DETECTING CRACKS IN PIPELINES USING ULTRASCAN CD

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INTRODUCTION

Stress Corrosion Cracks (SCC) are among the defects in pipelines that are least understood and most difficult to detect, but which have accounted for some of the severest ruptures in pipelines throughout the world. Pipetronix has developed a new generation of internal inspection device for detecting SCC and other cracks and crack-like defects in pipelines, the UltraScan CD. It is a completely autonomous device that travels through the pipeline, carried by the fluid, uniformly scanning the pipe wall for defects with full circumferential coverage and for lengths of several hundreds of km. The information is processed on-line to allow for storage of huge amounts of data to be processed when the tool is retrieved from the pipeline. The UltraScan CD has, up to now, successfully inspected more than 1,000 km of oil and gas pipelines. Comparison of the findings with corresponding verifications from excavations illustrate the sensitivity and reliability of the inspection method and its ability to discriminate between different types of defects found in the pipelines.

INSPECTION TECHNIQUE

The technique applied uses shear waves which are generated in the pipe wall by angular transmission of the ultrasonic pulses through a liquid coupling medium (oil, water etc.). The angle of incidence is adjusted such that a propagation angle of 45° is obtained in pipeline steel. This technique has proven appropriate for crack inspection and it is established as one of the standard techniques in ultrasonic testing [1].

Because fatigue cracks as well as SCC are generally oriented perpendicularly to the main stress component, i.e. the hoop stress in a pipe, the ultrasonic pulses are injected in a circumferential direction in order to obtain maximal acoustic response. A schematic representation of the measuring principle is shown in Figure 1.

Review of Progress in Quantitative Nondestructive Evaluation, Vol. 16
Edited by D.O. Thompson and D.E. Chimenti, Plenum Press, New York, 1997

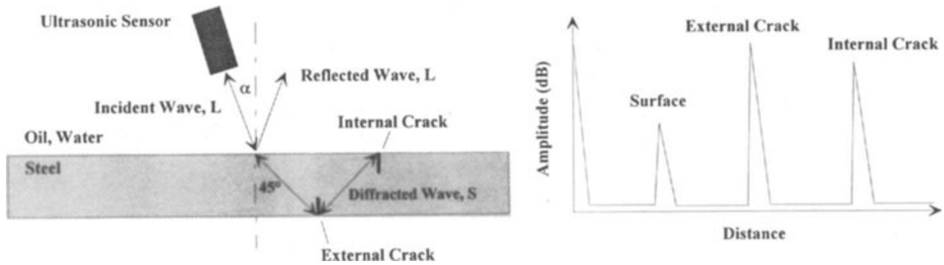

Figure 1. Measuring geometry (left) and corresponding A-scan (right).

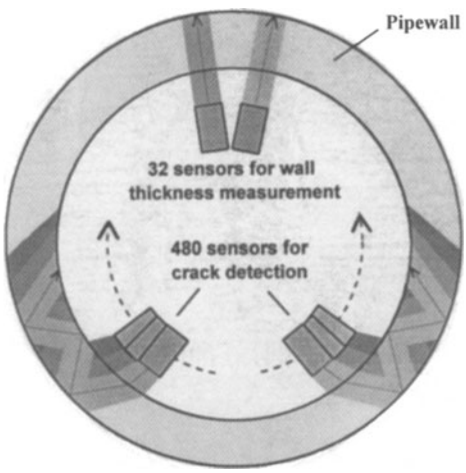

Figure 2. Sensor arrangement for ultrasonic crack inspection (schematic).

The sensor carrier of the UltraScan CD is designed such that the complete pipe circumference is uniformly scanned in both clockwise and counterclockwise directions using 480 sensors distributed on 16 sensor skids (24"/26") for crack detection (Figure 2). This arrangement provides multiple coverage which ensures that relevant reflectors are detected by up to ten sensors. Additionally, two sensors per skid serve to continually measure the actual wall thickness and to detect girth welds. This information is used as an aid to locate defects as precisely as possible with respect to the nearest girth weld. All sensors are mounted in a highly flexible polyurethane carrier, maintaining a constant distance from the pipeline wall at a defined angle of incidence.

The tool is designed to detect longitudinally oriented cracks or crack-like defects at any location in the pipe body wall. Particular emphasis is placed on the longitudinal weld zone that is recognized on-line and all the information from the two sensors detecting it from both inspection sides is stored completely.

