pig intelligence

Markus Ginten and Carsten Heinks, ROSEN Technology & Research Center, Germany,
discuss pipewall crack detection and inspection of the external pipeline coating condition based on intelligent pigging.

Figure 1. ROSEN RoCD² tool for crack inspection and detection of coating damages.

Intelligent pigging is a well-established procedure for the inspection of pipelines. Based on EMAT technology, the RoCD² inspection fleet is suitable for both detection of cracks in the pipe wall and inspection of external pipeline coating. The technology described here is available to oil and gas pipeline operators for pipe diameters from 14 to 56 in. Pipelines totalling more than 2000 km have been successfully inspected in North America, the Middle East and Europe. Figure 1 shows the 24/26 in. RoCD² tool at a launcher station.

EMAT (Electro-Magnetic Acoustic Transducer) technology uses ultrasound which is electromagnetically induced in the pipe wall. The ultrasonic waves are generated by a combination of two physical phenomena resulting from eddy currents in a static magnetic field: the Lorentz force and magnetostriction. These ultrasonic waves consist of lower and higher order horizontal shear waves which propagate in the circumferential direction of the pipeline wall.[1]

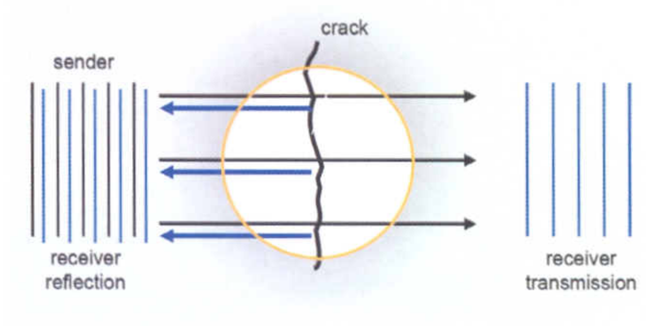

Figure 2. Schematic representation of the EMAT arrangement. Transmission signals are used to assess external coatings, whereas crack-like defects are analysed on the basis of reflection signals.

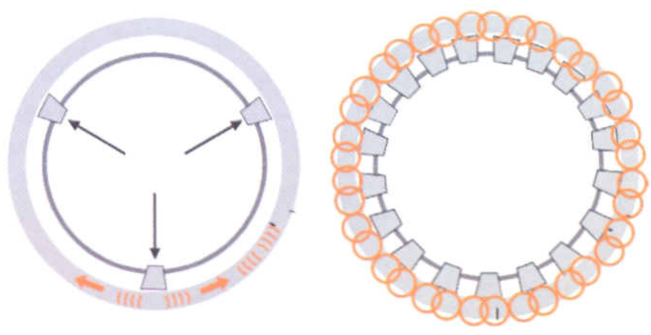

Figure 3. Comparison of different concepts regarding the arrangement of transducers. The high-resolution measurement setup used by ROSEN is shown on the right.

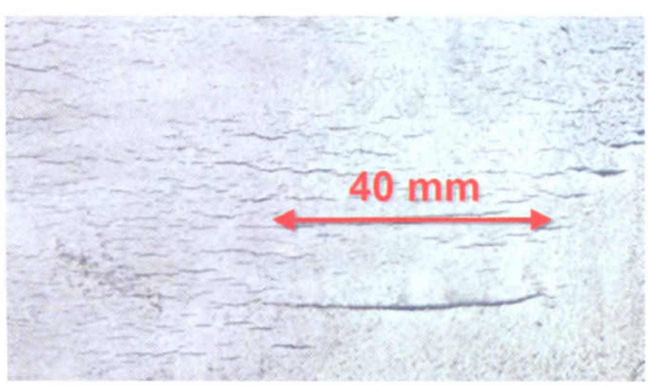

Figure 4. A stress corrosion crack detected with the RoCD[2].

A number of methods such as magnetic leakage and ultrasonic inspection with piezoelectric transducers are used in non-destructive testing of pipelines. However, the benefits of magnetic leakage as a method for crack detection are very limited. Based on piezoelectric transducers, the ultrasonic method can only be used in gas pipelines, if cost-intensive precautionary measures are taken. In contrast, no liquid couplant is required if the RoCD[2] tool is used, since EMAT technology induces ultrasonic waves directly in the pipeline wall.

