Internal Weld Scanning

Co Authors:

Dr Tim Clarke
Dr Richard Gooch

Optical Metrology Services Ltd

1 Abstract

This paper addresses the up and coming needs of projects to ensure that weld root profiles are within specification. The context of the requirement is outlined for such applications as internally coated pipe, CRA clad pipes, carbon steel pipes and manifolds. A new service has been introduced into the market which addresses all of the stringent requirements of the industry. The operation of the weld scanning tool is described in this paper and the way in which it is applied is discussed in different project settings.

2 Introduction

There are a number of reasons why scanning the region of the weld is required:

2.1 Application No 1. Internal pipe coatings checks

For pipes that are internally coated it is required that the cut back area in the region of the weld must be coated before the pipes are lowered into the sea from a lay barge. Tools exist which are capable of shot blasting the weld area and applying coating material in this region several stations down the firing line. The application of a coating is subject to certain constraints. Any feature of a weld which is sharp or projects above a certain height could cause a coating flaw at that location. In addition features projecting from the pipe wall could render the coating vulnerable to damage during a future pigging process. Any coating flaw or subsequent damage would be likely to cause a corrosion site and shorten the length of service of a pipe.

Figure 1. Before and after coating of pipes

2.2 Application No 2. Checking CRA Clad welds are within specification

CRA clad pipes have very stringent requirements regarding the quality of every weld. Essentially welds must be defect free. What this means in practice is that the weld profile must be checked to ensure it meets these requirements. For example there can be no lack of penetration at any location. If the specification is not met then the defect may result in a corrosion site and eventually lead to an in-service failure. Inconel welding is typically more difficult than Carbon steel welding; the welding process also takes longer. As a consequence, early detection of a root weld defect is necessary to avoid a costly cut out. Typical requirements for clad pipe welds are:

- Root penetration : max 1.5mm
- Root concavity : max depth 1.5mm (as measured by calibrated laser) maximum length 25mm over any 150mm length
- Cracks : Not acceptable
- Lack of penetration : Not acceptable
- Lack of root fusion : Not acceptable
- Surface porosity / pinholes : Not acceptable
- Burn-through : Not acceptable
- Discolouration : Light tinges only as established by qualification program
- Oxidation / Coking : Not acceptable

The following figure is of a crater in a CRA clad pipe weld which would be out of specification and a possible corrosion site.

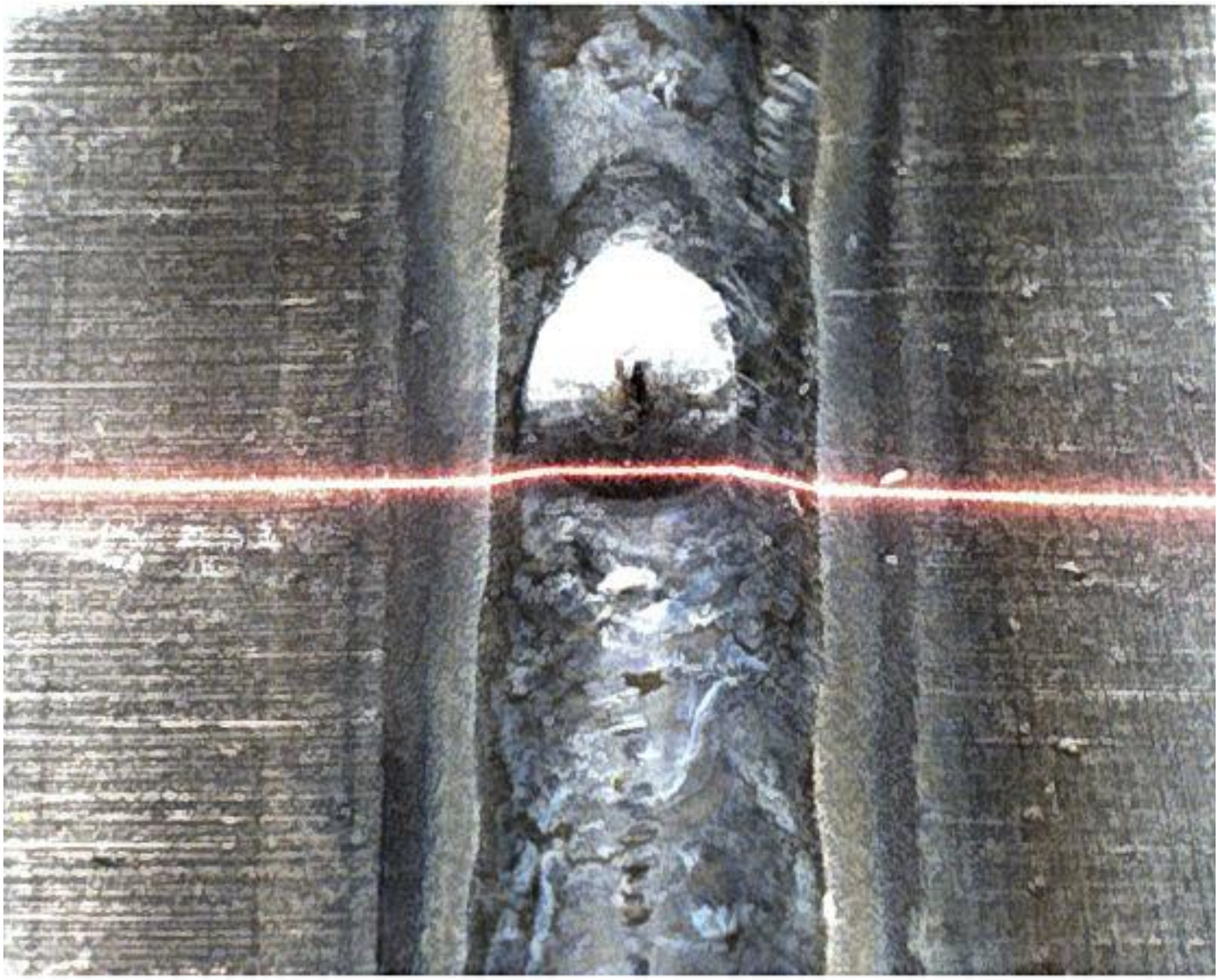


Figure 2. Example of a feature on a CRA Clad pipe

2.3 Application No 3. Prolonging the fatigue life of a pipeline

Excellent welds are critical to the fatigue life of a pipeline. This is a particularly important for fatigue sensitive pipes. It is an accepted engineering fact that a HiLo between the interior faces of a girth weld should be less than 0.5 mm to ensure that stress concentrations in the region of the weld do not lead to a stress fracture. The weld profile is also critically important in this region. The following figure illustrates a typical sample that has been subject to testing over many cycles to assess fatigue life. The purpose of the scanning of the pipes in this case was to relate the geometry of the pipe weld to the fatigue testing results.

