Table 1 Shielding factors

ID: 58

Performance analysis of superconducting generator electromagnetic shielding

D Xia[1] and Z Xia[2]

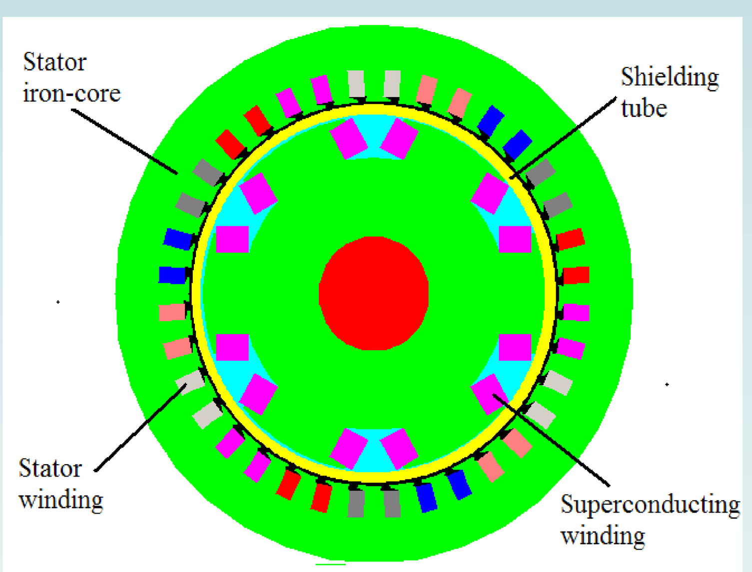
1. Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing, China

2. Electrical Engineering College, Shenyang University of Technology, Shenyang, China

Abstract

Considering the non-iron-core rotor structure of superconducting generator, it is proposed that the stator alternating magnetic field generated under different operating conditions could decompose into oscillating and rotating magnetic field, so that complex issues could be greatly simplified. A 1200KW superconducting generator is put as calculated object. The distribution of the oscillating magnetic field and the rotating magnetic field in rotor area and the distribution of the eddy currents in electromagnetic shielding tube are calculated without electromagnetic shielding system and with three different structures of electromagnetic shielding system respectively. On the basis of the results of FEM, the shielding factor of the electromagnetic shielding systems is calculated and the shielding effect of the three different structures on the oscillating magnetic field and the rotating magnetic field is compared.

Structure of calculation prototype



Apparent rated power: 1200KW
Rated voltage: 6300V
Number of armature winding phases: 3
Number of pole pairs: 3
Stator outer diameter: 800mm
Stator inner diameter: 570mm
Stator core length: 500mm
Gap width: 5mm
Shielding tube outer diameter: 560mm
Shielding tube inner diameter: 530mm
Rotor inner diameter: 170mm

Finite element analysis model

Transient or alternating magnetic fields

Oscillating magnetic field

$$\nabla \times \frac{1}{\mu}(\nabla \times A) = (\sigma + j\omega\varepsilon)(-j\omega A - \nabla\phi)$$

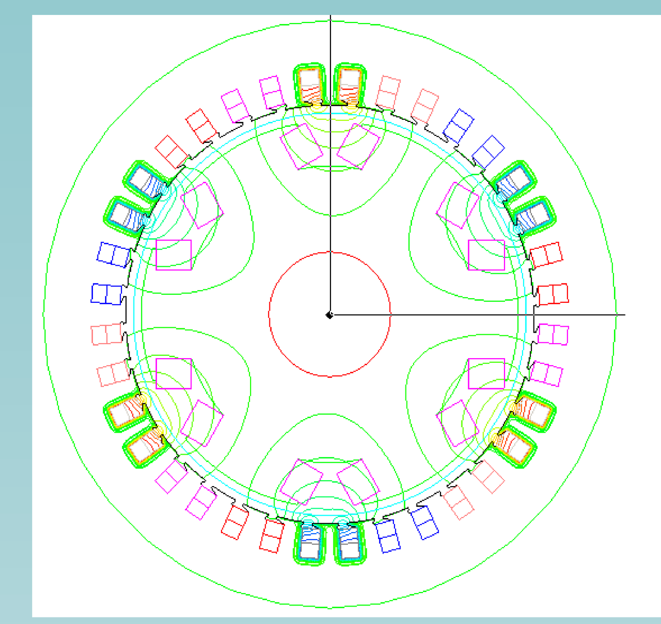
Rotating magnetic field

$$\nabla \times \frac{1}{\mu}(\nabla \times A) = J_S - \sigma\frac{dA}{dt} - \sigma\nabla v$$

