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Automation of Superconducting Cavity Cooldown Process Using Two-Layer Surrogate Model and Model Predictive Control Method

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Superconducting cavity is the key equipment of the superconducting accelerator, which provides higher acceleration voltage and higher frequency power per unit length, and saves equipment space. Superconducting cavities need to be gradually cooled from ambient temperature (300K) to the superconducting temperature (4.2K or below) during the test and operation. The temperature difference on the cavity must be strictly limited during the cooldown process to prevent excessive thermal stress on the surface of the superconducting cavity. Since this cooldown process for the superconducting cavity is a typical large hysteresis, non-linear process that is difficult to control automatically using decoupled proportion integral derivative (PID) methods directly, a less efficient manual control scheme is normally adopted. In this paper, 3D numerical simulation, 1D pipe and 0D tank model with artificial neural network (ANN) were combined to generate a two-layer surrogate model that can balance computational accuracy and speed, to improve the automation and cooling efficiency of the superconducting cavity cooldown process. In order to achieve automatic control of the cooling procedure for the superconducting cavity, a model predictive control (MPC) approach was also built on the basis of this two-layer surrogate model. According to the results of the experiment test, the improved method could realize a quick and smooth cooldown process of the superconducting cavity, during which the temperature difference on the cavity could satisfy the requirements. Additionally, the improved automatic cooldown method was more adaptable and saved 40% more time than the original manual control method. The foundation for a more intelligent automated control of future large cryogenic systems or other system with the large hysteresis, non-linear properties, was laid.

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