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DESIGN AND EXPERIMENTAL STUDY OF ALUMINUM ALLOY PIPE DETECTION PROBE BASED ON ACFM

Li Wei, Zhao Jianming ,Xin'an Yuan, Xiaokang Yin and Guoming Chen
Center for Offshore Engineering and Safety Technology, China University of Petroleum (East China)
Qingdao, China

ABSTRACT

Aiming at the deficiencies of the traditional alternating current field measurement probes, it is not suitable for the aluminum alloy pipe detection. A Helmholtz coil-type pipe detection probe and its experimental system are proposed and built. Through the finite element software Comsol, the finite element model of the alternating current field measurement in the axial crack in aluminum alloy pipe detection is established. The distribution and variation law of the electromagnetic field in the pipeline are explored. The characteristic signals and are extracted. And the influence of the length and depth of the crack on the characteristic signal is analyzed. The aluminum alloy pipe detection experimental system is established. The experimental results show that the detection system can realize the full circumferential scan of the axial crack on the inner surface of the aluminum alloy pipe.

Keywords: Aluminum alloy pipe detection; ACFM; Helmholtz coil; axial crack

1. INTRODUCTION

Aluminum alloy pipes are widely used in industry, including high pressure tubes, fluid conveying tubes, heat exchange tubes. However, the wall of the pipe is prone to fatigue cracks due to corrosive media in the pipeline and alternating cooling and heating environments [1-3]. Generally, fatigue cracks accumulate and grow in the longitudinal direction [4], which eventually leads to leakage and failure of the pipe, so the pipeline needs to be detected regularly.

Magnetic powder and permeation detection technology is the most reliable non-destructive testing technology at present, but magnetic powder and permeation detection need to be in direct contact with the material to be tested. The detection of cracks can be realized, but the crack cannot be quantified [5]. Ultrasonic testing technology needs to add a coupling agent between the testing tool and the pipe to be tested [6]. However it is hard to smear the coupling agent the tube without thorough clean; magnetic flux leakage detection technology is only suitable for the ferromagnetic tube [7]. Eddy current detection technology is susceptible to lift. The alternating current field measurement (ACFM) is a novel method of NDT. It is promising techniques for detection and evaluation of defects in the conductive material.

In view of the shortcomings of the ACFM probes that are not suitable for pipe inspection, a Helmholtz coil-type aluminum alloy pipe detection probe is proposed and an experimental system is built. The aluminum alloy pipe detection simulation model is proposed, the distribution and variation law of electromagnetic field in aluminum alloy pipeline are analyzed. The influence of crack size on characteristic signals is analyzed. The detection probe aluminum alloy pipeline and pipe inspection system are designed and built.

2. FINITE ELEMENT METHOD MODAL

The Helmholtz coil structure is used in the detection probe of the uniform electromagnetic field. The Helmholtz coil is a pair of parallel current-carrying identical current-carrying coils. When the coils are energized in the same direction and the two coils are equal to the coil radius, the total magnetic field of the coil is uniform near the center of the shaft.

2.1 MODEL SETUP

The 3D simulation model was built using the finite element software COMSOL as shown in Figure 1. The model includes Helmholtz coil, pipe and air. The lift of the probe is 1mm .A sinusoidal signal with the parameters of duty cycle =50%, frequency =1 kHz and amplitude = 50 mA was used as the excitation signal. A frequency domain analysis was used for model.

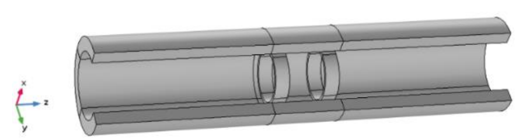

Fig.1 Simulation model

2.2 CHARACTERISTIC ANALYSIS

[*] Corresponding author. *E-mail address: liwei@upc.edu.cn@163.com*

To get the distorted magnetic field caused by the disturbed uniform current field, the magnetic field in axial direction (B_z) and radial direction (B_r) are picked up in the center of the excitation coil at the lift-off of 6 mm. Thus, as the excitation coil moves one step, the B_z and B_r are plotted once at each position, as shown in Fig. 2. The B_z shows a peak in the center of the crack. Meanwhile, the B_r plots a positive and negative peak at the tips of the crack.