Measurement technology and high-resolution sensor configuration

Figure 2 shows a schematic representation of the EMAT arrangement. The EMAT probe inspects only a small, well-defined area between sender and receiver. This area is called the measuring pixel. Transmission and reflection signals are captured by means of two separate receiver sensors within the EMAT arrangement. The waves which propagate from sender to receiver (transmission) through the pipe wall without hindrance are used for assessing the external pipeline coating. The waves are attenuated by intact coatings so that a lower signal amplitude is captured by the receiver. In case of coating disbondment or coating defects, the ultrasonic wave attenuation is reduced. If there are cracks within the EMAT pixel which run parallel to the pipe axis, as is the case, for example, with stress corrosion cracking (SCC), the ultrasonic waves are reflected on the crack surface. Information on frequencies, times of flight and modes is used for the analysis to identify cracks and determine crack length and depth. The analysis is supported by the quantification of possible lift-off effects and magnetisation measurements.

A large number of overlapping transducers are arranged on the inspection tool in such a way that a high-resolution image of the pipeline is generated. Due to the short propagation time of the waves between the measuring elements, this design ensures high signal quality which is the basis for accurately determining the position and dimensions of flaws. The difference between this type of high-resolution design and an arrangement – also used in the industry – of just a few transducers is illustrated in Figure 3.

Inspection data and data analysis

After the inspection run, the stored measurement data is downloaded from the tool and prepared for further analysis. Figures 4 and 5 compare a typical example of a stress corrosion crack verified in the field and the corresponding EMAT signals. Together with the integrated transmission and reflection data, the signals of the time and frequency domain visualised here provide the basis for data analysis. The defects are classified by means of a correlation analysis model (multiple parameter correlation = MPC). This step is necessary, because the RoCD[2] is also capable of detecting other types of pipe wall defects in addition to cracks, for example corrosion and lamination. The subsequent step of determining crack dimensions,

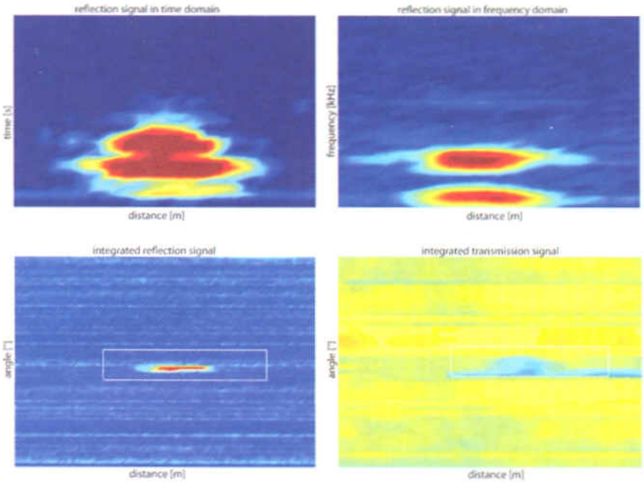

Figure 5. Representation of the basic data sets used for data analysis.

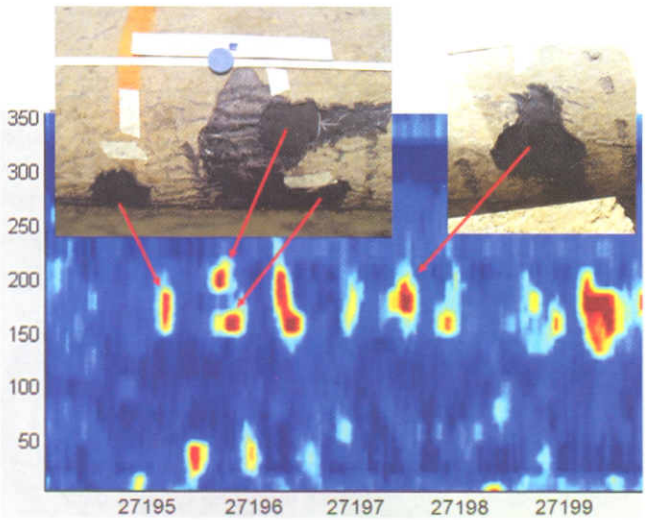

Figure 6. Damaged asphalt coating. The integrated transmission data is shown as a function of the circumferential position in degrees and of the log distance in meters.

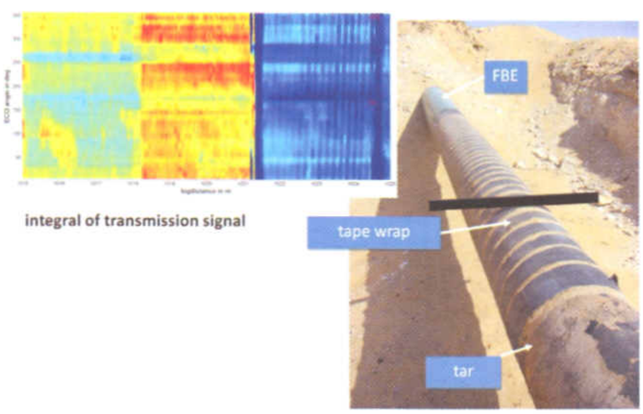

Figure 7. Differentiation between various types of coating on the basis of varying attenuation characteristics. The integrated transmission data is shown as a function of the circumferential position in degrees and of the log distance in meters.

i.e., length and depth, and, in the case of crack colonies, of calculating their size in circumferential direction, is done with the EMAT sizing engine (ESE). All automatically generated results are verified by experienced evaluation personnel.

