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EFFECT OF MAGNETIC FIELD DEPENDENT VISCOSITY ON DARCY-BRINKMAN FERROCONVECTION WITH SECOND SOUND[†]

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The problem of buoyancy-driven convection in a ferromagnetic fluid saturated porous medium with the Maxwell-Cattaneo law and MFD viscosity is investigated by the method of small perturbation. The fluid motion is described using the Brinkman model. It is assumed that the fluid and solid matrices are in local thermal equilibrium. For simplified boundary conditions, the eigenvalue problem is solved exactly and closed form solutions for stationary instability are obtained. Magnetic forces and second sound were found to enhance the beginning of Brinkman ferroconvection. However, ferroconvection is hampered when the porous parameters are increased. The results show that MFD viscosity inhibits the beginning of Darcy-Brinkman ferroconvection and that MFD viscosity stabilizing effect is decreased when the magnetic Rayleigh number is significant. Furthermore, it is demonstrated that oscillatory instability arises before stationary instability, assuming that the Prandtl and Cattaneo numbers are sufficiently large.
Keywords: Ferrofluid, MFD viscosity, Porous Media, Magnetic Field, Second Sound
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1. INTRODUCTION

The term "ferromagnetism" refers to materials that have a significant magnetic attraction to other materials that have permanent magnetic characteristics. The presence of spontaneous magnetization caused by the parallel spin alignment of molecular magnetization causes significant magnetism in ferromagnetic materials. In 1907, Weiss suggested an instrument for the appearance of spontaneous magnetic induction. He believed that ferromagnetic materials have an effective field called the molecular field. As a result of their extraordinary physical features, the thermoconvective instability of magnetic fluids is becoming more important. The viscosity of ferrofluid appears to be a well-defined concept. Magnetic liquids are used in a variety of fields, including variable-speed machine tools, pharmaceuticals, high-speed noiseless printers and other equipment. Convective phenomena are studied in high-capacity capacitor devices because ferrofluid is used as both a core material and a transformer coolant.

When an external magnetic field is imposed on a horizontal layer of ferromagnetic fluid having a changing attractive susceptibility, Finlayson [1] described how a temperature gradient generates an unequal attractive body force, which leads to thermomagnetic convection. Gotoh and Yamada [2] looked into the fluctuation of a uniform magnetic fluid layer that was confined between strong magnets and heated from below. In the presence of a uniform vertical magnetic field and a strong vertically attractive field, Stiles and Kagan [3] studied the heat conductivity instability of flat film ferrofluids. Venkatasubramanian and Kaloni [4] explored how rotation affects the initiation of convection in a horizontal layer of ferrofluids revolving about their vertical axis and heated from below. Sekar et al. [5] analyzes the linear theory, which has been applied to how rotation affects ferrothermohaline convection. When comparing the stationary and oscillatory modes for heat transfer, it was discovered that the stationary mode is favored.

Porous media is a substance composed of a solid matrix with a network of voids. The firm structure would either be stiff or slightly deformable. In a natural porous medium, the arrangement of pores is unusual in terms of shape and size. Natural porous media include beach stone, mudstone, granite, rye bread, wood and the human lung.

Lapwood [6] investigated the distribution firmness of a fluid layer in a permeable material exposed to a vertical temperature gradient as well as the prospect of convective movement. Wooding [7] explores the circumstances that lead to instability. Kordylewski and Karjewski [8] studied the relationship between synthetic reactions and free advection in permeable media scientifically. Using the Brinkman model, Vaidyanathan et al. [9] analyzed the performance of MFD viscosity on ferroconvection. Ramanathan and Suresh [10] studied the impact of MFD viscosity on the initiation of ferroconvection in an anisotropic, closely packed porous material. Nisha Mary Thomas and Maruthamanikandan [11] studied the effect of a time-periodically varying gravity field on the initiation of convective flow in a magnetic fluid-saturated porous surface. The value of the Darcy-Rayleigh number and the resultant wavenumber are estimated using the regular perturbation method based on the tiny amplitude of modulation. Sekhar et al. [12] investigates the effect of throughflow on the beginning of thermal convection in ferromagnetic liquids with temperature and magnetic field

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dependent viscosity for all feasible barrier configurations. Soya Mathew and Maruthamanikandan [13] discuss the subject of ferroconvective porous medium uncertainty using an inverse linear viscosity-temperature relationship. The Galerkin procedure is utilized to govern the critical values of porous media magnetic volatility under more accurate boundary circumstances. Vidya Shree et.al [14] study the effect of variable viscosity on the convective instability of a fluid saturated a porous medium subject to gravitational filed.

