THE SUMMARY OF Ph. D. DISSERTATION No. 1

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Title

The analysis of the flow which heat and the coriolis force and the electromagnetic force act on by using GSMAC-FEM

Abstract

Magnetohydrodynamics includes natural phenomena involving fluid, thermal, and electromagnetic fields. Mutual relationships among these three fields are classified as follows: the relationship between a fluid field and a thermal field, that between a fluid field and an electromagnetic field, and that between a thermal field and an electromagnetic field. Since actual natural phenomena involve complex issues among these three fields, the development of appropriate methods of solution for each relationship is desired. At present, for issues involving significant factors in terms of engineering such as high Re number, high Ra number and electromagnetic coupling, a finite element method using nonstructural mesh is often adopted. Under such circumstances, in this study, I aim at the introduction of the GSMAC finite element method for a flow with high Re number that has electromagnetic effects and a thermal source, and at the clarification of a method of upwind. I also aim to perform analysis using a certain analytical model, to clarify mutual relationships among the fluid, thermal and electromagnetic fields, and discuss the results obtained.

Chapter 1 is an introduction, in which previous studies regarding numerical analytical methods, issues of upwind, and thermal convection and electromagnetic effects are outlined in order to clarify the framework of this study.

In Chapter 2, basic equations for solving the problems of magnetohydrodynamics using the finite element method are presented, and a resolution method, the GSMAC method, is described in detail. Methods for analytical expression of coefficient matrices and for stabilization using the finite element method are also described. In addition, a method of solving natural convection with a high Ra number and issues of surface tension are discussed.

In Chapter 3, analyses of natural convection are performed using an analytical model consisting of two concentric spheres. The parameters used in the calculation are Pr=0.71 and Ra=7.1×10^5, Ra=7.1×10^6. Stationary solutions are obtained in the calculations. In addition, calculation is performed for the radius ratios of two spheres (D_i/d) of 0.86, 3 and 18, using Ra=7.1×10^6, and the results are examined in detail. Results obtained for Ra=5,964, Ra=229,330 and Ra=749,760 are compared with results of visualization experiments carried out by Yin et al., and good agreement is confirmed.

In Chapter 4, analyses are performed using an analytical model of a rotary spherical shell having a uniform thermal source. For the analysis of an induction magnetic field, the B method is developed and analyzed using the two concentric sphere analytical model. The results obtained are compared with those obtained by the ϕ method, and the efficacy of the B method is demonstrated. In addition, the superiority of the calculation by the B method is confirmed for the control of fluid fields, compared with the ϕ method. Parameters used in the calculations are Pr=0.025, Ra=100, Ta=0, Ha=100(ϕ method, B method), Rem=1(B method).

In Chapter 5, mutual relationships among the fluid, thermal and electromagnetic fields are discussed. The analysis of the growth of crystals is performed using the biquadratic element GSMAC-FEM and a cusp-magnetic-field-applied CZ method; three conditions for the synthesis of high-quality crystals are examined with respect to stationary solutions. In addition, problems concerning electromagnetic fluid inside a three-dimensional cylindrical container are analyzed using an alternating current magnetic field. To clarify the behavior of the free surface of a liquid metal induced by nonstationary electromagnetic force, the ALE method is applied to the fluid field and the A-ϕ method is applied to the electromagnetic field. Analyses are performed by coupling the two methods. In these analyses, changes in the electromagnetic field and in the free surface are discussed, and the results are in good agreement with the experimental results obtained by Kaneko et al.

In chapter 6, results of this study are summarized and conclusions are given.