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Multiphysics field topology optimization design of heat conduction structure of high-temperature superconducting magnets

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A high-temperature superconducting magnet is one of the core technologies of a superconducting maglev train. The multiphysics fields including electromagnetic, mechanical, and thermal effects should be taken into consideration in design. Traditional design methods rely on the initial configuration and the engineer's experience, and only consider the optimization design for the heat conduction performance of the heat conduction structure, without considering the strength of the thermal structure, which often significantly increases the weight while increasing the cold conductivity. To solve the above problems, aiming at the heat conduction structure of superconducting magnets, based on COMSOL Multiphysics software, the mathematical model of topology optimization of the heat conduction structure is established with Lorentz force as the input load. The objective function was assigned to dissipation of heat potential capacity, combined with volume fraction constraint conditions. The solid isotropic material with penalization (SIMP) theory is used to construct the material interpolation model and carry out the topological analysis of multiphysics and the innovative structure of heat conduction structure is obtained. Through finite element numerical simulation of multiphysics fields, the maximum temperature, stress safety factor, and weight were taken as evaluation indexes to compare the heat conduction performance, structural strength, and lightweight degree of the topology optimization structures with the traditional structures. The results show that this method can effectively enhance the cooling efficiency and alleviate the stress concentration without increasing the weight of the heat conduction structure. The work of this paper provides a theoretical foundation for the engineering design of the heat conduction structure of a high-temperature superconducting magnet.

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