NDT Global
The Power of Clarity.

White Paper

UT Shear Wave and Compression Wave Inspection Capabilities for SSC

White Paper

Ultrasonic Shear Wave and Compression Wave Inspection Capabilities for SSC

Selective seam corrosion

Ultrasonic inspections

Simulations

Pull test

NDE correlation

SSW assessment based on UT ILI inspections

Conclusions

Technical recommendations

References

Authors

Rogelio Guajardo
Director Data Analytics

Debbie Wong
Data Analysis Manager

Anna Rodriguez
Data Analysis Project Leader

Diego Luna
Pipeline Integrity Engineer

Abstract

Selective seam corrosion (SSC) is localized corrosion that occurs specifically in the welded seams or joints of a metallic structure. It is characterized by the preferential attack of the weld area compared to the surrounding base metal. When inspecting with ultrasonic technology, SSC is considered a complex feature as it suggests that a compression wave inspection is the best technology to address those features. However, because of its geometry and dimensions, it provides reflections like cracks, so the shear wave technology would be optimal for detecting narrow corrosions.

SCC is a threat to a pipeline and needs to be known to the pipeline operator so that the required actions are taken to ensure the safety of the asset. This raises two questions: 1. Which UT technology should be used to detect these features? and 2. What are the capabilities of ultrasonic compression wave and shear wave ILI tools in regard to selective seam corrosion (SSC)?

This paper will present the results from a systematic approach where simulations, pull tests, and NDE correlations with ILI runs were performed. In conclusion, it will provide the reader with a guide on:

- UT ILI capabilities on detecting (POD), identifying (POI), and sizing (POS) selective seam corrosion (SSC) for compression wave and shear wave
- Analysis methodology to address these features
- Technical recommendation on the technologies to be used for these features

Selective Seam Corrosion

Low-frequency electric resistance welds (LF-ERW) and electric flash welds (EFW) are two examples of pipeline manufacturing processes, these processes relate to how the longitudinal weld of the pipe joint is created. These manufacturing processes started to be used around a century ago, a steel plate was folded into a cylinder and the edges were joined by applying heat and pressure. Before the 1970s, manufacturing process quality control had areas of improvement. As a result, some anomalies that are more susceptible and found in these types of long seams such as hook cracks and selective seam corrosion (SSC).

What is SSC?

SSC is a localized corrosion attack along the bond line of low-frequency electric resistance welding (LR-ERW) and electric flash welding (EFW) piping (PHMSA, 2011). Three main factors can be used to determine if the corrosion can be considered SSC, these are **1.** long V-shape groove, **2.** location in/at the longitudinal weld, and **3.** weld type LF-ERW/EFW. Figure 1 shows a typical SSC from above (A), and a cross-section (B) where the V-shape groove (corrosion) is located at the bonding line.

SSC is considered a time-dependent threat and may or may not have a crack at the deepest point of the groove.

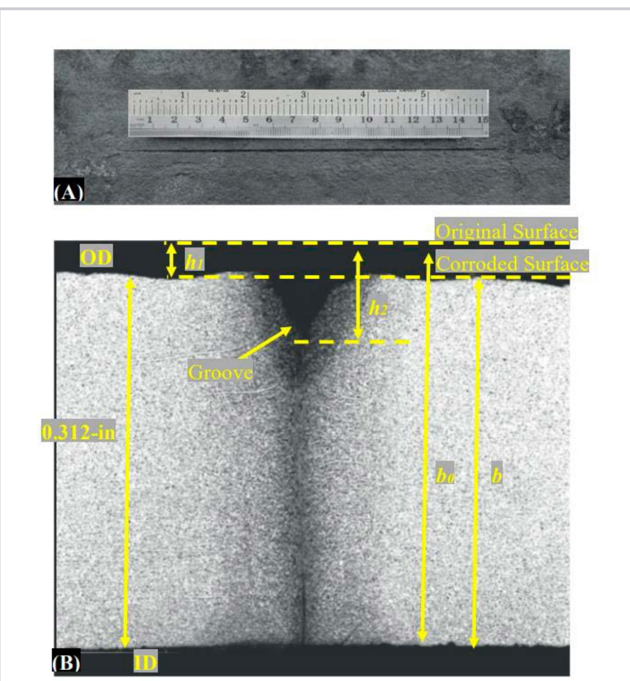


Figure 1 – (A) selective seam corrosion seen from above, (B) cross-section of a typical SSC. (Ritchie, 2020)

Why does SSC occur?

Literature can attribute the presence of SSC to two main factors: 1. operational factors which include the pipe exposure to corrosive conditions due to poor coating and ineffective cathodic protection; and 2. steel manufacturing quality where the steel composition with high carbon and sulphur content and/or reduced post-weld heat treatment increase the susceptibility.

Why is SSC a threat?

In general, inline inspections (ILI) can detect and size a wide variety of anomalies using multiple measurement techniques such as Magnetic Flux Leak (MFL), Ultrasonic Technologies (UT), and Electromagnetic Acoustic Transducer (EMAT). Each technique has its pros and cons. However, SSC is a special case as its morphology and location challenge the technology capabilities. (API RP 1160, 2019) suggests that circumferential MFL is a technology to detect and size SSC, while (Ritchie, 2020) suggests that none of the ILI current tools have been developed to detect this type of anomaly. This paper will focus on the UT capabilities for this type of anomaly later.

SSC becomes a threat as: "The growth rate for SSC, based on failure experience, is typically two to four times the rate growth in base metal. This condition can lead to the rapid development of critically sized flaws in a defective seam" (API RP 1160, 2019).

