NONDESTRUCTIVE TESTING USING MAGNETIC FIELD VISUALIZATION TECHNIQUE

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INTRODUCTION

This paper describes a new technique to detect cracks or flaws in conducting or ferromagnetic materials using a magnetic field visualization system. In this system there are two sources for magnetic field generation, i.e. electrical current and magnetization. And the magnetic field generated by the source could give us useful information on cracks or flaws included in the material. Thus, visualization of magnetic field would enable us to identify the shape and size of cracks. We developed a preliminary system to verify the validity of the speculation and applied it to both ferromagnetic and conducting materials with flaws. The applicability of magnetic visualization has been confirmed to be an effective method in NDE and diagnosis of magnetic equipments in the present experiment. Furthermore, combination of this method with numerical prediction could demonstrate more potential capability in the field of NDE

The visualization technique is also applicable, if it is fully developed with assistance of numerical evaluation, to prediction of magnetic field distribution of electrical machines using limited data and solving numerically governing equations. In Table 1 are summarized measurement systems of magnetic field and its application.

MEASURING SYSTEM

The magnetic field visualization system is shown in Fig. 1 in a form of a flow chart. The system consists of many components such as 1-D sensors, a switching circuit, an amplifier, a personal computer and a CRT. On a plate designated with D in the figure are there three columns on which magnetic fields in the X, Y, and Z directions are measured as shown in Fig. 2. Thirty-two Hall devices are arranged on each line. The sensor consisting of ninety six (32 x 3) Hall devices is scanned to measure three components of magnetic field at each point and then those at another point of interest. Output from each Hall device is obtained sequentially by switching from one to another and is sent to a personal computer after amplifying the data and then applying A/D conversion. In the personal computer measured off-set values from each device are stored in advance, and then these values are subtracted from measured magnetic fields through an I/O board shown in Fig. 1. The stored data through A/D conversion and information on measured points are processed in the computer to demonstrate colored graphic display on the CRT where 640 x 400 pixels are prepared. Determination of color on each pixel is made

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Table 1 System and Application magnetic Field Visualization

ITEM \ MODE	STATIC	A.C.	TRANSIENT
MEASUREMENT	Magnetic Flux		
	Flux with magnetization		
	———	Eddy current	
PROBE	Multi-sensor		single-sensor
SYSTEM	· Amplifire · Changing circuit	· Phase detection · Changing circuit	Digital memory
NDI	Magnetic flux leak method (Ferromagnetic)	Eddy current testing	———
DIAGNOSIS	Magnet	Electro-Magnetic equipment	· Pulse magnet · Fusion reactor

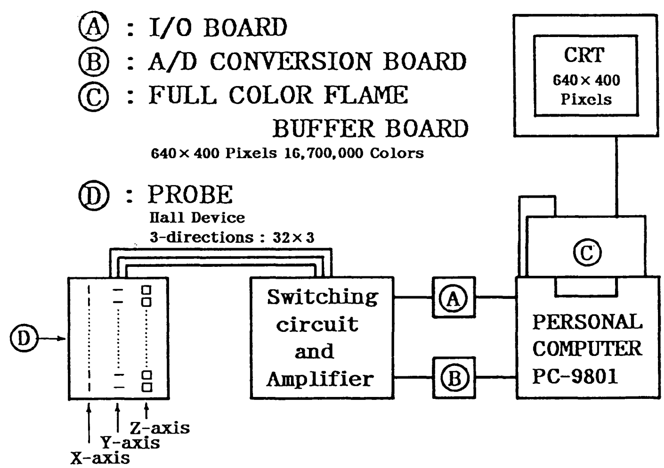


Figure 1. Magnetic flux visualization system.

with use of an interpolation function common in finite element analysis. In this system it is possible to express data in 8 bit x 3 colors in either a continuous or step-wise way.