Thermal wave propagation is also known as the second sound effect. The non-classical Maxwell-Cattaneo heat flux law employs wave-type heat transport to avoid the physically unacceptable problem of infinite heat propagation speed. The energy equation in this study is essentially a damped wave equation, making it hyperbolic rather than parabola. Knowledge of second sounds has provided a rich source of information through the study and understanding of the superfluid state. Sound is not a sound wave in any sense, but rather a temperature or entropy wave. It was recently discovered that this is more than just a low temperature, but that it has important applications in fields such as skin burns, phase changes, biological materials, and nanofluids.

Gurtin and Pipkin [15] investigated a general principle of thermal conduction in nonlinear analysis, including memories, a concept having a finite propagation speed. Straughan and Franchi [16] address Benard advection when the Maxwell-Cattaneo heat flow law is utilized in place of the ordinary Fourier theory of thermal conductivity. Dauby et al. [17] studied the impact of applying general Fourier equalities instead of Fourier's regulation. The problem of thermal convection is investigated for a layer of fluid when the heat flux law of Cattaneo is adopted by Straughan [18]. Soya Mathew [19] studied free convection in a ferrous liquid-filled porous material subjected to the non-classical Maxwell Cattaneo law, focusing on how the presence of both pore spaces and second sound affected the stability threshold for the onset of ferroconvection. Mahanthesh [20] examines the instability caused by the Maxwell–Cattaneo heat flux, along with internal heat generation and absorption, in non-Newtonian Casson dielectric fluid. Soya Mathew and Maruthamanikandan [21] are exploring the problem of porous medium convectional fluctuation in a second sound ferromagnetic fluid in order to investigate the possible range of variables that might result in oscillatory porous medium ferroconvection.

Under these conditions, the current paper is devoted to investigating qualitatively the effect of thermal wave propagation on the onset of ferroconvection in a horizontal porous layer. The normal mode technique is used in the linear stability analysis. The Galerkin technique is used to determine the critical values of porous media thermomagnetic instability while taking into account more realistic boundary conditions. The modified Darcy-Brinkman law is used to model the momentum equation, and the heat flux model of Cattaneo is used to account for a thermal wave of finite speed.

2. MATHEMATICAL FORMULATION

A Cattaneo magnetic fluid saturated permeable film is considered, which is surrounded by two infinitely long horizontal surfaces of finite thickness. From Fig.1, the liquid film is cool at a temperature of T_0 from above and hot at a temperature of T_1 from below. A magnetic field behaves as though it is equal to the vertical z-axis and gravity is a vertically behaving downward force.

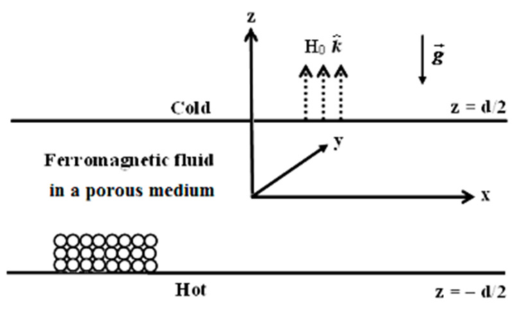

Figure 1. Schematic of the Problem

The problem of governing equations is as follows:

$$\nabla\cdot\ \vec{q}=0 \tag{1}$$

$$\rho_0\left[\frac{1}{\varepsilon}\frac{\partial\vec{q}}{\partial t}+\frac{1}{\varepsilon^2}\left(\vec{q}\cdot\ \nabla\right)\vec{q}\right]=-\nabla p+\rho\vec{g}-\frac{\mu_f}{k}\vec{q}+\nabla\cdot\ \left(\vec{H}\vec{B}\right)+\nabla\cdot\ \left[\ \bar{\mu}_f\left(\nabla\vec{q}+\nabla\vec{q}^{Tr}\right)\right] \tag{2}$$