After an inspection run is completed, collected data are pre-processed taking advantage of built-in detection redundancy, thus considerably reducing the amount of indications to be looked at by the interpretation group. The evaluation of the data is then performed on personal computers using advanced data visualization software. Detected features are classified and cracks and crack-like defects are sorted out for detailed analysis.

RESULTS

The UltraScan CD tool has to date successfully inspected over 1,000 km crude oil and gas transmission pipelines. The sensitivity of the detection method has been tested extensively. It has been found that the UltraScan CD, designed to detect 2 mm deep and 30 mm long cracks, exceeds the design specifications. A significant number of internal and external notches with depths from 0.5 mm upwards, located in the weld area and the base material, were reliably detected. Typically, individual defects with a depth of 1 mm are detected by three to six sensors, in some cases by as many as ten sensors all dependent upon depth and location of the defect [2].

Repeatability

A 26" crude oil pipeline was inspected twice and the repeatability of the tool could be analyzed by comparing the recordings from the two runs. A total of 80 notch-like indications have been compared with respect to length, amplitude and circumferential position. These reflectors, with depths smaller than 1 mm, were detected in both runs and

Table 1 - Comparison of length, amplitude, and circumferential position of 80 notch-like indications as recorded from two runs

Mean deviation in length of indications	Mean deviation in S/N-ratio of max. amplitude of indications	Mean deviation in circumferential position
± 7 mm	± 3 dB	± 2°

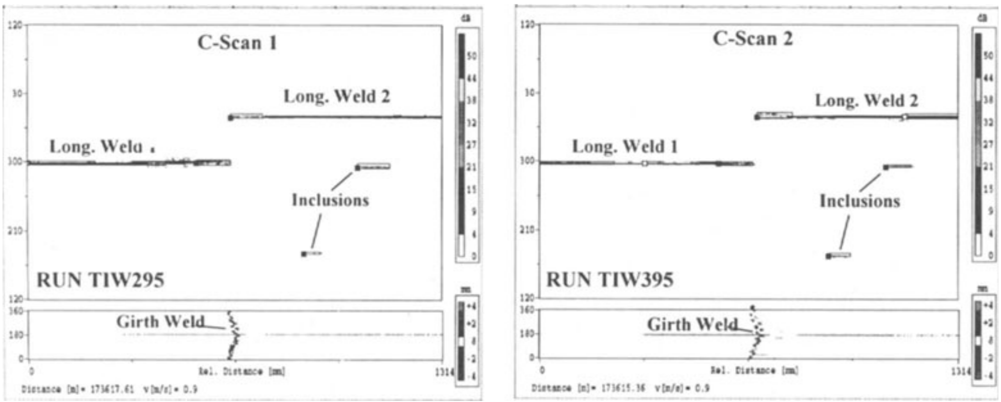

Figure 3. Comparison of C-scans from the same pipe joint recorded during two separate runs (26" crude oil pipeline). The C-scans at the bottom show the results of the wall thickness sensors indicating the location of the girth weld.

the repeatability with regard to the relevant parameters was very good as can be seen from the standard deviations given in Table 1.

Another example demonstrating the repeatability of data from the tool is given in Figure 3. It shows the C-scans of the same location on a crude oil pipeline as recorded from two subsequent inspection runs. On the C-scans, the longitudinal welds as well as indications from two inclusion-like reflectors can be matched with impressive exactitude. The amplitudes of these indications are well below the design criteria. Nevertheless, even such minor reflectors are repeatedly detected by the tool and properly classified during subsequent off-line data evaluation.

Discrimination of Defects

Many indications detected in operational pipelines exhibit crack-like characteristics originating from scratches or grooves usually caused during manufacture or transportation of the pipe. Even though non injurious, they act as stress concentrators and hence are potential sites for crack initiation. Some of the more pronounced notch-like indications found during inspection runs, have been verified by manual ultrasonic testing as well as by MPI (Magnetic Particle Inspection). The results, with regard to defect type, length and position were in full agreement with the interpretation of the data from the tool. An example is shown in Figure 4, showing a C-scan (Figure 4a) and a MPI trace (Figure 4b) of an external, approximately 1.5 mm deep, groove located near the girth weld.

Stress Corrosion Cracks (SCC)

Stress corrosion cracking (SCC) is a phenomenon gaining more and more attention as the rate of SCC-induced pipeline failures increases worldwide. SCC is generated under the influence of internal pressure and a corrosive environment, combined with a particular microstructural susceptibility found in some pipeline steels. The mechanisms of SCC initiation and growth are still not well known and are the subject of ongoing research [3].

