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Numerical modeling of MHD stability in a cylindrical configuration

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Abstract

A numerical modeling of natural convection under the influence of either axial (B_z) or radial (B_r) magnetic field in a cylindrical configuration filled with a low-Prandtl number electrically conducting fluid, is studied. The finite volume method is used to discretize the equations of continuity, Navier Stokes and energy. A computer program based on the SIMPLER algorithm is developed. The flow and temperature fields are presented by stream function and isotherms, respectively. Stability diagrams are established according to the numerical results of this investigation. These diagrams put in evidence the dependence of the critical Grashof number, Gr_{cr} with the increase of the Hartmann number, Ha. The strongest stabilization of the convective flows occurs when the magnetic field is applied in the radial direction. This study confirms the possibility of stabilization of a liquid metal flow in natural convection by application of a radial magnetic field.

1. Introduction

The convection of electrically conducting fluids such as liquid metal in the presence of magnetic field has been one of the major interesting research subjects due to its direct

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Nomenclature

B	intensity of magnetic field, Tesla
B_r	radial magnetic field, Tesla
B_z	axial magnetic field, Tesla
F	Lorentz force, N m^{-3}
g	gravitational acceleration, m s^{-2}
Gr	Grashof number [dimensionless]
H	enclosure height, m
Ha	Hartmann number [dimensionless]
J	electric current density, A m^{-2}
P	dimensionless pressure [dimensionless]
Pr	Prandtl number [dimensionless]
R	cylindrical radius, m
r,z	radial and axial coordinates, respectively
T	temperature, K
t	dimensionless time [dimensionless]
Δt	dimensionless time increment [dimensionless]
u,v	dimensionless radial and axial velocities, respectively [dimensionless]

Greek symbols

α	thermal diffusivity of the fluid, m^2 s^{-1}
β	thermal expansion coefficient of the fluid, K^{-1}
γ	aspect ratio$=$H/R [dimensionless]
Θ	dimensionless temperature [dimensionless]
ν	kinematic viscosity of the fluid, m^2 s^{-1}
ρ	density of the fluid, kg m^{-3}
σ	electric conductivity, Ω^{-1} m^{-1}
ψ	dimensionless stream function [dimensionless]
Ω	angular velocity, rad s^{-1}

Subscripts

cr	critical
c	cold
EM	electromagnetic
h	hot
r,z	radial and axial directions, respectively

application to various physical phenomena as well as to crystal growth processes. Some crystal materials are good electrical conductors in their liquid state. During manufacturing of the crystals, unwanted convective flows can significantly be suppressed in liquid metals and other electrically conducting fluids by applying an external magnetic field. A thermal gradient, a magnetic field or various aspect ratios has been also considered in such a flow.