Eddy Current Field Analysis of HTS Tapes Considering Hysteresis Characteristics by Using Improved XFEM

Nana Duan[1,2], Weijie Xu[1,2], Shuhong Wang[1], Jianguo Zhu[2], Zhiwei Lin[2] and Youguang Guo[2]

[1]Faculty of Electrical Engineering, Xi'an Jiaotong University, Xi'an, 710049, China
[2]Faculty of Engineering and Information Technology, University of Technology, Sydney, NSW2007, Australia
duannana87@163.com

***Abstract*—This paper presents a hysteresis model for high temperature superconductor (HTS) by using simplified Preisach Model, in which the Preisach distribution function is determined only based on the B−H limiting loop. The nonlinear eddy current field of HTS tapes in 2D is simulated by using an improved extended finite element method (XFEM) combined with the HTS hysteresis model. This technique allows the interfaces to be represented independently of the mesh. The support of a node or an element can be cut by several nearby interfaces. Finally, the influence of hysteresis on superconducting tapes is analyzed and discussed. The convergence studies, error analysis and magnetic field computations are provided to demonstrate the utility and robustness of the proposed approach.**

***Index Terms*—Eddy current, HTS tape, magnetic hysteresis, XFEM.**

I. Introduction

The superconducting layer of the high temperature superconducting (HTS) cable with 6 layers is showed in Fig. 1. The number, twisted angle and twisted direction of the tape are different in each layer. The tapes are about 4 mm wide and 0.20 mm thick while the outside diameter is about 30 mm and the length of the tape in a pitch is more than 100 mm. In addition, the distance between two layers is nearly equal to the thickness of the tape [1]. Therefore, the mesh, computational cost and the accuracy are a big challenge. This is why the current sharing is usually studied by using the equivalent circuit which cannot consider the proximity effect and hysteresis effect well at the same time [2]. The pinned magnetic flux constitutes a memory that gives rise to a hysteresis with corresponding losses and produces an additional voltage in the HTS cable, which affects the current distribution seriously.

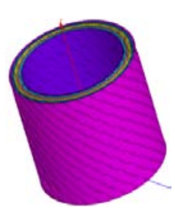

Fig. 1 Superconducting layer of HTS cable

II. Principle of the Improved XFEM and Hysteresis Model of HTS

The improved extended finite element method (XFEM) magnetic vector potential approximation can be expressed by

$$\mathbf{u}_h(\mathbf{x}) = \sum_{i\in I} N_i(\mathbf{x})\mathbf{u}_i + \sum_{k}^{N_{\text{int}}} \sum_{j\in J^{ek}} N_j(\mathbf{x})\psi^{(k)}(\mathbf{x})\mathbf{a}_j^{(k)} . \quad (1)$$

where k=1, 2,…, N_{int} which is the indexing of the interface Γ^k. When multiple interfaces cross the support of a node or an element, multiple enrichment functions have to be considered to make derivative field jump along these interfaces. In order to preserve the accuracy of the approximation, the high order enrichment function which is no longer a ridge function is chosen.

In this paper, the simplified Preisach model is applied to describe the magnetic performance of HTS. Figure 2 shows the hysteresis loop of Bi-2223.

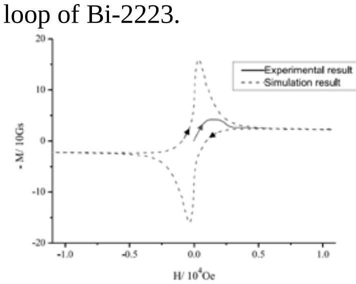

Fig. 2 Hysteresis loop of Bi-2223

III. Numerical Example

HTS tapes carrying $\sqrt{2}\sin(100\pi\cdot t)$ $\text{A}\cdot\text{m}^{-2}$ are showed in Fig. 3. The relative errors of the magnetic vector potential, the magnetic flux density and the eddy current density by using improved XFEM are calculated to compare with traditional XFEM. The inference of magnetic hysteresis is also analyzed.

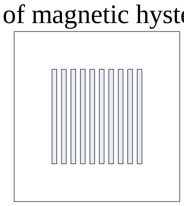

Fig. 3 HTS tapes

IV. Conslusion

Although the numerical example is only 2D HTS tapes, this method can be extended to the complex 3D HTS cable or other electromagnetic devices with nearby interfaces and the singularity condition where the conventional FEM is not an effective method.

References

[1] Y. Xin, W. Z. Gong and J. Y. Zhang, "A nontrivial factor in determining current distribution in an ac HTS cable-proximity effect," *Science China Technological Sciences*, vol. 53, pp. 922-928, 2010.

[2] S. H. Wang, J. Qiu, X. Y. Liu, *et al.*, "Current distribution analysis for high temperature superconducting cable considering hysteresis characteristics," *International Journal of Applied Electromagnetics and Mechanics*, vol. 33, pp. 511-517, 2010.