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Thermal Stability Analysis of No-insulation Magnet under Dynamic Operational Conditions

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Abstract*——Due to excellent thermal stability and high-power density in steady state, no-insulation (NI) winding technology is widely used in the application of superconducting magnets. However, current ripple and background magnetic field fluctuations caused by relative devices result repetitive turn-to-turn current of the NI interpolated coil, which will impose a great impact on the thermal stability of NI magnet. This paper analyzes the power characteristics and other electromagnetic parameters of NI magnet under dynamic operating conditions by 2D finite-element method. The results provide references of thermal conductive structure design and assessment of operational reliability of NI magnets in changing working conditions.

1. Magnetic field of a toroidal magnet

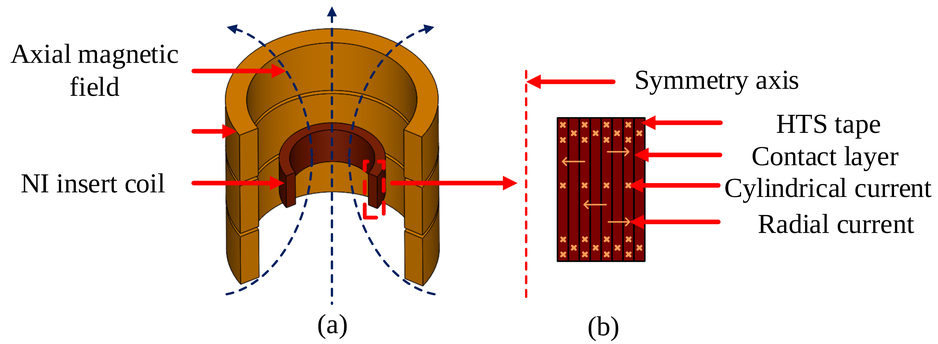

Fig.1. The structure of hybrid superconducting magnet . (a) Actual working model; (b) Cross-sectional view of NI insert coil and current distribution.

2. The 2D Finite element method

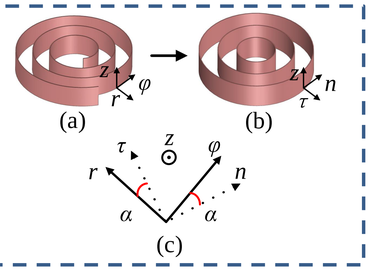

Fig.2. The transition from actual model to simulation model

$$h=\begin{Bmatrix}\cos\alpha & -\sin\alpha & 0\\ \sin\alpha & \cos\alpha & 0\\ 0 & 0 & 1\end{Bmatrix}$$

$$\rho=\begin{Bmatrix}\rho_{ct} & 0 & 0\\ 0 & \rho_{sc} & 0\\ 0 & 0 & \rho_{z}\end{Bmatrix}$$

Fig.3. Rotation matrix *h* and resistance matrix *ρ*

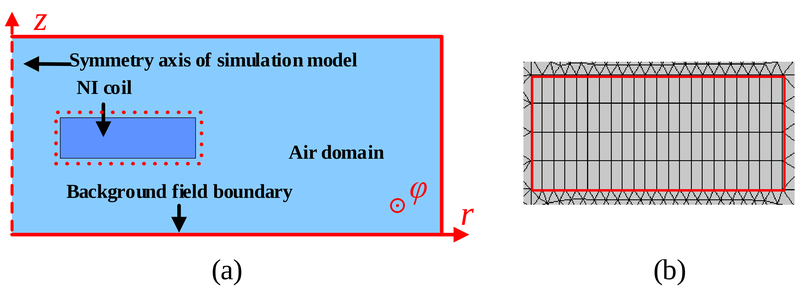

Fig.4. Model settings. (a) 2D axisymmetric finite model. (b) grid of NI coil.

3. Analysis of the calculation results

TABLE I
PARAMETERS OF THE NI coil

Items	Value	Items	Value
Inner dimension of the coil (mm)	100	Resistance of contact layers (μΩ·cm²)	70
Outer dimension of the coil (mm)	120	Background magnetic field (T)	12
Height of the coil (mm)	5	Critical current at (4.2K,12T) (A)	142.5
Turns of coil	100	Operating temperature (k)	4.2
Thickness of the HTS tape (mm)	0.1	Operating current (A)	100

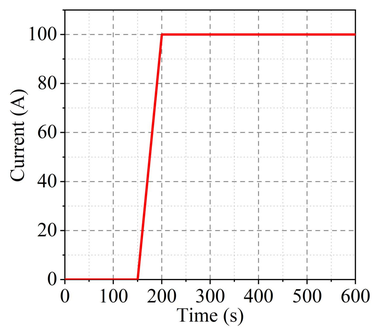

Fig.5. Charging current curve of NI coil

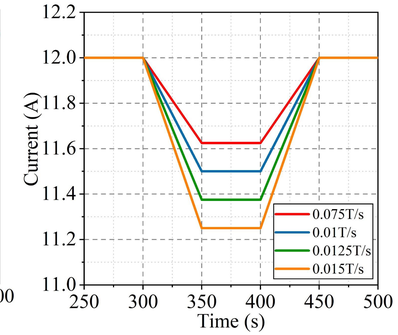

Fig.6. Curves of background field with different rates

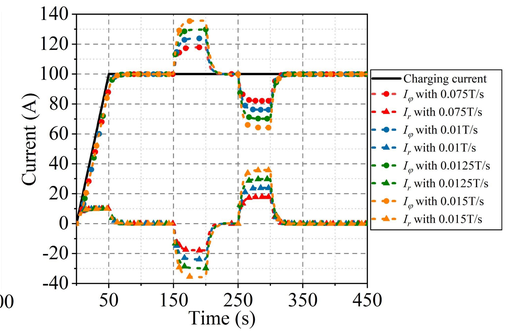

Fig.7. Current distribution under changing background field

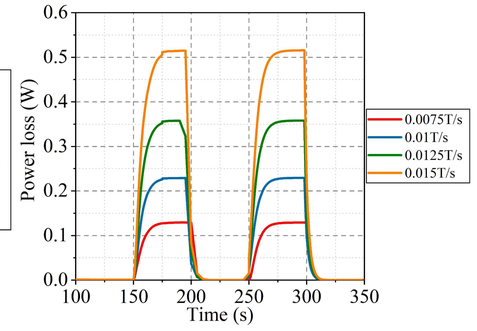

Fig.8. Power loss during the transient process

4. CONCLUSION

1) Currents in different directions will rise or decrease as the background magnetic field changes, and the peak value of the current is related to the changing rate of the background magnetic field. Cylindrical current and radial current have completely opposite trends during transients, which keeps the sum equal to the operation current.
2) According to the references, the fluctuation of background field will affect the working condition of the insert coil .The total AC loss of NI insert coil increases with the rate of the background magnetic field, the coil which undergo faster rate of change generates more AC loss during the transient process.
3) 2D method can simulate the dynamic process of NI insert coil under different background magnetic field, and shorten calculation time. Besides, benefit from the excellent physical coupling characteristics of finite element software, we can add other analysis module in the model

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