Coating condition assessment

Apart from the analysis of the reflected shear waves to detect cracks, the condition of the pipe coating can be determined by analysing the signals of the transmission receiver. Impeccable adhesion of the coating material to the pipe wall results in attenuation of the acoustic waves propagating through the pipe wall. If the coating is damaged, acoustic signal attenuation is reduced. The large number of sensor heads allows for a high-resolution image of the coating condition. Figure 6 shows the consistency between the transmission data image and the coating damage found in the subsequent field survey. For the coating disbondment areas, a clear increase in signal strength is recorded.

Different types of external coatings have different attenuation properties. On the basis of signal dynamics of the transmission amplitudes and special pattern recognition coatings can be classified (coating identification). Figure 7 shows the different attenuation characteristics for the various types of pipe coatings. The following coating types were confirmed by field tests: Fusion Bonded Epoxy (FBE), pipeline tape coating and tar coating.

Extended analysis of coating damage

Steel pipes are protected against corrosion mainly by means of coatings. This method is called passive corrosion protection. The industry offers a large number of coating materials for this purpose including tape coating systems, bitumen, PE coatings, FBE coatings etc.

Coating defects can be caused during the pipe installation or by excavation works carried out in the vicinity of the pipeline. If the pipe metal has a direct contact to the surrounding soil, which then acts as an electrolyte, corrosion occurs. Electrons leave the metal surface and flow into the soil. With cathodic protection (active corrosion protection), a negative potential is applied to the pipeline system to suppress the corrosion process. To detect coating defects which are in direct contact with the soil, measurement technologies of the cathodic protection (CP) are used such as intensive measurement, the Pearson method, direct current voltage gradient (DCVG) and pipeline current flow measurement.[2]

Another type of coating damage is coating disbondment, which is principally the result of the ageing process or deficient workmanship in the application of the coating. Despite disbonded coating, the coating can still be intact as shell. Consequently, the pipeline is not in direct contact with the surrounding soil which in turn means that the pipe is protected from corrosion. As numerous North American examples show, however, the probability of stress corrosion cracking increases at disbonded areas.[3, 4] It has been observed that moisture penetrates into the areas affected by coating disbondment where it causes low-level corrosion. Active corrosion protection by means of CP is not possible due to the fact that the actual coating is still intact as shell. Disbonded area cannot be detected by cathodic protection measurement methods, since no direct connection exists between the pipeline and the soil.

The RoCD[2] tool detects both coating defects and coating disbondment. Differentiating between defects and disbondment is an important parameter for SCC susceptibility models.[5] By correlating the EMAT data with the cathodic protection measurement data it is possible to distinguish between coating defects and coating disbondment (Figure 8). Since the CP measurement method for pipeline current flow measurements can be carried out by pigging, this distinction can, furthermore, be based exclusively on inline inspection data.

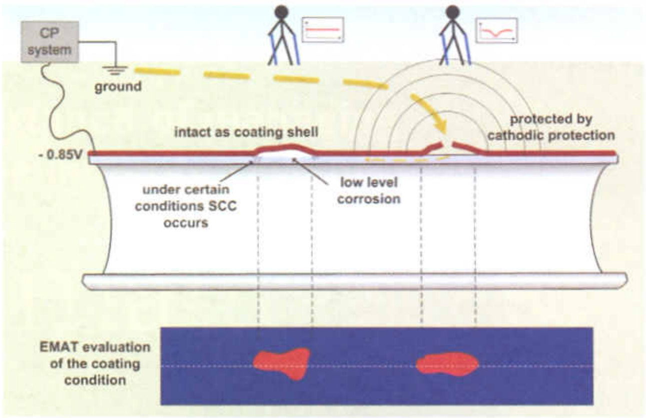

Figure 8. Correlation of EMAT data with measurements of cathodic protection.

Conclusion

Based on EMAT technology, the RoCD[2] tool fleet developed by ROSEN enables inspection of liquid and gas pipelines for cracks in the pipe wall and analysis of pipeline coating condition. With the unique high-resolution sensor configuration, pipelines totaling more than 2000 km have been successfully inspected since 2005. Numerous field verifications carried out in North America, the Middle East and Europe have confirmed the reliability of this tool fleet.

Correlating the EMAT data with cathodic protection measurement data enables extended analysis of pipeline coating conditions. In addition, the combination of these data sets permits differentiation between coating defects and coating disbondment. This information constitutes an important parameter for SCC susceptibility models. WP

References

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