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Numerical study of the relation between the thermal effect and the stability of the levitation system excited by an external source

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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-Tc superconductor (HTSC) excited by an oscillatory external source where the thermal effect inside the superconductor is taken into account in a macro-model of superconductivity. The comportment is comprehensively displayed by comparing the dynamic responses of such systems in which the thermal effect in superconductor is and is not taken into account. The obtained results show that the thermal effect is related to the stability of the levitation system. This effect appears significantly in the case of unstable levitation systems. The results obtained show that the thermal effect and the stability of the levitation system depend mainly on some parameters related to the external source, such as the frequency and the amplitude of the applied external source. In this paper, the numerical problem is solved by using the control volume method (CVM) and the electromagnetic and thermal coupling is ensured by an alternate algorithm.

1. Introduction

High-Tc 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. In this context, some experiments and simulations exhibited that the magnetic levitation force has somewhat time-dependent relaxation, and the vibration center of levitated body drifts downward when a time varying excitation is applied to the system [4–6]. This is due to the joule losses caused by the flux flow and creep phenomena. So, it is important to estimate the magnetic levitation force by taking into account the flux flow and the flux creep phenomena.

Having measured the dynamic vibration of a permanent magnet above a superconductor, Yoshida et al. gave some numerical analyzes based on the flux flow and creep model. Their numerical results differ from those obtained by experimental tests [5]. The discrepancy between the numerical and experimental results is caused by the dependence of the material constants on the magnetic flux density as described by the Kim model [7] on the one hand and by the dependence on the temperature inside the superconductor on the other hand. Several numerical works were proposed [8–10] to analyze the dynamic features of the high-Tc superconducting magnetic levitation systems where the flux flow and creep are taken into account in a macro-model of superconductivity, but in these works, only the dependence of the material constants on the magnetic flux density is taken into account. We can say that these models are incomplete because the losses associated with the motion of vortices when the superconducting materials are penetrated by a variable magnetic field created in the case of the superconducting magnetic levitation systems by the displacement of the PM and by the oscillatory motion of the superconductor imposed by the presence of external source may give rise to a significant temperature increase and a degradation of the superconducting properties. So it is important to take into account the dependence of the material constants on the temperature inside the superconductor. To investigate this dependence, this paper presents a numerical analysis of dynamic features of the levitation system generated by an interaction between a PM

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