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Pulsed Eddy Current Testing of Inner Wall Flaws in Pipe under Insulation

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Abstract

The localized inner wall corrosions in the pipe under insulation are especially hazardous to pipelines. An inspection system is designed to detect inner wall flaws in pipe based on pulsed eddy current technique. Simulation specimens with large area thinning, localized grove-like corrosions and pit-like corrosions are machined, and probes are designed and manufactured. A series of experiments are performed to optimize testing parameters and improve detection sensitivity. The experiments show that the system can detect 10 percent thinning of wall under insulation when the thickness of pipe and insulation is respectively 10mm and 110 mm. The detection accuracy can meet the requirement in the inspection of pressure pipeline. The system can also detect some localized corrosions under insulation.

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Keywords: Pulsed eddy current; insulation; pipe; Inner wall corrosion; localized corrosion

1. Introduction

Ferromagnetic pipes are widely used in the petroleum, energy, chemical, power and other industries. The cladding layer, including both insulation and metal coating, is installed in the outer of pipe, in order to prevent energy loss from transmission medium and improve the corrosion resistance of the wall. The corrosions under insulation (CUI) likely to happen when the outer layer of cladding is broken. Rupture of the outer layer likely to cause pipe corrosion out of the wall, and media of toxic, high temperature and pressure, as long-term erosion, can

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easily result inner wall corrosion. Use of new corrosion-resistant insulation materials can reduce the outer corrosion to a certain extent, however, it is difficult to control internal corrosion and eliminate. The detection of inner wall flaws under insulation is also a problem, as the localized corrosion of inner wall can become a big harm when its depth is large.

Several testing technologies are applied in the detection of pipe under insulation such as ray inspection, ultrasonic guided wave testing and magnetic flux leakage detection, among which, the guided wave testing and pulsed eddy current testing technology is currently developing more mature, and are used relatively broadly [1-3].

In the field of ultrasonic testing, the Teletest testing equipment produced in British TWI Group and Wavemaker produced in British ultrasound guided wave company are applied in long-distance pipeline corrosion detection [4]. Ultrasonic guided wave can achieve long-range detection and rapid positioning inner wall corrosion with removal of a small portion of insulation, however the detection sensitivity is not very high as guided wave attenuation and large external noise. According to the EU's "corrosion under insulation guidelines", the guided wave, as a scanning means, needs careful examination in combination with other techniques, one of which is pulsed eddy current testing technology [5].

The pulsed eddy current testing (PECT) technology can carry the detection of inner and outer wall flaws without remove of insulation and can’t be affected by the temperature of the flowing medium in the pipe, which are the biggest advantages. The PECT is currently applied in the detection of corrosions in pipe under insulation in RTD company, Shell and other American companies and achieved good results [6,7]. The PECT system has been developed several years in China for the detections of area corrosions under insulation and research of localized corrosion testing [8-10].

A testing method of localized wall corrosion under insulation is studied in this paper, and a PECT system which carried the detection of artificial inner wall flaws under insulation is established. This study has great significance for discovering wall flaws, especially the localized corrosion of inner wall, and reducing economic losses caused by pipeline leakage.

2. Pulsed Eddy Current principle in pipe

Figure 1 is the PECT schematic in the pipe under insulation. When the excitation coil of probe is passed through a bipolar square low-frequency pulse and the excitation is carried out in the detection of ferromagnetic material, its mechanism can be approximately interpreted as the effect of truncated current as shown in Fig. 2. The pulse signal of a frequency is transmitted to sensor’s excitation coil when the excitation pulse signal is cut off at a moment, so the excitation coil will generate a pulsed magnetic field and has rapid decay. Rapid decay of the pulse magnetic field in the pipe specimens induces a pulsed eddy current which will produce a secondary magnetic field decay at last, and changes of the secondary magnetic field can represent the changes of eddy current on ferromagnetic specimens, so as to reflect metal loss of inner and outer wall of pipe near receiving coil of probe.

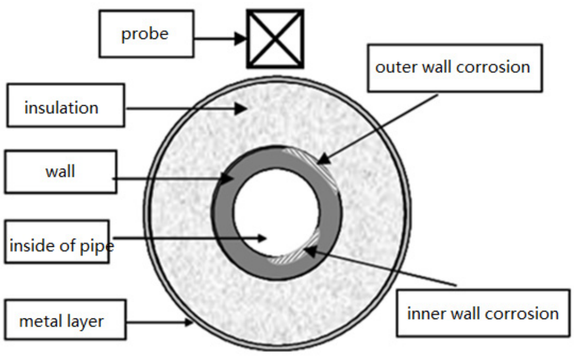

Fig. 1. PECT schematic in the pipe under insulation.

