MT26 International Conference on Magnet Technology
Vancouver, Canada | 2019

Tue-Af-Po2.23-04 [91]

Research on the Squeeze Current Effect of the Foil-type Excitation Windings at High Frequency

Ming Yang[1], Yongjian Li[1], Qingxin Yang[1,2], Changgeng Zhang[1], Shuaichao Yue[1], He Sun[1], and Chengcheng Liu[1]

[1]State Key Laboratory of Reliability and Intelligence of Electrical Equipment, Hebei University of Technology, Tianjin, 300130, China

[2]Tianjin University of Technology, Tianjin, 300384, China

E-mail: liyongjian@hebut.edu.cn

1. INTRODUCTION

- The foil windings has lower DC resistance and higher fill factor. Now we apply it to the magnetic properties measurement structure. Compared with the wire windings, the loss of foil windings is lower in a higher frequency range. The impedance of the windings will be smaller than that of multi-turning wire windings due to fewer turns of windings. Larger excitation current can be applied on the exciting windings at the same output voltage.
- This paper mainly studies the squeeze current effect of foil windings in engineering practice. The influence factors of current density distribution in foil windings are analyzed from the width, thickness, segment number of windings and frequency. And the influence of the parameters of magnetic shielding plate on the squeeze current effect is analyzed in detail.

2. SIMULATION MODEL

At high frequency, the effect of the displacement current I_d and the eddy current I_e should be considered in the Maxwell equation. The total current density in each layer of copper foil is the superposition of the conduction current density J_s, the displacement current density J_d and the eddy current density J_e.

$$\boldsymbol{J}_s = -\sigma\nabla\phi \qquad \boldsymbol{J}_e = -j\omega\sigma\boldsymbol{A} \qquad \boldsymbol{J}_d = j\omega\varepsilon(-j\omega\boldsymbol{A} - \nabla\phi) \qquad \boldsymbol{J} = \boldsymbol{J}_s + \boldsymbol{J}_e + \boldsymbol{J}_d$$

The total current is a combination of three currents, and it is also the integral of the total current density on the cross section.

$$I = \int_\Omega (\sigma + j\omega\varepsilon)(-j\omega\boldsymbol{A} - \nabla\phi)\, d\Omega$$

The model is limited to a 2-D problem defined in the x-y plane. The basic equations of transient magnetic field-circuit coupled problem. It is the calculation constraint equations for the two dimensional simulation model.

$$\frac{l d_p N}{Sa}\iint_\Omega \frac{\partial \boldsymbol{A}}{\partial t}\, d\Omega = 0$$

$$\boldsymbol{J} = \upsilon\mu\left(\frac{\partial \boldsymbol{M}_y}{\partial x} - \frac{\partial \boldsymbol{M}_x}{\partial y}\right)$$

Where υ is the equivalent reluctivity, M_x and M_y are respectively, the x - and y -components of the magnetization vector, d_p is the polarity to represent, respectively, the forward paths or return paths. S is the total cross-sectional area of the region occupied by the windings in the solution domain, N is the total conductor number of this windings, a is the number of parallel branches in the windings.

