Development and Application of Pulsed Eddy Current Testing System for Ferromagnetic Pipes

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Abstract

Pulsed eddy current (PEC) testing technology is widely used in the field of large area corrosion detection. According to the material attributes of detected objects, there are mainly two fields in which PEC technology is used: Non-ferromagnetic and ferromagnetic material testing. When the testing object is ferromagnetic, the decaying speed of the received signal differs according to the difference of the material's electrical conductivity, magnetic permeability and thickness. This paper states the realization of a type of PEC testing system and its application in ferromagnetic pipe testing from inside and outside of the pipe. The system consists of an exciting module, a signal receiving module, coil probes and a personal computer (PC). The exciting signal is generated by Direct Digital Synthesis (DDS) integrated circuit and the exciting coil is powered by an integrated power operational amplifier. The received signal is filtered and amplified by low noise wide dynamic range amplifying circuit. The signal is then digitized by USB data acquisition system. A PC is used for signal processing and analysis. Experiments were taken with two kinds of coil structure probes to test ferromagnetic pipe from outside and inside of the pipe respectively. One type of coil probe which has the advantage of eliminating vibration effect during the well logging process in oil industry is employed to find the coupling part of casing from the inside. Another type of coil probe is used to test the wall thickness loss through coatings from the outside of the pipe and it is able to detect 10% wall thickness loss with probe lift-off up to 80mm so it can be employed to test high temperature parts without removal of coatings.

Keywords: Pulsed eddy current, ferromagnetic pipe, wall thickness loss, lift-off

1. Introduction

The ferromagnetic pressure vessels and pipes are key components to store or carry the crude material in petrochemical industry. Corrosion may occur in these vessels or pipes because of long-term electrochemical effects [1]. Similarly, the flow accelerated corrosion may occur in the feed water system of the power plants [2]. When the wall thickness of these vessels or pipes reduces to certain level, the vessels or pipes may break under high pressure and cause severe accident. If traditional non-destructive methods (e.g. Magnetic Flux Leakage Testing, Ultrasonic Testing) are applied to detect these objects, generally the removal of the coatings is inevitable.

When the testing is over, the coatings should be installed again. The disassembly and assembly of the coating are time consuming and expensive. When PEC testing technology is applied, the troublesome procedure of coating manipulation is not needed because PEC testing technology is suitable for testing the area corrosion of the ferromagnetic objects with various coating thickness [3, 4].

In oil industry, the segments of casing are connected by coupling part to protect the tubing. The coupling part is usually thicker than the casing body. When inspecting the corrosion situation of the casing, it is needed to firstly locate the casing's coupling part. The pulsed exciting of PEC testing technology is able to penetrate the casing wall and coupling. The signal characteristics are related to the metal volume surrounding the probe. It is possible to find the coupling parts of the casing if proper probe coil structure is chosen.

The authors have developed a PEC testing system to test the ferromagnetic object. Two types of coil structure probe are designed for internal and external testing of ferromagnetic pipes. Internal testing has been taken on a casing with coupling part. External testing has been taken on a pipeline and a step wedge plate respectively.

2. PEC system development

The key component of pulse generating part is a Direct Digital Synthesis (DDS) integrated circuit (IC). The DDS IC is controlled by a Single Chip Micyoco (SCM). The SCM controls the DDS IC to generate sine wave signal with adjustable frequency ranged from 0.1 Hz to 300 kHz. The sine wave is converted to square wave with rising and falling time less than 200ns by a voltage comparator with adjustable threshold voltage.

The square wave is then amplified by a current feedback power amplifier to excite the exciting coil. The pulsed exciting in exciting coil stimulates eddy currents in the object to be tested. The eddy current varies to the object's wall thickness loss produced by the corrosion and its signal is detected by the detection coil. The signal is then amplified and digitized by USB data acquisition system and uploaded to a PC. The tested object wall thickness information can be obtained by signal processing and analysis. There are two factors to be considered in the system development. One is the coil parameters such as coil's shape, number of turns and enameled wire gauge. The coil parameters will affect the signal characteristics. The other is the signal amplitude between the ends of detection coil. The peak amplitude of the signal is between several decade volts to 100 volts, so a voltage clamp circuit is applied to protect the signal amplifier stage. The developed PEC system is illustrated in Figure 1.