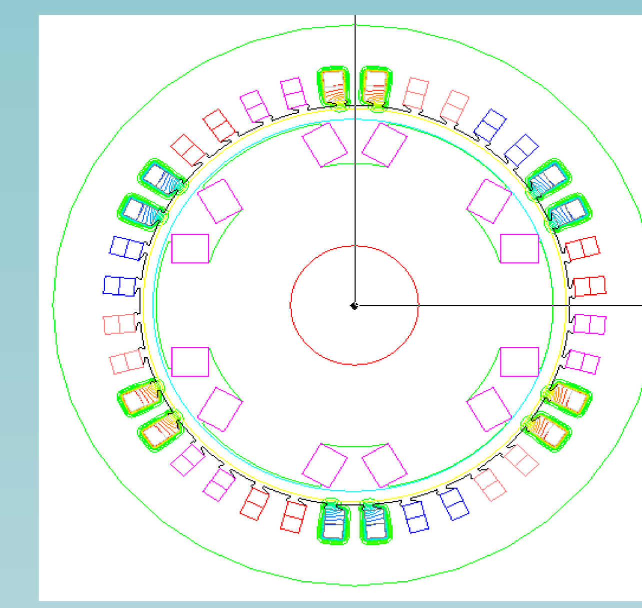
Sinusoidal currents

$$\nabla^2 \dot{A} = j\omega\mu\sigma\dot{A} - \mu\dot{J}$$

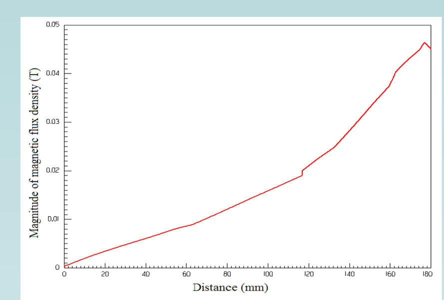
Oscillating magnetic field



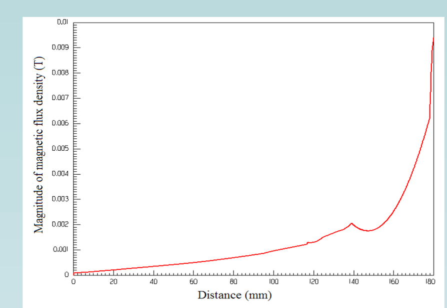
Magnetic field lines without shielding



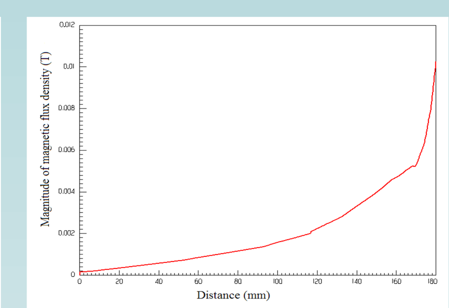
Magnetic field lines with shielding



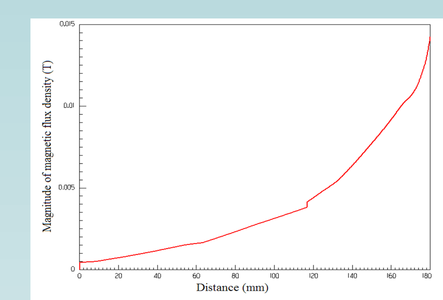
Without shielding



Scheme 1

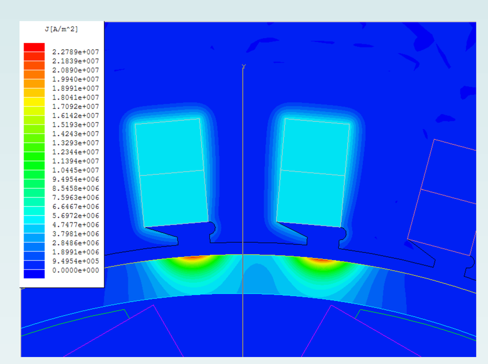


Scheme 2

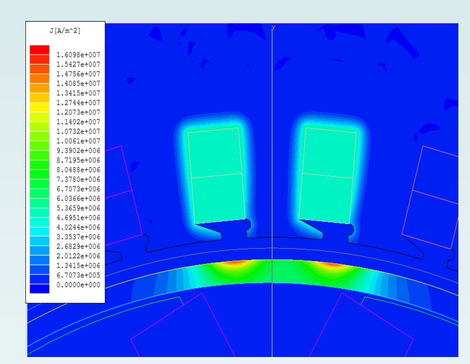


Scheme 3

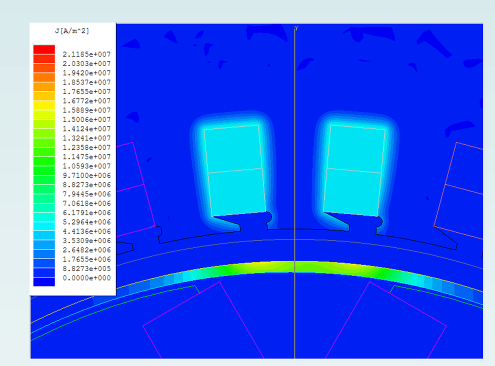
Magnetic flux density amplitude distribution curves