Figure 3. A typical fatigue sample ready for assessment

2.4 Application No 4. Checking critical joints are welded correctly

Structures such as PLETs, PLEMs, manifolds and other spool pieces are subject to high pressure and can have complex internal geometry that is difficult to interpret using traditional inspection methodologies. For example internal bevels can be difficult to interpret using video inspection or AUT. Nevertheless, pipes of this type must be checked to ensure there are no welding defects. Weld scanning is an ideal solution, allowing the inspector to see, measure, and quantify all details of the root weld.

Figure 4. A typical weld from a manifold spool piece

2.5 Application No 5. Quality control of spiral weld

A common method of cladding specialist pipes is to spirally weld layers of Inconel onto the internal surface of a pipe. In order to obtain the correct level of purity of cladding it is normal to do this in two passes. If the welding process is not consistent it is possible that the welds will not overlap properly. This could cause a corrosion site and for this reason pipes are needed to be critically assessed to ensure that the weld meets the specification.

Figure 5. Clad welding of a pipe

2.6 Review

As a consequence of the critical nature of the five application areas it will often be required that a visual inspection and a Laser based measurement of internal girth welds is undertaken. The next section illustrates the tools that have been developed in order to ensure that welds can be comprehensively inspected to ensure that the specification is met.

3 Measuring Equipment

3.1 Overview

Three tools are available from OMS to address all pipe sizes from about 150 mm to 1000 mm. These tools have been used in a number of projects for major clients. The general arrangement of a tool is illustrated in the schematic in figure 6.

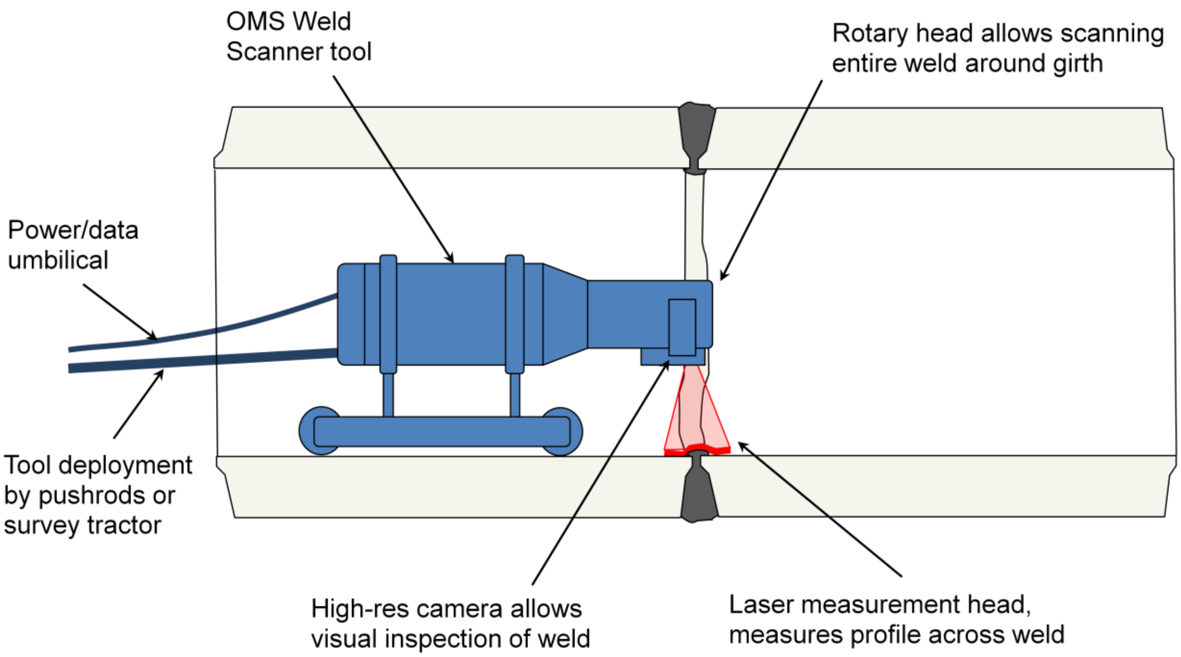


Figure 6. Schematic of internal weld scanning system

3.2 Large pipe tool

The Large Range OMS weld scanner covers the range 450 to 1000 mm and is illustrated in figure 7.

Figure 7. Large diameter pipe measurement system for pipes ID of 450 to 1000 mm

This tool consists of a Laser and camera head which can be configured to any ID size within the diameter range of the tool.

3.3 Medium range tool

The medium range tool covers the range from 200 mm to 400 mm and is illustrated in figure 8.