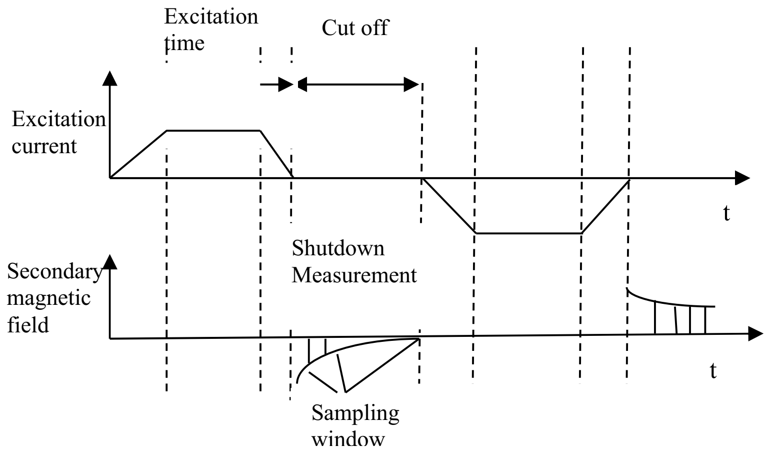

Fig. 2. Pulse excitation and reception curve

3. Testing system

3.1. Design of the testing system

The designed PECT system includes a pulse excitation, acquisition device, probe, signal analysis software and specimen, as is shown in Fig. 3.

Fig. 3. PECT system in the pipe under insulation.

3.2. Design of the probe

The PECT Probe's structure is design of cylindrical shape with the unbiased coaxial excitation and reception. The excitation coils' diameter is 1.0 mm, wounded 300 turns, and the detection coils' diameter is 0.42 mm, wounded 1200 turns. The excited pulsed current is 1 amp with its frequency of 4 kHz and duty cycle of 50%.

3.3. Design of the specimen

The inner wall artificial flaws are machined in the carbon steel pipe whose length is 6000mm, the nominal diameter is 159 mm and wall thickness is 10 mm. The artificial defects include large area thinning, localized grove-like corrosions and pit-like corrosions shown in Fig. 4 and Fig. 5 The thickness deviation of specimen is almost the same as used in the production. The allowable thickness deviation is ± 10%, and actual wall thickness is between 9.20 mm and 10.74 mm.

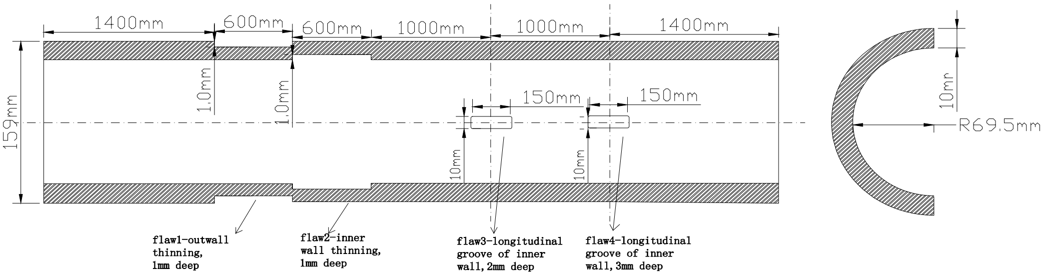

Fig. 4. Distribution of artificial inner flaws in specimen A.

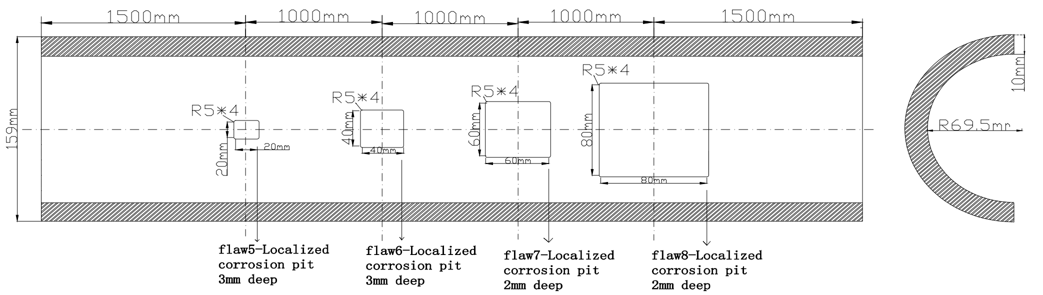

Fig. 5. Distribution of artificial inner flaws in specimen B.