Additionally, no ILI systems can properly characterize this anomaly following the same line of thought. So, the question to answer is what are the capabilities from the UT perspective in detecting and sizing SSC?

Ultrasonic inspections

UT inspections can be divided into two families based on the type of waves used for different anomalies. 1. Compression waves are used for volumetric anomalies such as metal loss and laminations and belong to the first family. These anomalies have a length, width, and depth, we will abbreviate this family as UMp. The second family is 2. Shear wave which is used for 2D anomalies such as cracks or linear anomalies as they only have a length and a depth. It is considered that the width of these anomalies is zero. This family is abbreviated as UC.

Compression wave (UMp)

Conventional ILI UMp technology considers a probe with a fixed diameter perpendicular to the surface. The probe emits a UT pulse generating compression waves that travel through the coupling medium into the steel. When the inner pipe wall is reached part of the pulse is reflected (stand-off) and part of it is transmitted into the pipe wall. When the transmitted pulse reaches the external pipe wall part of it will be transmitted into the coating and the rest will be reflected to the sensor. Figure 2 provides a schematic of the technology setup.

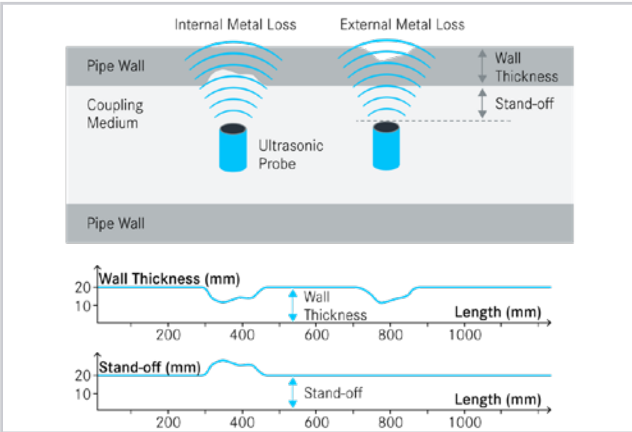


Figure 2 – Compression wave schematic

The detection of the metal loss is related to the reflective area available for the UT pulse to be reflected. Figure 3 provides a schematic illustrating the (A) reflective area of a metal loss when the diameter is ≥ 6 mm (0.236 in) which is the UMp minimum POD for external features, and (B) provides an example when the diameter is below minimum POD dimensions. (C) will be described later in the paper.

For additional information on compression waves refer to Reference 8 (Hennig & Lokwani, 2015).

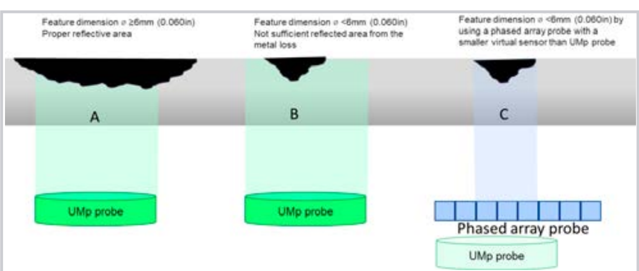


Figure 3– Schematic showing the reflective area of a metal loss anomaly when the feature minimum dimensions are within UMp specification (ø ≥6mm (0.060 in.))

Shear wave (UC)

The most common technique to inspect cracks using ultrasonics is called pulse-echo which uses a 45° shear wave in the steel. This technique relies on the probe having an incidence angle that will allow the UT beam to travel in the steel in a zigzag until it is reflected by an anomaly. The reflection is possible because of the corner echo or corner effect which is formed when the 45° shear wave interacts with an anomaly that is perpendicular to the surface. The magnitude of the reflection is related to the feature depth where the deeper the feature, the higher the amplitude reflected. This is considered a positive signal.

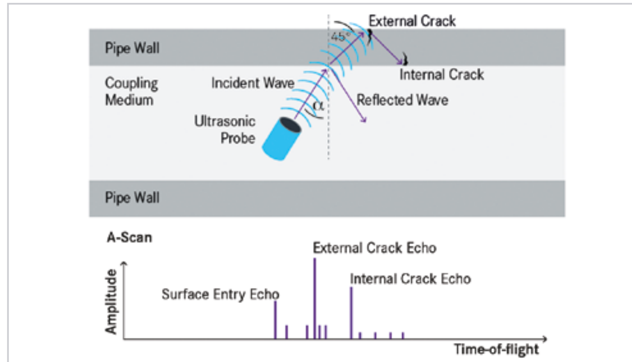


Figure 4 – Shear wave schematic in pulse-echo configuration

Figure 4 provides a schematic of the sensor arrangement required to generate the shear wave, and as with any measurement technique, pulse-echo has limitations when the features are not perpendicular to the surface and for SSC this is the case. The implications of corner echo and recorded amplitudes are described in detail in Reference 13 (Willems, Kopp, & Haro, 2017).

One additional crack depth technique that complements pulse-echo is pitch & catch. In this technique, the same sensors used for pulse-echo are re-arranged in the ILI tool facing each other in pairs. This technique relies on one sensor (transmission – TX) emitting the UT pulse and its counterpart the receiving sensor (RX) recording the pulse. In this technique, the energy transmitted from TX to RX is recorded. The higher the energy received the shallower the feature, therefore, in comparison to pulse-echo, this is a negative signal. Figure 5 provides a schematic of the arrangement of the probes to the pitch & catch technique.