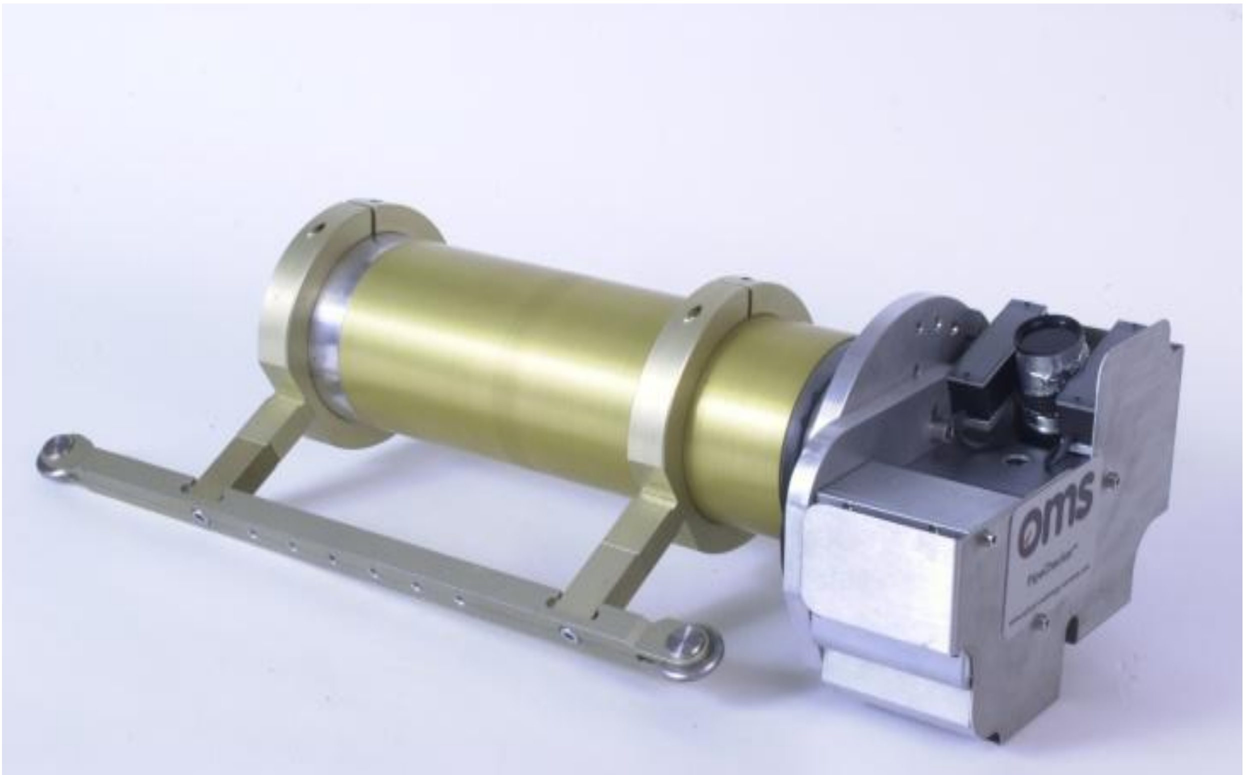


Figure 8. Medium diameter pipe measurement system for pipe ID of 200 – 400 mm

3.4 Small range tool

The third tool operates in a different way to the previous two systems in that it does not have fan beam laser striper but an alternative technology which scans the weld root in any number of cross sectional slices one at a time. The range of this device is from 100 to 200 mm and is shown being used in figure 9.

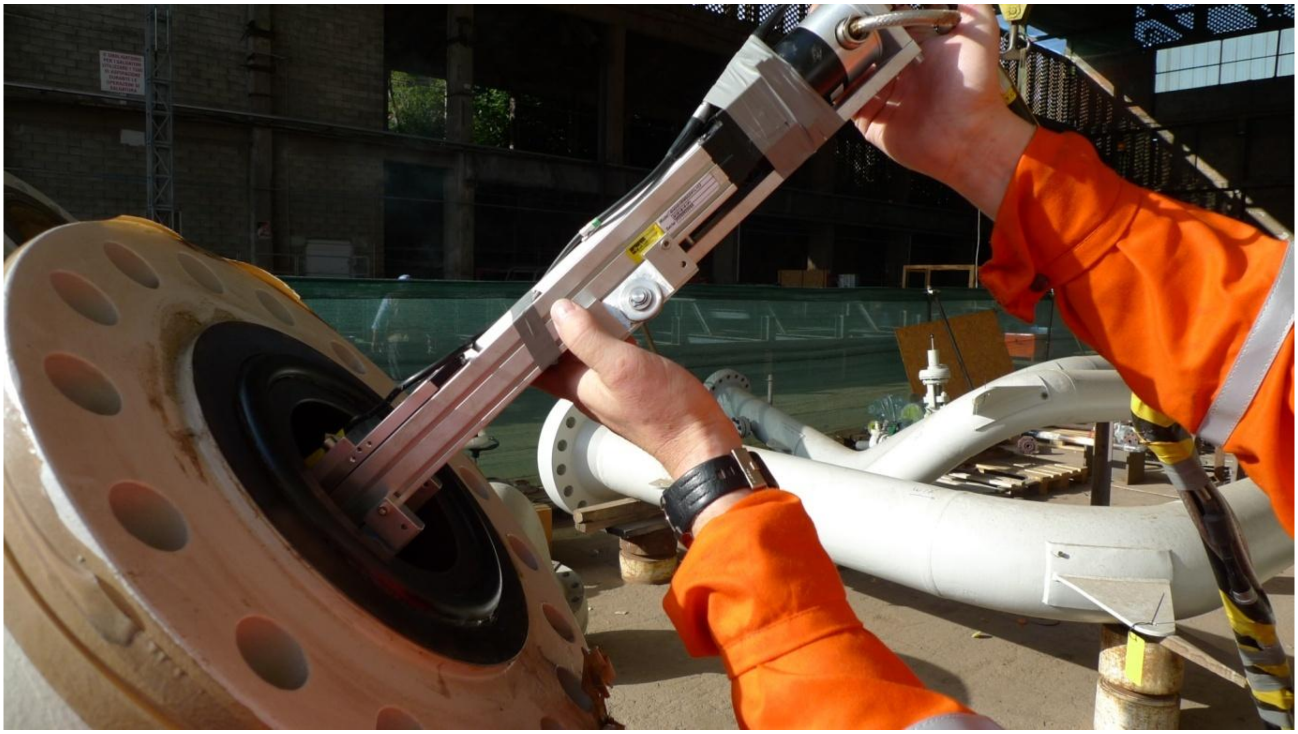


Figure 9. Small diameter pipe measurement system

3.5 Specification

The following table (1) is a general specification for the weld scanning tools

Characteristics	Description
Laser stripe	25 mm long x 1 mm wide, accuracy 0.1 mm.
Camera	High quality colour digital camera which takes images of 25 x 25 mm in size. Image size 640 x 480. Larger images captured if required
No of images per scan	20-50% overlap between images, up to 256 images per scan
No of cross sectional profiles	Up to 4000, typically 1 mm apart for high density scans to any other user selected distance
Time to scan	Large system (approx 1 minute), medium system (approx 30 seconds, small system (10 seconds per cross section).
Analysis	Within a period of less than two minutes for initial PASS/FAIL assessment and within five minutes for confirmation, documentation and archival.

