Contribution ID: **312** Type: **Poster Presentation (120m)**

Study on Extreme Condition Stability of Miniaturized High-Temperature Superconducting Magnets Based on Sterling Conduction Cooling System

Wednesday 24 July 2024 14:00 (2 hours)

In order to meet the demand for high-performance magnetic fields in extreme environments such as magnetic levitation trains, compared with traditional copper or permanent magnets, superconducting magnets with high current density can achieve light weighting of the overall system, which is of great significance for the safe operation and cost saving of high-speed magnetic levitation. In this paper, a miniaturized high-temperature superconducting magnet structure is designed, which provides cooling for the magnet through Sterling conduction cooling instead of traditional liquid helium or GM refrigerators with large compressors, reducing the weight of the superconducting magnet from over 200 kg to below 50 kg. In addition, aiming at the operating conditions of high-temperature superconducting magnets under 10-g acceleration and during operation, stability analysis calculations of Sterling conduction cooling high-temperature superconducting magnets under background magnetic fields of 0.5 T, 1 T, and 2 T are carried out based on the T-A numerical analysis method. The results show that under a maximum operating current of 60 A, the stability margin of the superconducting magnet still exceeds 1000 mJ/cc. Furthermore, through analysis of AC losses, the superconducting magnet will only experience quenching when the current frequency exceeds 250 Hz, meeting the high-frequency excitation operation requirements of superconducting magnets. Finally, the low-temperature characteristics of the Sterling conduction cooling high-temperature superconducting magnet are verified through cooling and energization tests, and the magnet maintains stable operation for over 10 hours under conduction cooling with a temperature difference not exceeding 1 K, confirming the feasibility of the miniaturized conduction cooling superconducting magnet proposed in this paper, laying the technical foundation for the safe service of high-speed magnetic levitation extreme condition superconducting magnets in the future.

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Session Classification: Wed-Po-2.6

Track Classification: Tracks ICEC 29 Geneva 2024: ICEC 10: Cryogenic applications: large magnet systems