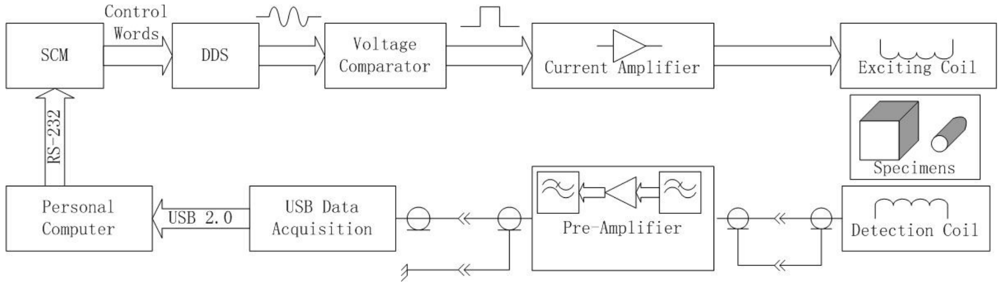


Figure 1. PEC system setup

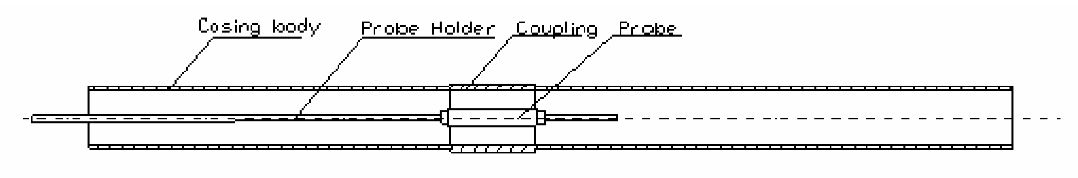
3. Application of the PEC system

3.1 Internal testing of coupling and casing body

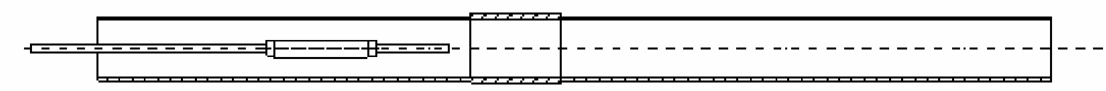
One type of casing with the dimension of 177.8 mm diameter ×10 mm thickness × 2715 mm length is employed. A 20mm thick coupling part is in the middle as Figure 2 shows.

Figure 2. Casing with coupling

The placements of the probe for internal testing of the coupling and casing body are illustrated in Figure 3(a) and Figure 3(b). The probe is centrally placed in the casing.



(a) Internal testing of coupling



(b) Internal testing of casing body

Figure 3. Probe placement for casing and coupling testing

The signals in Figure 4 shows the developed PEC system is able to distinguish coupling and casing body when probe is placed as shown in Figure 3.