Table 1. Characteristics of the Weld Scanning Tools

4 Examples of tools in use

4.1 Defect assessment prior to internal coating

The process of offshore internal field joint coating is critically dependent upon having good weld root profiles in order to provide coating to the level of quality required for the project. Any features which stand up from the pipe wall beyond a critical amount are likely to cause the coating to be thin at this location. Coating “Holiday” detection can identify flaws but this usually results in the need for the cut-out of a section of pipe, which is a significant issue as “Holiday” detection is carried out at one of the last stations in the firing line. Another pernicious issue with internal protrusions that are coated is that a pigging vehicle can subsequently puncture the thin coating on the protruding feature. Examples of how these features are created are:

- Line up clamp gaps
- Line up clamps not fitting pipe contour properly
- Excessive HiLo
- Large vertical edges
- Welding debris

Welding pipes together is a process which is not completely controlled otherwise perfect welds would be created each and every time. There are a number of factors that can result in welds having features which would be a problem to coating or to a pigging operation. The following figure illustrates a feature left in a pipe due to weld material that has been able to get between the copper backing shoes of a line up clamp.

Figure 10. Example of a feature caused by penetration through a pair of line up clamp shoes

The following figure (11) shows how the height of this feature, which is difficult to determine visually, but can easily be measured using the Laser scanner and the software viewer. The profile and contours of the feature can be fully determined.

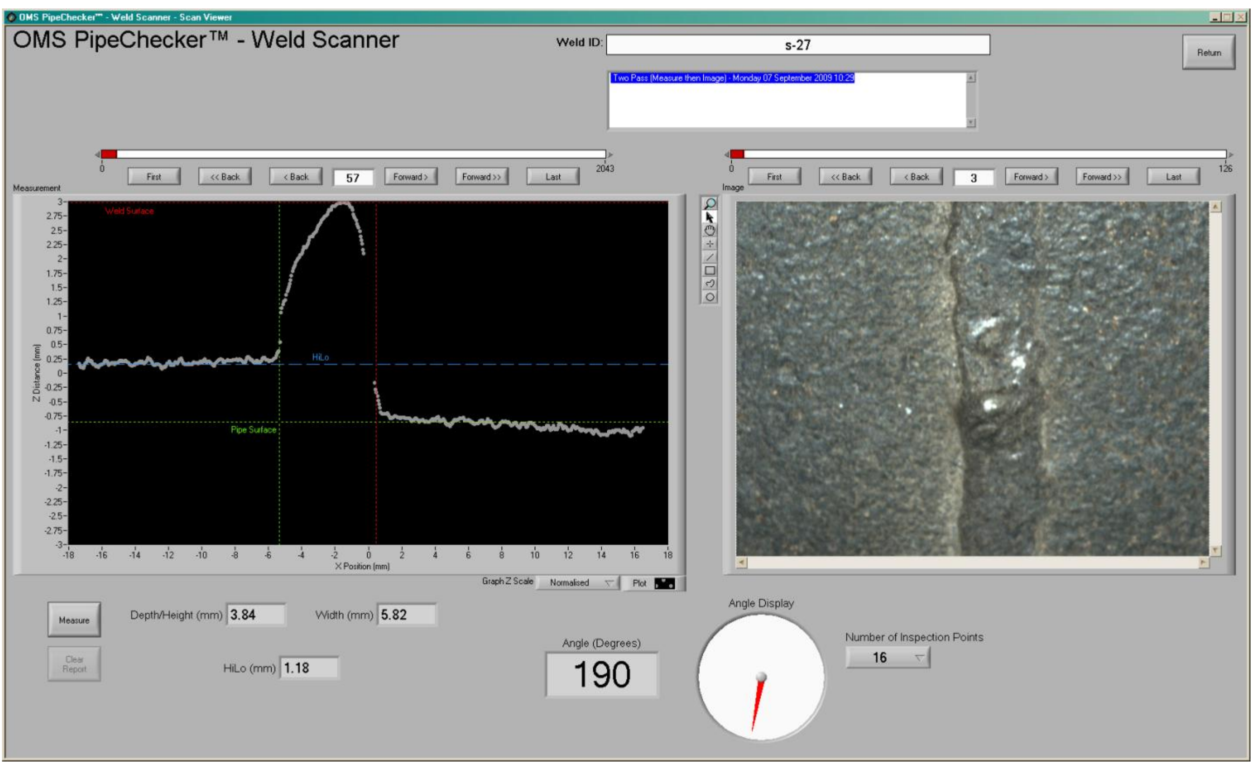


Figure 11. Software view of the weld on the right and the measurement data on the left

In the software screenshot in figure 11 the middle feature in the right hand side image is caused by a gap in the line up clamp copper backing shoes. It is not easy to estimate its height above the pipe surface or even whether there is any HiLo difference between the pipes. The graph of the measurements of the weld profile on the left hand side provides information about the weld bead which is easy to interpret. There is a HiLo difference between the two sides of the weld of 1.18 mm and the height of the weld bead from the lowest side is 3.84 mm. In this case the feature would be uncoatable and could cause either a cut out when the pipe is coated resulting in a 12-16 hour delay on a vessel laying the pipe or a 1-2 hour delay if some remedial work is required.

4.2 CRA clad weld assessment

CRA clad welds are a critical part of the integrity of a pipeline where corrosive substances are being transported. Any defect can cause a dilution of the CRA material, or a path to the carbon steel. Any such defect could result in a corrosion site. The following figure (12) illustrates how the weld scanner is able to provide the ultimate in assessment of whether the weld is in specification or not.

