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EFFECTS OF FERROMAGNETIC PLATE THICKNESS TO FEATURE SIGNAL USING PULSED UNIFORM EDDY CURRENT

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ABSTRACT

In this paper, a 2D electromagnetic finite element model of a pulsed uniform eddy current probe has been developed and it has been used to investigative the effects of the ferromagnetic plate thickness on the corresponding magnetic field .A pulsed uniform eddy current experiment system has also been founded to validate the model. Iron plates are used as the sample whose thickness from 3 mm to 5 mm. The results show that the simulation and experimental results have a very close correlation. The results show that the thinner the thickness of the ferromagnetic plate, the slower the decay rate of Bx. The conclusions indicate that the decay rate of Bx is an important feature for evaluation thickness of ferromagnetic plate using pulsed uniform eddy current.

Keywords: ferromagnetic materials, thickness, pulsed uniform eddy current

NOMENCLATURE

σ	Conductivity
μ_r	Relative permeability

1. INTRODUCTION

Alternating current field measurement (ACFM) is a novel technology of Non-destructive testing technologies ,which has become an increasingly popular method as an alternative to magnetic particle inspection to detect and characterize the flaws in structures or materials in oil and gas industry [1-3]. But ACFM is only used to detect surface defects because of skin effects. Pulsed uniform eddy current is regarded as a new technique where a broadband pulse excitation is used, as opposed to single frequencies employed in conventional ACFM [4-6]. The strength of the pulsed uniform eddy current comes with its wide bandwidth of excitation frequencies that are excited simultaneously [7-8]. Pulsed uniform current eddy response signal provides more information about different depths and thickness [9].

The aim of this paper was to analyze response signal law of uniform electromagnetic field at different ferromagnetic plate thicknesses. Finite element method was used to analyze the relationship between the decay rate of magnetic field signal and thickness. A experiment system was setup to validate simulation rules.

2. FINITE ELEMENT METHOD MODAL

The mechanism for uniform electromagnetic field propagates in the test piece was studies in this section by the FEM model. The decay of different specimen thicknesses of *Bx* signals is analyzed.

2.1 MODEL SETUP

The 2D simulation model for simplify calculations was built using the finite element software COMSOL as shown in Figure 1. The model includes U-shaped magnetic core, coil, specimen and air. The lift of the probe is 1 mm and the magnetic field pick-up point was located in the middle of the U-shaped magnetic core, and the lift-off is 1 mm. A pulsed signal with the parameters of duty cycle =50%, frequency =10 Hz and amplitude = 10 V was used as the excitation signal. A transient analysis was used for model. Step time is 0.1 s and the number of steps are 1000 steps. The detailed material parameters was shown in Table 1.

Table 1. Parameters of the model

Name	Value
Specimen	Iron, σ =1.07×10^{7} Sm^{-1}, μ_r =4000
coil	Pulsed ,duty cycle =50%, frequency =10 Hz, voltage=10 V, coil turns=200,
core	μ_r =10000

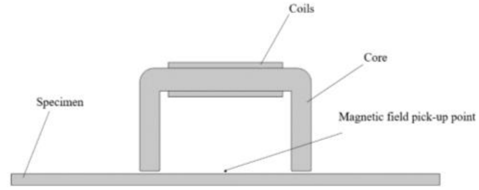

Fig 1. The FEM model of thickness evaluation

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2.2 CHARACTERISTIC SIGNAL ANALYSIS

The thickness of specimen vary from 3 mm to 5 mm with a 0.5 mm increment whereas other parameters remain under change. It is prescribed that the direction parallel to the direction of the test piece is the X direction, and the direction vertical to the direction of the test piece is the Z direction. The *Bz* (magnetic flux density in the Z direction) in pulsed uniform eddy current is 0. So The *Bx* (magnetic flux density in the X direction) as magnetic field analysis signal is extracted on magnetic field pick-up point, as shown in Fig. 2. It can be seen from the figure that the *Bx* signals change due to variation of the plate thickness. The thinner the wall thickness, the larger the peak value of the signal. At the same time, the thinner the thickness, the stronger the magnetic field of X direction.

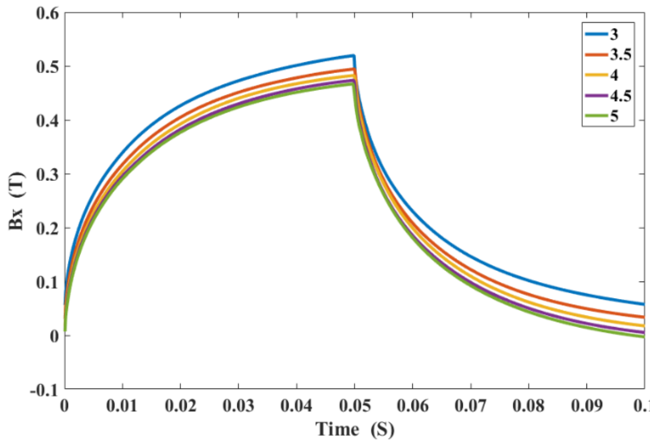


Fig 2. The *Bx* signal of different thickness

The semi-logarithmic domain of the Y-axis was taken for the decay segment of *Bx* signal and the obtained result was shown in Fig. 3. It can be seen from the figure that when the excitation was just cut off, the curve of the 3 mm wall thickness was first separated. the thinner the thickness, the sooner it will be separated. As the thickness of plate increases, the decay rate increases.