MAGNETIC FIELD VISUALIZATION

In fig. 3 is shown location of magnets. A plate is put on these permanent magnets and magnetic field on the plate is surveyed by the sensor plate for a simulation test to locate magnetic sources. In Fig. 4 are shown three components (Bx, By, Bz) of the measured magnetic field. A pattern processed by the previous procedure is shown in this figure, where it is very easy to identify the location and source intensity of

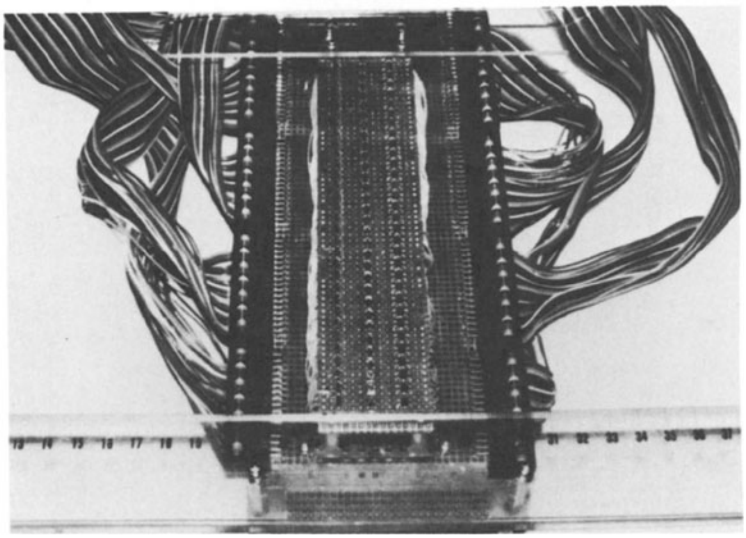


Figure 2. Appearance of 1-D probe (32 sensors x 3 direction).

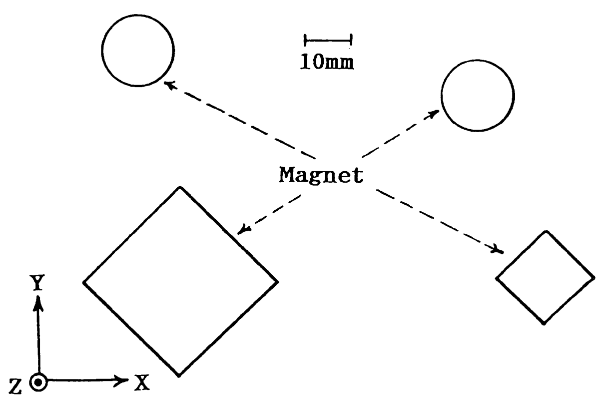


Figure 3. Arrangement of magnets.