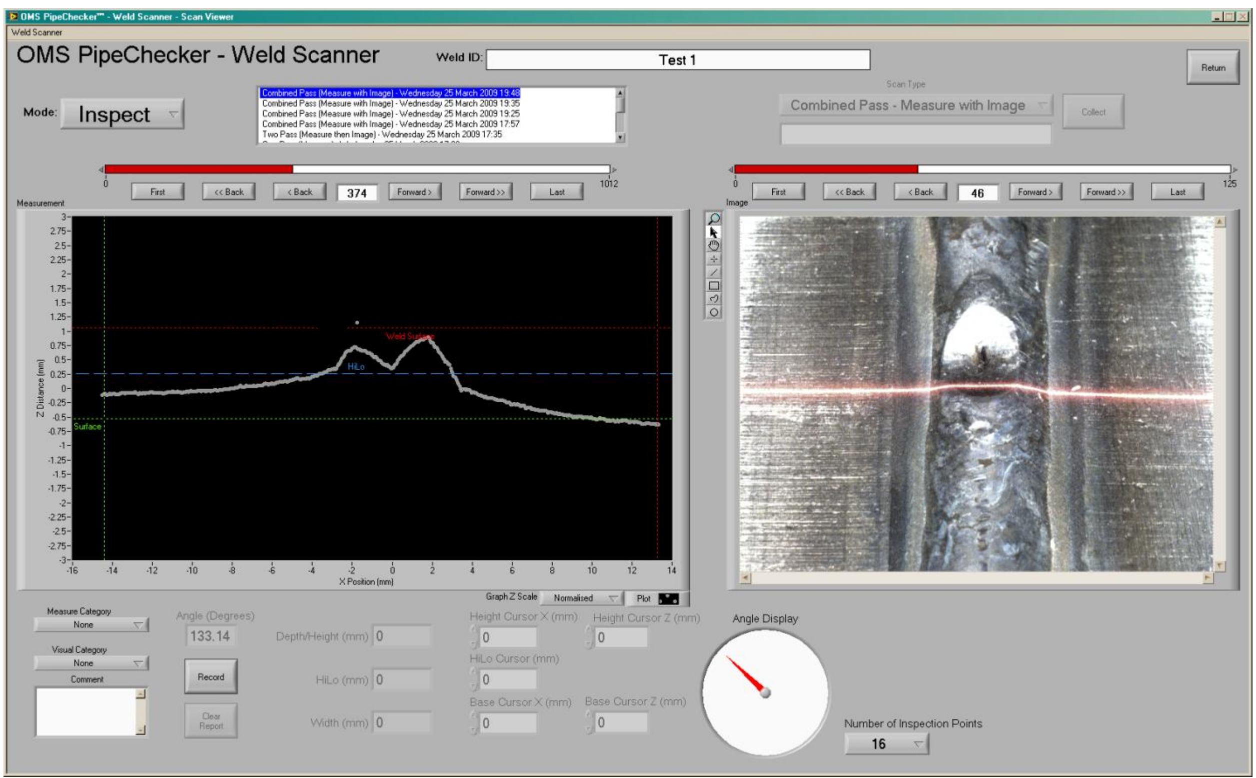


Figure 12. Visualisation software with the defect and the defect cross section

This system is also suitable to assess the discolouration/oxidation of the weld as required by standards such as NORSOK M-601.

4.3 Carbon Steel weld assessment

Assessment of the root profile of fatigue sensitive pipes can provide valuable information regarding the quality of a weld which could prove vital to the fatigue life of a steel catenary riser. The following figure (13) illustrates the information that can be derived from the measurement of a carbon steel weld.

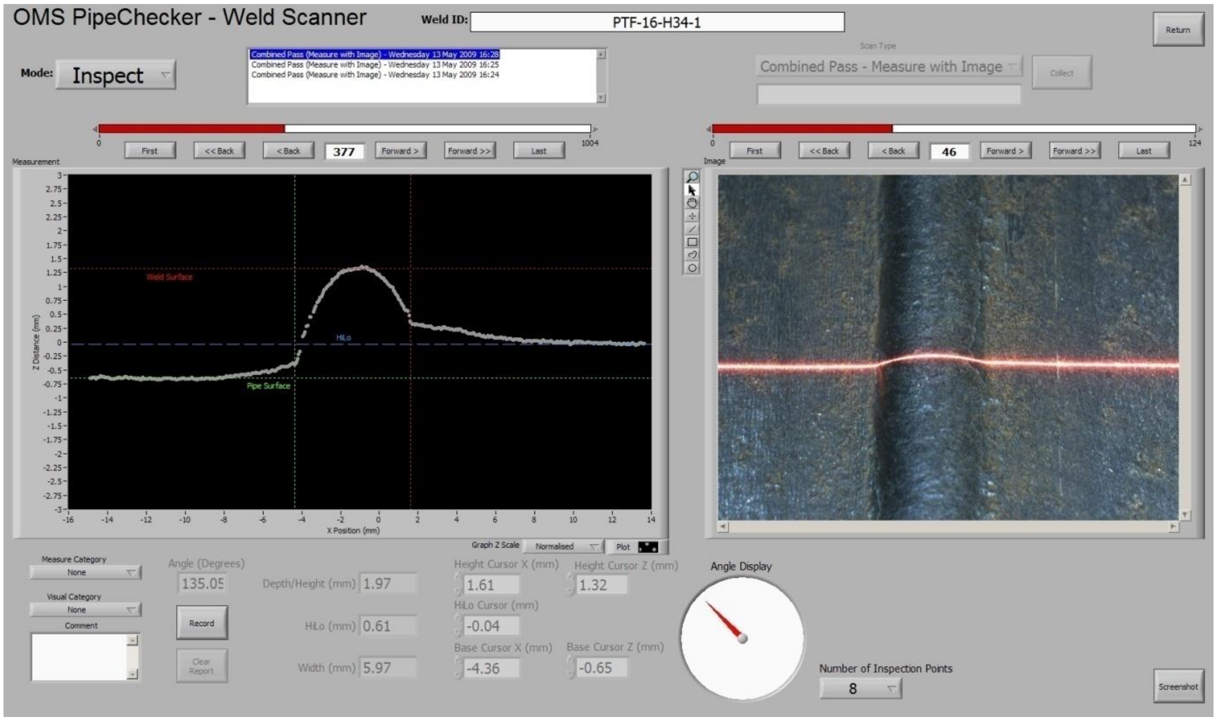


Figure 13. Visualisation of a carbon steel weld

In this case the pipes surfaces have a HiLo of 0.62 mm which is over the 0.5 mm specification for this weld. In a recent case a fatigue crack was found to have occurred in an area where the HiLo mismatch was greatest. This result is exactly as would have been expected according to theory, but the weld scanner now allows an inspection to determine the actual HiLo in order to detect this type of problem. The following two graphs (figure 14 and figure 15) illustrate the HiLo and the weld height statistics provided by the system.

