Three component Ferroconvection in a couple stress fluid with cross diffusion

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1. INTRODUCTION & OBJECTIVE

Three Component Convection (Triple Diffusive Convection) is gaining more importance because of its physical and engineering applications in astrophysics, oceanography, chemical engineering, food processing, solidification of molten alloys and crystal growth. The study of triple diffusive convection has been reported by many authors Griffiths [1], Pearlstein et al. [2], Zhao et al. [3] , Rudziva et al. [4], Pranesh et al. [5].

The cross-diffusion effect refers to the coupled molecular- diffusion between heat and mass caused by mixtures of solute concentrations with each other and temperature. This scenario occurs due to differences in temperature and concentration- gradients, which generate energy-fluxes in the fluid, contributing to convective motion around the fluid interface even in the absence of chemical processes. It also causes electrostatic contacts, chemotaxis, and weakly non-bonding solute-solute interactions, among other things. The study on cross-diffusion under various situations is carried out by Srivastava et al. [6], Ragunatha et al. [7], Saha and Pranesh [8] and Sangamesh et al. [9].

The literature on ferroconvection in the absence of couple stress is extensive where as the literature pertaining to the ferroconvection in the presence of couple stress is very few. The study on single component convection in a ferro-couple stress fluid in the absence of cross-difuusion effects is carried out by Nadian et al. [10], Meghana and Pranesh [11] . To the best of our knowledge the literature pertaining to cross-diffusion effects on three-component ferroconvection in couple stress fluid is missing.

Thus, the objective of this paper is to investigate the influence of cross-diffusion on the onset of three-component ferroconvection in a couple stress fluid.

2. PROBLEM FORMULATION AND METHODOLOGY

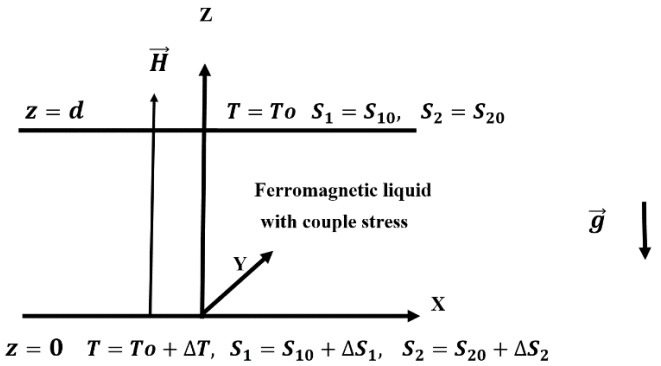

Figure 1 Physical Configuration of the problem.

We consider three component ferroconvection in a couple stress fluid with cross diffusion confined between the two parallel plates situated at $z = 0$ and $z = d$. The liquid layer is heated and solutes are added from below. The temperature and concentrations difference between lower and upper plates are respectively $\Delta T$and ΔS_i (where $i = 1,2$). A uniform gravity acts vertically downwards. Further the boundaries are assumed to be stress-free, isothermal and isoconcentration. The set-up of the problem is as shown in Figure 1. The normal mode analysis is employed to obtain the expression of critical Rayleigh number. The study of non-linear analysis is important to extract the information on rate of heat transfer, as linear analysis is inadequate to explain this concept as it is sufficient for obtaining the stability condition for the onset of convection. The non-linear analysis is performed by deriving Lorenz model. An expression for Nusselt number is obtained by solving the Lorenz model.

3. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

Stability analysis of triple diffusive ferroconvection in a couple stress liquid with cross-diffusion is carried out in this paper using linear analysis. The non-dimensional parameters arising in the problem are $R, R_{s1}, R_{s2}, \tau_1, \tau_2,\ M_1, M_3, C, Du_1, Du_2, Sr_{11}, Sr_{12}, Sr_{21}$ and Sr_{22}. The first five parameters are related fluid parameters. The parameter M_1 and M_3 arises due to the presence of ferromagnetic fluid. The parameter C arises due to the presence of couple stress where as the parameter $Du_1, Du_2, Sr_{11}, Sr_{12}, Sr_{21}$ and Sr_{22} arises due to the presence of cross-diffusion. The impact of these non-dimensional parameters on the onset of convection and heat transport is studied in this paper.

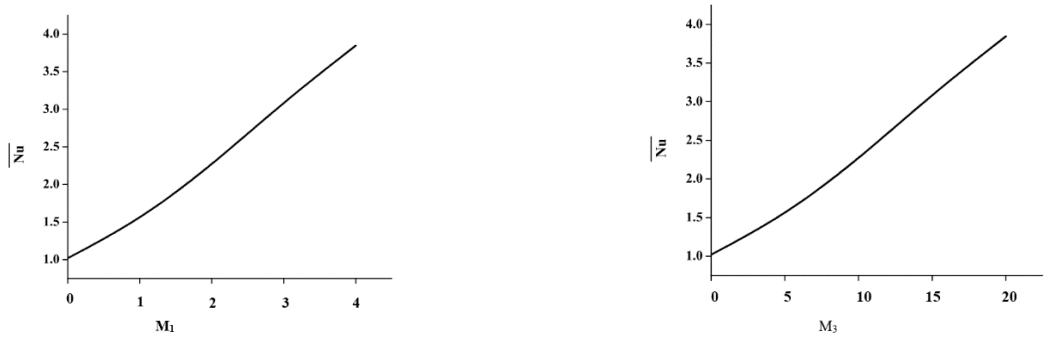

Figure 2 Variation of M_1 and M_3 with $\overline{Nu}$

Figure 2 shows the plot of average Nusselt number $\overline{Nu}$ versus the ferromagnetic parameters M_1 and M_3. It is clear from these figures that the ferromagnetic parameters enhances the heat transfer in presence of cross difussion.

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