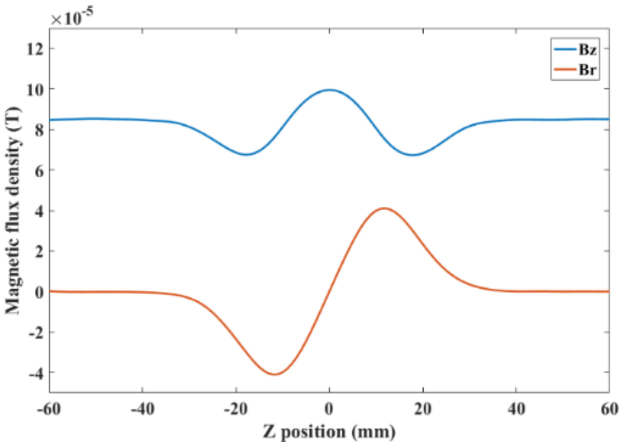

Fig. 2. Axial direction signal B_z and radial direction signal B_r above crack

3. RESULT AND DISCUSSION

A sensor array containing TMR was employed in the Helmholtz coil type electromagnetic probe to achieve rapid full circumferential detection, as shown in fig 3. Considering the space of Helmholtz-coil-type electromagnetic probe and actual manufacturing difficulty, a 10 equal-spaced sensor array was selected.

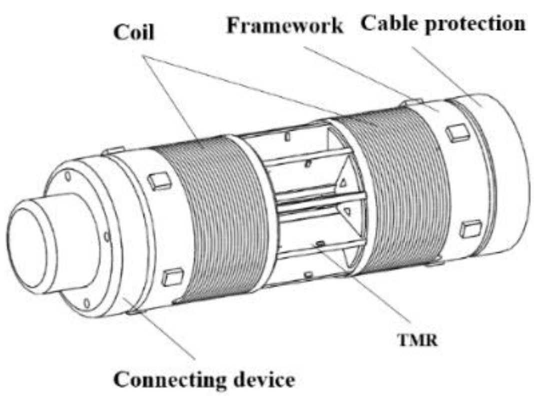

Fig.3. Structure of testing probe

A aluminum alloy pipe detection system was built. The excitation source produced an alternating current signal with frequency of 1 kHz and magnitude of 0.1 A. The turns of the coil were 400 in total. The current was transferred to the excitation coil through the power amplifiers. The detecting sensor array measured the magnetic field and translated it into electric signals. The signals were amplified and filtered in the signal processing module. And then, the signals were converted into digital signals by an A/D convertor and sent to PC for signal processing. A detection software was developed .The probe was fixed in an axial scan table, the pipe was coaxially moved through the probe at a speed of 10 mm/s.

The samples are two aluminum alloy pipes, which external diameter 65 mm, inner diameter 47, as shown in Fig.5 and Fig. 8. It can be seen from the results that when there is a crack, the B_z signal has a peak, and the characteristic signal B_r has peaks and troughs, and the depth and length of the crack affect the characteristic signal.

For cracks of different depths and the same length, as shown in Fig.5 and Fig.6. The deeper the crack, the larger the distortion of the B_z and B_r signals, but the peak-to-valley spacing of B_z does not change substantially. Observing the characteristic signal of each channel, the distortion of the No. 7 sensor is the largest, and the defect can be preliminarily determined that it exists near the No. 7 sensor.