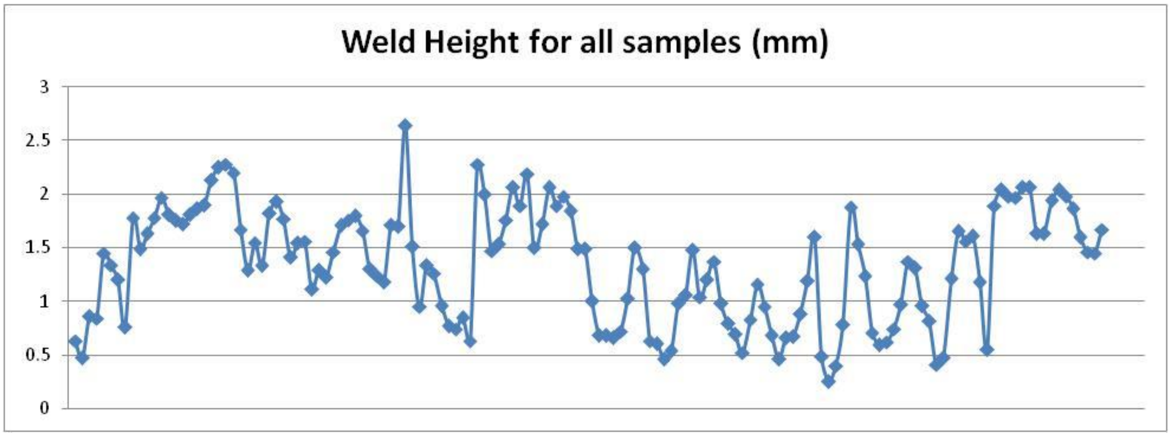


Figure 14. Weld maximum height (mm) for all samples (8 spot checks per sample)

The graphs illustrate that the weld height for all the samples varied between a little less than 0.25 mm to more than 2.5 mm. The following graph illustrates the HiLo for the samples

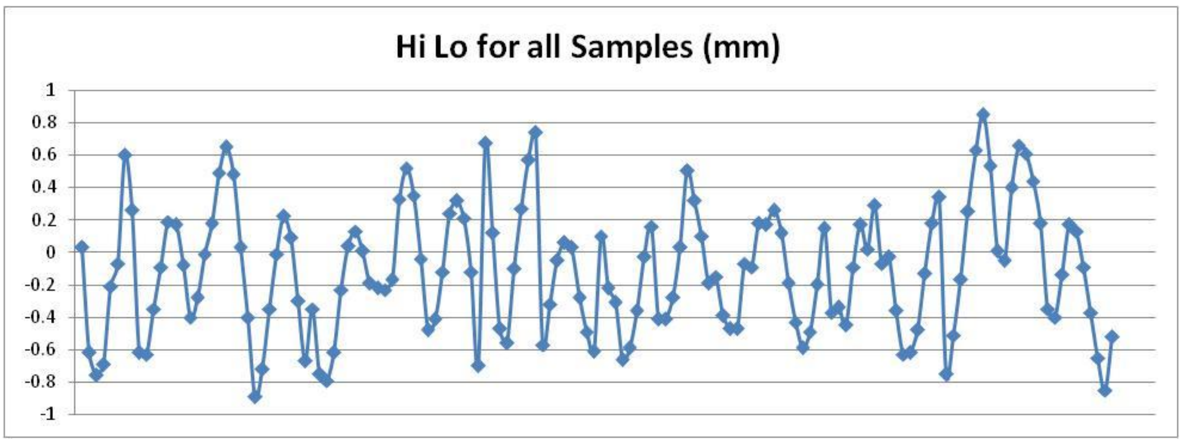


Figure 15. HiLo (mm) for all samples (8 positions per sample)

The post welding HiLo value was up to 0.9 mm in several cases compared to a pre-welding specification of 0.5 mm. Weld scanning now makes it practical to acquire this type of critical information.

4.4 Spirally welded pipe

Spirally welded pipe requires careful quality control in order to avoid areas where the welds do not overlap properly thus causing corrosion sites. Figure 16 illustrates an image from part of a spirally welded pipe and the measurement data related to that section.

