ULTRASONIC IN-LINE INSPECTION TOOLS TO INSPECT OLDER PIPELINES FOR CRACKS IN GIRTH AND LONG-SEAM WELDS

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Abstract

The number and variety of different in-line inspections tools has been increasing in the last years and thus it is getting more and more difficult to maintain an overview of what kind of inspection is suitable for what purpose. This paper will especially target the question of crack detection. Before going into details about the ultrasonic inspection method, flaws in girth welds are described. Many flaws are manufacturing related und thus not a special problem of older pipelines. However, when inspecting for flaws typical of aging pipelines a distinction between the two is of utmost interest. The abilities and limitations of the MFL-Technology, as one means of flaw detection in welds, are described. Finally the principle and several examples of ultrasonic detection of flaws at welds are presented.

Introduction

In-line Inspection has been established as a very useful means to detect and find corrosions-like defects. The quest for crack detection tools has a rather recent history and was driven by the need to mitigate Stress Corrosion Cracking in longer on-shore pipelines. Nowadays, however, the need for crack detection is broadening. Cracks of various origins like fatigue or hydrogen embrittlement in sour service is receiving more and more attention.

Ultrasonic Inspection tools had been introduced into the inspection business in 1984. With their perpendicular incidence they were only sensitive to detect cracks with a surface perpendicular to the sound beam. This is true for hydrogen induced cracking (HIC), but not for most other cases of cracking. Thus an ultrasonic crack detection tool with angled beam incidence was introduced in 1994 [1]. This tool was proven to be the first reliable in-line inspection method to mitigate Stress Corrosion Cracking (SCC).

Regular magnetic flux tools although designed for the detection of corrosion-like flaws have always been able to find some cracks. Most cracking environments, however, produce cracks in the axial direction, which MFL-tools are not sensitive for. An MFL-tool with a redirection of the magnetization field to account for this weakness has been introduced in 1999 [2]. The technique shall be named transverse MFL-tool in the following.

Flaws in welds

Flaws and defects in welds should be separated into those introduced at the manufacturing process and those that are developing during service. While it is not always trivial to distinguish between the two, the latter are prone to grow further and thus threatening the integrity of the line to a higher degree.

The flaws could also be separated into those that occur in girth welds and those that are found in seam welds. While it does make a difference for the inspection method, the appearance it very similar. Naturally the seam welds are of higher quality, as they are factory made, compared to field-made girth welds. In general both welds are inspected with various NDE-methods in the production process.

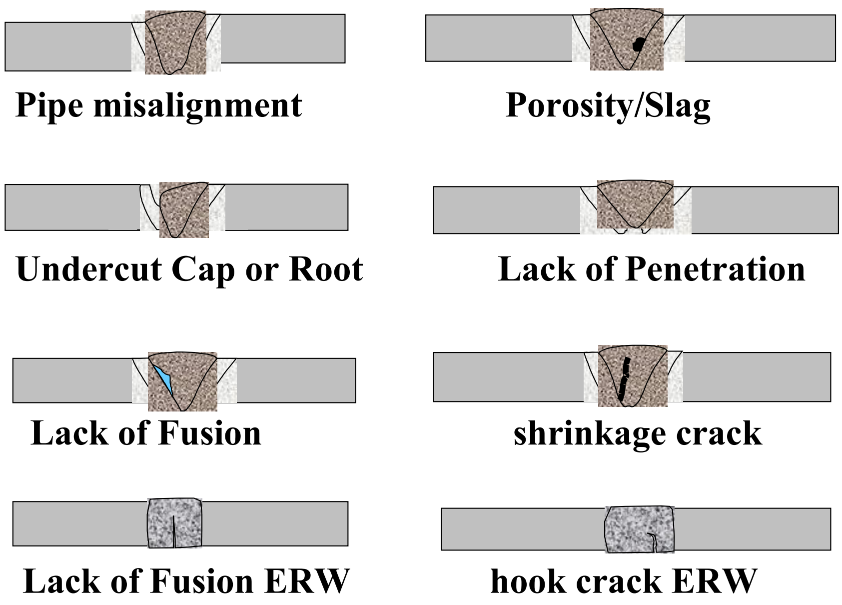

Figure 1: Different types of flaws in welds that are manufacturing related. All of these flaws can be detected by ILI-tools in one way or the other. The distinction between the flaws is difficult.

