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The effects analysis of electrical steel material for the no-load loss of EI transformer

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Abstract:

The no-load loss is one of the key indicators for EI transformer. In this paper, by means of the finite element simulation software, the effects of electrical steel material for the no-load loss of EI transformer was analyzed, pointed out the Iron loss of electrical steel material is the main factor to the no-load loss of EI transformer, and was verified by comparing the simulated data by using electrical steel of different grades.

Key words: no-load loss; EI transformer; electrical steel; magnetic; iron loss

1 Introduction

China wants to create a conservation oriented society, so energy saving, environmental protection products will be the new development direction of manufacturing industry in recent years. Transformer is one of the important equipment in power system, which has important economic significance to reduce the loss and reduce noise.

No-load loss is an important parameter of the transformer, as long as the power into the grid, no matter how much load, no-load loss is the same, no load loss has nothing to do with the load of transformer. The no-load loss is equal to the active power absorbed by the transformer when the rated voltage is applied to a winding of the transformer, and the rest of the windings are open circuit. There are many factors affecting the no-load loss of transformer, such as, insulation between the electrical steel sheet is not good; a part of electrical steel core contact with each other; the damage of core screw, screw or plate yoke, cause the iron partial short-circuit; windings or winding parallel branch short-circuit; the unequal turns of parallel branch; improper yoke design causes a part of the magnetic flux density is too large, and so on[1-3].

In this paper, by means of the finite element simulation software, the effects of electrical steel material to the no-load loss of EI transformer was analyzed based on a real application example, pointed out the Iron loss of electrical steel material is the main factor to the no-load loss of EI transformer, and was verified by comparing the simulated data by using electrical steel of different grades.

2 Theoretical analysis

The main performance of EI electrical steel that can affect no-load loss of transformer including insulation, lamination coefficient, iron loss and magnetic, the theory analysis as follows:

2.1 The effect analysis of insulation on no-load loss

Because the electrical steel sheet itself is a conductive body, under the condition of the magnetic flux exchange, the induction current is also produced in the iron core, this is inevitable. And because the core is a whole, which is equal to a large area of a conductor, and the circuit is short, so the resistance value is very small, although the induction voltage is not high, but the current is large, so that there is more eddy current loss is produced in the core [4].

After coated with insulating layer in each piece, the section of a core where eddy current loss is produced is divided into many small sections, so its resistance value increases significantly, which can decrease the iron loss[5].

2.2 The effect analysis of the lamination coefficient on the no-load loss

The lamination coefficient is the ratio of the effective cross-sectional area of the core and the theoretical section, and also equal to the ratio of the number of the actual stack and the number of theoretical plates. By the voltage balance equation "$U_1 \approx E_1 = 4.44 f N_1 \Phi$ = constant" can be known, for a given input voltage, frequency and the number of turns of the winding, the main flux Φ is constant. So be known by $\Phi = BS$:

If the effective cross-sectional area of the core decreases, then to maintain the main magnetic flux, the working magnetic flux density of EI transformer is on the need for a corresponding increase. According to the Bertotti iron loss separation theory, iron loss is approximately proportional to the square of magnetic flux density.

$$P_{ir} = P_h + P_{ec} + P_e \quad = afB_m^x + bf^2 B_m^2 + ef^{1.5} B_m^{1.5} \qquad (1)$$

So, when the effective cross-sectional area of the core was reduced, the flux density of the EI transformer will be increased, and then the iron loss increases, which is equal to the increase of no-load loss, so the lamination coefficient has a direct effect on no-load loss [6].

2.3 The effect analysis of iron loss on no-load loss

The core loss of the transformer is not only decided by the electrical steel material, but also depends on the working frequency in the alternating magnetic field and magnetic induction intensity B_m value, but also with the voltage of the power supply. When the power supply voltage is given, the iron loss is basically a constant amount and has nothing to do with the value and nature of the load current, so basically the core loss is equal to the of no-load loss[7].

2.4 The effect analysis of magnetic induction on no-load loss

By the voltage balance equation "$U_1 \approx E_1 = 4.44 fN_1\Phi$ = constant" can be known, for a given input voltage, frequency and the number of turns of the winding, the main flux Φ is constant. So be known by $\Phi = BS$:

In the case that the effective cross-sectional area of the iron core is given, the magnetic flux density B remains unchanged. So for the electrical steel materials with different magnetic properties, the designed magnetic flux density B and the main magnetic flux Φ of the EI transformer can be maintained by adjusting the magnetizing current.

Therefore, the influence of the magnetic induction on no-load loss is reflected in the magnetization current, the magnetic current on the high side can cause the copper loss of the primary winding. The advantage of high - magnetic electrical steel material is that the higher magnetic induction intensity (magnetic flux density) can be obtained at low magnetic current[8].

