A Study on the Estimation of the Shapes of Axially Oriented Cracks in CMFL type NDT System

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***Abstract*—Axially oriented small crack is hard to detect in conventional system. CMFL (Circumferential Magnetic Flux Leakage) type PIG(Pipelines Inspection Gauge) in the NDT(Non-Destructive Testing), is used to detect this cracks in pipeline. It is necessary to decompose the size and shapes of cracks for the maintenance of an underground pipelines. This paper focused on the decomposing method of the size and shape of the axially oriented cracks by using defect signals. Estimated shapes in this paper agreed well with measuring ones.**

***Index Terms*—Magnetic flux leakage, Pipelines, Finite element method, Nondestructive testing.**

I. Introduction

The CMFL type nondestructive testing method is applied to detect axially oriented cracks of the ferromagnetic materials such as gas pipelines [1]-[2]. In this system, the object is magnetically saturated by the magnetic system with permanent Nd-Fe-B magnet and back yoke. CMFL PIG generates circumferentially oriented magnetic fields that can maximize the leakage field in the vicinity of axial cracks on the pipe [3].

In this article, the CMFL PIG is designed and magnetic leakage field is computed by using finite element method [4]-[5]. In addition, experimental measurements are performed according to cracks which size and shape are different from each other. Therefore, from the analysis of leakage field signal, the mechanism of estimation for determining defect size and shape is proposed.

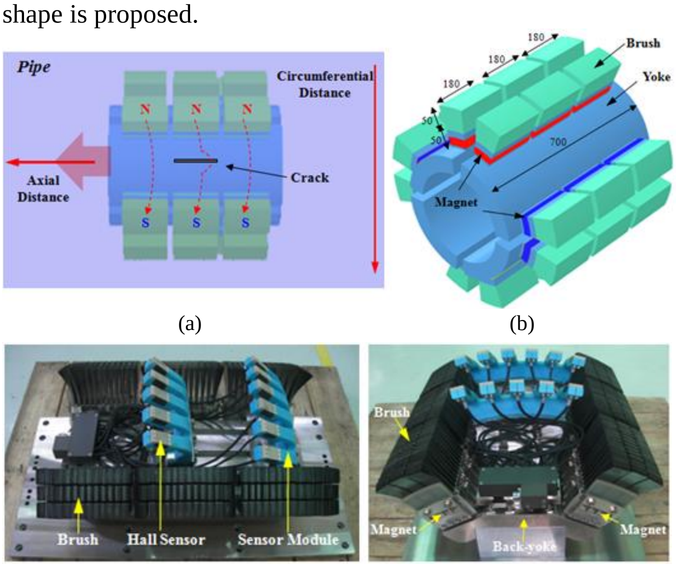

Fig. 1. (a) Diagram of CMFL PIG, (b) Design and structure of CMFL PIG, (c) and (d) are photograph of the module

II. Structure and Design

The structure and operating principle of CMFL PIG is shown in Fig. 1(a) and Fig. 1(b). The CMFL PIG is consisted of magnetic field transmission system and sensor module. There are 165 hall sensors on the CMFL PIG and they are aligned close interval each other.

III. Analysis of Sensing Signal

The calculation of magnetic flux density on the surface of the pipe or leakage flux density in the vicinity of the crack is performed by finite element method as shown in Fig. 2. Wherever axial cracks are detected on the pipe, both distribution and amplitude of sensing signal for magnetic leakage field are changed with respect to the shape of cracks.

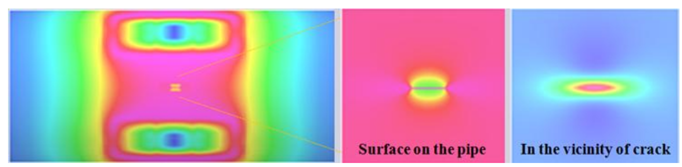

Fig. 2. The distribution of magnetic flux density (B_ϕ)

A. Sensing signal with respect to the length of cracks

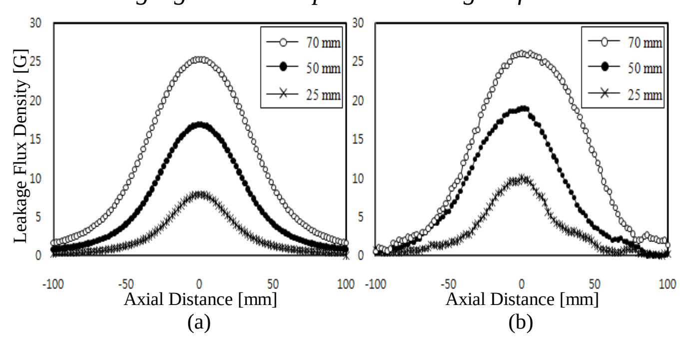

Fig. 3. Defect signals with respect to the defect Length: (a) FEM data, (b) experimental data

B. Sensing signal with respect to the width of cracks

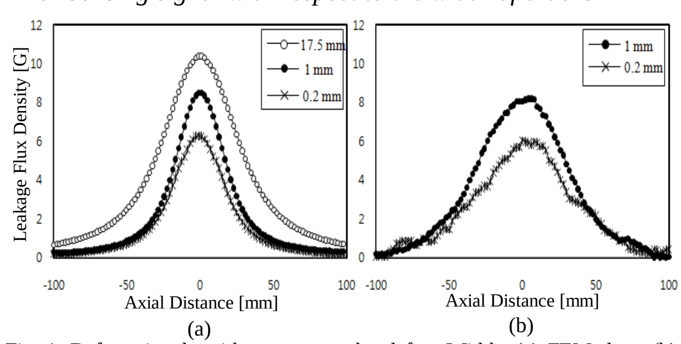

Fig. 4. Defect signals with respect to the defect Width: (a) FEM data, (b) experimental data