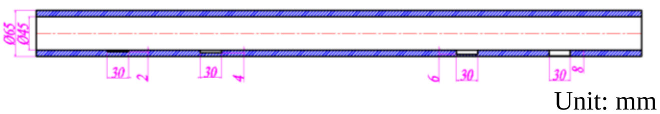

Fig .4. Pipe with different depth cracks

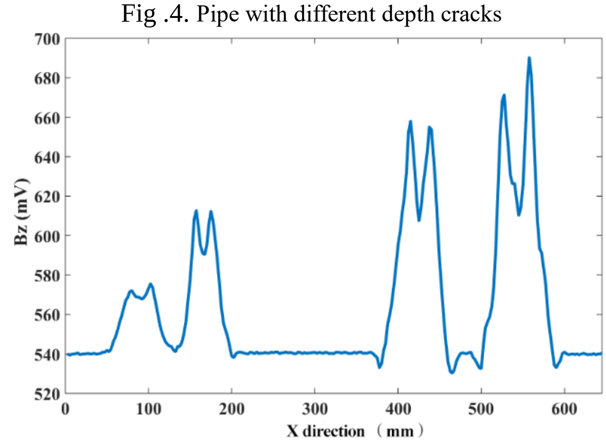

Fig. 5. B_z with different crack depths

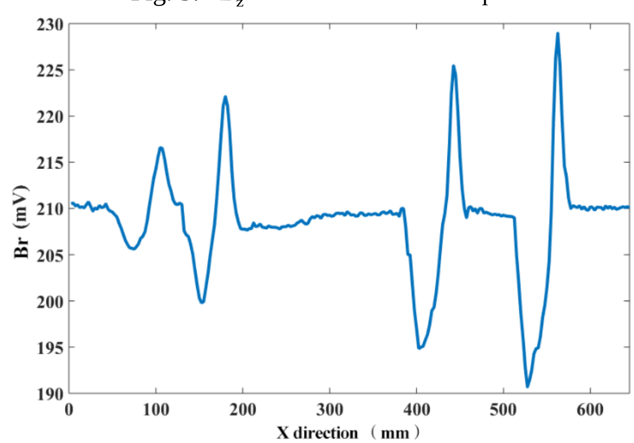

Fig.6. B_r with different crack depths

For cracks of the different depth and the same depth, as shown in Fig. 8 and Fig.9. The longer the crack, the larger the distortion of the B_r and B_z signals, but the amplitude of B_z the change has no large depth change, and the peak-to-valley spacing of B_r increases with the increase of the crack length. Signal of sensor No. 5 has the largest distortion, so it can be preliminarily concluded that the crack exists near the No. 5 sensor.

Unit: mm

Fig.7. Pipe of different length cracks

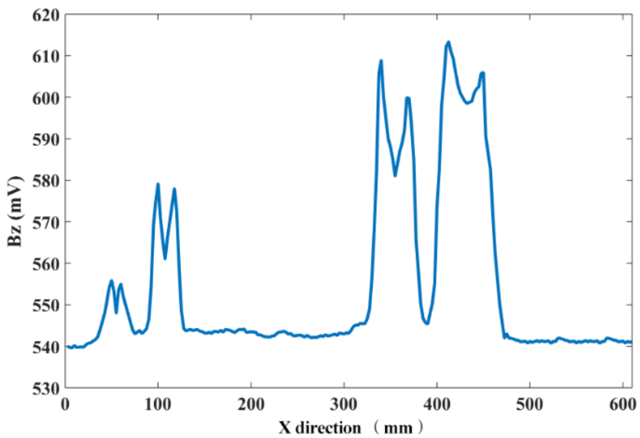

Fig.8. B_z with different crack lengths

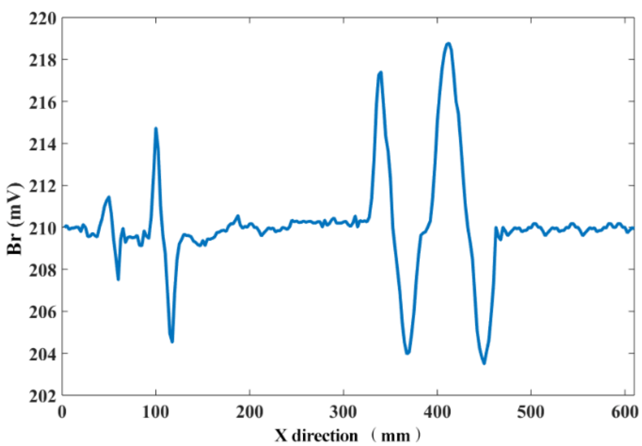

Fig.9. B_r with different crack lengths

4. CONCLUSION

In this work, a novel pipe detection probe is present using uniform electromagnetic field detection technology. The FEM model is developed to extract the characteristic signal of the crack. The structure of the pipe detection probe is designed and experimental studies are conducted to verify the effect and ability for detecting the axial crack of pipe. The result of experiment shows that the detection probe can realize a full circumferential rapid scanning of the axial crack on the surface of the aluminum alloy pipe.

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