As will be described below, most weld flaws will generate a signal in the crack detection process. The task is to determine, what kind of flaw is present.

MFL-tools for Crack Detection

In the beginning of MFL-signal analysis analytical solutions were sought based on a dipole model [3]. The surfaces are modeled with uniform surface magnetic charge density. Förster has applied conformal mapping [4] and introduced the Detour Flux Dipole [5]. All models were mainly applied to the problem of crack detection. Eddy current effects can hardly be considered in a satisfactory way. Regular Finite Element Modeling always is a way to relate measured field values to theoretical defect geometries. Required are magnetization curves, magnetic circuit design and defect shape. FEM however does not yield any understanding of the signal generation. In all cases the inverse approach can result in lengthy iterations until a shape is found that matches the measured fields.

The principle of transverse MFL-tools is depicted in Figure 2. The magnetic flux is diverted in the circumference of the pipe, leaving some blind areas where the flux is fed into the steel pipe. Thus a second body is required to ensure full coverage.

The MFL tool will pick up any change in the magnetizability of the material, yielding a signal for most of the weld flaws shown in Figure 1. The pipe misalignment will rather be detected by a lift-off of the sensors. Since the permeability of the material in the Heat Affected Zone is usually reduced and the material thickness is higher, any weld will give a signal. Weld flaws are thus detected by a deviation from the regular weld signal.

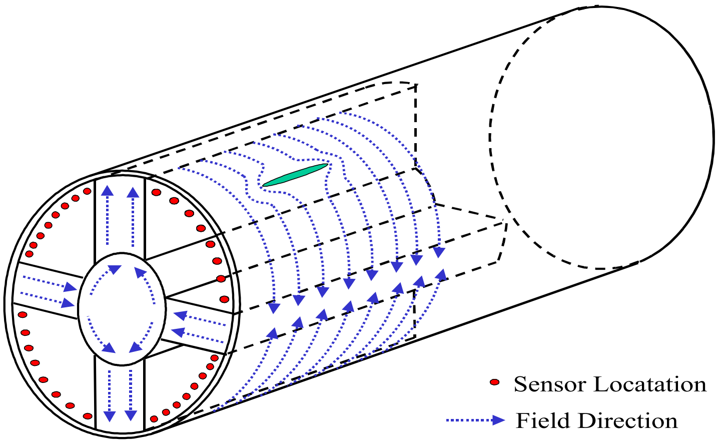

Figure 2: The transverse MFL Principle

Since MFL inspection is the widest spread Inspection technology and compared to other methods is also the cheapest due to its straight forward data analysis, why didn't it become the method of choice for cracking problems? The main problem is, that crack detectability depends on crack opening. Although small crack width like 0.1 mm is detectable, most cracks are much smaller and are usually not visible with the unaided eye. Most vendors of transverse MFL tools state the limit of detection to be 0.1 mm in crack width (opening). This discrepancy is depicted in Figure 3. Moreover the transverse configuration is not ideal for MFL measurement, because it does not make use of the cylindrical symmetry of the pipe. The sensors are positioned at different distances from the magnetic poles. This results in different magnetization levels and eddy current effects at the various sensor positions and needs to be compensated. Also the sensor grid is much too coarse for crack detection. The sensor pitch is in the range of several mm. This being quite an achievement, it is still not what is required. In regular hand-held tools the sensor would scan in a perpendicular direction to the crack allowing for a better resolution.