The most common technique to inspect with cracks using ultrasonics is called pulse-echo

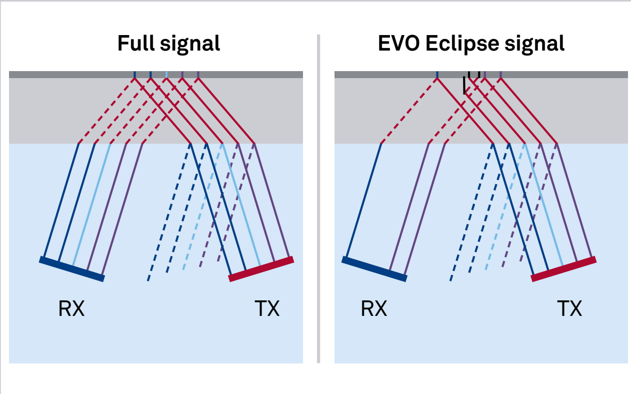


Figure 5 – Shear wave schematic in pitch & catch configuration

For additional information on pulse-echo and pitch & catch refer to Reference 7 (Guajardo & cho and pitch & catch refer to (Guajardo & Hennig, 2019).

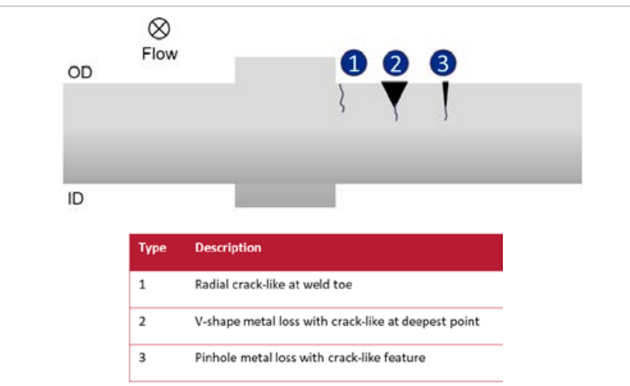


Figure 6 – Simulation schematic showing three types of simulated features

Ideally, because of the geometry from the SSC being narrow, the shear wave technology used for cracks should be ideal to detect this specific type of corrosion as suggested in (API RP 1160, 2019) table 3.

Simulations

The goal of the simulations was to understand three feature types and geometries **1.** crack-like at the toe of the weld, **2.** V-shape metal loss with crack-like at the deepest point, and **3.** pinhole metal loss with crack-like feature what would be the detection (POD), identification (POI), and depth sizing capabilities for those features using compression wave and shear wave in pulse-echo and pitch & catch configuration. The schematic of the features simulated is presented in Figure 6. To achieve this an extensive simulation campaign was performed using commercial software: EXTENDE's CIVA 2017 Non-Destructive Testing Simulation Software. For this paper only Type 1 and Type 2 results will be described as these have similar geometries to SSC.

The pipeline was simulated with a diameter of 20" and a nominal wall thickness of 6.35 mm (0.250 in). The sensors mimic the behavior of the ultrasonic crack detection (UC) sensor with a diameter of 15 mm (0.590 in). For the ultrasonic metal loss (UM) simulations, the probe diameter was 8 mm (0.314 in). The angle of incidence was chosen so it refracts 45° angle shear waves into steel. For the crack simulations pulse-echo and pitch & catch signals were evaluated.

Table 1 shows the overview of the parameters simulated in CIVA in agreement with Figure 7 schematic which provides the reference to the features. In total 112 simulations were performed.

Feature type	Parameter	Type 1	Type 2	Type 3
Metal loss (V-shape)	L (mm)	-	10, 20	2, 20
	W (mm)	-	10	2
	D (mm)	-	1.5	2
Crack-like	1 (mm)	20	10, 20	2, 20
	d (mm)	0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 6.4	0, 0.5, 1.0, 2.0	0, 0.5, 1,0, 2.0
Weld distance	r (mm)	0, 10, 20	5, 10, 20	1, 5, 10, 20
Total # of simulation	2802	24	24	64

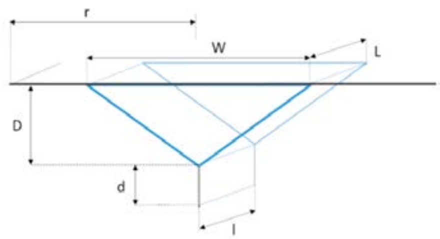
Table 1 – Parameters simulated in CIVA

Type 1 simulation results

Type 1 is a standard crack-like feature that is perpendicular to the pipe wall. The signal response agrees with the performance specification from the crack tools where detection, identification, and sizing are possible. The UMp technology does not have capabilities for a feature with this geometry as the width is too narrow as described in Figure 3 (B). This feature will emulate an SSC which has a metal loss width below the minimum POD diameter.

Type 2 simulation results

Type 2 represents a V-shape metal loss with a crack-like (SSC). For this feature Figure 8 provides an amplitude color code cross-section of the simulation where it is possible to observe the response from the pulse-echo shear wave. Figure 8 (A) provides a reference where no reflections are generated in base material as there is no feature. Figure 8 (B) simulates a 2 mm (0.079 in)



Flaw Parameter	Description
L	Metal loss length
W	Metal loss width
D	Metal loss depth
l	Crack-like length
d	Crack-like depth
r	Distance from weld toe to center of the flaw

Figure 7 – Feature parametrization assuming a V-shape metal loss with a crack

deep crack-like which provides amplitudes that are within reporting thresholds and in agreement with the pulse-echo and pitch & catch calculated depths. Figure 8 (C) simulates a metal loss with 10 mm (0.393 in) in diameter and a depth of 1.5 mm (0.060 in). For this feature, it can be observed that the edges of the metal loss and the deepest point from the metal loss provide reflections (yellow and green respectively) recorded by the crack sensors. These amplitudes are highlighted by the red arrows and are below analysis thresholds. The magnitude of these amplitudes will increase when the width (W) from the metal loss decreases as the edges become steeper and closer to 90° to the pipe wall. Figure 8 (D) provides the combination of metal loss and crack at the deepest point. The edges from the metal loss remain with the same amplitude, however, the amplitude reflected from the deepest point from the metal loss increased because of the crack (orange amplitudes). The crack was simulated at 2 mm (0.079 in) in depth, but the amplitudes obtained are equivalent to <1.0 mm (0.039 in) for pulse-echo. The reason for the underestimation is the lack of a 90° angle between the crack-like feature and the external surface because of the interaction with the metal loss. As the width (W) from the metal loss becomes narrower the amplitudes increase and it is possible to get proper depth estimations, but the calculated depth will be the combination of the metal loss and the crack.

