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Study on the Influence of Spacing of the Nearby Corrosion Defects on Magnetic Flux Leakage Signals

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ABSTRACT: Magnetic flux leakage technique is a widely used and effective approach for detecting and sizing of the corrosion defects in ferromagnetic pipelines. In general, corrosion defects occur in dense clusters and affect each other. However due to the interaction between the magnetic flux leakage signals, these defects can-not be accurately characterized using the traditional magnetic flux leakage method. In order to discriminate the individual defects and improve sizing performance, tri-axial magnetic flux leakage technique is used. The study is performed using the extensive finite element modeling focusing on the spatial distribution of tri-axial magnetic flux leakage components produced by the nearby corrosion defects. This type of defect geometry comprises two pits that are sufficiently close to influence flux distributions in the area between them. Various degrees of closeness are considered by varying the spacing of the two pits. Following the simulations, experimental magnetic flux leakage tests are performed on the steel plates containing nearby pits. The experimental and finite element modeling results indicate that combining the axial, radial and tangential magnetic flux leakage data can discriminate and characterize the nearby pits. Finally, the experimental and finite element modeling results are compared and validated.

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1- Introduction

Magnetic Flux Leakage (MFL) technique is a widely used and effective approach for detecting and sizing of the corrosion defects in ferromagnetic pipelines [1, 2]. In this method, powerful permanent magnets are used to magnetize to saturation the steel pipeline under inspection. If corrosion defects are present, the magnetic flux is distorted outside the wall of the pipeline. The quantity of this leakage flux is measured using the magnetic sensors such as the Hall Effect sensors and used to locate and estimate the size of the defects [3, 4].

Corrosion defects usually occur in colonies. The corrosion growth rates of a colony of nearby corrosion defects are bigger than the corrosion growth rates of single defects. The increase in the corrosion growth rate is due to the interaction between the nearby defects. Unfortunately, these types of defects cannot be accurately characterized using the traditional MFL method [5, 6]. The literature review indicates that the simultaneous implementation of tri-axial magnetic flux leakage signals can improve the sizing accuracy of the defects [7].

The major contributions of this paper are to: (a) obtain the tri-axial MFL C-scans for nearby pits using the Finite Element Modeling (FEM) and experimental tests, (b) study the influence of the spacing between the nearby pits on the interaction of MFL signals, (c) study the capability of the tri-axial MFL method in discrimination and size estimation of the nearby pits, and finally (d) improve the size estimation of the nearby pits using the combination of tri-axial MFL signals. For this purpose, 3D FEM model is used to simulate MFL signals from the nearby pits of different spacing. Then, experimental MFL tests are carried out. Finally, FEM results are validated with the experimental results.

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2- 3D Modeling of MFL Technique

FEM is a powerful tool to model the process of corrosion detection of MFL method. In this paper, COMSOL software was used for 3D FEM modeling of MFL method. Also, the magnetic flux leakage signals are obtained and studied for the nearby defects.

Fig.1 shows the model geometry of the magnetizer

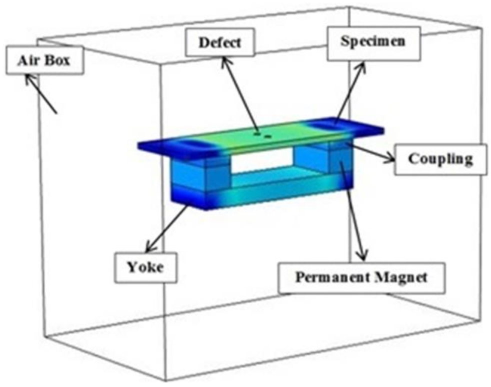

Fig. 1. Three-dimensional geometry of the magnetic flux leakage method

assembly and the specimen under inspection. The magnetizer assembly has two permanent magnets, two couplings, and one yoke. The permanent magnets are used to produce the magnetic flux. Couplings are used to direct the magnetic flux to the specimen under inspection. Yoke is meant to complete the magnetic circuit. The material of the specimen, couplings, and yoke is steel X52. The nearby pits are located at the central area of the specimen. Nearby pits of different spacing ranging from 5 mm to 30 mm on specimens have been modeled. The diameters of the pits were 10 mm and the depths of the pits were 8 mm and 3 mm. After defining geometry and materials, the boundary conditions and mesh elements are defined. Then, the solution by the finite element method is calculated and the results are evaluated.

The results of the FEM modeling of the magnetic flux leakage method can be represented as the C-scan images. Fig.2 shows the tri-axial MFL C-scans for the nearby pits with the spacing of 20 mm. As it can be seen from Fig. 2, the magnetic flux leakage signals have interaction with each other. However, the combination of tri-axial MFL signals (axial, tangential and radial signals) can be used to discriminate the nearby pits and determine the length and width of the pits.