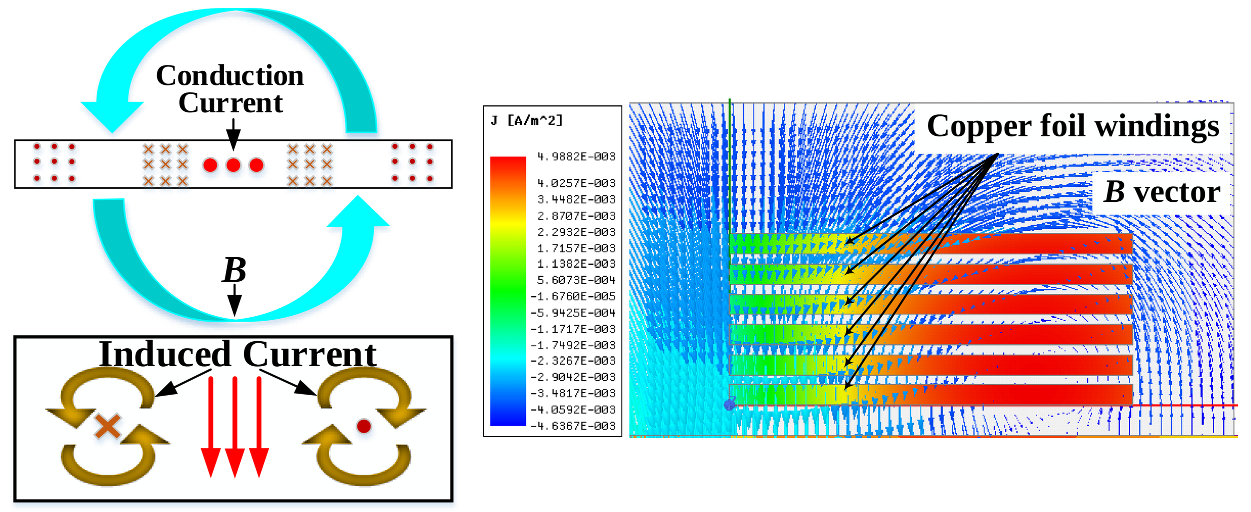

Fig. 1 shows the squeeze current effect of the foil windings comes from the magnetic induction strength perpendicular to the copper foil. The varying magnetic flux produces the eddy effect inside the copper foil windings. And the induced current will affect the distribution of the conduction current in the windings.

Fig. 1 The principle diagram of squeeze current effect and simulation example.

2. PRINCIPLE OF SIMULATION

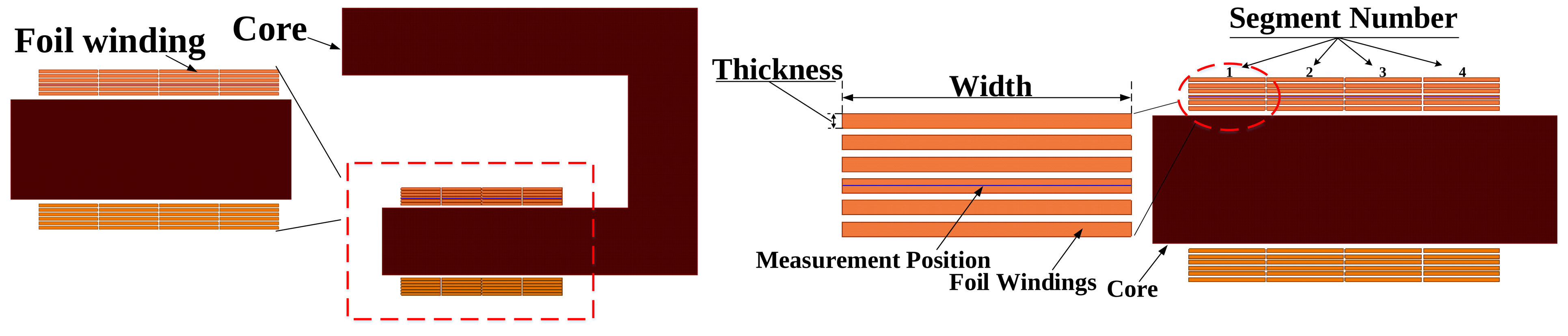

Fig. 2 Study on the influence of the parameters of windings and the parameters of shielding plate on the squeezing effect.

Fig. 2 shows the main purpose is to study the thickness, width and segment number of the windings. Also, the single variable method is adopted to reduce the squeeze current effect by setting the windings parameters. And it is to reduce the influence of squeeze current effect by adding the magnetic shielding plate.

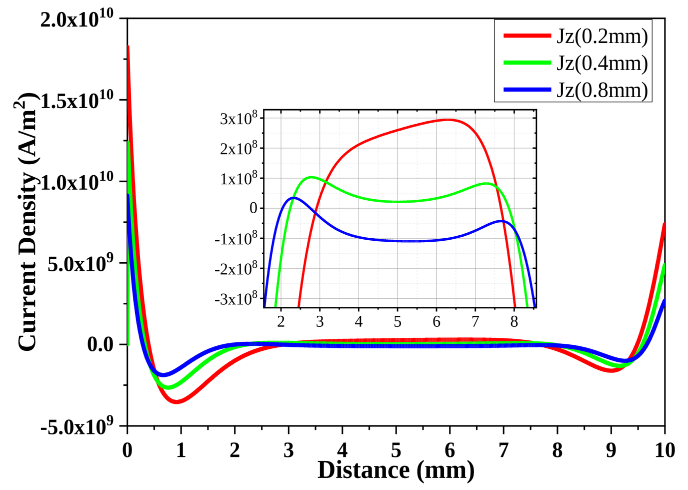

Fig. 3 Comparison of squeeze current effect among three kinds of windings thickness.

Fig. 3 shows the distribution of current density on the edge of the windings decreases with the increase of the windings thickness, but the thicker the windings, the smaller the current density in the central region, and the current density may even be reverse with the frequency increasing.