To address this type of feature it is required to use UMp technology to properly detect, identify, and size the metal loss component. For the crack component, shear wave pulse-echo will not be sufficient, pitch & catch in combination with data integration of the UMp technology can provide indications of the presence of a crack in the metal loss and estimate its depth.

Simulations summary

Table 2 provides a summary of the simulation results for Type 1 and Type 2 features based on the varying characteristics in Table 1. For Type 1 features, UMp is not able to detect anything therefore the technology is omitted from the table.

From the simulations, it was observed that the most important parameter for an ultrasonic tool to detect, identify, and size SSC is the metal loss width (W). When the width is close to zero, crack technology is best to characterize this feature, however, as the width increases, the crack capabilities decrease, and the metal loss technology increases. The complimentary crack signal, pitch & catch, becomes relevant when the width (W) is greater than 6 mm (0.236 in) as that is the point where there would be possibilities to identify that two features are interacting, a metal loss and a crack-like, enabling individual feature sizing. Table 3 provides a summary of the capabilities of a UMp inspection in combination with a crack tool with pulse-echo and pitch & catch (Eclipse UCx) to detect and identify the features. The assessment of identification of a combined flaw (POI) is based on the width W of the

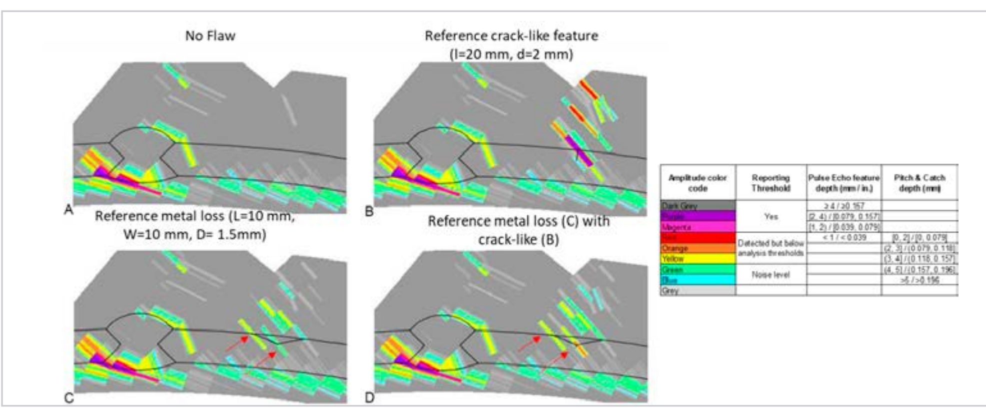


Figure 8 – Example of simulated cross-sections showing measured amplitudes in color code

	Type 1	Type 2		
Flaw type	UC	UMp	UC	Combined
POD	●	●	●	●
POI	●	●	○	●
Depth sizing	●	●	⎵	⎵

● *≥80%* ○ *between 50%-80%* ⎵ *≤50%*

Table 2 – Summary of the results from CIVA simulations varying the characteristics

metal loss: “yes” refers to POF terminology POI>90%, “maybe” POI between 50% and 90%, and “no” POI< 50%. The length of the combined flaw needs to be higher than 10 mm (0.393 in).

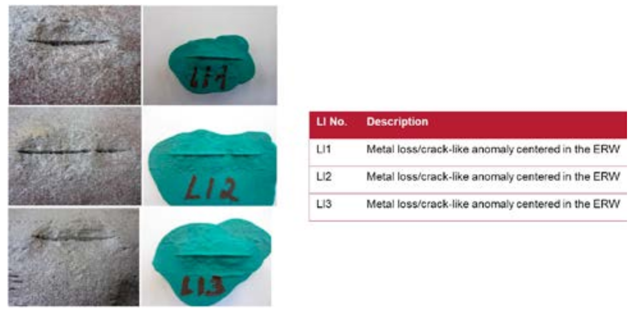


Figure 9 – Picture and imprint from linear indications in the test spool

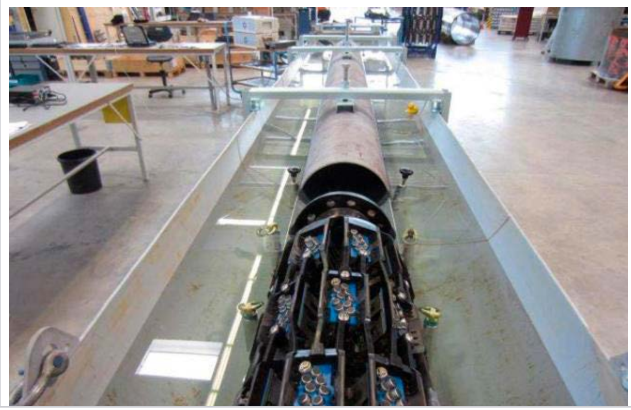


Figure 10 – UC test setup

Pull test

Pull tests on two 16" pipe samples of 1.22 m (4 ft.) and 2.45 m (8 ft.) length were performed. One of these pipe samples contains three metal loss anomalies with cracks. All anomalies are centered in the ERW long seam (Figure 9). The other pipe sample was used as a lead in/out. UC and UMp inspection tools were used for this test. The measured wall thickness of the spool was 7.6 mm (0.299 in).

