J Supercond Nov Magn (2013) 26:1275–1281
DOI 10.1007/s10948-012-1880-y

ORIGINAL PAPER

The Influence of Excitation Frequency on Magnetic Levitation Systems with a High-T_c Superconductor

K. Ben Alia · L. Alloui · F. Bouillault · S.M. Mimoune

Received: 7 November 2012 / Accepted: 30 November 2012 / Published online: 22 December 2012

Abstract In this paper we present a numerical analysis of dynamic features of the levitation system generated by an interaction between a levitated permanent magnet (PM) and a high-T_c superconductor (HTSC) excited by an oscillatory external source. The obtained results show that the value of the frequency (f_{free}) of the PM displacement in the case of the levitation system generated by an interaction between a levitated PM and a fixed HTSC is equal at the resonance frequency (f_{re}) of the levitation system generated by an interaction between a levitated PM and HTS excited by an oscillatory external source and the resonance frequency (f_{re}) is mainly dependent upon the cooling position (Z_0) and the mass of the PM. The numerical problem in this paper is solved by using the control volume method (CVM).

Keywords High-T_c superconductor · Control volume method · Levitation system · Excitation frequency · Resonance frequency

K. Ben Alia · L. Alloui (✉) · S.M. Mimoune
Laboratoire de Modélisation des Systèmes Énergétiques LMSE, Université de Biskra, 07000 Biskra, Algérie
e-mail: lotfi.alloui@lgep.supelec.fr

S.M. Mimoune
e-mail: s.m.mimoune@univ-biskra.dz

L. Alloui · F. Bouillault
Laboratoire de Génie Electrique de Paris, LGEP, CNRS UMR 8507, Supélec, Université Pierre et Marie Curie-Paris 6, Paris, France

L. Alloui · F. Bouillault
Université Paris Sud-Paris 11, Plateau de Moulon, 11 rue Joliot Curie, 91192 Gif-Sur-Yvette Cedex, France

F. Bouillault
e-mail: bouillault@lgep.supelec.fr

1 Introduction

High-T_c superconducting magnetic levitation systems are able to maintain stable levitation without control. Therefore, their application to mechanical systems with very little energy loss is expected. For example, flywheel bearings for energy storage and maglev vehicles for mass transportation have been studied and developed so far [1–3]. In design of these systems, it is important, from the viewpoint of mechanical stability, to predict exactly their dynamics in the presence of external disturbance. However, mechanical resonance characteristics of a high-T_c superconducting magnetic levitation system in the mechanical resonant state are not clearly understood. In this context, we propose in this paper a 3D numerical method to study the dynamics of a levitation system in which a permanent magnet is freely levitated above a high-T_c superconductor excited vertically. The aims are determining the value of the resonance frequency and study the influence of some parameters on the resonant frequency.

Several works have shown that the influence of the flux creep on dynamic behavior of magnetic levitation systems with a high-T_c superconductor is considerable and significant [4–6], in particular, the numerical works presented in [7, 8]. In the literature, some macroscopic mathematical models were proposed to reflect the flux creep and the flux flow phenomena of superconductivity such as the model proposed by Anderson–Kim [9] or the model of power law proposed by Rhyner [10]. These models lead to good agreement with the experimental data [6, 11]. In our paper, the effect of flux creep in the superconductor is simulated by using the power law. In this case, to avoid convergence problems and numerical oscillations involved in the strongly non-linear character of the 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 [12],