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# EXAMINATION OF TIME DOMAIN REFLECTOMETRY FOR FAULT LOCATING IN PIPELINES

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**Abstract**

Simulation processes and an experimental test are performed to investigate the practicability of using the time domain reflectometry (TDR) for the detection of defects in pipelines. Similar to the employment of TDR in checking electrical wiring it may serve to evaluate the position and the degree of a defect. Various simulation models are used to learn about the correlation between the quality of the defect and the reflected signals. A simplified laboratory model is set up for conducting trials with a TDR measurement device. Especially for online monitoring of horizontal pipeline drillings the method could provide an improvement over conventional approaches.

## INTRODUCTION

Horizontal pipeline drillings are employed when pipeline routes encounter natural or man-made obstacles, such as rivers, highways or channels. In this case a directional horizontal drilling is performed passing under the respective obstacle. At the target position the hole exits from the ground, enabling the retraction of the isolated pipeline. The pipe consists of individual segments that are welded together. The joints are subsequently coated and protected from corrosion. The pipe is connected to the drill string via a coupling element, the pulling head, and pulled through the created hole.
The pulling process of pipes is ideally monitored by measurement in order to detect as early as possible damage to the coating of the pipes, for example, by rocks and to

locate the position of these flaws. Based on these results appropriate countermeasures can be initiated [1]. This is very important, because damages can be economically protected by cathodic corrosion protection only to a certain degree. Therefore, if the damage is not detected by measurement at an early stage, the drilling can result in an expensive economic loss, because the pipeline has to be salvaged and repaired or must be abandoned. The damage detection and locating the position of the damaged area and the assessment of the respective size are therefore of great economic importance.

The standard measurement method used for locating of damage can be done only after the collection of the entire pipeline , since in this case measurements must be made and analyzed from both ends of the pipe [2-3]. This is not of great utility for an horizontal drilling given the mentioned reasons. Recently an improvement over the existing eddy-current based methods has been made[4]. Measurement devices are integrated in the pulling head so that both ends of the pipeline are accessible. A control cable is laid through the inside of the pipeline to the surface to acquire the data. In the rough environment of the drilling construction site the cable is very prone to damage and so high effort and caution are necessary to conduct the measurements.

Various monitoring techniques based on the generation of acoustic elastic waves have been developed and used for the maintenance of installed pipelines[5-6]. According to these techniques, the possible defect which represents a discontinuity point, produces reflected and transmitted waves, and therefore a distortion in the elastic waves propagation. Even if these techniques are still now considered, they present some drawbacks related to the limited range and again to the fragility of the measuring system in a rough environment.

This work presents the investigation of the propagation of electrical signals instead of traditional acoustic waves along metallic pipelines to carry out the feasibility of using the TDR method for the detection of defects in pipelines. Latest researches regarding TDR for monitoring pipelines have achieved good results by introducing an auxiliary conductor acting as signal return. In this way the pipeline can be treated as a transmission line. The auxiliary conductor is either a metallic wire laid on the surface parallel to the pipeline [7] or a cable directly attached to the pipeline [8]. These approaches though are not practicable for monitoring the state of the pipeline during the horizontal drilling process.

## SIMULATION OF TDR SIGNALS ON A PIPELINE MODEL

Time domain reflectometry has been used intensively for the detection of faults in transmission line, waveguide, and optical fiber systems. In fact, radar may be regarded as a TDR instrument that uses free space as the propagation medium. A TDR instrument consists of a circuit that launches a pulse of energy into a medium and then monitors the launching point for reflected energy. The magnitude of the reflected pulse of energy indicates the size of the discontinuity in the medium and the time delay of the returned pulse indicates the distance to the discontinuity. [9]

To estimate the characteristics of TDR Signals on damaged pipelines a small scale model is set up in the simulation software ANSOFT HFSS. The model consists of a polyethylene-coated steel pipeline with a defect in the middle of the pipe. The pipeline is embedded in sand. The excitation signal is introduced at the open end of the pipe.

The results show that the defect location can be easily identified in the TDR signal (see fig.1-6). Given the propagation speed of $2 \cdot 10^8$ m/s with which the signal travels along the pipe, the distance can be evaluated.

To approach the effects caused by different boundary conditions, the parameters concerning the defect itself as well as the pipeline are varied.