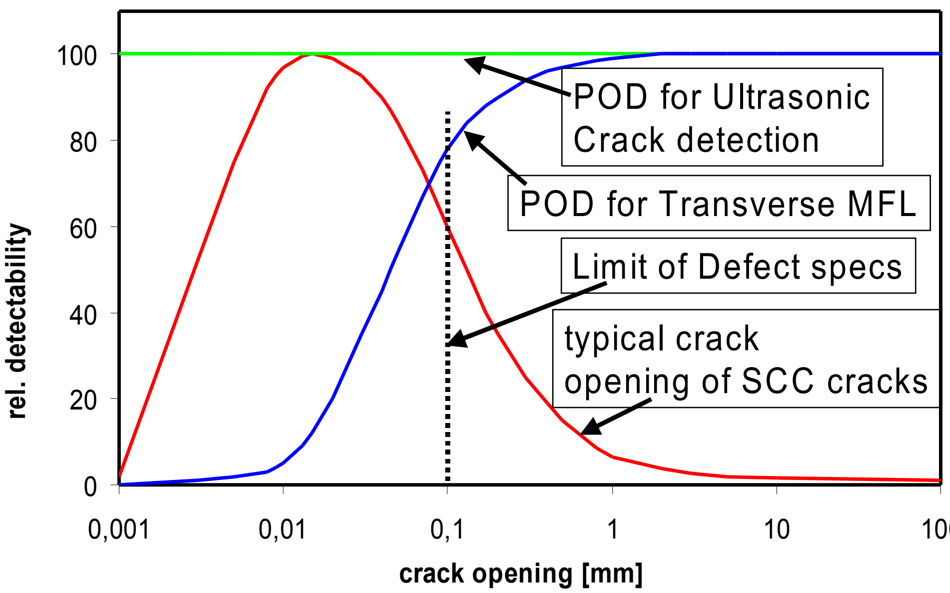

Figure 3: The use of MFL crack detection is limited in case of SCC, where the crack opening is usually to small.

Ultrasonic Crack Detection

In UT crack detection ultrasonic waves are sent through the pipe wall at an angle close to 45 º. Any reflector will sent a part of the wave back to the transducer, where the signal will be recorded as an echo. The principle is depicted in Figure 4. If no cracks or other reflectors are present, no signal is received. If signals are received elaborate algorithms will determine, whether it is useful to record the signal. Certain signal thresholds will have to be reached and the signal will have to reappear several times for it to be considered a potential crack candidate.

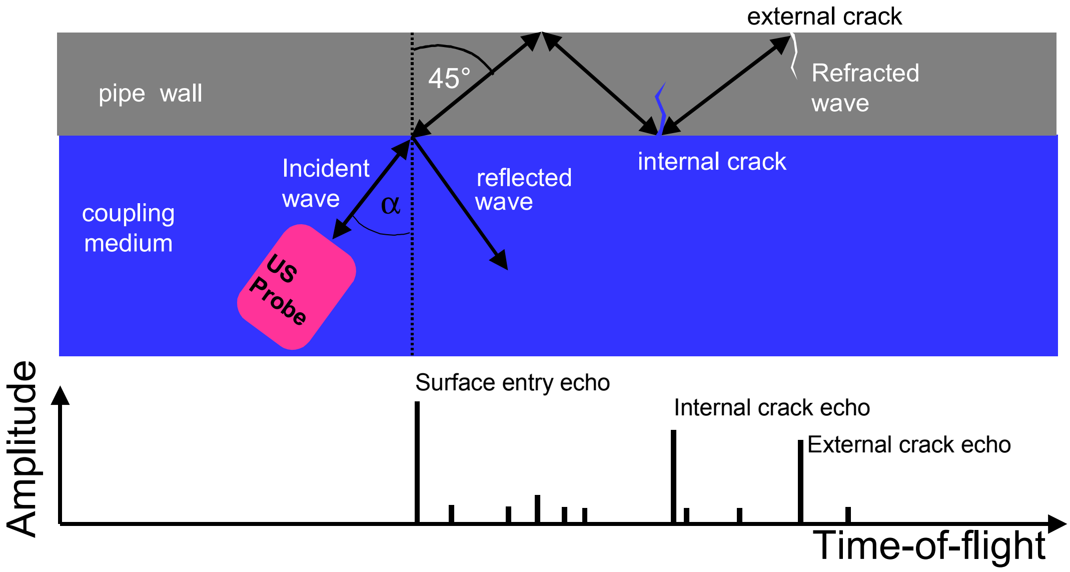

Figure 4: The principle arrangement for ultrasonic crack detection. Sound waves will travel through the pipe wall at an angle close to 45 °.