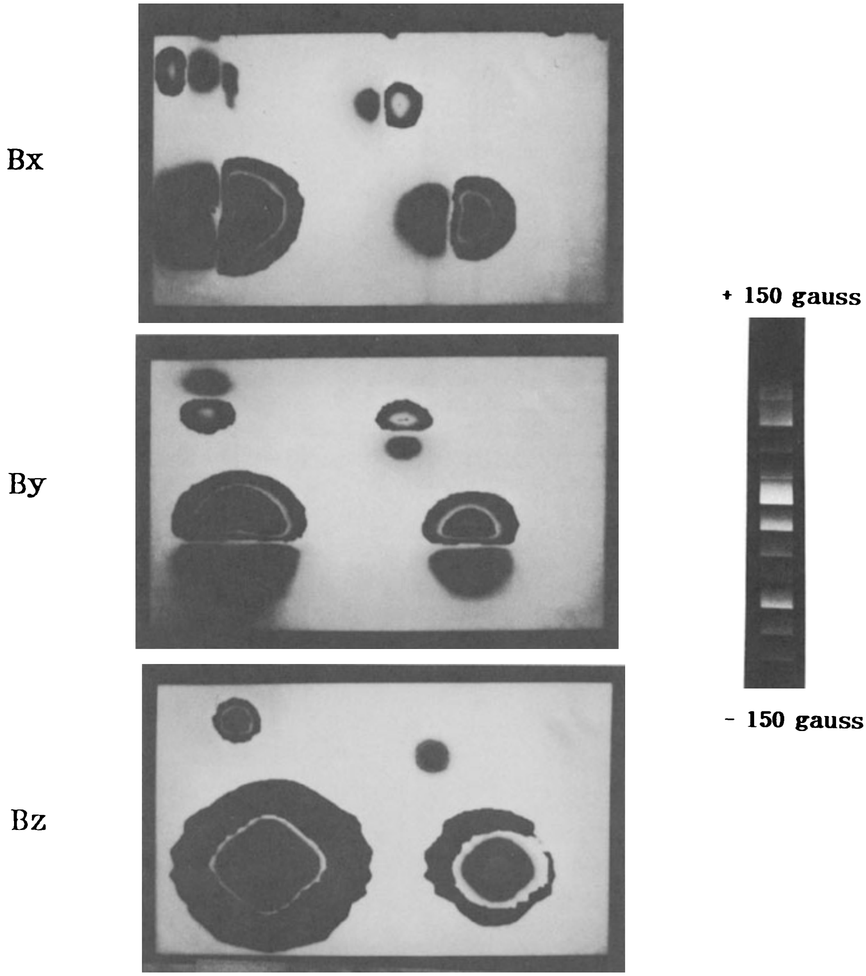
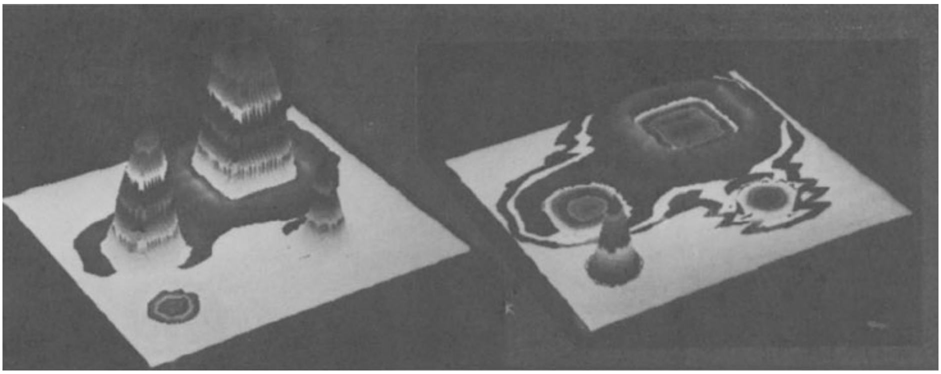


Figure 4. Visualization graphics magnetic flux (Bx, By, Bz).

the magnets. Fig. 5 shows a three dimensional display of the Z-component of the field for clear visualization of magnetic field distribution. This measurement teaches us that it is possible to express localized magnetic field change accurately and smoothly in terms of colored display with as strong a magnetic field as 150 Gauss.

APPLICATION TO SURFACE FLAWS OF FERROMAGNETIC BODY

It is interesting to check the application feasibility of the present method to a surface flaw of a ferromagnetic body. Configuration of a test piece and artificial flaws is shown in Fig. 6. The test piece is made of mild steel. Its size is 200 mm x 200 mm x 1.5 mm (thickness) and six flaws were machined, three of them are penetrated flaws, other three part-through ones. An experimental set-up is shown in Fig. 7. A magnetizable appliance of C-shape is magnetized due to applied field produced by an external coil and the test piece is put on the appliance to form a magnetic circuit. Magnetic field of the test piece is disturbed by the existence of the flaws and the perturbed field (leak field) is measured by scanning the planar sensor as shown in Fig. 7.



The upper indicate plus values   The upper indicate minus values

Figure 5. Visualization graphics in 3-D of Bz.

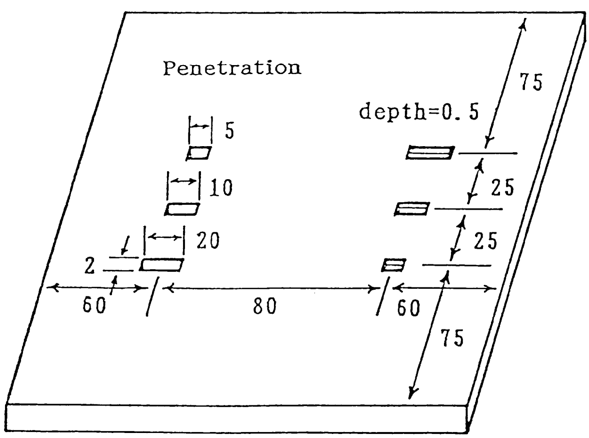


Figure 6. Size of test piece and cracks.