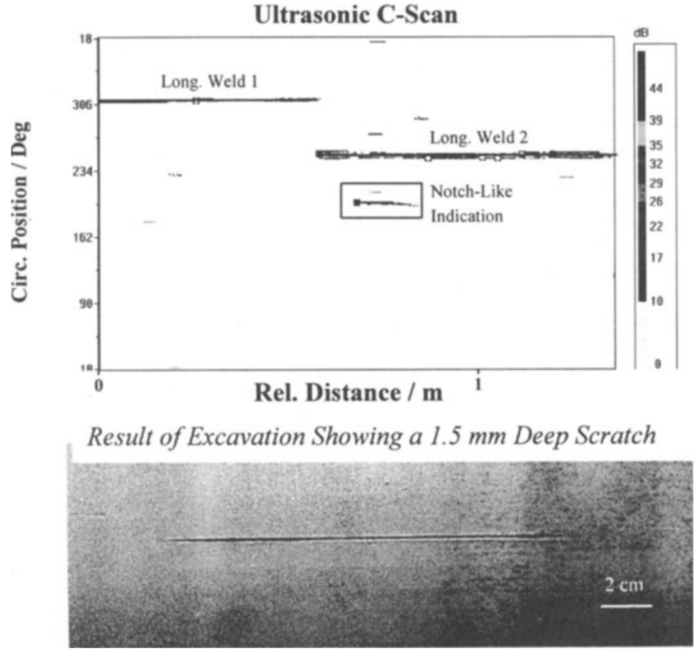

Figure 4. Top: C-scan of a pipe joint from a 26" crude oil line indicating an external notch-like defect. Bottom: Results of the verification excavation show a 160 mm long, 1.5 mm (18 % WT) deep groove.

In order to facilitate ultrasonic coupling for inspecting gas pipelines, the tool has to run in a slug of liquid (the performance of the tool has already been proven in water, crude oil and diesel, but other liquids can also be used) [4,5]. A 56" gas transmission line with individual section length of 110 km was inspected with the UltraScan CD in such a configuration The tool performed very well and excellent data was obtained. A significant number of pipe joints containing SCC were identified, and the indications were classified into four categories based on the amplitude and the length of the cracks. Excavations have been performed, and agreement between predicted and actual was very good, in particular, no false calls have been reported. So far, 41 excavations have been performed on pipelines inspected with the UltraScan CD. The findings proved out to be SCC, cracks, weld damage and some crack-like defects (e.g. scratches and grooves). The excavations showed that the sensitivity of the tool is such that even cracks and crack-like defects with depths below 1 mm are detectable.

The SCC-colonies sometimes have lengths in excess of one meter and contain hundreds of cracks, but in some pipe joints isolated single cracks are detected. Figure 5 shows a C-scan of a pipe joint containing three SCC-colonies near the longitudinal weld. In the C-scan image, the ultrasonic data from all sensors is projected on the pipe surface. From the C-scan image the size and location of the colonies are easily recognized. More detailed information is obtained from the B-scans showing the crack indications as recorded by an

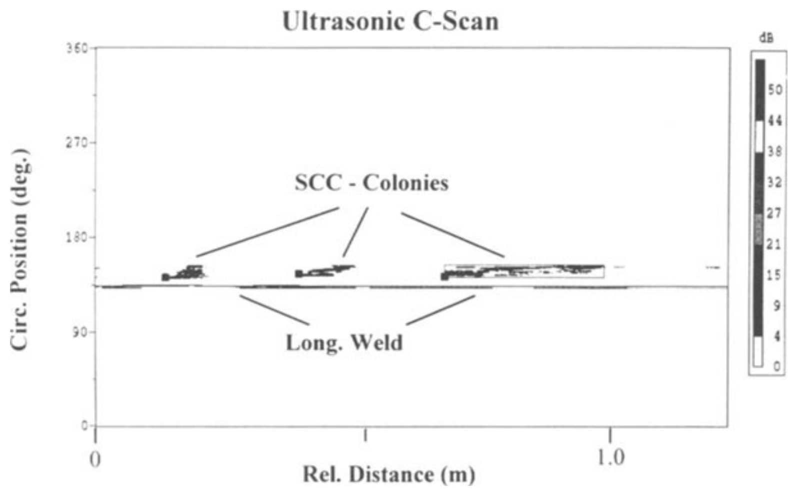

Figure 5. C-scan of a 56" pipe joint showing three SCC-colonies adjacent to the longitudinal weld.

individual sensor (Figure 6). In the B-scan image, individual cracks can be resolved and their length as well as the distances between the cracks can be estimated. In most SCC colonies, the length of the majority of the cracks is below 30 mm. The classification of the crack colony depends in particular on those indications with the largest sizes and the highest amplitudes.