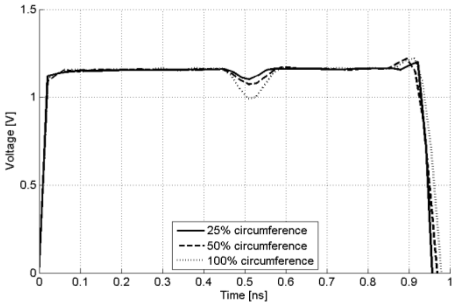


**Figure 1: Variation of defect area**

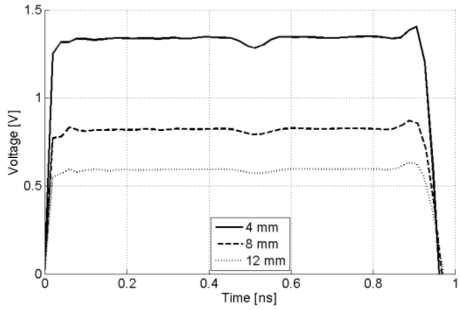


**Figure 4: Variation of pipe diameter**

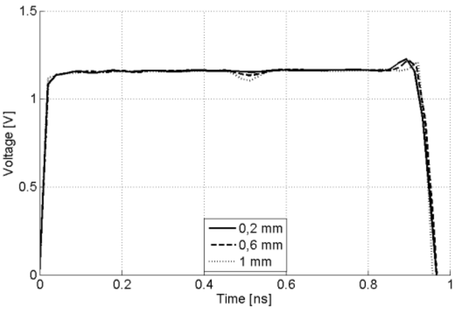


**Figure 2: Variation of defect depth**

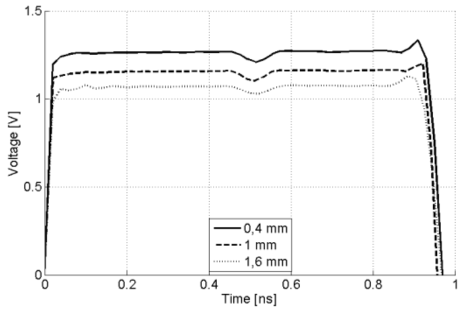


**Figure 5: Variation of pipe thickness**

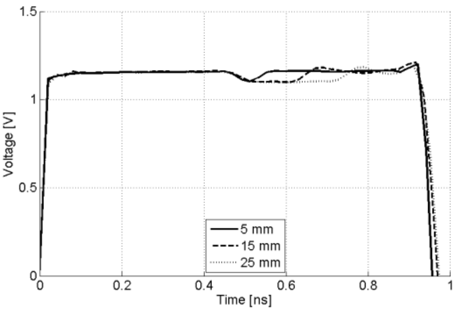


**Figure 3: Variation of defect length**

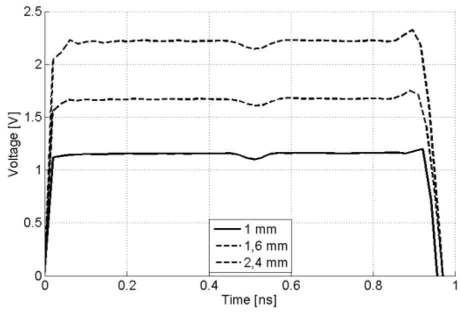


**Figure 6: Variation of pipe coating thickness**

Figure 1 shows the variation of the defect area around the pipe circumference. The larger the area the higher is the negative peak in the reflected signal. Even if the coating of originally 1 mm is not completely perforated a small negative peak can be recognized (see fig.2). If the defect length is extended along the direction of the pipe,

the peak in the reflection signal is also widened. Through the width of the peak the defect length can be calculated (see fig.3).
Variation of the pipe diameter and pipe thickness result in a shift of the TDR signal level (see fig. 4-5). The higher the diameter an thickness the higher is the conductivity and so the voltage level drops. Thickening the pipe coating has the same effect (see fig.6).

## EXPERIMENTAL TDR TEST ON AN SIMPLIFIED LABORATORY MODEL

The simulations show encouraging results, so that further experimental TDR tests are conducted on a simplified laboratory model of a pipeline. The test setup in these experiments is shown in Figure 7 and Figure 8.