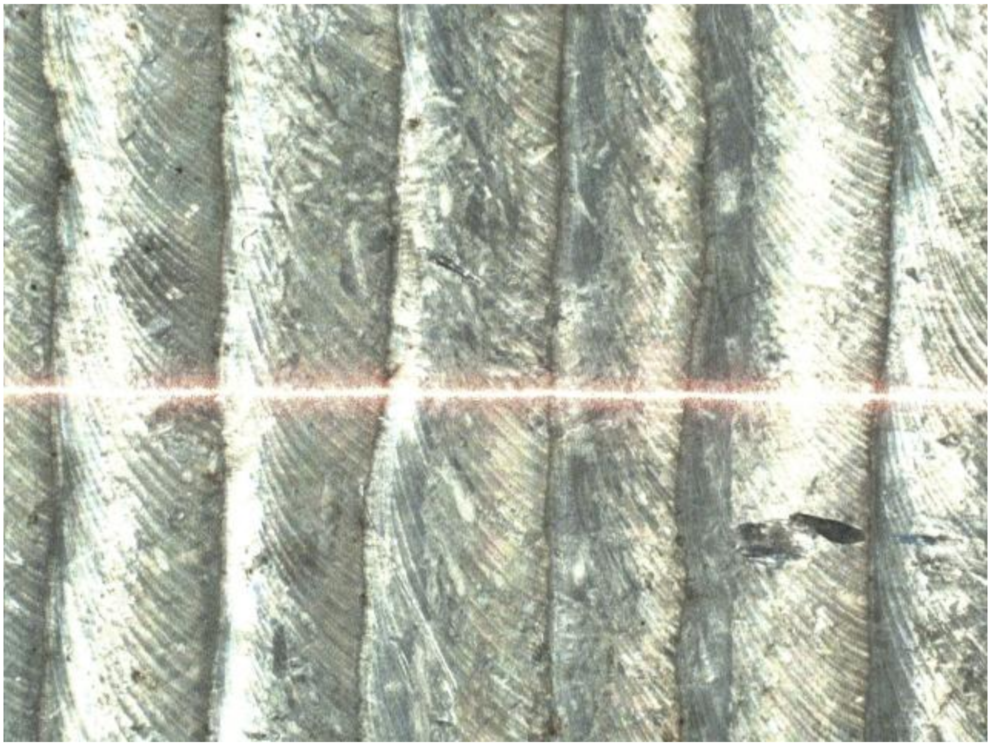


Figure 16 (a) Spirally welded pipe image with Laser Stripe overlay

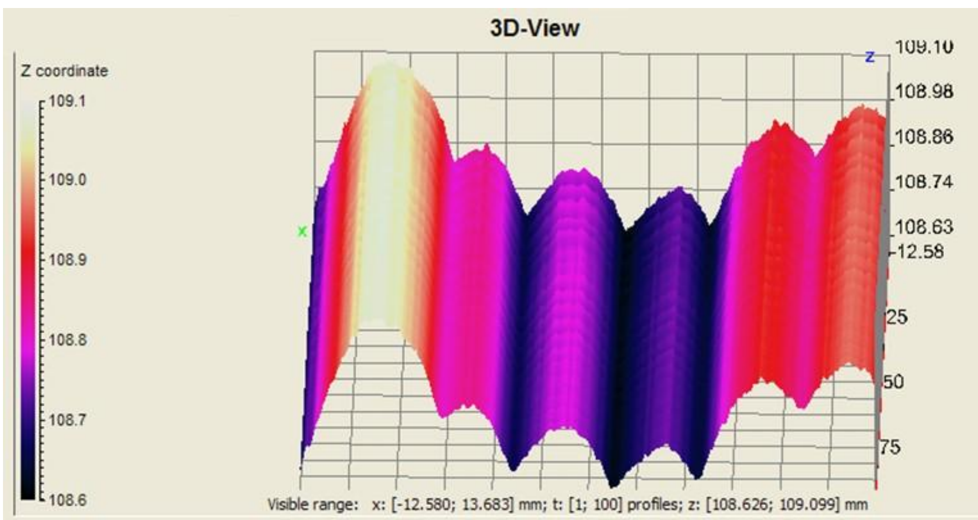
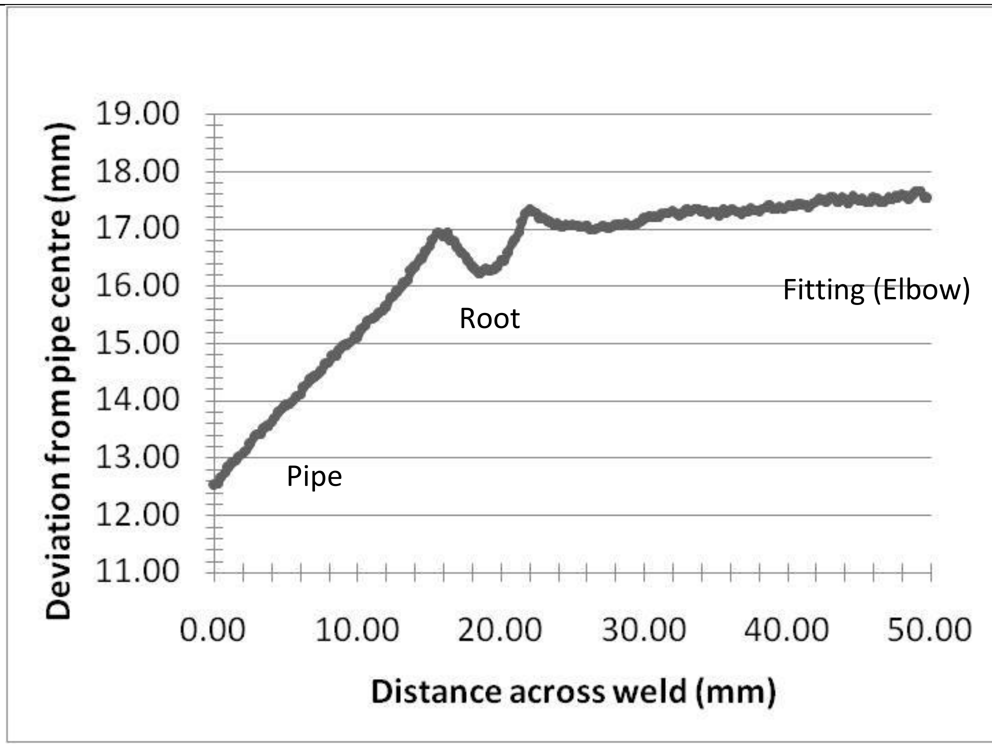