During data recording, all pull tests were performed with an axial sampling of 0.75 mm (0.03 in) but later reprocessed to mimic 1.5 mm (0.06 in) and 3.0 mm (0.120 in) sampling distances for UC (Figure 10) and 1.5 mm (0.06 in) for UMp. Three pull tests were performed for the UMp technology and 5 for UC.

Pull test results

Data quality throughout the tests fulfilled the expectations from the UMp perspective recording a total of three pull tests. In comparison, the UC technology had to record five pull tests as two of the datasets showed 9dB lower amplitudes compared to the remaining three, therefore these will not be used for the evaluation.

Identified	UMp	Eclipse UCx	Combined or single anomalies
W ≤ 2 mm (≤0.079 in)	No	Yes, as crack-like	Combined
2 < W < 6 mm (0.079 < W < 0.236 in)	No	Maybe, as crack-like	Combined
6 ≤ W < 30 mm (0.236 < W < 1.18 in)	Yes, as metal loss	Maybe, as crack field	Maybe single anomalies depending on the depth integration
W ≥ 30 mm (≥1.18 in)	Yes, as metal loss	Maybe, as crack-like with metal loss indications	Single anomalies

Table 3 – Identification of one or two features based on the metal loss width (W) using UMp and Eclipse UCx

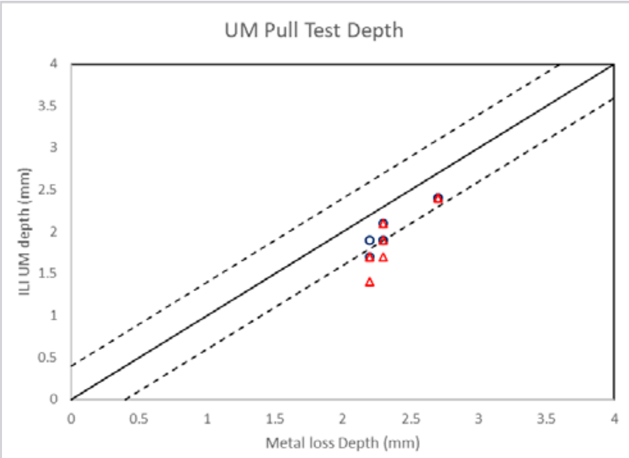


Figure 11 – UM Pull test results for 0.75 mm and 1.5 mm axial sampling

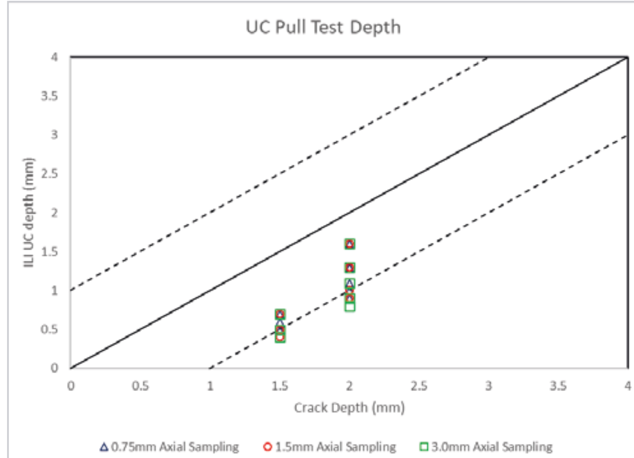


Figure 12 – UC Pull test results for 0.75 mm, 1.5 mm, and 3.0 mm axial sampling

UM pull test results

Metal loss tests showed consistent results for the three test features throughout the pull tests meeting the UMp performance specification. They also observed that different axial sampling distances showed no significant influence on the results as seen in Figure 11. Note that the metal loss depth used for the comparison against the ILI is only from the corrosion.

The lengths and widths of each one of the anomalies were consistent with the measured data and showed no significant influence based on the axial resolution.

UC pull test results

Regarding detection, the crack tool detected the anomalies with both clockwise (CW) and counterclockwise sensors (CCW), however, the amplitude was at the lower limit of the analysis thresholds. On average, the features are reflecting 6dB less than expected for the depth they have. Because of the latter, the feature depths show a systematic underestimation, and the performance specification is minimally achieved (Figure 12). Feature depth underestimation is aligned with the simulation results as there is no proper corner echo for the UT pulse to be reflected because of the metal loss geometry and the crack. These results align with the simulations and the description provided in Figure 8.

The UC tool uses the corner effect for detection, identification, and sizing. This works well if an anomaly is perpendicular to the surface see Figure 13 (a). In this case, a large portion of the UT beam is reflected to the sensor. In the pulse-echo depth technique, the strength of the signal is used for depth sizing. If an anomaly is not perpendicular to the surface the reflected signal strength depends on the angle between the anomaly and the pipe surface. Figure 13 (b) shows the reflection from a metal loss with a crack, in this example, the UT beam is scattered and reflected in all directions and only a part of the UT beam is reflected to the probe. Because of this, the reflected signal in pulse-echo is weaker than expected leading to an underestimation of the anomaly or worse, the anomaly being missed. Additional signals such as pitch & catch can aid with the detection, identification, and sizing as the pitch & catch signal will show time of flight variations from the back wall echo and amplitude drops caused by the shading of the metal loss and the crack-like. The ability to discriminate if the resulting depth with pitch & catch corresponds to the crack-like only or the combination of the metal loss and the crack will be determined by the width of the metal loss.

