Understanding COMPLEX ANOMALIES

Christopher Holliday, Andrew Wilde and Alasdair Clyne, ROSEN Group, Switzerland, **outline the assessment of coincident anomalies in pipelines.**

There are many threats to in-service pipelines, and pipeline operators have robust integrity management plans and programmes to counter such threats – indeed, many regulators demand such plans and programmes.

Although not an exhaustive list, most anomalies that affect pipeline integrity can be identified as falling into one of three categories:

- Three-dimensional, volumetric metal loss, such as corrosion, pitting and gouging.
- Geometric, or deformations, such as dents, wrinkles, bending strain etc.
- Crack-like, for example lack of fusion, hydrogen cracks, fatigue and stress corrosion cracking (SCC).

Published methodologies are available for the assessment of each of the above anomaly types; for example, remaining strength (RSTRENG) within ASME B31.G for corrosion anomalies, API RP 1183 for dents, and

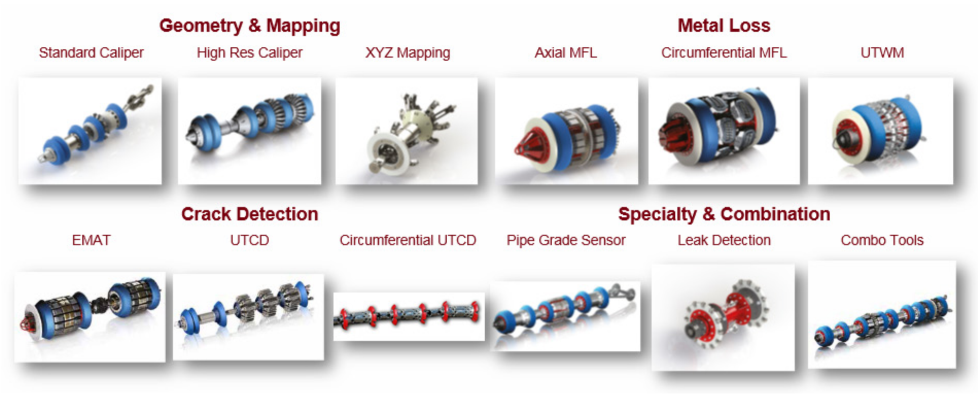

Figure 1. Examples of different ILI tools.

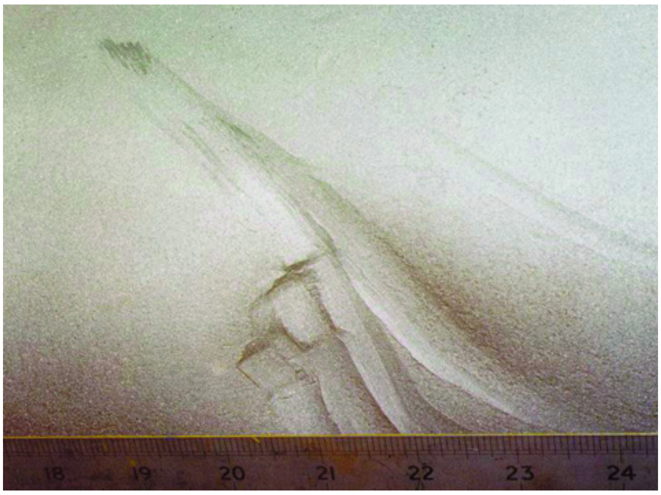

Figure 2. A typical dent-gouge combination.

API 579 or BS 7910 for assessing cracks. Extensive research, full-scale testing and numerical modelling have validated such methodologies, which are widely accepted and are referenced in many codes and regulations, including CSA Z662:19 and the PHMSA regulations.

An engineering assessment can be conducted using approved and industry-accepted methodologies, allowing the pipeline operator to make, among other things, a repair/no repair decision, provided that an integrity engineer has access to:

- The stresses to which an anomaly is subjected, including those due to internal pressure, residual stress, thermal stress and (where appropriate) external loading.
- The through-the-wall depth and axial/circumferential lengths of anomalies.
- Material properties, such as diameter, wall thickness, strength and toughness.

However, when different anomaly types coincide, or interact, possibly under the influence of external loading as well as internal pressure, assessments can become more complex:

- How do I know if different anomaly types are actually interacting?
- What is the likely effect on failure pressure if, say, a dent interacts with a gouge?
- How do I assess coincident anomalies?

Inline inspection (ILI)

Prudent pipeline operators have for many years used ILI systems as part of their integrity management programmes. Typical ILI tools are shown in Figure 1 and, as the picture makes apparent, there are different types of tools available to detect and measure the dimensions of anomalies associated with the threats referred to in the introduction.

It is worth noting that many of the tools in Figure 1 can be run in combination, thereby saving operators time and money by optimising the number of ILI runs. For example, probably the most common type of inspection is an axial magnetic flux leakage (MFL-A) tool to detect and size general metal loss anomalies, together with a high-resolution caliper (to detect and size deformations) and an inertial measurement unit (IMU) for the accurate location of anomalies and identification of possible areas of bending strain.

