Some Applications of the Electrically Conducting Non-Newtonian Fluids Flow through Wavy Surfaces

THESIS

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(Applied Mathematics)

By

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LIST OF PUBLICATIONS

(1) Magnetohydrodynamics Flow of a Bi-viscosity Fluid through Porous Medium in a Layer of Deformable Material, Journal of Porous Medium, March, 2009 (in press).

List of papers have been sent to be published:

(1) Analytical Study of the MHD Flow of a Bi-viscosity Fluid with Heat and Mass Transfer in a Circular Wavy Tube, Journal of Computers and Fluids.

(2) Bi-viscosity Dissipation and Chemical Reaction Effects on the Magnetohydrodynamics Flow of a non-Newtonian Fluid through Porous Medium Confined between a Long Wavy Surface and a Parallel Flat Surface, Journal of Approximation Theory.

(3) Unsteady MHD Stokes Flow of a Bi-viscosity Fluid with Heat and Mass Transfer Through Porous Medium between Two Wavy Surfaces, Calcutta Mathematical Journal.

(4) Unsteady Flow of an Incompressible Carreau Fluid between Two Wavy Surfaces with Heat and Mass Transfer, I. J. of Non-linear Mechanics.

(5) MHD Flow of an Incompressible Maxwell Fluid with Heat and Mass Transfer between Two Wavy Surfaces with Constant Suction, European J. of Mechanics B / fluids

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Summary

SUMMARY

The main aim of the present thesis is to study some applications of the electrically conducting non-Newtonian fluids flow through wavy surfaces.

The thesis consists of seven chapters with two summaries one of them is in Arabic language and the other is in English language and a list of references related to the subject of the thesis.

Chapter (1)

Includes an introduction about the following items which are related to the subject of the thesis

1. Fluid mechanics.
2. Relationship to continuum mechanics.
3. Definition of fluids.
4. Stress and strain.
5. Classification of fluids.
6. Classification of non-Newtonian fluids.
7. Basic equations.
8. Flow through porous medium included an introduction about porous medium and different models of this flow.
9. Heat transfer of the fluids and its different types (conduction-convection-radiation).
10. Mass transfer and its basic equations.
11. Magnetohydrodynamics fluids (MHD) and their equations.
12. Wave motion.
13. Perturbation method.

Chapter (2)

In this chapter, we were studied the problem of two dimensional steady magnetohydrodynamics (MHD) flow of a non-Newtonian fluid of type Bi-viscosity with heat and mass transfer in a circular wavy tube. A uniform magnetic field was assumed to be applied parallel to the axis of the tube. The equations governing the fluid flow with heat and mass transfer have been solved analytically subject to a set of appropriate boundary conditions. The velocity components have been obtained in terms of the stream function using the regular perturbation technique, under the assumption that the waviness of the tube is very small. The effects of the problem parameters have been illustrated graphically in the end of this chapter and important applications of this study have been presented.

The results of this chapter have been rewritten and have been sent to be published in (Journal of Computers and Fluids)

Chapter (3)

In this chapter, the hydromagnetic flow of a non-Newtonian fluid of type Bi-viscosity through porous medium under a uniform magnetic field in a layer of deformable material has been studied. The deformable material is considered as a homogeneous binary mixture of solid and fluid phases. The equations governing the fluid flow have been deduced for the solid displacement phase and the fluid velocity, it have been solved analytically by using Fourier series. The effects of the magnetic field parameter and interaction between the solid and the fluid phases in the porous layer on the fluid flow have been investigated and have been illustrated graphically for both steady and unsteady flow when the solid phase is rigid.

The results of this chapter have been rewritten and have been accepted to be published in (Journal of Porous Medium, March, 2009).