Figure 13 – (a) Feature perpendicular to the surface with proper corner echo, (b) UT beam being scattered because of the metal loss.

NDT Global

> This review considered the learnings from the simulations and pull tests

The axial sampling for crack runs shows a slight influence in the depth, the pull tests with smaller axial sampling showed 1-2 dB more amplitude than the ones with higher sampling such as 3.0 mm (0.120 in).

NDE correlation

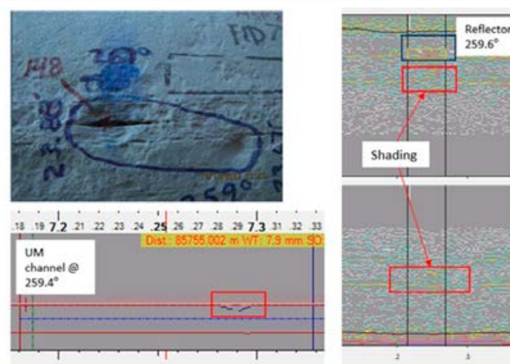
NDE comparison to ILI data

Field results from a historic 16" SSC susceptible pipeline was reviewed against ILI data collected from a wall thickness and crack detection tool. This review considered the learnings from the simulations and pull tests. The process consisted of a pattern analysis based on the NDE information and what was recorded by the ILI tools. An outcome classification matrix was subsequently proposed. With the aid of the matrix the recorded data sets were re-evaluated with the goal to identify the most severe external SSC in the line. The investigation was divided into two phases, phase 1 – reviewed reported metal loss anomalies in the long seam crack data. The goal was to refine and validate the attributes documented in the matrix and highlight anomalies where there might be a presence of cracks interacting with metal loss or metal loss was underestimated because of the reflective area. At the time of the paper, only phase 1 was completed. Phase 2 will use the crack data (UC) as a baseline to identify additional areas in the long seam where the patterns from the matrix were fulfilled and then review those locations in the UMp data lowering analysis thresholds as the metal loss widths will most likely be below minimum POD dimensions.

The tool types for this investigation are EVO 1.0 UMp for the metal loss features and EVO 1.0 UC. This crack tool is standard resolution and pulse-echo based only.

NDE example pattern analysis

Figure 14 compares the field photo of the SSC to the ILI data. The UMp inspection reported the indication as general corrosion. The UC tool detected a linear indication that coincides with the location of the infield feature. The shape of the SSC resembles a gouge or slotting and appears to be located at the center of the weld (Figure 14). Due to the linear shape of the SSC, the UC tool detected a linear indication projected at both the 0.5 and 1.5 skip (Figure 15). The reflector was projected at a lower time of flight (ToF) than the internal edge of the weld and the weld was shaded (Figure 14). The signal patterns contributed to the classification rules used for the next phase of the investigation.



Source	Feature ID	Feature type	duGW [m]	Length [mm]	Width [mm]	Depth [mm]	Rel. position
NDE		corrosion	7.21	64.01	28.45	3.76	isw
2018 UM	301176	corrosion	7.18	148	84	2.3	alw
2018 UC	5003532	possible SSC	7.22	54		0.6	alw

Figure 14 – GW 65110: NDE field photo, UM FID 301176, UC FID 5003532

Phase 1

For this phase of analysis, the UMp database was queried for all metal loss reported anomalies with a minimum length 25 mm (0.098 in) located at/in long weld. 1,289 corrosion features were selected for correlation to the UC ILI data. The classification matrix and ranking system for UC signals are presented in Table 4. Rank 1 represents a higher probability that the feature represents possible SSC, and the probabilities decrease as the rank number increases. The ranking only considers the B-Scan signals. Ranking is independent of the reported crack depth estimation of the feature.

Technology	Analysis Phase	Clue No.	B-Scan Patters	Rank 1	Rank 2	Rank 3
UC	1,2	1	• Linear indications close to the weld indications in ToF • Linear indication with lower ToF than weld indications • Linear indication at 0.5 skip • Amplitude equivalent to a depth >0.5mm (0.020 in.) and length of 2mm (0.080 in.) • Linear indication at similar circ. Position in CW and CCW sensors	Y	Y	N
UC	1,2	2	• Clue 1 patterns • Linear indication reflections at 1.5 skip for CW and/or CCW sensors with amplitude equivalent to 0.12mm in depth	Y	Maybe	N
UC	1,2	3	• Clue 1 patterns • Shading from the internal edge of the weld	Y	Maybe	Maybe
UC	1,2	4	• Linear indication detected at 0.5 and 1.5 skip from one side of the sensors	N	N	Y

Table 4 – Classification matrix and ranking

After the review of the features was completed the features that had NDEs were compared against the field results. In this exercise, some false positives were identified. This is an indication of the complexity of the feature geometry SSCs have, as the recorded data must not only be able to address the individual feature geometries (metal loss and crack) as standalone but address them together. As well, the technology needs to be able to manage any of the weld geometries interacting with the feature. The false positives also indicate that there can be guidelines to highlight potential areas of SSC but from the ILI perspective, an increased sample and proper NDE documentation are required to further refine the characterization.

Phase 2

This phase involves the re-analysis of the UC dataset. The long weld features will be reviewed and assessed based on the classification matrix (Table 4). The resulting features will be then re-assessed in the metal loss data. This phase was not completed at the time of the paper.

