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Thermosolutal convection in a viscoelastic dusty fluid with hall currents in porous medium

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ABSTRACT

An incompressible Oldroydian viscoelastic fluid layer heated and soluted from below in the presence of suspended (dust) particles and uniform vertical magnetic field to include the effect of Hall currents in porous medium is considered. Following the linearized stability theory and normal mode analysis, the dispersion relation is obtained. For the case of stationary convection, Oldroydian viscoelastic fluid behaves like an ordinary Newtonian fluid. Dust particles and Hall currents are found to have a destabilizing effect on the thermosolutal convection, whereas magnetic field is found to have a stabilizing effect on the thermosolutal convection. Medium permeability has both stabilizing and destabilizing effect on the thermosolutal convection under certain conditions. Graphs have been plotted by giving numerical values to the parameters to depict the stability characteristics. The case of overstability is also considered.

1. Introduction

The growing importance of the use of viscoelastic fluids in technology and industries has led various researchers to attempt diverse flow problems related to several non-Newtonian fluids. Recently an attention has been drawn by calculations of the rheological behavior of dilute suspensions and emulsions to the idealized incompressible viscoelastic liquids whose behavior at small variable shear stresses is characterized by three parameters coefficient of viscosity μ, a relaxation time λ, and a retardation time $\lambda_0(<\lambda)$. A theoretical model is proposed by Oldroyd [1] for a class of viscoelastic fluids. An experimental demonstration by Toms and Strawbridge [2] revealed that a dilute solution of methyl methacrylate in n-butyl acetate agrees well with the theoretical model of the Oldroyd fluid. Sharma [3] studied the problem of the thermal instability in a viscoelastic fluid layer in hydromagnetics.

The problem of thermal instability of a Maxwellian viscoelastic fluid in the presence of magnetic field is studied by Bhatia and Steiner [4]. The effect of magnetic field on thermosolutal instability of an Oldroydian viscoelastic fluid in porous medium is considered by Sharma and Bhardwaj [5]. They found that magnetic field has a stabilizing effect on the system while medium permeability has dual effect. In thermal

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Notations

a	dimensionless wave number
c	speed of light
d	depth of layer
D	derivative with respect to z $(= d/dz)e$ Charge of an electron
λ	relaxation time
λ_0	retardation time $(<\lambda)$
$\mathbf{g}(0,0,-g)$	acceleration due to gravity field
$\mathbf{H}$	uniform magnetic field having components $(0,0,H)$
(h_x,h_y,h_z)	perturbation in magnetic field having components
$k_x,\ k_y$	horizontal wave numbers
k	wave number
$k_T\|$	thermal diffusivity
k_s	Solute diffusivity
M	Hall current parameter
N	electron number density
n	growth rate
p	fluid pressure
p_1	Prandtl number
p_2	magnetic Prandtl number
$\mathbf{q}$	velocity of fluid
(u, v, w)	perturbations in fluid velocity
Q	Chandrasekhar number
R	Rayleigh number
t	Time coordinate
T	temperature
C	concentration
$\mathbf{x}(x,y,z)$	space coordinates

Greek Symbols

η	electrical resistivity
α	coefficient of thermal expansion
β	uniform temperature gradient
θ	perturbation in temperature,
γ	perturbation in concentration,
δp	perturbation in pressure$p$,
ρ	fluid density
$\delta\rho$	perturbation in densityρ
μ_e	magnetic permeability
∇	del operator
∂	curly operator

and thermosolutal convection problems, the Boussinesq approximation is used, which is well justified in the case of incompressible fluids. Usually the magnetic field has a stabilizing effect on the instability. A numerical study of the hydromagnetic thermal convection in a viscoelastic dusty fluid in a porous medium is discussed by Goel and Agrawal [6].

The Hall Effect is likely to be important in many geophysical situations as well as in flow of laboratory plasma. There is growing importance of non-Newtonian fluids in chemical technology, industry and geophysical fluid dynamics. The Hall currents have relevance and importance in geophysics, MHD generator and industry. Hall effect on thermosolutal instability of Rivlin-Ericksen fluid with varying gravity field in porous medium is discussed by Sharma and Kishor [7]. Sunil et al. [8] investigated the Hall effects on thermosolutal instability of Walters' (model B') fluid in porous medium and found that magnetic field has a stabilizing effects, whereas the Hall currents have a destabilizing effect on the system. Kumar et al. [9] studied the Rayleigh–Taylor instability of rotating Oldroydian viscoelastic fluids in porous medium in the presence of a variable magnetic field.

The problem on a couple-stress fluid heated from below in hydromagnetics has been studied by Kumar and Kumar [10]. They found that magnetic field has both stabilizing and destabilizing effects on the thermal convection under certain conditions. Singh and Dixit [11] considered the stability of stratified Oldroydian fluid through porous medium in hydromagnetics in presence of suspended particles. Vikrant et al. [12] studied the problem of thermal convection in a compressible Walters' (model B') elastico-viscous dusty fluid with Hall currents and found that Hall currents have destabilizing effect on the system. The effect of Hall currents on thermal instability of compressible dusty viscoelastic fluid in porous medium is discussed by Kumar [13] and found that Hall currents have destabilizing effect on the thermal convection. The instability of the plane interface between two viscoelastic Kuvshiniski superposed fluids in porous in the presence of uniform rotation and variable magnetic field has been considered by Kumar [14].

Wang and Tan [15] considered the stability analysis of Soret-driven double-diffusive convection of Maxwell fluid in a porous medium. Bishnoi and Goyal [16] studied the problem of Soret-Dufour driven thermosolutal instability of Darcy-Maxwell fluid and found that the Dufour number enhances the stability of Darcy-Maxwell fluid for stationary convection as well as overstability. Kumar and Mohan [17] included the double-diffusive convection in an Oldroydian viscoelastic fluid under the simultaneous effects of magnetic field and suspended particles through porous medium.

In the past studies, instability in an Oldroydian viscoelastic fluid layer in porous medium heated and soluted from below has been investigated including the external constraints such as magnetic field and/or rotation. During the survey it was noticed that effect of Hall currents is completely neglected from the studies of Oldroydian viscoelastic dusty fluid in porous medium. Further, magnetic field and medium permeability have dual character. Therefore, an attempt has been made to study the effect of thermosolutal convection in an Oldroydian viscoelastic dusty fluid in presence of Hall currents in porous medium.

2. Formulation on the problem

Consider an infinite layer of an incompressible, finitely conducting (electrically and thermally both) Oldroydian viscoelastic dusty fluid, confined between two horizontal planes situated at $z = 0$ and $z = d$, acted upon by a uniform vertical magnetic field $\mathbf{H}(0, 0, H)$ and gravity field $\mathbf{g}(0, 0, -g)$. The fluid layer is heated and soluted from below leading to an adverse temperature gradient $\beta = \frac{T_0-T_1}{d}$, where T_0 and T_1 are the constant temperatures of the lower and upper boundaries with $T_0 > T_1$ and$\beta' = \frac{C_0-C_1}{d}$, where C_0 and C_1 are the constant