One thing that is distinctly different from other in-line inspections is, that there is a large degree of redundancy in the coverage of the pipe surface. Possible crack candidates are detected by up to six different sensors. Naturally crack candidates are especially abundant at the weld area. In particular submerged arc welded pipes generate a large number of reflections. In order to be sufficiently sensitive all signals (i.e. Echos) are recorded at the weld area. A special weld detection algorithm will determine the position of the weld and ensure no signals are discarded. To ensure that no shadow-effect will hide cracks behind a welded part, the ultrasonic waves will travel through the pipe wall in both directions.

Data analysis will have to be carried out using the so-called B-Scan. In this picture the echos of a single sensor are depicted with their time-of-flight versus the traveled distance. The reflected amplitude is usually shown in a color-code. For clarity only signals above a certain amplitude are shown in Figure 5.

Naturally there is also some limitations concerning the crack orientation an size that is detectable. Cracks should exceed a length of about 30 mm. Shorter cracks are too difficult to distinguish from other sources of reflection. They should be deeper than 1 mm. In the weld area a minimum depth of 2 mm is required. The orientation of the cracks should be such, that they have to be aligned perpendicular to the sound beam. For sensors that emit beam in the circumferential direction, the cracks should not be out of the pipe axis by more than 10 °. Sensors that emit up- and downstream to detect circumferential cracking will be limited to cracks that do not deviate too much from this orientation. Also cracks should have an angle with the surface of not less than 45 °. In other cases, the inspection tool with perpendicular incidence will have to be used.

As mentioned signals from crack candidates have to be distinguished from several other features that will also act as ultrasonic reflectors. Pipe-inclusions, laminations, corrosion and other inhomogeneities will also reflect, but their signal appears in a different manner in the B-Scan. This signal classification is still done mainly manually, resulting in very long reporting times. However, if the necessary care has been taken, crack detection in this manner has proven to be a highly reliable method.

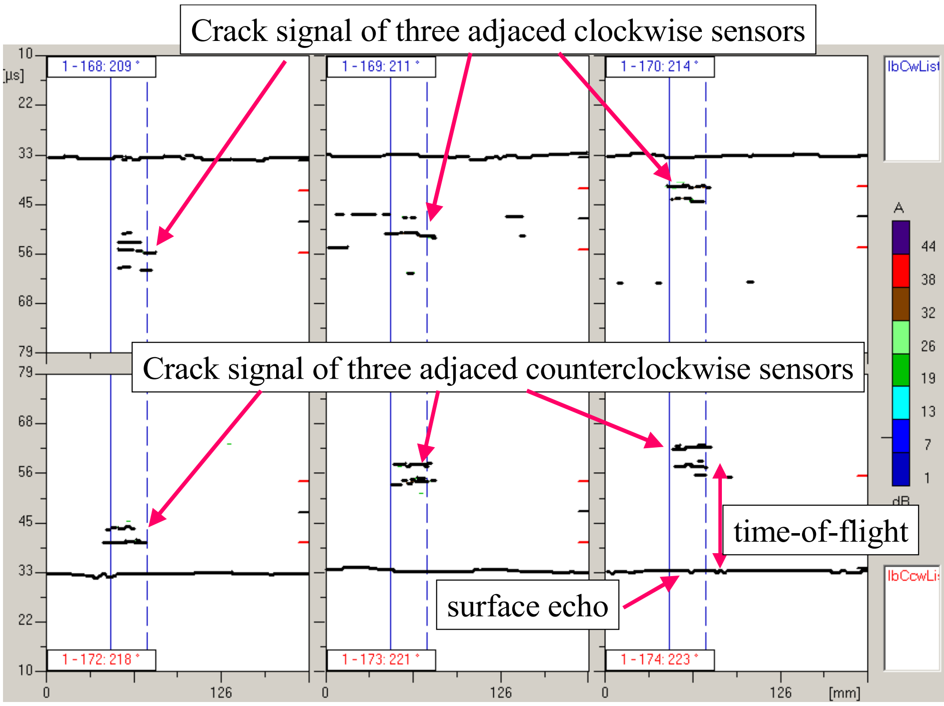

Figure 5: Analysis of Ultrasonic Crack Detection Data is carried out in the B-Scan. Signals of several sensors contribute to the decision on whether the reflector is a crack or not.