3 The no-load loss simulation analysis of EI transformer

In this paper, the influence of iron loss and magnetic performance of electrical steel material on no-load loss of EI transformer is analyzed based on an example, the following is the basic parameters of the EI transformer:

The type of the transformer：EI×48

The coil number of the primary winding：1110T

The length of the core：20mm

The dimensions of the core (mm)：

Whole length a	Whole width f	Window height e	Window width c	Tongue width d	Edge width b
48	32	24	8	16	8

3.1 The compare between two different electrical steel material

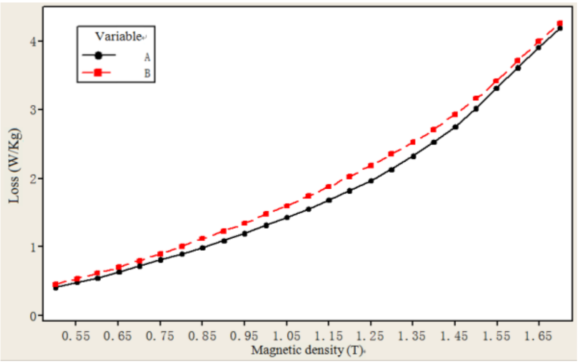


fig.1 the iron loss compare of two electrical steel A and B

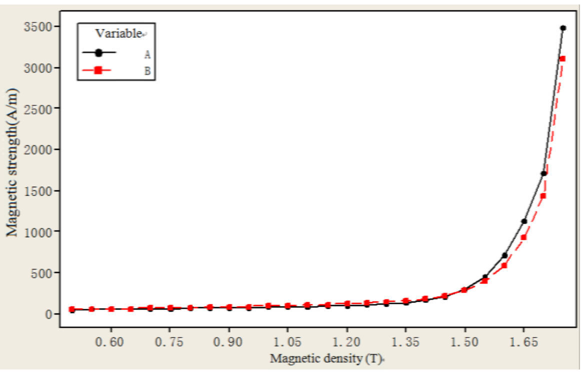


fig.2 the magnetic density compare of two electrical steel A and B

As shown in fig.1 and fig.2, which are the iron loss and magnetic density compare of two typical electrical material A and B, we can know that :

(1) The iron loss of Material A is smaller than material B in the whole range, that is to say that the iron loss of material A is better than B.

(2) The magnetic density of material A is better than B in the range of 0 to 1.45T, but a little bit worse than B behind 1.45T.

3.2 Simulation model of EI transformer

Based on the basic parameters of the EI transformer, the simulation model of EI transformer is built, and the preprocessing work is done before the solution of the finite model, they are: the fine mesh of the finite model, adding the air solution region, loading a sinusoidal excitation power to the primary winding, loading a 0A current power to the second winding.

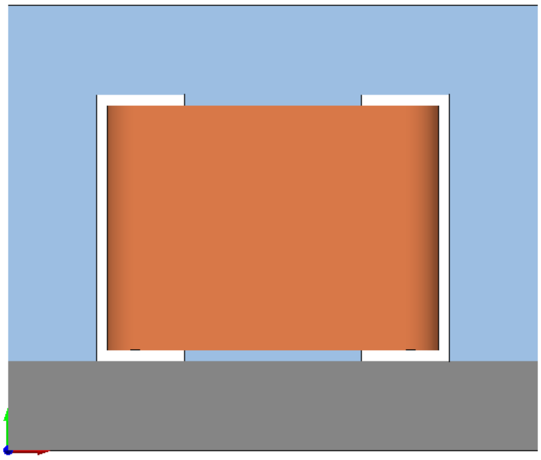


fig.3 the simulation physical model

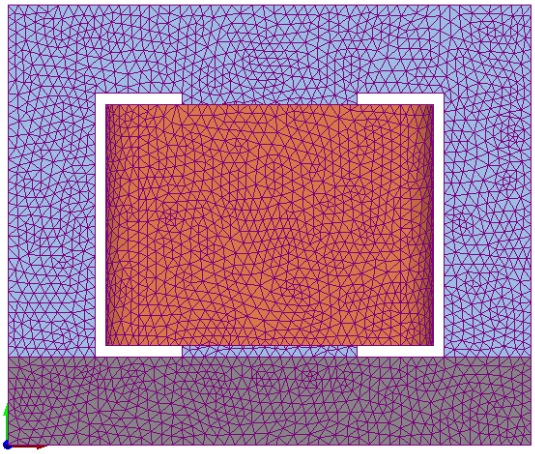


fig.4 the infinite meshed model

3.3 The compare analysis of no-load simulation data of EI transformer

According to the magnetic data of electrical steel A and B, based on the simulation model of EI transformation, the no-load iron loss of EI transformer is analyzed as follows.