C. Sensing signal with respect to the depth of cracks

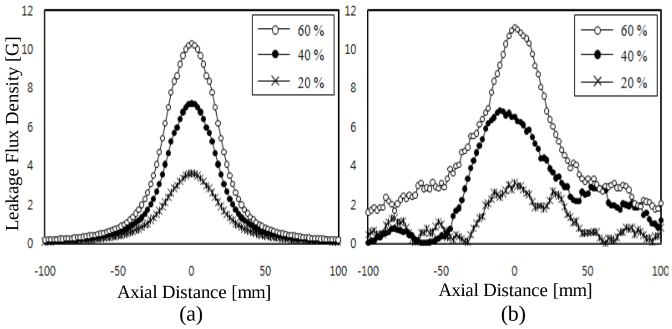

Fig. 5. Defect signals with respect to the defect Depth: (a) FEM data, (b) experimental data

IV. MECHANISM OF DEFECT ESTIMATION

The shape of cracks occurred on the surface of the pipe can be estimated from the distribution and the amplitude of leakage signals.

A. Estimation method of the length

The relation between the length change of defect and the distribution change of leakage signal with respect to axial distance is an linear increase.

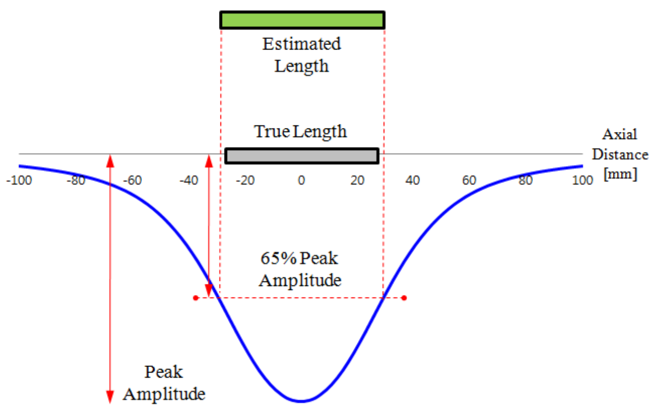

Fig. 6. The estimation method of defect length

B. Estimation method of the width

To estimate the width of defect, it is need to consider the relation between the width change and the distribution change of leakage signal with respect to circumferential distance. Fig. 7 shows how to determine the width of crack.

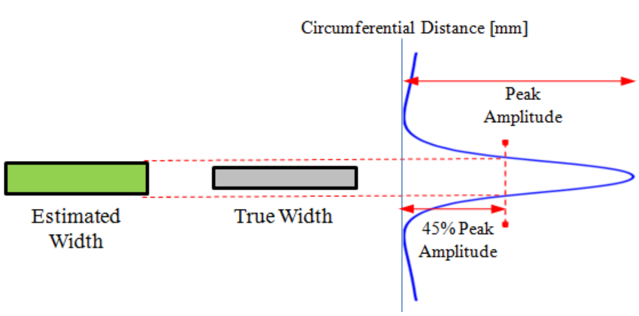

Fig. 7. The estimation method of defect width

C. Estimation method of the depth

The amplitude of leakage field signal is closely related with the change of defect depth. Also, the peak amplitude of signal depends on the shape of cracks such as length or width. So the depth of defect can be expressed as a quadratic function of the peak amplitude of leakage signal included variables for size of length and width.

$$D_{depth} = C_2(l,w)B_{peak}{}^2 + C_1(l,w)B_{peak} + C_0(l,w) \qquad (1)$$

V. RESULTS AND DISCUSSION

By measuring the sensing signals such as flux leakage density and using the mechanism of estimation, it is able to determine the shape of cracks. The result of depth estimation is shown in Fig. 8.

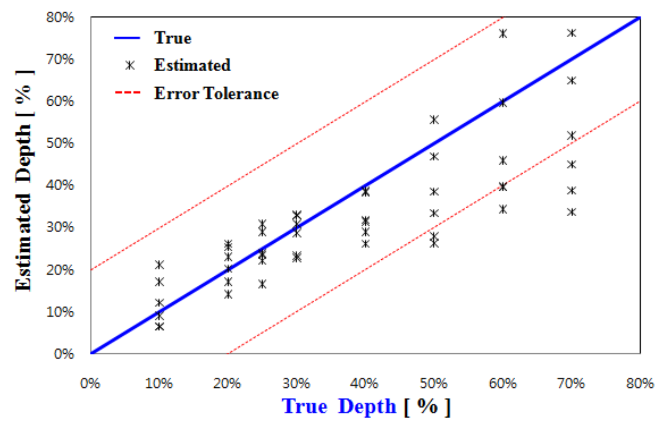

Fig. 8. The experimental result of depth estimation of cracks

VI. CONCLUSION

In this research, we propose the CMFL type NDT system to detect axially oriented cracks with small size. To verify the performance of the system, numerical analysis and experimental results are compared to each other. Finally, the mechanism of estimation for determining the shape of cracks is performed.

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