The C-Scan below shows an area with many cracks and metal loss defects. The upper part of the picture shows the signals of the inclined sensors. The lower picture shows data of perpendicular sensors as used for wall thickness measurement. Cracks are not visible in the lower picture. However, some metal loss features are also visible in the crack detection mode. Hence, the corrosion-like features have to be distinguished from cracks. If a wall thickness measurement is available, as shown in the Figure 6, this is easily accomplished. In other cases the decision has to be based on the B-Scan information. Smooth metal loss features do not reflect to such a degree as cracks do. The signals us much more spread in the time-of flight axis. Nevertheless, some ambiguous features will always remain.

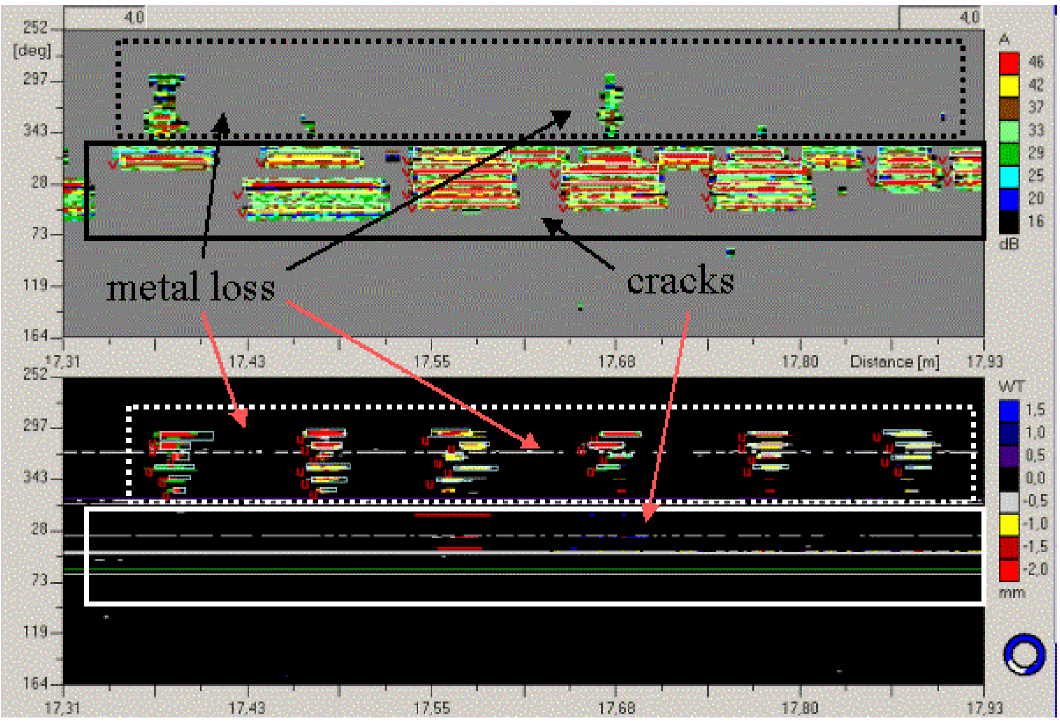

Figure 6: Cracks are not visible in Wall thickness measurements, but metal loss is sometimes picked up in crack detection. However, the probability of detection is poor.

Conclusion

Crack-like defects are no longer an incalculable factor in pipeline integrity management. While the feasibility of some special applications still has to be introduced to most pipeline operators, the technical problem is solved in most conceivable circumstances. The challenge remaining in in-line crack inspection is the data analysis. While the analysis of data recorded in an inspection run can still take very long, several projects have been set up to considerably reduce this reporting time.

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