Interactive threats can occur from within either the individual categories or across different categories. Examples of interactive threats within individual categories could be corrosion in close proximity (clusters) or coincident internal/external corrosion. An example of an interactive threat across categories is a dent with metal loss and/or cracking.

Finding interactive threats from within a category

Finding interactive threats from within an individual category is relatively simple and may utilise a single ILI system (typically equipped with an IMU unit). For example, metal loss anomalies can be clustered according to standard interaction criteria (e.g. 6t by 6t), interlinking cracks can be grouped into crack colonies, and deformations in close proximity to one another can be flagged. Coincidental internal and external metal loss is typically sized accurately in terms of total depth but may be (mis)classified as internal metal loss, depending on the technology used. Utilising an ultrasonic wall measurement tool can assist with sizing both internal and external components of coincident metal loss, but the correct classification of this feature type can be very challenging.

Finding interactive threats from different categories

This section looks at some examples of how combined ILI data evaluation and integrity assessment of different

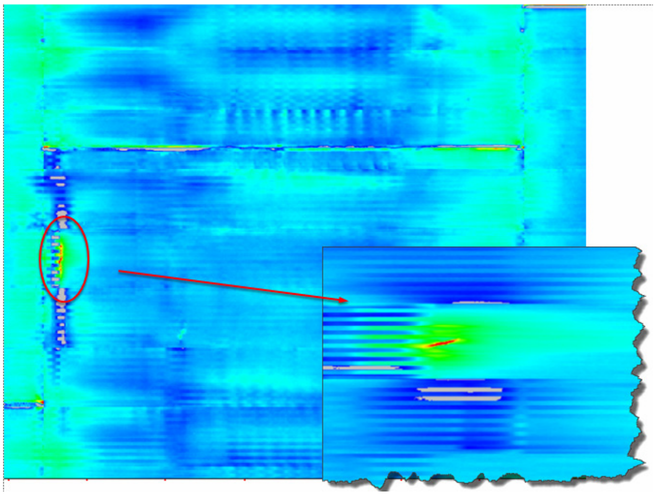

Figure 3. MFL-C data showing pronounced dent indication due to sensor lift-off and linear indication within dent.

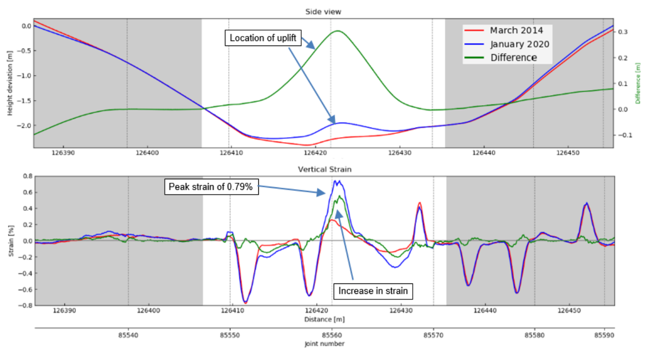

Figure 4. Elevation and strain plots for area of interest.

datasets has assisted operators in making informed decisions regarding the possible need for in-field intervention when faced with coincident threats from different anomaly types.

Dents and gouges

Probably the most common form of interacting feature is a dent with metal loss. These are typically found by the alignment of data from an MFL-A/caliper combo tool. MFL tools are very sensitive to deformations, and dents can therefore be detected (but not sized) via the ID/OD sensors. Standards such as CSA Z662:19 typically treat a dent associated with a gouge as a defect, and so remedial action is required; however, coincident dents with corrosion may be permitted, depending on their respective dimensions. Consequently, to make a repair decision for a dent/metal loss combination, sizing is required for both anomaly types, but detection and classification are the key requirements to make a repair decision for dent/gouge combinations.

Gouges and corrosion may give rise to similar inspection-system signal characteristics, but skilled data evaluators supported by integrity engineers can classify anomalies using factors such as signal orientation, location of metal loss in a dent, satellite imagery, coating survey results and information from verification digs. The restraint condition of a dent can also provide useful information with regards to the likely origin of the dent and therefore whether gouging is likely. Unrestrained dents are more likely to have been caused during the operational life of the pipeline, e.g. due to third-party damage, and are therefore more likely to contain gouging. The major concern with a dent/gouge combination is that during formation, cracks may occur at the base of the gouge, thereby creating a deeper defect than may be immediately apparent from metal loss ILI and resulting in a concomitant reduction in failure pressure.

A Canadian operator had a pipeline that had been in service for over 30 years and approached ROSEN with the challenge of increasing their normal operating pressure for a temporary period. In collaboration with the operator, a defect of interest was identified that had previously been reported as a dent with metal loss. Following a more detailed review of the ILI signal data, it was concluded that the metal loss was highly likely to be a gouge in a dent. An example of a dent/gouge combination is shown in Figure 2. A subsequent analysis to API 579 Part 12 demonstrated that although the predicted failure pressure was higher than historical operating pressures, it was lower than the planned temporary increase in pressure.