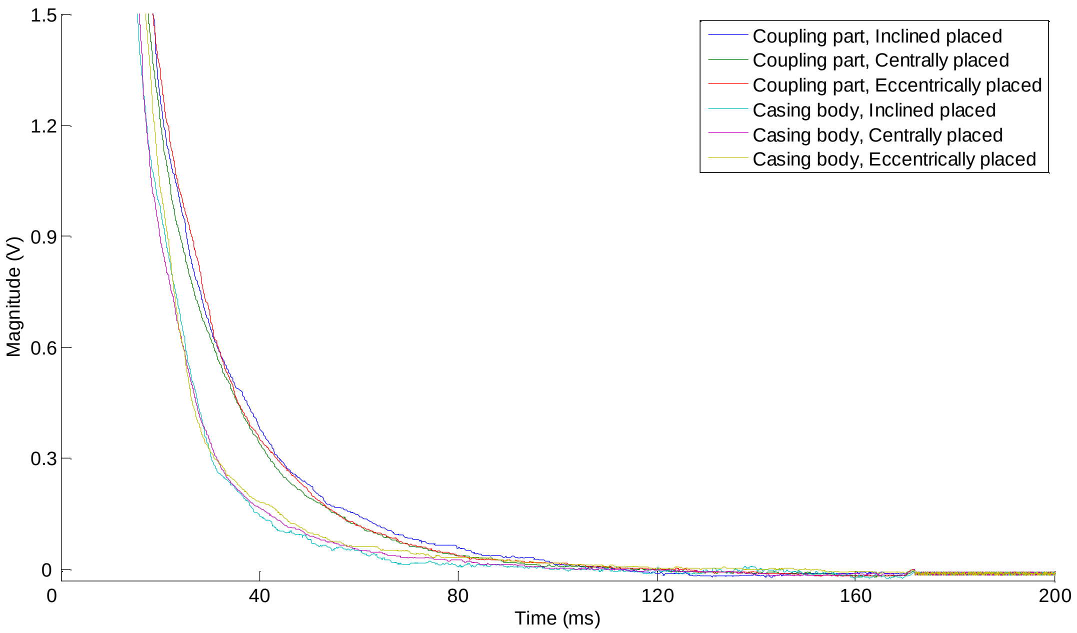


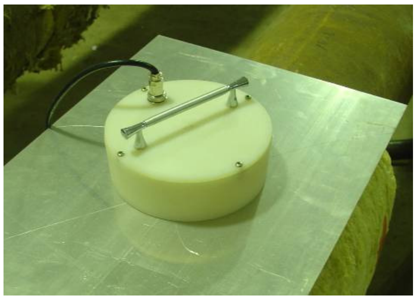
Figure 4. Signals of casing and coupling internal testing

Experiments are also taken with the probe placed eccentrically and inclined. Figure 4 also shows the signals acquired under the other two probe placement conditions. According to Figure 4, the probe position variation along the radial direction of the casing has little influence on the signal decaying rate. For internal testing of the casing or pipe, no centralizer is needed. The signal is immune to the vibration effect along radial direction of the pipe. Thus, the developed PEC system can be used in logging procedure in oil industry.

3.2 External testing of pipeline at 80 mm lift-off distance

The 219 mm diameter × 20 mm thickness pipeline with a manufactured 10 mm thick section is employed to check the performance of external testing by the developed PEC system. A block of 80mm thick polyurethane foam is encircled around the pipe as the coating material. The 1.3 mm thick Al plate and 1 mm thick stainless steel (SS) plate are used as the mock-ups of sheeting wrapped around the pipe's coating. Figure 5 shows the probe placement without and with sheeting at 80 mm lift-off distance.

(a) Pipeline testing with sheeting



(b) Pipeline testing without sheeting

Figure 5. Probe placement for external testing of pipeline

Figure 6 shows the signals acquired on 20 mm thick section and 10 mm thick section of the pipeline when probe is placed without and with Al/SS sheeting.

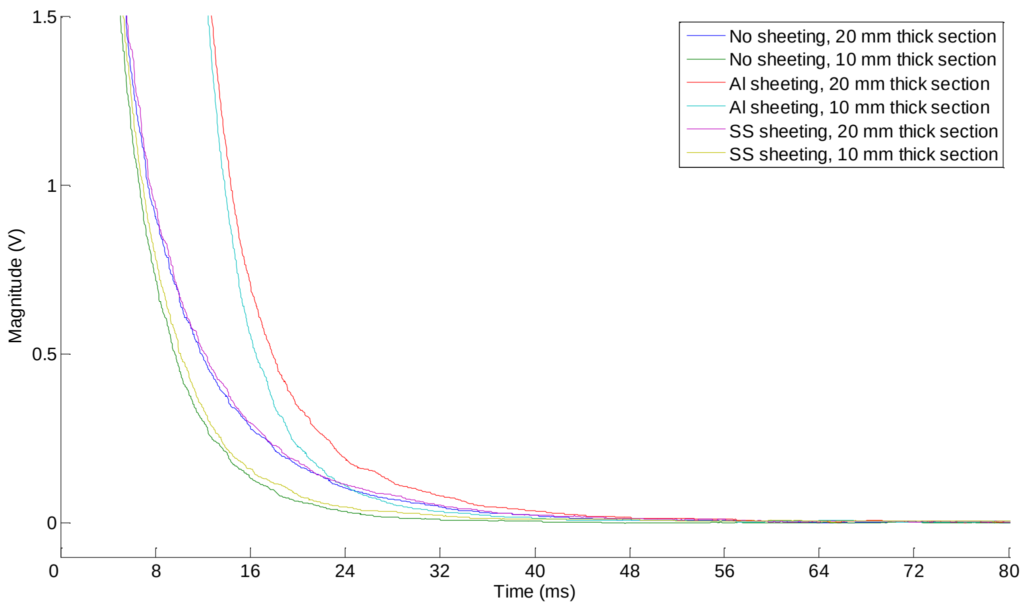


Figure 6. Signals of pipeline testing with 80 mm lift-off

According to Figure 6, the PEC system can distinguish the 20 mm thick section and 10 mm thick section at a distance of 80 mm without or with Al/SS sheeting. Therefore, the developed PEC system is suitable for testing of wrapped ferromagnetic object such as insulated pipes and vessel.