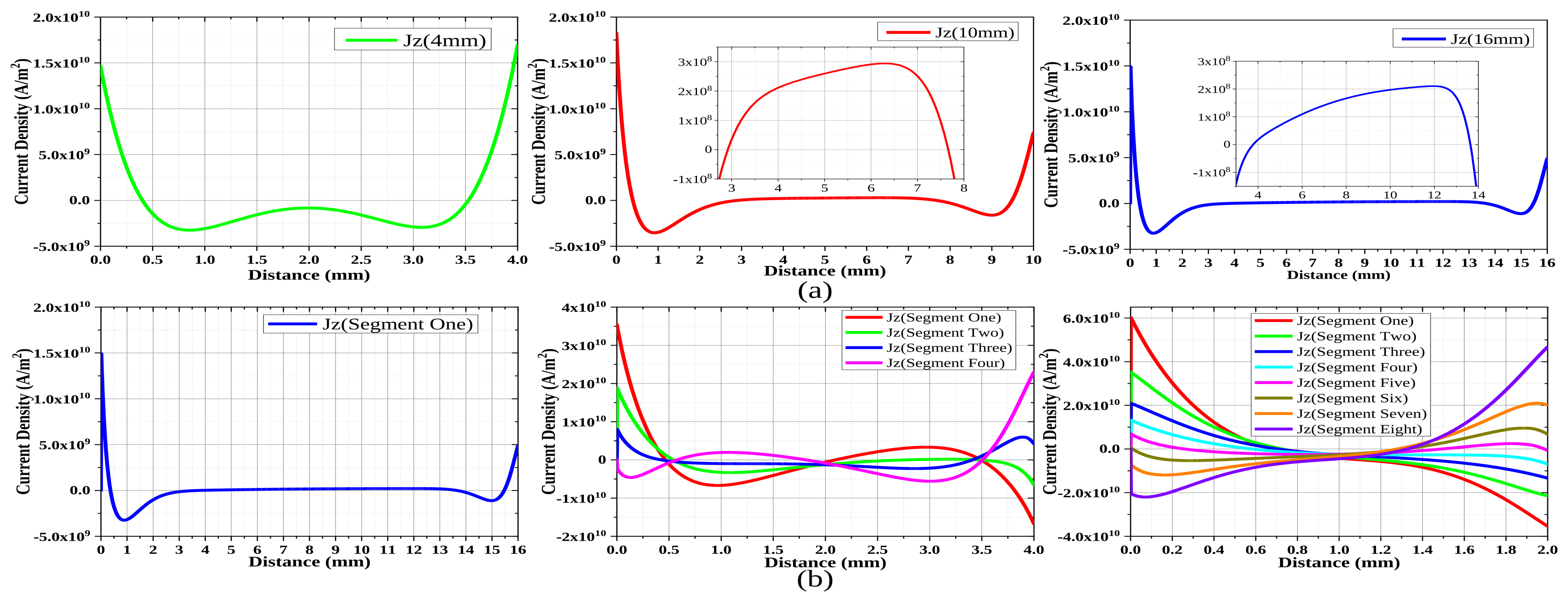

Fig. 4 (a) Comparison of squeeze current effect of three kinds of windings width;
(b) Comparison of squeeze current effect of three kinds of segment number.

In Fig. 4, with the increase of the width, the difference of current density between the two sides and the central region becomes small. Since the windings width is so small, the eddy current generated at both sides has a strong effect on the conduction current in the central region.

4. SIMULATION PLAN AND RESULTS

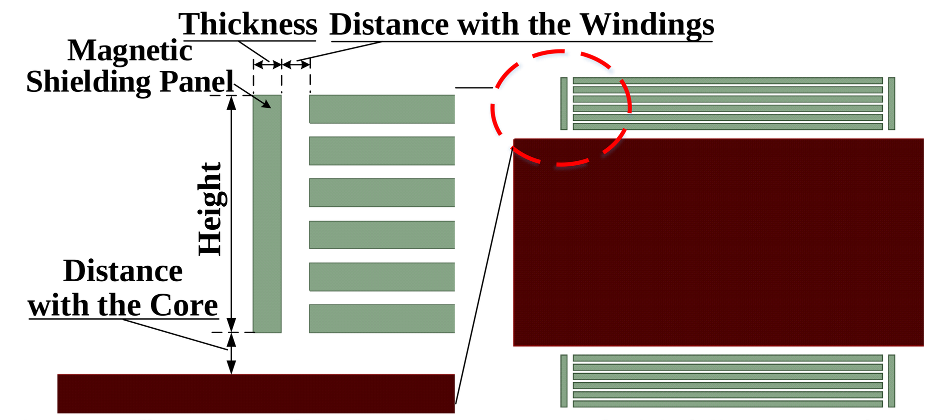

Fig. 5 Influence of the parameters of shielding panels on the squeeze current effect

In Fig. 5, it is to reduce the squeeze current effect by adding the magnetic shielding panels. As to magnetic shielding panels, materials with low conductivity and high magnetic permeability should be selected as far as possible..