4. Testing and data analysis

In order to avoid the affect of the pipe port, the first data acquisition is carried out at a distance of 1000mm from the port of pipe, with every interval acquisition of 200 mm and form a decay curve. Fig. 6(a) shows an acquisition curve of testing in the specimen. When the pipe exists defects, the receiving coil's voltage attenuation will accelerate, which can be used to identify defects. The attenuation curve is divided into 4 time slices and each time slice corresponds to an induction voltage, thereby forming the C27, C28, C29 and C30 time window signals (time-slice signal) as shown in Fig. 6(b). The horizontal axis represents the position of acquisition on the pipe, and the ordinate axis represents the voltage of the receiving coil in Fig. 6(b).The voltage at a time slice will attenuate when the pipe exists flaws, and the greater is the flaw, the greater the voltage signal attenuates, so we can choose a different time slice to identify the flaw. The detection system selects the best window signal of C27 in the detection of inner wall flaws under insulation.

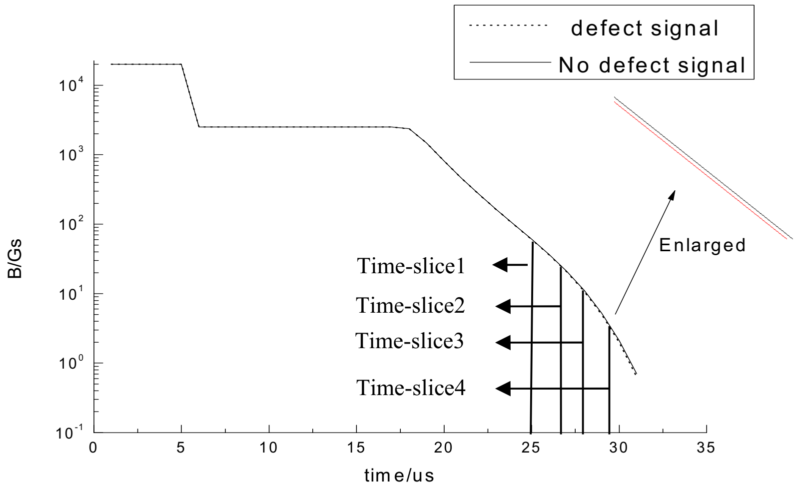

Fig. 6. (a). Time slice of PEC fast decay signal.

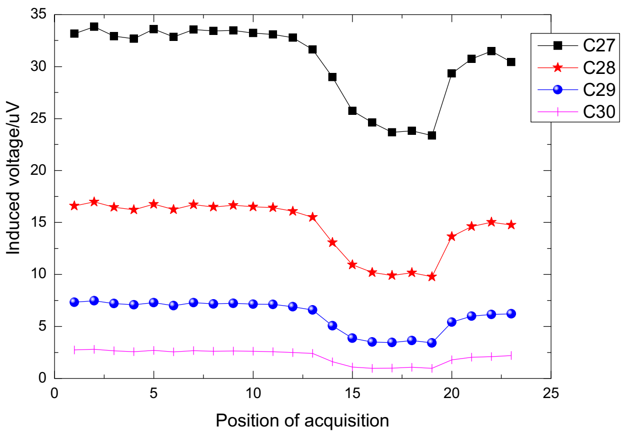

Fig. 6. (b) Sectional view of the Pulsed Eddy Current.

Figure 7 shows the testing results of artificial flaws in specimen A under insulations with the insulation's thickness of 75 mm, 90 mm and 110 mm. A significant decline happens in the first groove flaw (flaw 4) which is in the 4th data acquisition, however, the signal of second groove flaw (flaw 3) is relatively weak. The signal of inner wall thinning (flaw2) declines significantly from the 14th position to the 17th position, and the signal of outer wall thinning (flaw1) also obviously declines from the 17th position to the 20th position. As is shown in Fig 7, when the thickness of insulation is 110mm, the device can significantly detect the large area corrosions of inner and outer wall with thinning of 10%. It can also detect the local flaw 4 with the length of 150mm, width of 10mm and depth of 3mm, however, the signal of local flaw 3 is not significant. The decline at the 6th position is a non-artificial defect signal, as it is the thinner wall due to the deviation of steel production. The 6th position in the pipe is measured by ultrasonic thickness gauge, and its thickness is between 10.03mm and 10.12mm which is thinner than the surrounding wall thickness of 10.46mm-10.70mm, so it displays a little decline at the 6th position in the pipe.