Figure 16 (b) 3-D Colour representation of weld heights

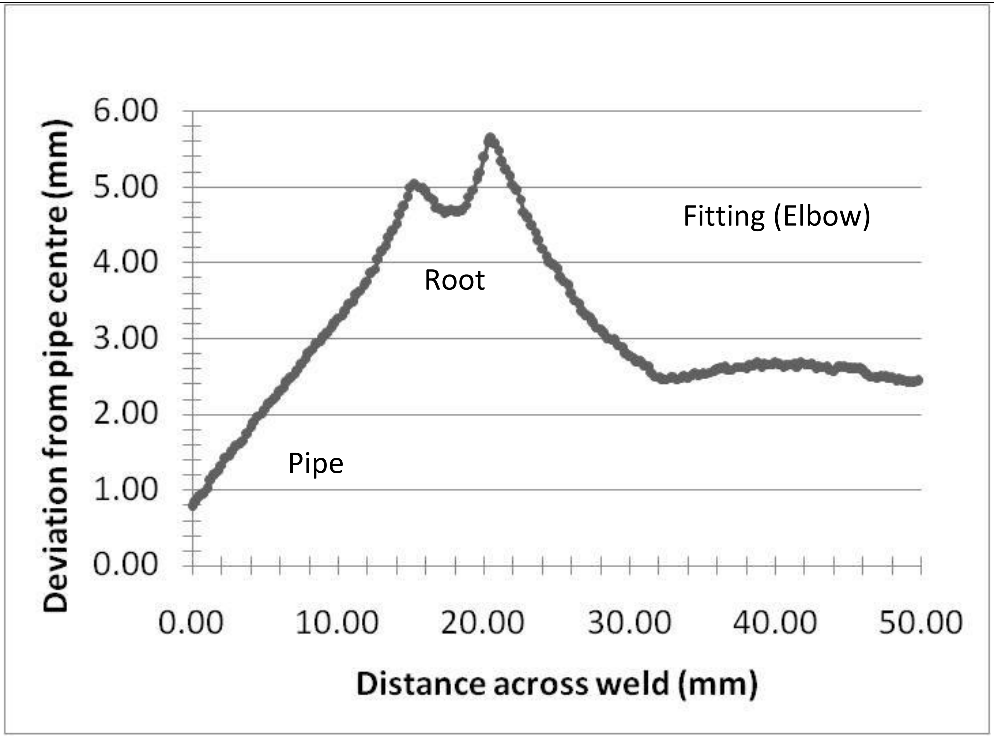
Defects in the welding can be highlighted by a particular colour to warn an operator of an area of the pipe which is out of specification.

4.5 PLETs, PLEMs, Manifolds

Manifolds and other similar structures have critical welds which are under high pressure and hence must be assessed to show that they are within specification. Many traditional inspection techniques have difficulty in the context of complex internal and external geometries associated with this type of structure. The following figure (17) illustrates two cross sections from a manifold spool piece. Diameter changes and deep internal back bevels are common in this type of application, and the weld scanner can provide complete scans of the weld root and adjacent pipe wall to allow the weld characteristic to be fully understood.



12” Spool example



12” Spool example

Figure 17. Two example cross sections from a spool piece

4.6 Additional information that can be obtained by the root weld scanning tools

Weld scanner tools are capable of uses beyond those detailed in the above examples. The following figure illustrates how the information available can be used to gain a full 3-D map of the weld of a pipe.

Figure 18. Example of how the data gathered by the tool can be used to provide a 3-D map of the pipe weld.

This methodology can also be extended to a measurement of a full length pipe. For instance for surveys of bending trial clad or carbon steel pipes.

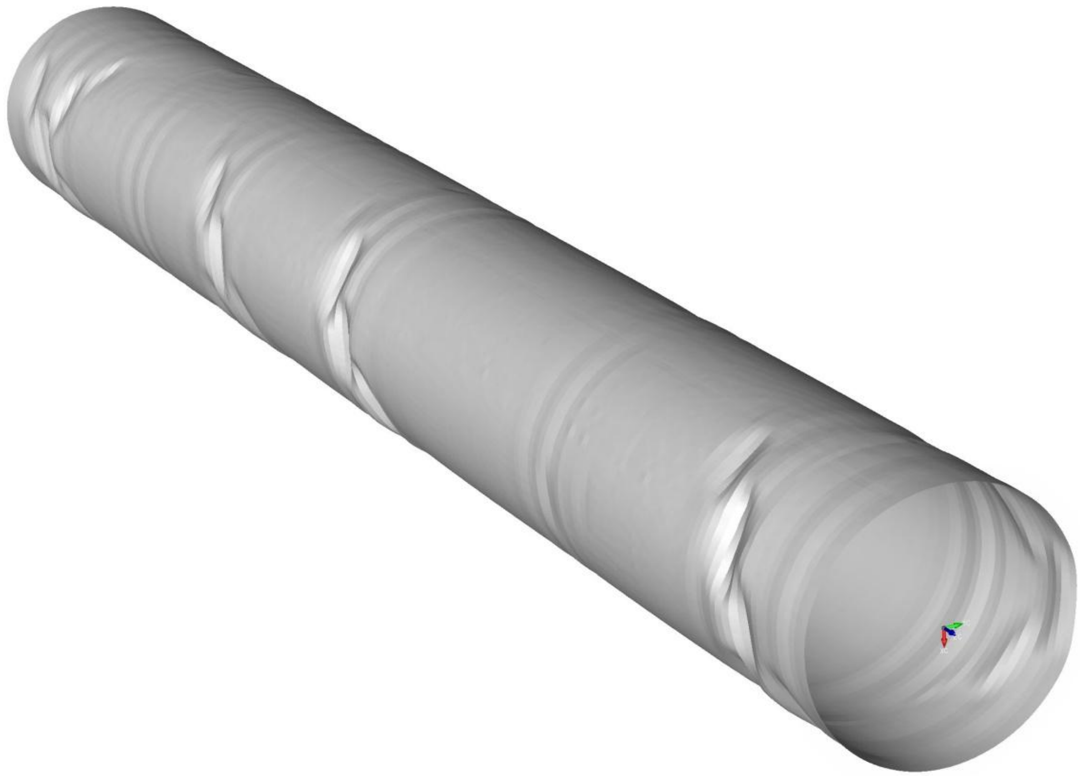


Figure 19. An example of a wrinkled pipe internal surface that has been 100% surveyed

Measurement of corrosion and wear in pipes is another area application area where the tool can provide a significant value to engineers concerned with integrity management.

5 Conclusions

Internal Weld scanning is available. It is being increasingly used to provide vital information to increase efficiency of pipe laying, improve weld quality, assess corrosion resistance, monitor manufacturing processes to name a few benefits. This paper has illustrated a variety of weld scanning application areas. In these applications, weld profiles can be inspected with accuracy, reliability, speed and ease. The tools illustrated provide the means to **See** the weld, **Measure** it in order to **Quantify** the pass or fail of a given weld.

Contact:

hugh.davies@omsmeasure.com

info@omsmeasure.com