# CRAs – inspected

**Herbert Willems, NDT Global, Germany, explores corrosion and cracking in corrosion resistant alloys that are used in the oil and gas pipeline industry.**

The use of corrosion resistant alloys (CRA) is increasing in the pipeline industry. Although, CRA clad and lined pipes are less expensive than solid CRA pipes, their main advantage consists of a balance between good mechanical properties of the carbon steel carrier pipe and the corrosion resistance of the internal CRA layer.

Clad pipes consist of an internal CRA layer, which is metallurgically bonded to the backing carbon steel. Different manufacturing processes (e.g. hot rolling or weld overlay) are used to bond the CRA layer to the carbon steel. In contrast to clad pipes, lined pipes have a CRA lining that is mechanically bonded to the carrier pipe.

Figure 1. Cross section of a CRA lined pipe.

Figure 2. Example of wrinkling and buckling in a CRA lined pipe.

## Corrosion in CRA pipes

Highly corrosive environments increase pipeline vulnerability to corrosion attack. This has considerably increased with the exploration of new oil and gas fields, higher levels of water cut and concentration of $CO_2$ and $H_2S$ and the higher temperatures and pressures of deep sea exploration.

CRA materials are used to prevent corrosion, especially in offshore applications. Nevertheless, under certain conditions, severe corrosion processes may develop in such pipes. The effectiveness of the corrosion resistance depends on the selection of the proper alloy for the expected operational conditions. Manufacturing related anomalies and imperfections of the CRA pipes can also lead to corrosion development. Furthermore, unfavourable handling during transportation, storage and installation can significantly impair the corrosion resistance characteristics.

In Nickel Institute's 2011 'Corrosion Resistant Alloys (CRAs) in the oil and gas industry – selection guidelines update', Bruce D. Craig and Liane M. Smith explain a common factor behind corrosion development: "... a CRA selection method that is not recommended but is often used, is to select a CRA that is readily available or most economical, without regard to its corrosion resistance in the intended environment. Misapplication of CRAs is becoming more common for this reason and has resulted in corrosion and cracking problems of the inappropriately selected alloys."

In addition to a stationary non-destructive testing (NDT) for quality assurance during the manufacturing process, inline inspection (ILI) of pipelines is essential in order to ensure the integrity of the CRA material and, thus, the pipeline after commissioning (baseline survey) and its operational life.

### Improved corrosion resistance

CRA pipes offer improved corrosion resistance in pipelines while introducing new challenges for ILI. For a wide range of CRAs, pitting dimensions are smaller compared to carbon steel pipe and are well below detection limits of low-resolution inspection tools.

The following are a few examples of CRA pipe corrosion:

- Crevice corrosion: intensive localised electrochemical corrosion that occurs within crevices when in contact with a corrosive fluid.
- Pitting corrosion: highly localised attack that eventually may result in leaks in the metal.
- Galvanic corrosion: when two dissimilar metals/materials come into electrical contact with one another, causing corrosion.
- Stress corrosion: occurs in metal that is subject to both stress and a corrosive environment, often starting at 'stress risers'.

## Inspection of CRA pipes

The ultrasonic propagation and attenuation in solid CRA pipes (e.g. duplex stainless steel or 13% Cr steel) is similar to those in carbon steel. Therefore, the ultrasonic (UT) ILI tool performance (detection and sizing capabilities) valid for carbon steel is also valid for most solid CRA pipes.

As CRA cladded pipes are made of metallurgically-bonded plates with a seam weld, the internal surface is typically quite smooth and poses no limitations with regard to UT inspection. Disbonding between both layers can be detected and sized with high accuracy. Pipes constructed with internal cladding, produced by orbital or longitudinal welding can also be inspected by UT tools. Depending on the waviness of the weld overlay, the data quality can be affected.

In this case of lined pipe, the pipe has a CRA inliner that is mechanically bonded to the carrier pipe, such as by hydraulic expansion. UT tools can only inspect the inner layer, as ultrasonic pulses cannot propagate through this type of bonding.

As far as magnetic flux leakage (MFL) technology is concerned, austenitic stainless steels and high nickle alloys are not magnetisable and, therefore, they cannot be inspected with MFL tools. Only the ferritic carrier pipe can be inspected. However, the actual combination of the ferritic carrier pipe and austenitic cladding has to be taken into account.