Measured distribution of Bx, parallel to the test piece, is shown in Fig. 8. In this test a peak of magnetic field is 10 Gauss as shown in the figure. On the other hand, test results of normal component Bz to the plate show that the components at both ends of a flaw are same in an absolute value and opposite in sign. Thus it is expected that differentiation of the component in a direction of magnetization i.e. dBz/dx yields a significant change at the flaw, leading to definite location of flaws. The processed results are shown in Fig. 9. The color display with dBz/dx could give a very clear indication for a flaw of 5 mm length and 0.5 mm depth. Minimum distance between Hall devices is 5 mm as shown in Fig. 2 and thus it is expected that if integrated density of the device is increased and sensitivity of the probe is improved, finer flaws or cracks could be detected.

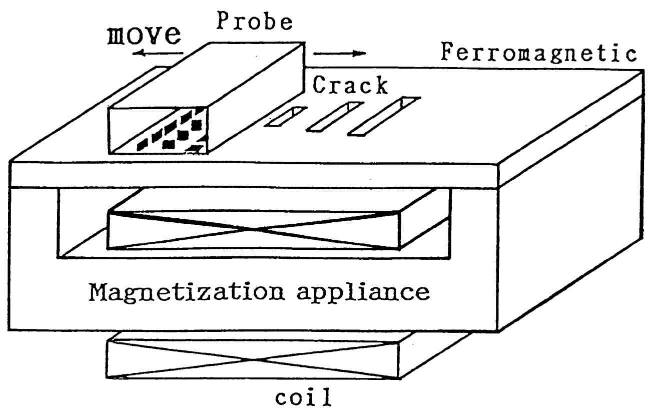


Figure 7. Experimental system.

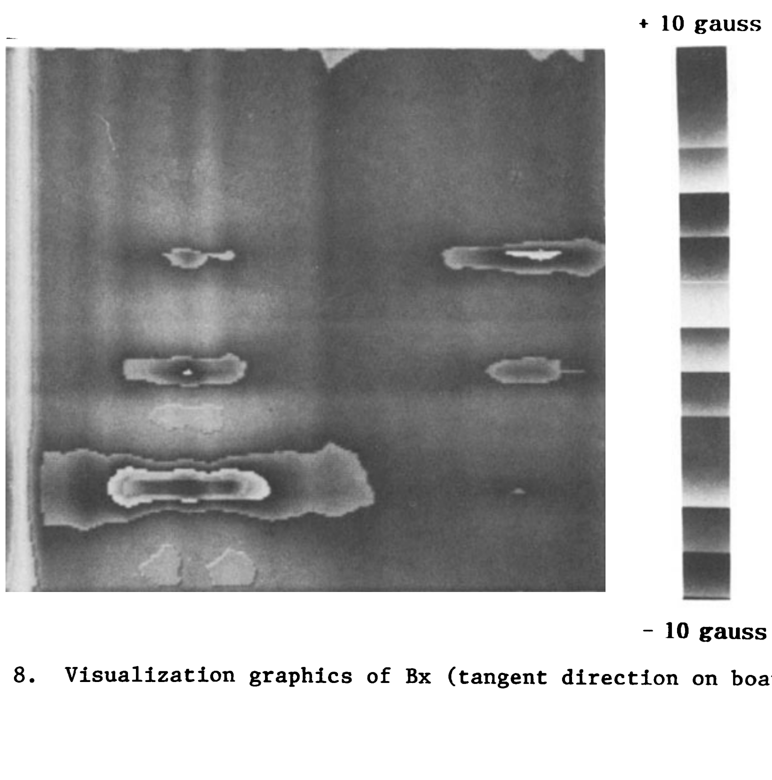


Figure 8. Visualization graphics of Bx (tangent direction on board).