3.3 Testing the ferromagnetic step wedge plate thickness at 80 mm lift-off distance

To evaluate the PEC system's resolution of the wall thickness, experiment is taken on a two step wedge plate which has the dimension as shown in Figure 7. The plate is tested at 80 mm lift-off distance without and with Al/SS sheeting respectively.

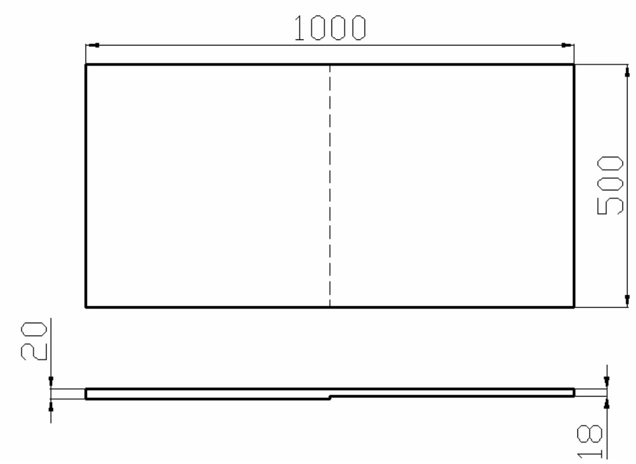


Figure 7. Dimension of two step wedge plate

Figure 8 shows the signals acquired on 20 mm and 18 mm thick sections of the plate when probe is placed without sheeting and with Al/SS sheeting. The PEC system is able to detect 10% wall thickness loss at a distance of 80 mm with Al/SS sheeting.

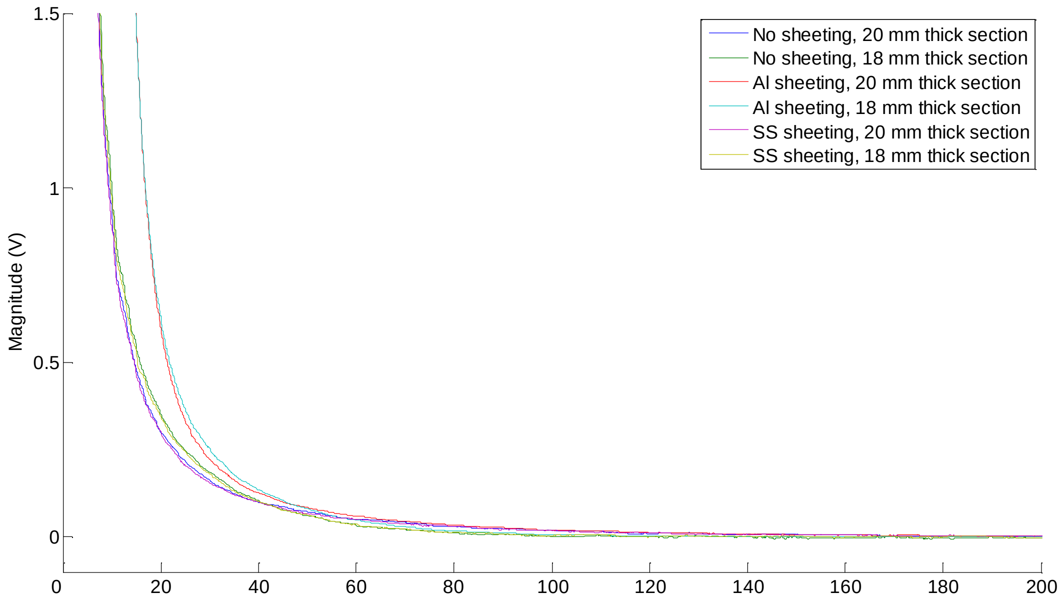


Figure 8. Signals of plate thickness testing with 80 mm lift-off

The external testing experiment results of pipeline and plate show that the signals acquired with SS sheeting have almost same signal shape and decaying rate as the signals acquired without sheeting, while Al sheeting has a relative large influence on the signal shape and decaying rate. A set of PEC testing instrument based on the mentioned PEC testing system may be applied in practical industry field for insulated vessel/pipe inspection.

4. Conclusions

A PEC system for ferromagnetic object testing is developed. Two kinds of typical application in internal and external testing for ferromagnetic pipe are stated in the paper. Experiment result of internal testing shows that the developed PEC system is suitable for casing or tube coupling testing during logging process in oil industry. If higher resolution can be achieved, it is suitable for casing/tube corrosion situation evaluation. External testing results show that the PEC system can be applied in the field of insulated pipes/vessels testing with the resolution of 10% wall thickness loss.

5. Acknowledgements

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