3-D Numerical Evaluation of Trapped Magnetic Field and Temperature of a Rectangular GdBaCuO Bulk Magnetized by MMPSC Method

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In this paper, numerical simulations of trapped field and temperature rise in a bulk superconductor during magnetization process are studied. The pulsed field magnetization method and the modified multi-pulse technique with stepwise cooling are presented. We adopt the control volume method for solving the thermomagnetic system describing the physical phenomena. The electromagnetic fields and temperature are computed because of an explicit algorithm. The results are compared with published experimental results and show a good concordance.

Index Terms—**Control volume method (CVM), high-temperature superconductor (HTS), modified multi-pulse technique combined with stepwise cooling (MMPSC), pulsed field magnetization (PFM).**

I. Introduction

BULK superconducting magnet is one application of high-Tc superconducting materials. Field-cooled and pulsed field magnetizations (PFMs) techniques are used to obtain the bulk superconductor magnets (SMs). These magnets produce more intense magnetic fields than ones obtained with the classical permanent magnets [3]. Indeed, the produced magnetic field can reach 5.20 T with a disk of GdBaCuO cools at 30 K [2]. The PFM is an important technique used to develop the SMs in industrial applications. This technique is inexpensive. The experimental setup is mobile with no use of superconducting coil magnet [2]. However, a problem exists when strength of the trapped field (B_T) is less than half of magnetized quantity when temperature is below 50 K [3]. The reason is that the trapped magnetic fields between 3.8 and 6.7 T have been produced on the surface at 30 K, by, respectively, the PFM method and FC technique [4]. This is due to the large temperature rise caused by the dynamical motion of the magnetic flux. The increasing of temperature lowers the critical current density (J_c) and degrades the trapped field (B_T). To improve the value of B_T in the PFM method, several techniques have been developed, such as the iteratively magnetizing pulsed-field operation with reducing amplitudes [10], the multi-pulse technique combined with stepwise cooling (MPSC) [11], and the modified MPSC (MMPSC) [5]. The latter method considered as the most efficient method allows to reach a maximum trapped field of 5.2 T in a sample of 45 mm diameter subjected to applied fields up to 6.7 T with pulses of 13 ms rise time [2], [5]. In this process, the heat generation was suppressed by applying iterative pulsed at two ranges of temperature during magnetizing process.

During PFMs processes, large shielding current are induced to prevent magnetic fluxes to penetrate into the superconductor. The trapped field is sensitive to this magnetic shielding effect. In addition, inhomogeneity of superconducting properties influences PFMs characteristics. This results in temperature rising and a reduction of J_c. Such complicated problem must be analyzed by 3-D numerical model. Several numerical works have been devoted to study the behavior of bulk superconductors during PFM processes. The 1-D and 2-D models are proposed to treat this issue when homogenous superconducting properties are assumed [3], [6]. A 3-D numerical model based on finite-element method have to face up the numerical oscillations that affect convergence properties. Different works based on flux approaches are introduced to handle theses convergence problem [7]–[9], [13]. Unfortunately, few of them are dedicated to study the thermomagnetic system that characterizes the superconductor materials. In this paper, a 3-D numerical model is proposed to study the behavior of bulk superconductor during magnetization. The PFM method is assumed and the case where several successively magnetic pulses are applied is treated. We adopt the control volume method (CVM) based on flux approach to avoid the convergence problems and the numerical oscillations involved because of the strongly non-linear character of the problem.

II. Mathematical and Numerical Analysis Methods

A. Basic Equations

A 3-D CVM analysis was carried out to investigate the magnetic and thermal behavior during magnetization processes.

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