Sizing of Cracks

The UltraScan CD detects longitudinal defects in all parts of the pipeline. External and internal defects can readily be distinguished as well as mid-wall defects (e.g. inclusions) which are detected and classified as such. Excavations have proved the axial defect location accuracy to be ± 150 mm relative to the nearest girth weld and the circumferential: ± 10°. Accuracy of length measurement is ± 7 mm.

In the above mentioned gas transmission pipeline crack depths were to be classified in four categories (in accordance with the pipeline operator's requirements) based on a percentage of wall thickness:

< 12% W.T.; 12% - 25% W.T.; 25% - 40% W.T.; > 40% W.T.

Locations and the depths as predicted by the tool were verified by excavation and all critical cracks indicated by the tool were so confirmed. All cracks predicted to be non critical were also verified to be such. In all the excavation there have not been any false calls. Fig. 7 shows the comparison between defect depths estimated by the tool with depths found after excavations from all the excavations that have been performed up to now.

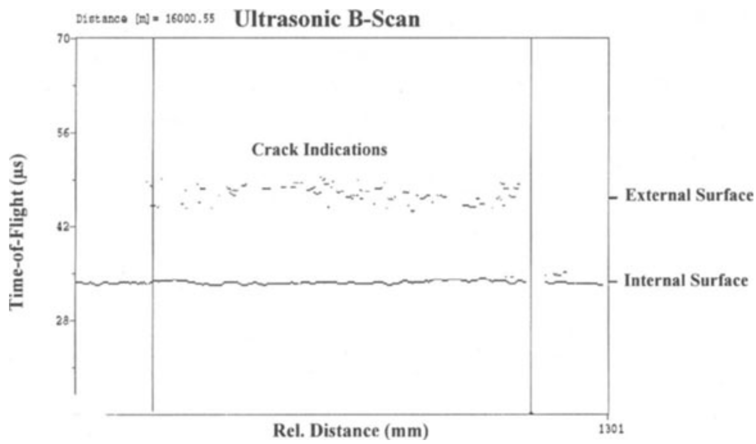

Figure 6. B-scan showing crack indications from part of a SCC colony at the external side of a 56" pipe joint. Here, the crack lengths are below 30 mm, the estimated depths are up to 3 mm.

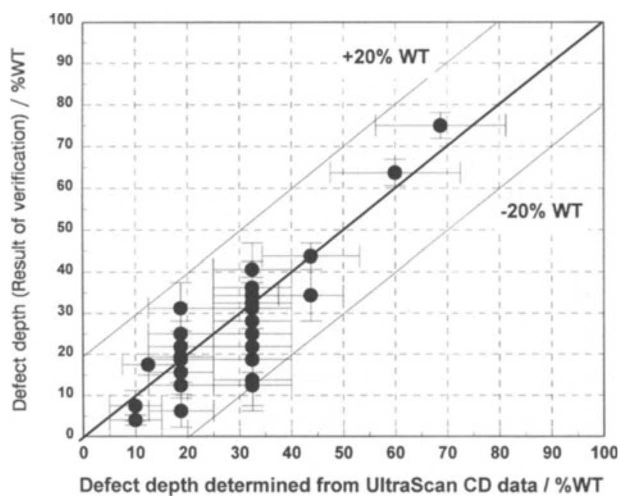

Figure 7. Comparison of crack depth determined from UltraScan CD data with verification results (from 40 excavations)

SUMMARY

The results obtained from the inspection of nearly one thousand kilometers of operational pipelines (crude oil and gas) confirm that the UltraScan CD meets the requirements for a sensitive and repeatable in-line crack inspection methodology. Due to its level of sensitivity, the new tool can reliably detect crack colonies as well as individual crack-like defects with lengths > 30 mm and depths > 1 mm. In particular, a successful inspection for SCC in a gas transmission line was performed yielding very detailed information about the state and the distribution of the damage.

The *on-line detection* of relevant defects is made possible by the high dynamic range of the newly developed ultrasonic electronics and the advanced signal processing. A reliable *off-line recognition and classification* of the recorded ultrasonic indications is ensured by the multiple detection concept which allows for a confident discrimination of the different reflector types involved.

ACKNOWLEDGMENT

The UltraScan CD was developed in close cooperation with the Fraunhofer-Institute for Nondestructive Testing (IzfP) in Saarbrücken and the Research Center Karlsruhe (FZK).

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