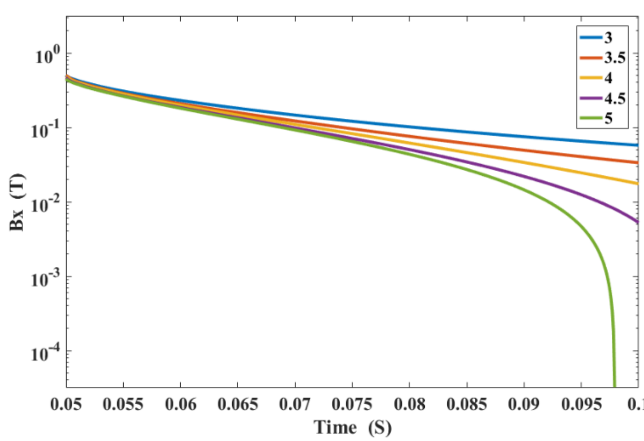


Fig 3. The decay signal of different thickness

3. RESULTS AND DISCUSSION

A pulsed uniform eddy current probe is development, as shown in Fig. 4. It includes coil ,U-shape core and TMR. The turns of coils were 200 total. The plate in experiment is iron material, as shown in Fig. 4. A pulse whose detail parameter is generated by a function generator and amplified by a power amplifier. The amplified pulse is provided to the exciter coil. The sensor signal mentioned above is converted into digital by capture card and it is stored in a computer. And a thickness evaluation software were developed.

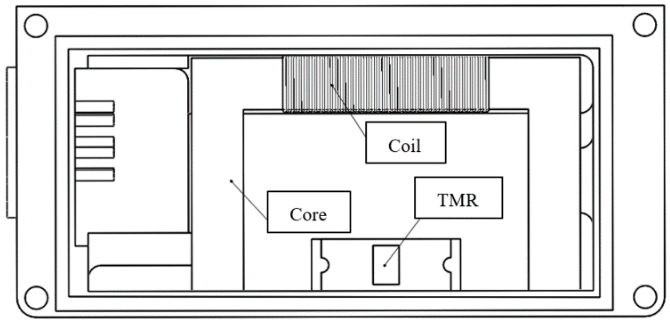
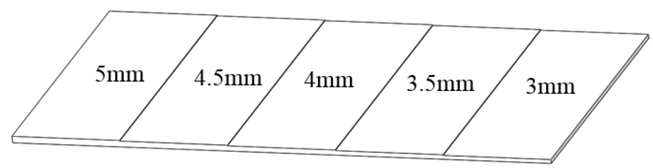


Fig 4 Probe



Unit: mm

Fig 5. The Specimen of Iron

The decay segment of each thickness *Bx* signal shown in Fig. 6 and Fig. 7. Signal changes due to variation of the plate thickness. It can be seen that the plate thickness of 3 mm magnetic field is the slowest decay rate.

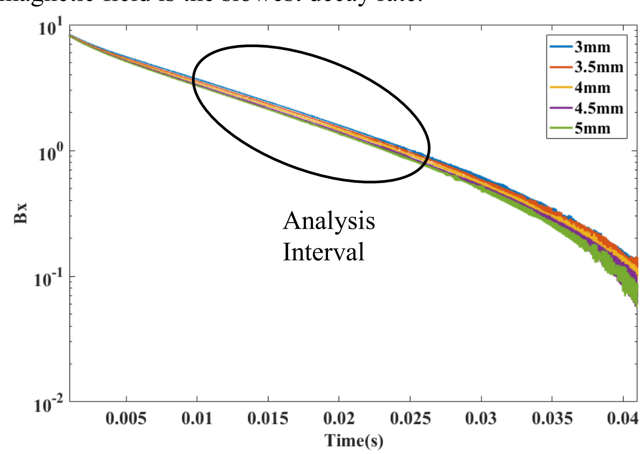


Fig. 6. Signal changes due to variation of the plate thickness

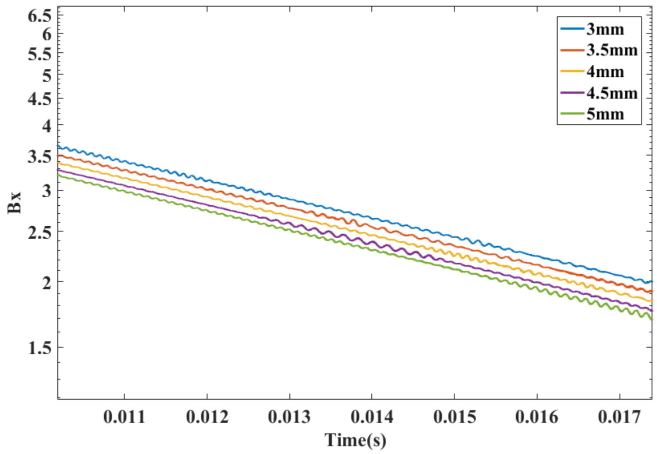


Fig. 7. Partial enlargement

4. CONCLUSION

In this work, response signal law of uniform electromagnetic field at different ferromagnetic plate thicknesses is studied. A FEM model is developed to analyze relationship between the decay rate of *Bx* and thickness. A experiment system is setup to validate simulation rules. In conclusion, as the thickness of plate increases, the decay rate of *Bx* signal increases. In the future, the decay rate of *Bx* can be a feature for evaluation thickness of ferromagnetic plate using pulsed uniform eddy current.

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