Given timeline sensitivities for the required pressure increase, rather than perform a more complex (FEA) analysis, the operator decided to excavate the feature. The deformation was confirmed in-field to be a dent-gouge with dimensions that merited repair. Repair was completed urgently, thereby allowing the operator to successfully increase the line pressure with no reported loss of containment.

Cracks within dents

One of the most challenging coincident threats is the identification of cracking in dents. The major challenge is that dents cause sensor lift-off, thereby affecting the data quality of crack detection tools such as electro-magnetic acoustic transducer (EMAT) technology. However, EMAT tools are usually run in combination with a circumferential MFL tool to assist in distinguishing genuine crack-like defects such as fatigue or SCC from, for example, steep-sided corrosion. Figure 3 shows MFL-C signal data associated with linear indications within a dent. While the deformation also causes lift-off of the MFL sensors, these systems are a little more tolerant than UT or EMAT, and a crack with sufficient opening (>0.1 mm) may be detected, although sizing is not feasible and the probability of detection cannot be specified. Collaboration between the MFL-C evaluator and the integrity engineer maximises the likelihood that key locations will be carefully reviewed, and potentially critical, but hard to identify, anomalies will be found. The feature in question was reported as an "immediate investigation feature" and, on excavation, the pipeline operator found a leaking crack-like defect within a dent.

Geohazard and deformation

In early 2020, a pipeline operator requested a bending strain assessment of 50 'at risk' locations identified by a geohazard provider. Since an additional (but not analysed) IMU dataset

Figure 5. **Sidebooms supporting pipe in the Coldwater area.**

was available from a previous inspection, it was agreed with the operator to analyse the entire length of the pipeline for both indications of bending strain and pipeline movement.

Figure 4 shows the elevation and strain plots from the two inspections, together with a 'difference' plot shown in green, for the region of the pipeline with the highest level of bending strain (0.79%). The 2020 data (blue line) is generally coincident with the 2014 data (red line), but the upper part of the figure shows an increase in vertical elevation of 0.3 m (green line) coincident with the location of maximum strain. The strain plots in the lower part of the figure are again typically coincident except in the area of peak strain, where an increase in strain of 0.56% was recorded between inspections. Caliper data were scrutinised at the strain location, and there was clear evidence of a developing ovality. This combination of a change in bending strain and a developing deformation provides strong evidence of movement due to geohazard loading, such as a landslide. Based on the above results, the pipeline operator mobilised 'in-field', confirmed the presence of the uplift in profile and the deformation, and carried out appropriate remedial action.

A particularly noteworthy point is that this location was not on the geohazard provider's original 'at risk' list, which demonstrates the value of assessing the entire length of the pipeline rather than 'targeted' locations.

Geohazard and circumferential girth weld anomalies

On 14 November 2021, a main arterial pipeline crossing British Columbia in Western Canada executed a precautionary shutdown due to forecasted storms and torrential rainfall throughout much of the province. Major highways were completely washed away, together with the ground surrounding the pipeline in some areas, leaving the pipeline exposed. As a result, numerous freespans were created, which were initially supported on wooden trestles or via sidebooms once field crews could access the site (Figure 5).

Some of the pipeline girth welds contained anomalies reported by historical UT crack ILI tools, and these anomalies were subject to additional stresses due to pipeline movement resulting from the washout. As part of the process to safely restart the pipeline, it was therefore necessary to compare positional surveys performed in-field with historical IMU data to review the magnitude and direction of the additional stresses. An assessment was then performed to develop acceptance criteria (allowable freespan length and anomaly dimensions), which considered coincident internal pressure and external loading. Calculations were performed utilising the EPRG Tier 2 and BS 7910 methodologies to determine the dimensions of anomalies that could safely remain in the pipeline without further mitigation. In-field NDT was carried out on accessible girth welds to confirm anomaly sizing for comparison with tolerable dimensions, as a result of which a number of repairs were completed prior to restart. Frequent discussions of the assessment results were held with both the pipeline operator and the Canadian Energy Regulator (CER) to assist with the restart decision. Although this part of the project was relatively minor compared to the immense scope of civil and rehabilitation work, it is understood that the results of the assessments allowed the operator to accelerate the restart of the pipeline. The pipeline was successfully restarted on 5 December, thereby securing fuel supplies for British Columbia.

Summary

This article has summarised some of the different coincident anomaly types pipeline operators may encounter. The article has shown how ILI systems, together with careful analysis by data evaluators and integrity engineers working hand in hand, can assist operators in understanding the nature of complex, coincident anomalies, thereby allowing informed decisions regarding in-field verification and likely repair requirements, resulting in possible cost savings.