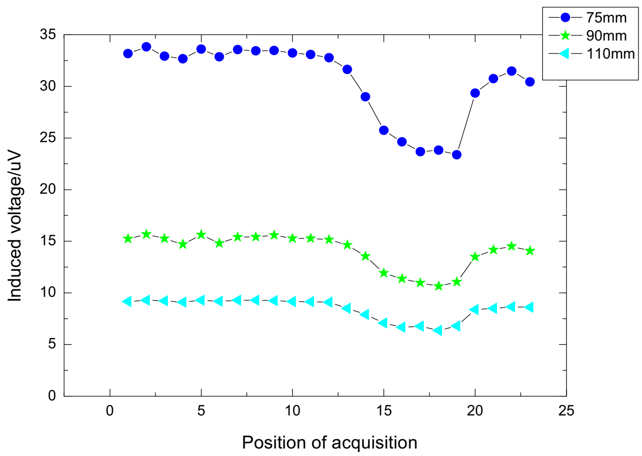

Fig. 7. Pulsed eddy current test results of artificial flaws in specimen A.

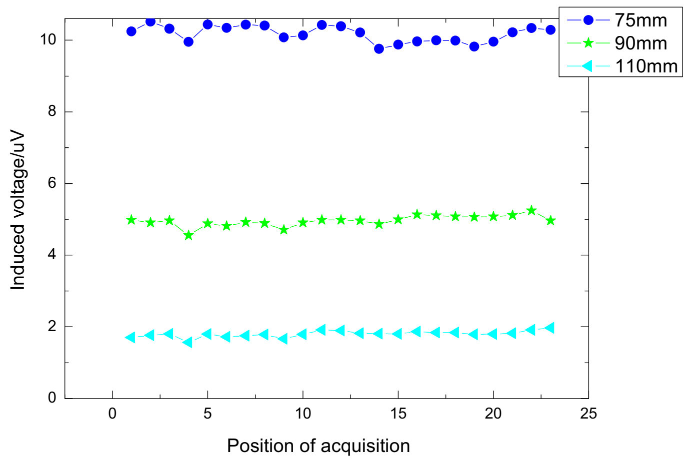

Fig. 8. Pulsed eddy current test results of artificial flaws in specimen B.

The testing results of specimen B in Fig. 5 are shown in Fig. 8. The probe is placed at a distance of 1000mm from the port of pipe, and the signals of flaw 8, flaw 7, flaw6 and flaw5 appear accordingly at the 4th, 9th, 14th, and 19th positions.

It can be seen from the Fig. 8 that all the signals of 4 localized corrosions pits in specimen B decline accordingly at the 4th,9th ,14th ,19th positions of the pipe, when the thickness of insulations is 75 mm, 90 mm and 110 mm. All flaws in specimen B show more obviously as the insulation's thickness is 75 mm. Experiment shows when the thickness of insulation is less than 110mm, pipe's diameter of 159mm, and the thickness of wall is 10mm, the pulsed eddy current system can obviously detect the local flaws of inner wall, with the area of about 300 square millimeters and depth of 20%.

The comprehensive testing results of specimen A and specimen B show that the pulsed eddy current system is able to detect the inner and outer wall thinning of 10% in the pipe under the insulation. Furthermore, the system has reached a certain degree of detection accuracy for the localized corrosion such as strips or localized area corrosions with the depth of 20%.

5. Conclusion

A kind of practical PECT system is established in this paper, and series of experiments are carried out in the test of large area thinning, localized grove-like corrosions and pit-like corrosions. Experimental results show that, as pipe's diameter of 159 mm and insulation's thickness of 110 mm, the designed PECT system can significantly detect the inner wall thinning of 10% and localized corrosions with the area of about 300 square millimeters and depth of 2 mm, which can meet the industry demand for testing. The system also has some sensitivity for the detections of smaller localized strip corrosion and pits.

Acknowledgements

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