SSW assessment based on UT ILI inspections

Industry standards and regulations recognize SSC as a significant threat to pipeline integrity. PHMSA through the Code of Federal Regulations establishes in 49 CFR 195.452(h)(4) that; an SSC anomaly should be remedied immediately or scheduled no later than 180 days after the condition was discovered. The response time allowed depends on its depth, or in its severity based on a calculation of remaining strength. In this way, the assessment becomes a key stage in the integrity management of SSC anomalies (PHMSA, 2023).

Immediate integrity

From an integrity point of view, SSC anomalies require detailed analysis, the problem is not limited to bond line corrosion susceptibility, mechanically this type of material exhibits very low levels of toughness. In combination with the high-stress concentration generated due to the sharp geometry or presence of cracks at the root of the cavity, the rupture failure mechanism is favored at very low-stress levels, even as low as 5% SMYS (Rosenfeld & Fassett, 2013).

(API RP 1160, 2019) recommended practice and the (API 579-1/ASME FFS-1, 2021) standard agree that these types of anomalies should be treated as crack-like. While the API 1176 standard states that although SSC is not a crack, it does produce mechanical responses like a crack. Therefore, crack and crack-like anomaly models are applicable for the assessment of SSC anomalies. API RP 1160 even suggests the Modified Log-Secant and API 579 models; however, it opens the door to any other operator-selected models such as CorLAS™ or MAT-8.

SSC anomalies can include secondary cracking at the root of the cavity (Type 2 feature from simulation) attributed to fatigue, this cracking is more likely to be detected and sized by shear wave ultrasonic technology UC. In terms of integrity assessment UC technology provides the most accurate measurement of the length and depth of the secondary anomaly allowing its proper assessment. When the only data set available is the UMp, the assessment is accompanied by uncertainties regarding the presence and dimensions of secondary cracking. The integrity assessment should incorporate security factors that tend to have very conservative results.

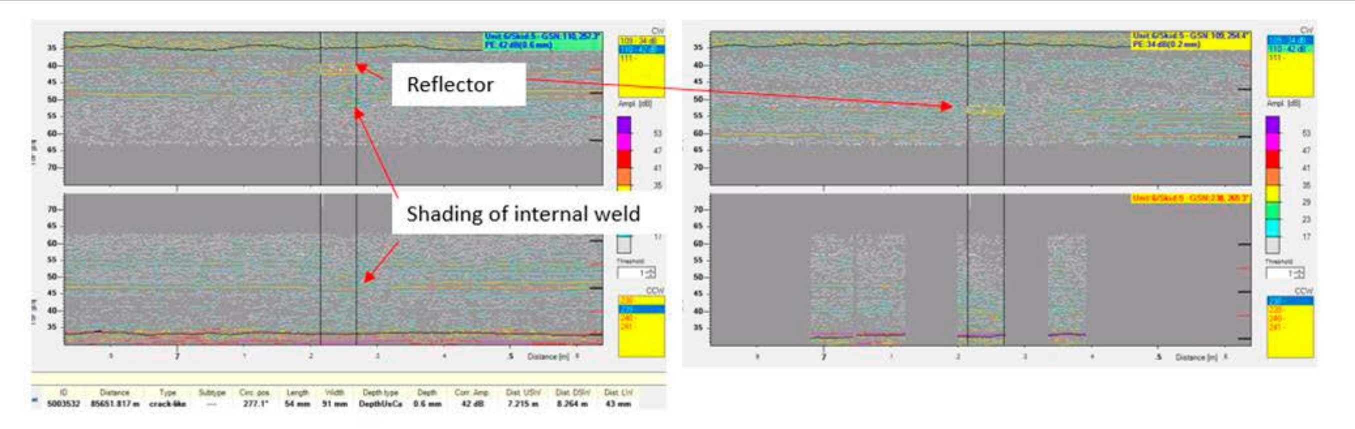


Figure 15 – B-Scans of the anomaly. To the left the reflector at the 0.5 skip and to the right at the 1.5 skip.

Future integrity

The future integrity of SSC anomalies is based on the estimation of anomaly growth, in this regard the following two scenarios should be considered:

- Scenario 1 — SSC anomalies with secondary cracking, the growth is derived by the growth of the crack in the root of the cavity. The growth and remaining life are estimated using fatigue growth methodologies, accompanied by appropriate re-inspection intervals.
- Scenario 2 — SSC without secondary cracking, the growth is controlled by the corrosion phenomenon.

$$\alpha = \frac{b_0}{h_1} = 1 + \frac{a}{h_1}$$

Where:
α = grooving factor
b_0 = wall thickness without metal loss
h_1 = metal loss since surface without metal loss to surface with metal loss
a = depth of SSC cavity

To address scenario 1, (API RP 1176, 2016) describes fatigue life assessment methodologies, which are based on methods such as the Paris' Law and the Miners Rule, where pressure cycles per operation are accounted for.

The treatment of scenario 2 cases is based on assuming that the corrosion rate in SSC anomalies is greater than the rate in base metal. Some authors suggest that the corrosion rate in SSC areas is 2 to 4 times greater than the corrosion rate in the base metal (Reference 6 Groeneveld, Davis, & Williams, 1991). For an initial consideration, it is recommended to use a multiplying factor of 2 times the corrosion rate of the base metal (Reference 5 Dr. Nestleroth & Rosenfeld, 2020)

> **SSC can be considered a complex feature as it may have the interaction of both crack and metal loss features.**

Ultrasonic inline inspection, UMp, and UC, can provide the input parameters to characterize the SSC anomalies. Because of this, the multiplying factor to estimate the corrosion rate can be calculated using the "grooving factor" approach according to API RP 1160 (see Equation 1). The immediate and future integrity assessment of SSC anomalies always requires detailed knowledge of the detection capabilities and uncertainties associated with the inspection technology to take applicable safety considerations and factors.