Chapter (4)

In this chapter, the problem of two-dimensional magnetohydrodynamics flow of a non-Newtonian (Bi-viscosity) incompressible fluid under bi-viscosity dissipation and chemical reaction effects through porous medium confined between a long wavy surface and a parallel flat plate moving with a uniform velocity U has been considered. A uniform magnetic field is assumed to be applied perpendicular to the wavy surface. The equations governing the fluid flow with heat and mass transfer have been solved subject to a set of appropriate boundary conditions. It was assumed that the flow consists of two parts; a mean part and a perturbed part. To obtain the solution of the perturbed part, long wave approximation has been applied. The expressions for the zero order and first order of velocity, temperature and concentration have been obtained analytically and have been evaluated for different parameters, such as the magnetic parameter M, The permeability parameter K and the upper limit of apparent viscosity coefficient β .The effects of this parameters on the fluid flow have been discussed in details and have been showed graphically.

The results of this chapter have been rewritten and have been sent to be published in (Journal of Approximation Theory).

Chapter (5)

In this chapter, the problem of unsteady MHD Stokes flow with heat and mass transfer of a non-Newtonian fluid of type Bi-viscosity between two wavy surfaces through porous medium has been studied. A uniform magnetic field is assumed to be applied perpendicular to the wavy surfaces. The equations governing the fluid flow have been solved analytically under low Reynolds number assumption. Expressions for the velocity, temperature and concentration have been obtained and have been showed graphically for various values of physical parameters of interest, such as the magnetic parameter M , the permeability parameter K and the upper limit of apparent viscosity coefficient β .

The results of this chapter have been rewritten and have been accepted to be published in (Calcutta Mathematical Journal, June, 2009).

Chapter (6)

In this chapter, we were studied the effects of magnetic field, porosity of the medium and the non-Newtonian property (Weissenberg number) on the unsteady flow of an incompressible Carreau fluid between two wavy surfaces. The effects of non-Newtonian dissipation and thermal diffusion under a long wavelength approximation are taken in our consideration. The governing equations of this problem have been solved analytically by using a regular perturbation series in a Weisssenberg number parameter. The distributions of the velocities, temperature and concentration have been obtained and have been illustrated graphically for the various parameters such as magnetic parameter, permeability parameter and Weisssenberg number parameter.

The results of this chapter have been rewritten and have been sent to be published in (I. J. of Non-linear Mechanics).

Chapter (7)

The effects of magnetic field and porosity of the medium on the steady flow of an incompressible non-Newtonian (Maxwell) fluid bounded by two wavy surfaces with constant suction have been discussed in this chapter. The non-Newtonian dissipation and the thermal diffusion are taken in our consideration. The non-linear partial differential equations governing this problem have been solved analytically by using a regular perturbation technique of a small non-dimensional amplitude parameter under a long wavelength approximation. The analytical formulae of the velocity components, temperature and concentration have been obtained. Also, it have been illustrated graphically for interest various parameters such as magnetic parameter and permeability parameter.

The results of this chapter have been rewritten and have been sent to be published in (European J. of Mechanics B / fluids).

Chapter (1)

General Introduction

General Introduction

(1) Fluid Mechanics

Fluid mechanics is one of the most important parts of the recent interdisciplinary activities concerning engineering and technological developments. Fluid mechanics is that branch of science, which is concerned with the study of the motion of the fluids or that of bodies in contact with fluids. The development of fluid mechanics passed through three distinct stages. The first stage dealt with the studies of an imaginary “ideal” fluid, that is with out viscosity and incompressible in nature. Evidently, the shearing motion will not rise to any shearing forces in such fluids hence the flow is said frictionless. The concept of boundary layer, introduced by Prandtl in 1904, marked the beginning of the second stage in the development of the classical fluid dynamics. Prandtl simply established that in flows over a solid surfaces, the friction of effects are confined to a relatively thin layer, known as the boundary layer, existing adjacent the solid surface. Finally, the third stage of fluid mechanics is currently being developed and is still in its infancy. This has been prompted by the increasing significance of complex materials, that its flow behaviour does not conform to the Newtonian postulate, and accordingly such materials called non-Newtonian fluids. Fluid mechanics is the branch of physics which deals with the properties of fluid, namely liquid and gases and their interaction with forces [52].

