Eur. Phys. J. Appl. Phys. (2014) 66: 10601
DOI: 10.1051/epjap/2014130479

THE EUROPEAN PHYSICAL JOURNAL APPLIED PHYSICS

Regular Article

3D analysis of applied field effect on trapped magnetic field during pulsed field magnetization of bulk superconductor

Mohamed Lotfi Khene[1], Lotfi Alloui[1,2,a], Souri Mohamed Mimoune[1], Frédéric Bouillault[2], and Mouloud Feliachi[3]

[1] Laboratoire de Modélisation des Systèmes Energétiques LMSE, Université de Biskra, BP 145, 07000 Biskra, Algeria
[2] Laboratoire de Génie Electrique de Paris – LGEP, CNRS UMR 8507, Supélec, Université Pierre et Marie Curie-Paris 6; Université Paris Sud-Paris 11, Plateau de Moulon, 11 rue Joliot Curie, 91192 Gif-sur-Yvette, Cedex, France
[3] Institut de Recherche en Electrotechnique et Electronique de Nantes Atlantique IREENA, CRTT, Boulevard de l'Université, BP 406, 44602 Saint-Nazaire Cedex, France

Received: 21 October 2013 / Received in final form: 7 March 2014 / Accepted: 11 March 2014
Published online: 21 April 2014 –

Abstract. External applied field effect in magnetization process by pulsed field (PFM) method of rectangular bulk superconductor is analysed by solving the A-V magnetic equation coupled to the thermal one in order to show the influence of the amplitude of the external field on the trapped magnetic field of bulk superconductor. A numerical model based on the control volume method (CVM) has been developed, which uses a power-law model with temperature dependency and magnetic field dependence on critical current density. For low cooling temperature $T_{co} = 20$ K, a good distribution of the trapped magnetic field of the bulk superconductor is obtained when we applied high external field.

1 Introduction

Several researches on strong magnets using high temperature bulk superconductor have been conducted for their application to electric motors [1,2], a magnetron spattering [3], a magnetic separation [4], etc. The high potential of high temperature bulk superconductor (HTS) has been obtained by Tomita and Murakami [5] for trapped magnetic field of 17 T at 29 K with a field cooling magnetization (FCM) and 5.2 T at 28 K by Fujishiro et al. [6] with a pulsed field magnetization (PFM). To magnetize the superconducting bulk for the quasi-permanent magnet, the PFM is suitable, instead of a conventional FCM, because the PFM is an inexpensive and mobile experimental setup [7]. The PFM does not need an expensive high field superconducting magnets, but bulk superconductor can be magnetized using a copper coil and a pulsed power supply. In the PFM, a large shielding current induced in the bulk superconductor prevents the magnetic flux from penetrating into it. Moreover, the generated heat by the shielding current has a complex influence on flux motions and the distribution of the trapped magnetic field [8]. Therefore, it is necessary to study and develop a precise magnetization method.

The purpose of this work is to study the effect of the external field on the trapped magnetic field of the bulk superconductor at cooling temperature $T_{co} = 20$ K and at $T_{co} = 44$ K during magnetization process by PFM method. For this, to have a precise calculation, we have to study the magneto-thermal behaviour of the bulk superconductor. The calculation is performed by using a three dimensional (3D) numerical analysis based on control volume method. The PFM method is applied with different value of external field from 4 T to 7 T.

The control volume method is very useful in treating thermal problems and it has been used successfully for magneto-thermal problems [9]. It permits to avoid convergence problems and numerical oscillations involved in the strongly non linear character of the magneto-thermal problem to be treated, in particular if the model of power law is used to describe the relation between the electric field and the current density [9,10]. The iterative algorithm is based on bloc diagonal Gauss-Seidel method [9] and it consists of coupling electromagnetic and thermal equations. It permits to separate the non symmetric and the non linear magnetic equation from the non symmetric and non linear thermal one.

2 Mathematical models

The PFM magnetization process in the HTS bulk is analysed by coupling electromagnetic and thermal phenomena. The mathematical model of the electromagnetic phenomenon is described by the $(\boldsymbol{A}, V)$ formulation based on the magnetic vector potential $\boldsymbol{A}$ and the electric scalar potential V using Coulomb gauge. The shielding currents create induced electromagnetic loses due to the thermal

[a] e-mail: lotfi.alloui@lgep.supelec.fr