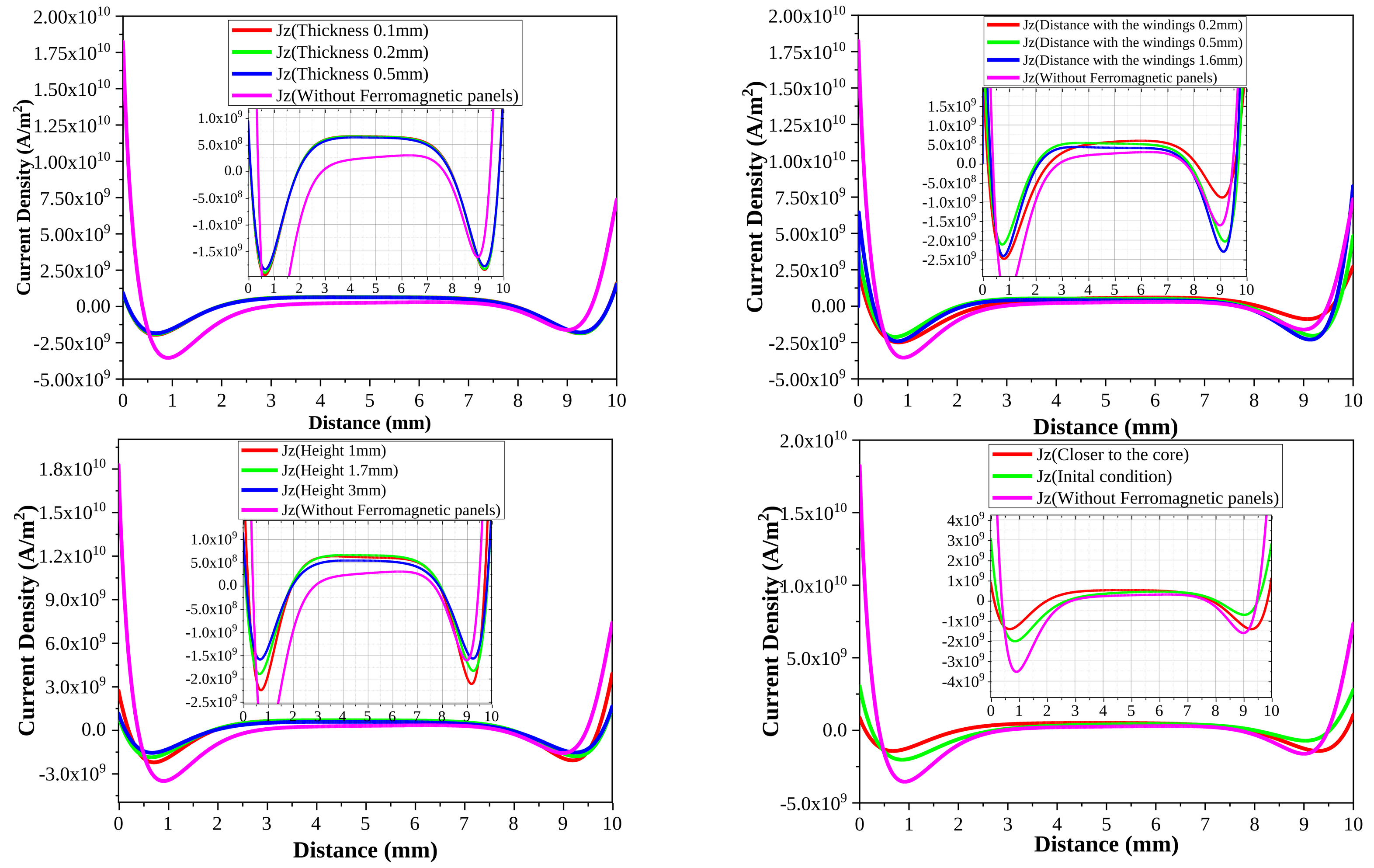

Fig. 6 Comparison of the squeeze current effect of shielding plate with different specifications.

The method of increasing the contact surface of the magnetic shielding panels and the core can be used to relieve the excessive concentration of magnetic field and take into account the current sharing effect.

5. CONCLUSIONS

(1)Several measures are applied to improve the squeeze current effect by reasonable design of the width, segment number and thickness of the windings at the corresponding frequency. But the local current density is still very large.

(2)When a magnetic path is guided by the magnetic shielding plate, a good current sharing effect can be obtained.