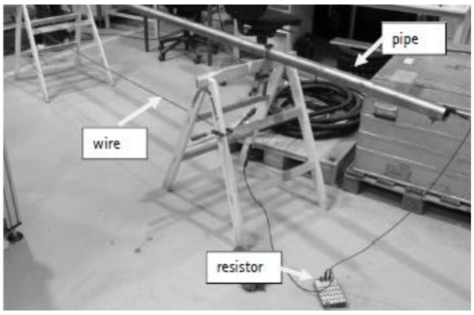


**Figure 7: Laboratory Model**

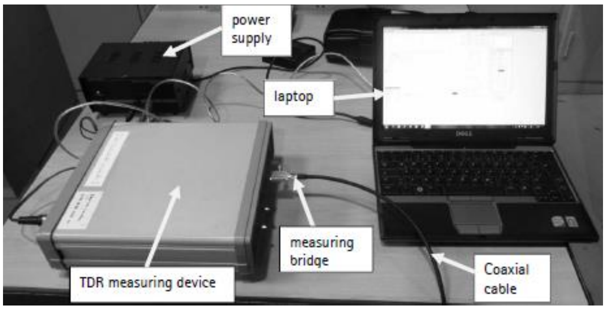


**Figure 8: Test setup**

A metallic tube serves as pipeline, the thin metallic wire in combination with an resistor reproduces the soil. The coaxial cable from the TDR instrument is divided into inner conductor and sheath and contacted to the tube and the wire.
The TDR instrument is a SYMPULS TDR-3000 normally used for radar measurements.
A defect to the pipeline is simulated by a short through a resistor between the pipe and the wire. The short is realized by a cable. The short is set up at different locations and the respective TDR trace is recorded.
Figure 9 shows the relevant section of the TDR traces of shorts in variable distance from the feed location.

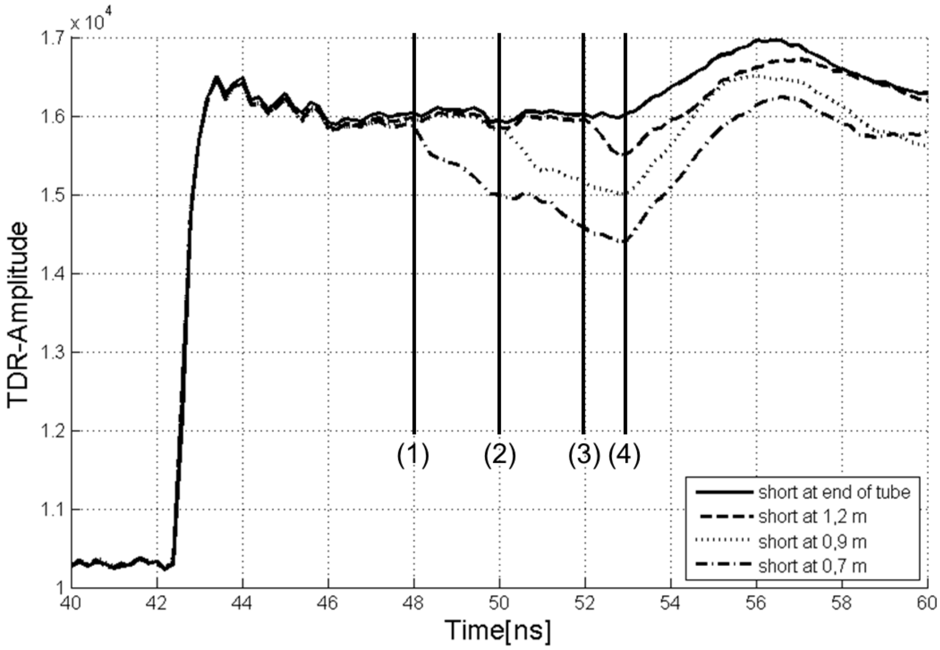


**Figure 9: TDR traces for shorts at variable distance to feed location**

The shorts can be identified at the given locations (detail 1-3) by a quality fall-off in the TDR traces. The end of the tube is also clearly visible in all of the traces (detail 4). However, it must be noted that the test was carried out under ideal conditions and neglecting negative edge effects.

## CONCLUSIONS

The simulative and experimental studies have shown that the TDR method provides chances of success for monitoring pipe installation processes. Both references to defect position as well as on the extent of the defect can be obtained. Because of the encouraging results further research studies are in progress such as larger scale measurements on a specially designed test rig as well as field test on installed pipelines up to one kilometer in length. The more complex the devices under test become the more complex the data analysis will become. Filter algorithms will be necessary to identify the characteristics of a defect in the recorded traces.

**Acknowledgements**

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