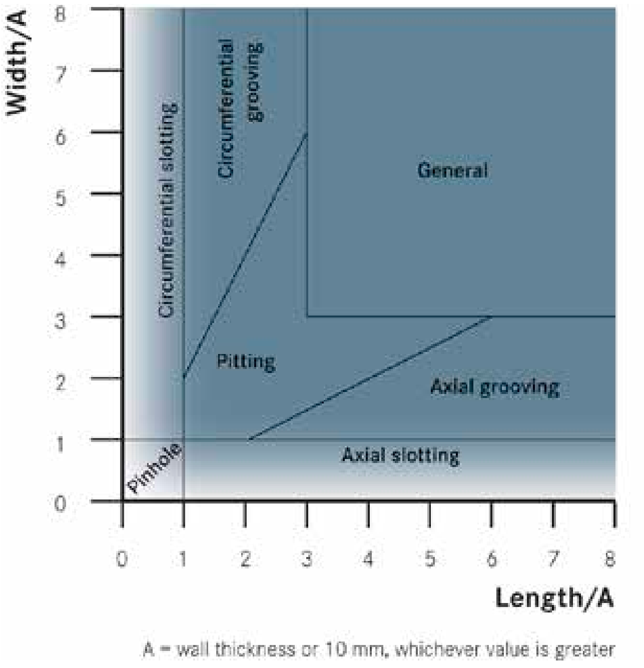


Figure 3. Metal loss feature classification according to POF and API 1163.

## Case study: girth weld cracking in CRA pipe

A new gas pipeline, operated by one of the largest gas processing companies in the world, experienced a failure. The 16 in. pipeline was commissioned in 2013 and had only been occasionally used prior to the incident. The failure consisted of circumferential cracking in the girth weld at a pipe bend. The pipeline has internal 3 mm (0.12 in.) stainless steel CRA cladding. When inspecting a CRA pipeline, with complex features the right technology must be selected to ensure success.

A previously completed expert report, identified circumferential cracking in the girth weld at a bend. The girth weld root had been made with a ferritic weld consumable, instead of an austenitic weld consumable. Given that this was a new line, a decision was taken to inspect the other joints. MFL technology was not suitable for identification of these types of features and was not suitable for use with cladded pipes due to the non-magnetic cladding.

Due to the importance of this pipeline, a sequence of two inspection runs was selected. The first used the NDT Global ultrasonic circumferential crack (UCc) tool to address the detection of circumferential cracks and crack-like anomalies within base material, girth welds and cladding. The second inspection run used the ultrasonic metal loss with pitting resolution (UMp) tool to detect metal loss anomalies (e.g. pitting) within base material and cladding.

The crack detection run found crack-like weld anomalies, which were independently verified by Bureau Veritas. Inspection performance was confirmed to be within the specification as per guidance in API 1163. The crack-like defects were only 1 mm (0.04 in.) deep, but were successfully identified by the ILI.

## Case study: lack of fusion between inner and outer layer of cladded pipe

A baseline inspection was required for an offshore deepwater pipeline (up to 2000 m or 6500 ft), flowline and riser systems. This baseline inspection is part of this customer's standard practice, providing a blueprint of the pipeline documenting the status (wall thickness, crack-like features) of the pipeline before starting operation.

The riser system on this line was constructed using cladded steel piping. To accurately inspect the complete line, an advanced ultrasonic tool was selected for high resolution metal loss inspection.

Previous inspections indicated a lack of fusion (disbondment) between the inner layer of stainless steel 3 mm (0.12 in.) and external carbon steel 15 mm (0.59 in.) risers. As this is a metallurgical bonded clad pipe the UT tools can only inspect the internal metal loss in the inner layer.

The pipeline characteristics suggested that this is most likely a manufacturing related defect, which has resulted in corrosion. Seam weld anomalies and disbondment are the main types of manufacturing related anomalies detected in this type of clad pipe. Corrosion pits with very small diameter were also detected both in the base material and in the girth welds.

For this project, the NDT Global UMp tool was used, which gives a true high definition picture of the pipeline wall thickness condition, including pinholes and pitting, gouging, disbonding (lack of fusion) or mid-wall flaws such as laminations.

## Conclusion

When selecting a CRA clad or lined pipe, it is essential that the selection is based on the environment and medium that the pipeline will be exposed to. Although not all, many anomalies are a result of the original selection decision being influenced by availability or cost.

CRAs offer improved corrosion resistance in pipelines, but also pose new challenges for ILI. For a wide range of CRAs, pitting dimensions are smaller than for carbon steel pipe and are well below the detection limits of low resolution inspection tools.

Both the inner CRA and the outer carbon steel need to be inspected. Cross-contamination must be avoided to maintain the CRA corrosion resistance, and no steel part of the tool must be in direct contact with the pipes clad.

Deep pits and severe weld anomalies are sometimes detected in CRA pipes, even before the pipeline is put into service. Therefore, a baseline ILI survey before the pipeline enters operation is highly recommended in order to have a precise picture of the pipeline state from the onset.