(2) Relationship to Continuum Mechanics

Fluid mechanics is a subdiscipline of continuum mechanics, as illustrated in the following table.

<table>
<tr><td rowspan="4">Continuum mechanics: the study of the physics of continuous materials</td><td rowspan="2">Solid mechanics: the study of the physics of continuous materials with a defined rest shape.</td><td colspan="2">Elasticity: which describes materials that return to their rest shape after an applied stress.</td></tr>
<tr><td>Plasticity: which describes materials that permanently deform after a large enough applied stress.</td><td rowspan="2">Rheology: the study of materials with both solid and fluid characteristics</td></tr>
<tr><td rowspan="2">Fluid mechanics: the study of the physics of continuous materials which take the shape of their container.</td><td>Non-Newtonian fluids</td></tr>
<tr><td colspan="2">Newtonian fluids</td></tr>
</table>

Table (1): Relationship between fluid mechanics and continuum mechanics.

In a mechanical view, a fluid is a substance that does not support tangential stress; that is why a fluid at rest has the shape of its containing vessel [51].

(3) Definition of Fluids

A fluid is defined as a substance that continually deforms (flows) under an applied shear stress. All liquids and all gases are fluids. Fluids are a subset of the phases of matter and include liquids, gases, plasmas and, to some extent, plastic solids. The term "fluid" is often used as being synonymous with "liquid". This can be erroneous and sometimes clearly inappropriate—such as when referring to a liquid which does not or should not involve the gaseous state. For example, "brake fluid" is hydraulic oil which will not perform its required function if gas is present. The medical profession relies on the term "fluids" in dietary references ("take plenty of fluids") where the presence of gases is irrelevant or even possibly dangerous. Fluids display such properties as:

- not resisting deformation, or resisting it only lightly (viscosity), and
- the ability to flow (also described as the ability to take on the shape of the container).

These properties are typically a function of their inability to support a shear stress in static equilibrium.

Liquids form a free surface (that is, a surface not created by the container) while gases do not. The distinction between solids and fluid is not entirely obvious. The distinction is made by evaluating the viscosity of the substance. Silly Putty can be considered to behave like a solid or a fluid, depending on the time period over which it is observed. However Silly Putty is correctly termed a viscoelastic fluid.

Solids can be subjected to shear stresses, and to normal stresses - both compressive and tensile. In contrast, ideal fluids can only be subjected to normal, compressive stress which is called pressure. Real fluids display viscosity and so are capable of being subjected to low levels of shear stress.

In a solid, shear stress is a function of strain, but in a fluid, shear stress is a function of rate of strain. A consequence of this behaviour is Pascal's law which describes the role of pressure in characterizing a fluid's state.

(4) Stress and Strain

Stress is a measure of the internal reaction between elementary particles of a material in resisting separation, compaction, or sliding that tend to be induced by external forces. Total internal resisting forces are resultants of continuously distributed normal and parallel forces that are of varying magnitude and direction and are acting on elementary areas throughout the material. These forces may be distributed uniformly or non-uniformly. Stresses are identified as tensile, compressive, or shearing, according to the straining action.

Strain is a measure of deformation such as (1) linear strain, the change of length per unit of linear dimensions; (2) shear strain, the angular rotation in radians of an element undergoing change of shape by shearing forces; or (3) volumetric strain, the change of volume per unit of volume. The strains associated with stress are characteristic of the material. Strains completely recoverable on removal of stress are called elastic strains. Above a critical stress, both elastic and plastic strains exist, and that part remaining after unloading represents plastic deformation called inelastic strain. Inelastic strain reflects internal changes in the crystalline structure of the metal. Increase of resistance to continued plastic deformation due to more favourable rearrangement of the atomic structure is strain hardening.