in defect depth[25].

This type of analysis is extremely valuable for predicting when repairs should be done, when the pipeline should be re-inspected, and helps extend the economic life of the line. However, it must be treated with caution, and knowledge of corrosion processes and pipeline operation must be incorporated into any assessment. For example, pig accuracy and tolerances will invariably produce anomalies such as negative corrosion rates (the corrosion is decreasing in size) for some locations.

Where an analysis is based on an unprocessed signal, the legitimacy of this method must be demonstrated with practical test results (signals from a sample of defects before and after a known increase used to give an estimated growth that can be compared with the actual growth): to date the authors have seen no such validation. Methods based on the sized defects must consider the corrosion process, treat the data consistently, and consider the sizing issues discussed above.

4.8 Standardisation and Accreditation

We have many excellent and reputable smart pigs on the market, and smart pig companies are to be congratulated in their commitment to improving both the pig technology and supporting services.

Unfortunately, the industry is not keeping pace! We have insufficient standardisation, , minimum requirements, and accreditation schemes for these pigs[26]. The standards that do exist, such as the Pipeline Open Data Standard[5] are not yet widely used, and whilst they give some guidance as to what should be reported, they do not and cannot give full details of the parameters (reporting levels, clustering rules etc.) that should be used for particular situations. Similarly, we are assessing the significance of defects detected by pigs with very few approved fitness for purpose methods, and no formal training requirements or accreditation of those conducting the assessments.

Compare the above lack of standardisation and control with that which we apply to the simple pipeline girth weld (in its fabrication, materials, inspection and certification)!

Consequently, there is a need for standardisation bodies, regulators, pipeline operators and pig companies to come together and resolve the above.

[5] for more information please go to www.pods.org

5. Conclusions

Smart pigs are becoming smarter! This is good news for the pipeline business, and smart pigs will continue to help improve the safety and efficiency of our pipelines.

The smart pigs alone will not improve pipeline integrity: it is how we use them and the data they collect that will improve integrity. The defect data collected must be properly assessed to determine if the pipeline is at risk.

The experiences reported above indicate why it is vital to take an holistic approach to any integrity assessment. This holistic approach can be ensured by the selection of suitably trained, experienced, and independent engineers to assess the processed smart pig data. The engineers will require an understanding of the design, history and operation of the pipeline, along with an understanding of the technology and limitations of the smart pigs being used, the corrosion and other damage processes, and the consequences of any defect failing.

We are now entering an era where the general public will automatically expect very high levels of pipeline integrity – operators can meet these expectations, in part, by sensible use of smarts pigs, and robust use and assessment of their reported data.

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