3- Experimental Tests and Discussions

Following the FEM modeling, magnetizer assembly was manufactured and used for MFL inspection of the specimens. Fig. 3 shows the experimental setup of the MFL measurements. The measurement system contains the magnetizer assembly, the specimen containing the nearby pits, the three-axis scanner, Hall Effect sensor and other associated units.

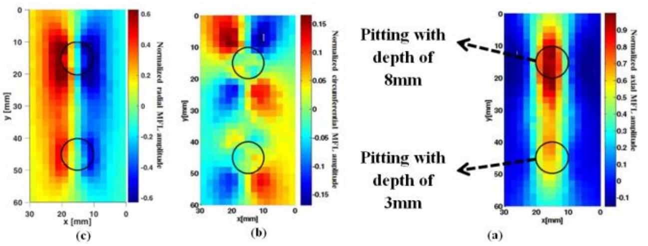

Fig. 2. MFL C-scans for the nearby pits with the spacing of 20 mm: (a) axial signal, (b) tangential signal, and (c) radial signal

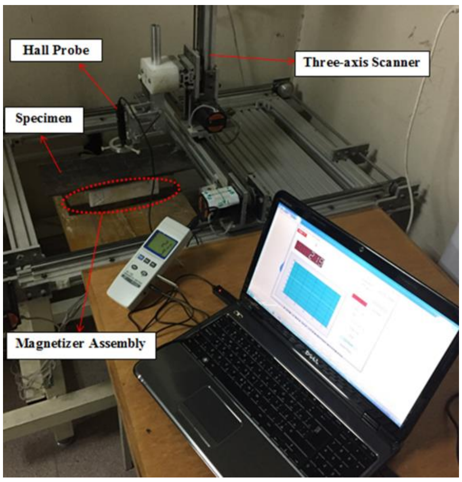

Fig. 3. Experimental system of the magnetic flux leakage method

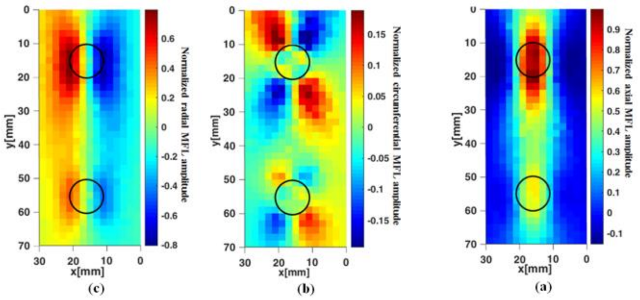

Fig. 4. MFL C-scans for the nearby pits with the spacing of 30 mm: (a) axial signal, (b) tangential signal, and (c) radial signal

The specimens under test were steel X52 plates with thickness of 10 mm. Five specimens were used for experimental tests. In order to perform this experimental study, a scanning area was defined on the surface of the specimens. The step resolution of the scanner was set to 2 mm in both axial and tangential directions. At every *x-y* position on the scanning area, tri-axial MFL data were accurately obtained and saved on a computer for further processing. During the scanning, the distance of the sensor from the surface of the specimen (lift-off distance) was constant. Fig.4 shows tri-axial MFL C-scans for the nearby pits with spacing of 30 mm. The positions of the pits are given by solid circles. As it can be seen from Fig.4, there is a weak interaction between the tri-axial MFL signals when the spacing between the pits is equal to 30 mm.

The experimental results indicate that the spacing between the nearby pits affects the amplitude and distribution of the magnetic flux leakage data. When the spacing between the pits is smaller than 20 mm, magnetic flux leakage signals have strong interaction with each other and discriminating the nearby pits is difficult especially using the axial and radial MFL signals. In comparison to the axial and radial MFL signals, tangential MFL signal is best suited for the discrimination and width estimation of the nearby pits. The width estimation error for the nearby pits is between 2 mm and 6 mm using the tangential MFL signal. The literature review indicates that defect width has great influence on the amplitude of the magnetic flux leakage signal. So, incorrect estimation of the defect width can lead to incorrect estimation of the defect depth [8-10]. Also in comparison to the axial and tangential MFL signals, radial MFL signal is best suited for length estimation of the nearby pits. The comparison between the FEM and test results indicates that there is a good correlation between the results. The mean error is below 6 percent

4- Conclusions

This paper has studied the performance of the tri-axial MFL in detection and sizing of the nearby pits. In conducting this research work, different types of nearby pits were studied according to the spacing between the pits. First, 3D FEM was used to study the interaction of the tri-axial MFL signals produced by the nearby pits. Then, experimental tri-axial MFL test were conducted and the obtained MFL signals were used for sizing of the nearby pits. When the spacing between the pits was decreased, the interaction between the radial and axial MFL signals was high. In this case, discrimination of the nearby pits was difficult. However, the results indicated that the tangential MFL signal was best suited for discrimination and sizing of the pits. Finally, the FEM results and experimental test results were compared. The comparison results showed that there was a good correlation between the FEM results and experimental results. These results showed that tri-axial MFL has a good potential for sizing of the nearby pits.

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