	Main Technology			Deliverables Rank 3	
Metal loss Width Threshold	**POD**	**POI**	**Depth Sizing**	**Reported feature as:**	**Reported depth**
W ≤ 2mm (≤0.079 in.)	UC	UC	UC	Crack-like	Combined
2 < W < 6mm (0.079 < W < 0.236 in)	UC	UC	UC (underestimation)	Crack-like	Combined
6 ≤ W < 30mm (0.236 < W < 1.18 in)	UMp	UMp	UMp	Metal loss	Metal loss with possibility to report crack depth using pitch & catch
W ≥ 30mm (≥1.18 in)	UMp + UC	UMp + UC	UMp + UC	Metal loss and crack-like	Metal loss and crack-like

Table 5 – UT detection, identification and sizing capabilities by metal loss width and main technology

Conclusions

SSC can be considered a complex feature as it may have the interaction of both crack and metal loss features.

The main attribute from the SSC that will influence the POD, POI, and depth accuracy is the metal loss width. Based on this attribute the crack or metal loss data sets will serve as the main technology to characterize the features. This implies that it is required to retrieve both data sets and perform a two-way data integration/correlation. This will allow the analysts to get an idea of the SSC geometry and if there is an interaction between a metal loss and a crack.

Table 5 summarizes the capabilities of UT technology regarding SSC. This table presents which is the main technology and as a deliverable what can be provided to pipeline operators.

Technical recommendations

ILI service

- Tool selection: UT metal loss and crack with pitch & catch capabilities are recommended. The ILI tools should aim for the highest circumferential resolution available for each technology.
- Tool setting: 1.5 mm (0.060 in) axial sampling for both crack and metal loss data sets.
- Combined analysis and data integration performing a two-way data comparison.
- Information sharing from the pipeline operator (i.e., NDEs).

ILI future improvement

NDE dig protocol to document SSC where the metal loss width is a key attribute for further ILI research. As well as the use of alternative validation methods as the Linear Polarization Resistance (LPR) suggested by (Beavers, Brossia, & Denzine, 2014) can allow ILI companies to further perform data pattern analysis to identify susceptible pipe joints and/or early detection of SSC.

ILI is based on phased array where the virtual sensors are smaller in width. This will allow to improve the reflective area from the UT metal loss data and potentially improve the minimum POD diameter. Refer to Figure 3 (C) schematic.

References

[1] API 579-1/ASME FFS-1. (2021, December). Fitness for Service. American Petroleum Institute & American Society of Mechanical Engineers.

[2] API RP 1160. (2019, February). Managing System Integrity for Hazardous Liquid Pipelines. API Recommended Practice 1160. American Petroleum Institute.

[3] API RP 1176. (2016, 07 01). Recommended Practice for Assessment and Management of Cracking in Pipelines. American Petroleum Institute.

[4] Beavers, J., Brossia, C., & Denzine, R. (2014). Development of Selective Seam Weld Corrosion Test Method. International Pipeline Conference. Calgary: ASME.

[5] Dr. Nestleroth, J. B., & Rosenfeld, M. J. (2020). Changes to In-Line Inspection Approaches to Consider with Changing Regulations. PPIM. Houston: Clarion Technical Conferences.

[6] Groeneveld, T., Davis, G. O., & Williams, D. N. (1991). Evaluations of the Susceptibilities of Electric Welded Pipe to Selective Seam Weld Corrosion. Eight Biennial Joint Technical Meeting Online Pipe Research. Edinburgh: EPRG.

[7] Guajardo, R., & Hennig, T. (2019). High-Resolution Inspections for Crack Detection: The Next Level of Accuracy. PPIM. Houston: Clarion Technical Conferences.

[8] Hennig, T., & Lokwani, G. (2015). EVO Series 1.0 -Latest Generation of UT Crack and Corrosion Tools For High-Speed Pipeline Inspection. Abu Dhabi International Petroleum Exhibition and Conference. Abu Dhabi: Society of Petroleum Engineers.

[9] PHMSA. (2011, 12 01). Fact Sheet: Selective Seam Corrosion (SSC). Retrieved from U.S. Department of Transportation: https://primis.phmsa.dot.gov/comm/FactSheets/FSSelectiveSeamCorrosion.htm

[10] PHMSA. (2023, 01 05). CFR 49 195.452 Pipeline integrity management in high consequence areas. Retrieved from Code of Federal Regulations: https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-D/part-195/subpart-F/subject-group-ECFRbe0c227f191b36d

[11] Ritchie, P. R. (2020). The Susceptibility of Electric Resistance Welded Line Pipe Steel to Selective Seam. Master Thesis. Ohio, USA: Ohio State University.

[12] Rosenfeld, M., & Fassett, R. (2013). Study of Pipelines that Ruptured While Operating at a Hoop Stress Below 30% SMYS. PPIM. Houston: Clarion Technical Conferences.

[13] Willems, H., Kopp, G., & Haro, V. (2017). Sizing Crack Indications from Ultrasonic ILI: Challenges and Options. Pipeline Technology Conference. Berlin: Pipeline Technology Journey.

[14] J. A. Beavers, C. S. Brossia, and R. A. Denzine (2014), "Development of Selective Seam Weld Corrosion Test Method", International Pipeline Conference IPC, Calgary, Alberta, Canada.

This paper was published at the 2023 Pipeline Pigging and Integrity Management conference.
© Clarion Technical Conferences and the authors. All rights reserved. Reprinted with permission.

Learn More

For more information about NDT Global and our inline diagnostics solutions, visit www.ndt-global.com

CIM-102-en Rev 1.0, 02/2024, © 2024 NDT Global