3.3.1 The data compare of no-load iron less

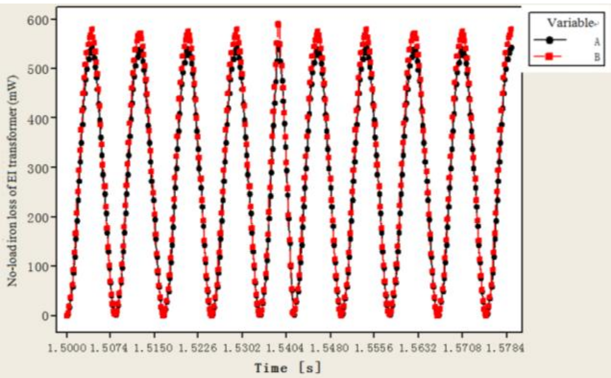


fig.5 the compare of no-load iron loss

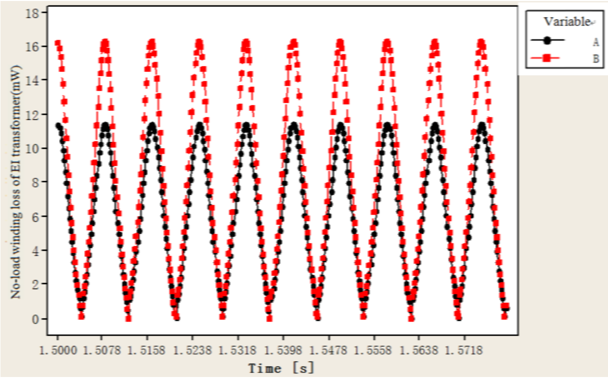
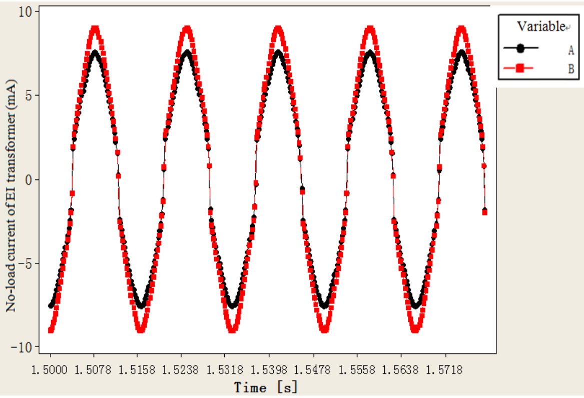


fig6. the compare of no-load winding loss

As shown in the simulation result, under the steady state, compared to electrical steel material A, the no-load iron loss is 42mW bigger and no-load current is 1.5mA bigger when the EI transformer is produced by the electrical steel material B, shown in fig.5 and fig.7.

3.3.2 Working magnetic density of EI transformer



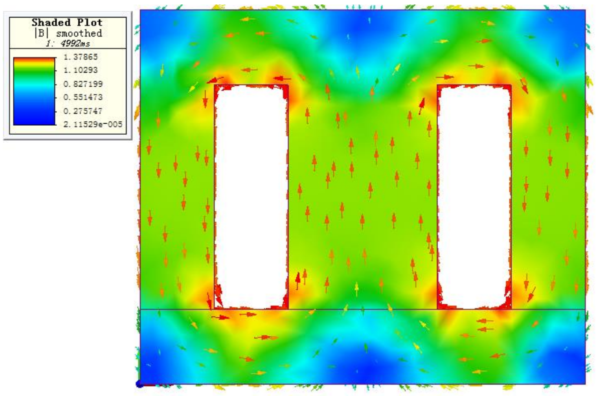


fig.7 the compare of no-load current

fig.8 the cloud chart of working magnetic density in EI transformer

The distribution of the magnetic density in the simulation result shown that, in the steady state, the max value of the magnetic density is 1.378T when the EI transformer is no-load, so combining the analysis above, we can see the magnetic density of the electrical steel material A is better.

3.4 The comprehensive analysis

Combining the performance of the electrical steel material, and according to the no-load simulation data of EI transformer, some conclusions can be got as follows:

When the EI transformer is no-load, the main loss is the iron loss, and the simulation results show that the 97.88% of the total loss is iron loss, and the winding loss is only 2.12% of total loss. And combining the theoretical analysis, we can get the conclusion that the no-load loss of EI transformer is mainly affected by the iron loss of electrical steel material.

Besides, the no-load winding loss of EI transformer is caused by the excitation current, the bigger excitation current will cause the winding loss increase of the primary winding. While the excitation current is related to the magnetic density of the electrical steel material, when the magnetic density of the electrical steel material is higher, EI transformer can get the bigger magnetic density even when the excitation current is small, so the magnetic density of electrical steel has little effect to the winding loss of EI transformer.

4 Conclusion

(1) The iron loss is the main part of the no-load loss in EI transformer, the winding loss is very lower and almost can be neglected.

(2) The iron loss of the electrical steel material is the main effect factor for the no-load loss of the EI transformer, the magnetic is only the minor factor.

(3) The analysis result of the composition of the no-load loss in EI transformer and the effect factors of the no-load loss, is consist with the result of theoretical analysis.

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