International Journal of Non-Linear Mechanics 46 (2011) 47–56

Contents lists available at ScienceDirect

International Journal of Non-Linear Mechanics

journal homepage: www.elsevier.com/locate/nlm

Thermal instability in a rotating anisotropic porous layer saturated by a viscoelastic fluid

Anoj Kumar, B.S. Bhadauria *

DST-Centre for Interdisciplinary Mathematical Sciences, Department of Mathematics, Faculty of Science, Banaras Hindu University, Varanasi 221005, India

ARTICLE INFO

Article history:
Received 27 October 2009
Received in revised form
10 May 2010
Accepted 14 July 2010

Keywords:
Viscoelastic fluid
Rayleigh number
Rotation
Porous medium
Anisotropy
Heat transfer
Nusselt number

ABSTRACT

Linear and non-linear thermal instability in a rotating anisotropic porous medium, saturated with viscoelastic fluid, has been investigated for free–free surfaces. The linear theory is being related to the normal mode method and non-linear analysis is based on minimal representation of the truncated Fourier series analysis containing only two terms. The extended Darcy model, which includes the time derivative and Coriolis terms has been employed in the momentum equation. The criteria for both stationary and oscillatory convection is derived analytically. The rotation inhibits the onset of convection in both stationary and oscillatory modes. A weak non-linear theory based on the truncated representation of Fourier series method is used to find the thermal Nusselt number. The transient behaviour of the Nusselt number is also investigated by solving the finite amplitude equations using a numerical method. The results obtained during the analysis have been presented graphically.

1. Introduction

The present paper deals with the study of thermal instability in a rotating anisotropic porous medium saturated with viscoelastic fluid, heated from below and cooled from above. The flow of viscoelastic fluids is of great interest in many areas of modern Sciences, engineering and Technology like material processing, Petroleum, Chemical and nuclear industries, Geophysics, Biorheology and Bio-mechanics engineering. Some oil sands contain waxy crudes at shallow depth of the reservoirs which are considered to be viscoelastic fluid. In these situations, a viscoelastic model of a fluid serves to be more realistic than the Newtonian model.

The onset of thermal instability in a horizontal porous layer saturated with Newtonian fluid was first studied extensively by Horton and Rogers [1] and Lapwood [2]. Katto and Masuoka [3] obtained a criterion for the onset of convective flow in a fluid saturated porous medium, and found experimentally the effect of Darcy number on the onset of convection. Important reviews of most of the findings on convection in porous medium are given by Nield and Bejan [4], Ingham and Pop [5] and Vafai [6]. However, thermal instability in a rotating porous medium saturated with Newtonian fluid was first investigated by Friedrich [7]. Some other investigations on thermal instability in a rotating porous medium are due to Patil and Vaidyanathan [8], Palm and Tyvand [9], Jou and Liaw [10,11], Qin and Kaloni [12], Vadasz [13–15], Vadasz and Govender [16], Straughan [17], Desaive et al. [18], Govender [19].

The problem of thermal instability in a porous medium saturated with Newtonian fluid has been studied extensively, while little attention has been given to the convective flow through a porous medium saturated with non-Newtonian fluid. Rudraiah et al. [20,21] studied the onset of oscillatory convection in a viscoelastic fluid of porous medium using different models. Kim et al. [22] studied the thermal instability of viscoelastic fluids in porous media, conducted linear and non-linear stability analyses; and obtained the stability criteria for convective flow. Later on Young-Yoon et al. [23] have studied the onset of oscillatory convection in a horizontal porous layer saturated with viscoelastic fluid by using linear theory. Tan and Masuoka [24] studied the stability of a Maxwell fluid in a porous medium using modified-Darcy–Brinkman–Maxwell model, and found the criterion for onset of oscillatory convection. Malashetty and Mahantesh Swamy [25] investigated the onset of convection in a viscoelastic liquid saturated anisotropic porous layer, using a generalized Darcy model and studied the effect of the mechanical and thermal anisotropy parameters. Sheu et al. [26] investigated the chaotic convection of viscoelastic fluids in porous media and deduced that the flow behaviour may be stationary, periodic, or chaotic. Stability analysis of double diffusive convection of Maxwell fluid in a porous medium heated from below has been investigated by Wang et al. [27].

* Corresponding author.
E-mail addresses: anojbhu@gmail.com (A. Kumar), drbsbhadauria@yahoo.com (B.S. Bhadauria).

0020-7462/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijnonlinmec.2010.07.002