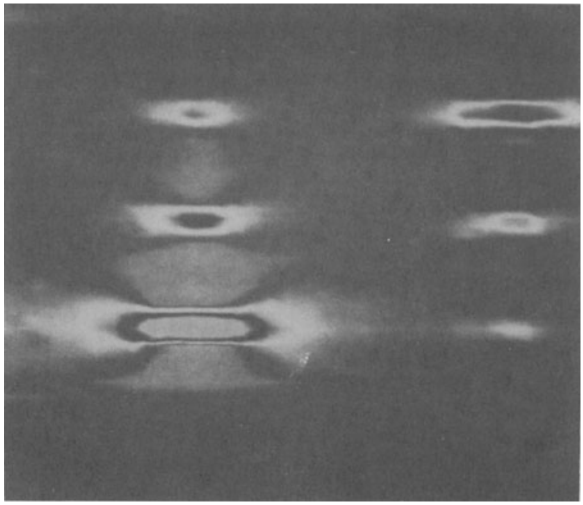


Figure 9. Visualization graphics of dBz/dx using continuous tone (z: normal direction on board).

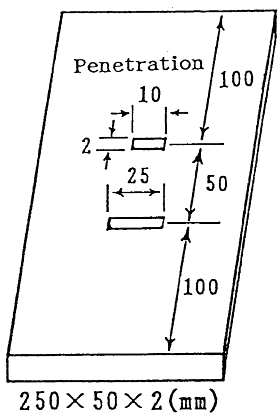


Figure 10a. Size of test piece and cracks.

APPLICATION TO NON-FERROMAGNETIC CONDUCTOR

We did an experiment where an aluminum plate (250 mm x 50 mm x 2 mm) having two flaws is provided with current of 50 A as shown in Fig. 10a. Parallel components of induced magnetic field were measured at locations above 5 mm the plate and their results are shown in Fig. 10b. Since magnetic field is less than 2 Gauss, it was very difficult to obtain continuous and smooth image due to low resolution. However, shape of the conducting plate and a 25 mm long flaw are clearly shown. It is concluded from the experiment that the nondestructive method with use of direct current is as good, due to the low magnetic field, but technical feasibility of A.C. eddy current induced a flawed conductor should be pursued.

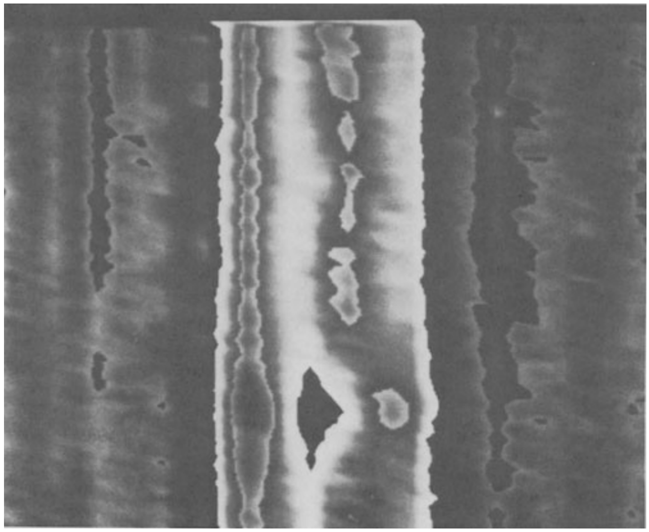


Figure 10b. Visualization graphics on conductor. Large defect (25 x 2mm) can be detected.

CONCLUSIONS

The following conclusions are obtained by the present study.

(1) We developed a preliminary system of magnetic field visualization.

(2) We applied the system to nondestructive evaluation, and (a) flaw (5 x 2 x 0.5 depth mm) in a ferromagnetic material was detected clearly, (b) for a current conducting material a hole of 25 x 2 mm was detected.

(3) These showed the applicability of the visualization technique to NDE and the diagnosis of magnetic devices.

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