Scheme 1



Scheme 2



Scheme 3

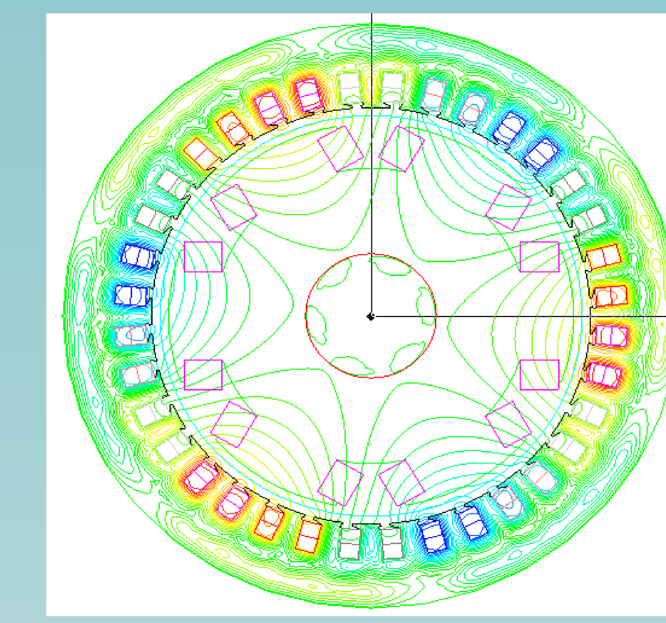
Eddy-current distributions in shielding tube

Table Shielding factors

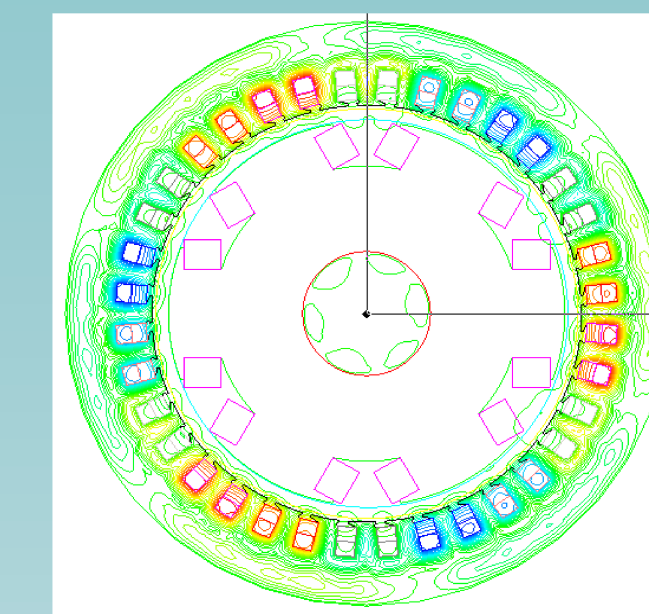
	Scheme1	Scheme2	Scheme3
50 Hz	0.075	0.11	0.21
250Hz	0.0074	0.022	0.07
550Hz	0.00055	0.0036	0.022

The higher the frequency of stator winding current, the smaller the shielding factor, which means that the electromagnetic shielding system has better shielding effect; the shielding factor of scheme 1 is smaller than scheme 2, the shielding factor of scheme 2 is smaller than scheme 3, that is, the shielding effect of scheme 1 is better than scheme 2, the shielding effect of scheme 2 is better than scheme 3. This shows that the thicker the copper tube of electromagnetic shielding system, the better its shielding effect on the oscillating magnetic field.

Rotating magnetic field



Magnetic force lines without shielding



Magnetic force lines with shielding

According to the calculation results of the magnetic field, the shielding factor was obtained. For scheme 1, 2, 3, the shielding factor value is **0.067, 0.125, 0.286** respectively. The results show that the shielding effect of the scheme 1 on the rotating magnetic field is better than scheme 2, the shielding effect of Scheme 2 is better than scheme 3.

Conclusion

For any working condition of the non-iron-core rotor superconducting generator, the magnetic field from the stator windings, which is able to generate the loss in superconducting windings or rotor parts, can be decomposed into oscillating magnetic field and rotating magnetic field. The shielding effect of electromagnetic shielding systems on the oscillating magnetic field and the rotating magnetic field are then analyzed respectively, so that the original complex problem is simplified.

The comparison of the shielding factors of the three electromagnetic shielding tubes shows that both of the copper tube and the stainless steel-copper composite tube can better shield oscillating magnetic field and rotating magnetic field, and the better the electrical conductivity of electromagnetic shielding tube, the better the shielding effect.

The calculation method presented here can be used to analyze the performance of electromagnetic shielding systems and calculate the losses of generator parts in low temperature area when considering various complex operating conditions.