$$\varepsilon\left[\rho_0 C_{V,H}-\mu_0\vec{H}\cdot\left(\frac{\partial\vec{M}}{\partial T}\right)_{V,H}\right]\left[\frac{\partial T}{\partial t}+\left(\vec{q}\cdot\ \nabla\right)T\right]+\left(1-\varepsilon\right)\left(\rho_0 C\right)_S\frac{\partial T}{\partial t}+\mu_0 T\left(\frac{\partial\vec{M}}{\partial T}\right)_{V,H}\cdot\left[\frac{\partial\vec{H}}{\partial t}+\left(\vec{q}\cdot\ \nabla\right)\vec{H}\right]=-\nabla\cdot\ \vec{Q} \tag{3}$$

$$\tau\left[\frac{\partial \vec{Q}}{\partial t}+\left(\vec{q}\cdot\nabla\right)\vec{Q}+\vec{\omega}\times\vec{Q}\right]=-\vec{Q}-k_1\nabla T \tag{4}$$

$$\rho=\rho_0\left[1-\alpha\left(T-T_a\right)\right] \tag{5}$$

$$M=M_0+\chi\left(H-H_0\right)-K\left(T-T_a\right) \tag{6}$$

In equations 1–6, numerous physical quantities appear and the fundamental assumptions have their usual meaning. Finlayson [1], Soya Mathew and Maruthamanikandan [11]. Following examination, Maxwell's approximations suitable for the problem exist.

$$\nabla\cdot\vec{B}=0,\quad \nabla\times\vec{H}=0,\quad \vec{B}=\mu_0\left(\vec{H}+\vec{M}\right) \tag{7}$$

3. Stability analysis

The following dimensionless equations can be obtained by applying the stability analysis of small perturbations encompassing normal modes (Finlayson [1], Soya Mathew and Maruthamanikandan [13]).

$$\begin{aligned}&\frac{\sigma}{\Pr}\left(D^2-a^2\right)W=-\left(R+N\right)a^2\theta-Da^{-1}g\left(z\right)\left(D^2-a^2\right)W+Na^2D\phi\\&+2\Lambda V^2g^3\left(z\right)\left(D^2+a^2\right)W-2\Lambda Vg^2\left(z\right)\left(D^2-a^2\right)DW\\&+\Lambda g\left(z\right)\left(D^2-a^2\right)W\end{aligned} \tag{8}$$

$$\left(1+2C\sigma\right)\left(\lambda\sigma\theta-W\right)+C\left(D^2-a^2\right)-\left(D^2-a^2\right)\theta=0 \tag{9}$$

$$\left(D^2-M_3a^2\right)\phi-D\theta=0 \tag{10}$$

where N is the magnetic Rayleigh number, R is the thermal Rayleigh number, Da^{-1} is the inverse Darcy number, Λ is the Brinkman number, C is the Cattaneo number, Pr is the Prandtl number, M_3 is the magnetization parameter.

The boundary conditions encompassing Rigid-Rigid and isothermal surfaces are

$$\begin{aligned}&W=DW=\theta=0\ \ at\ \ z=\pm\frac{1}{2}\\&D\phi+\frac{a\phi}{1+\chi}=0\ \ at\ \ z=\frac{1}{2}\\&D\phi-\frac{a\phi}{1+\chi}=0\ \ at\ \ z=-\frac{1}{2}\end{aligned} \tag{11}$$

4. Stationary instability

It can be shown that the principle of exchange of stabilities is valid. Hence the onset of the stationary mode of convection ($\sigma=0$), has been analyzed.

$$\begin{aligned}&\Lambda g\left(z\right)\left(D^2-a^2\right)W-2\Lambda Vg^2\left(z\right)\left(D^2-a^2\right)DW+2\Lambda V^2g^3\left(z\right)\left(D^2+a^2\right)W\\&-Da^{-1}g\left(z\right)\left(D^2-a^2\right)W-\left(R+N\right)a^2\theta+Na^2D\phi=0\end{aligned} \tag{12}$$

$$W-C\left(D^2-a^2\right)W+\left(D^2-a^2\right)\theta=0 \tag{13}$$

$$\left(D^2-M_3a^2\right)\phi-D\theta=0 \tag{14}$$

5. Method of Solution

The governing equations (12) – (14) together with the boundary condition (11) constitute an eigenvalue problem with R and N as an eigenvalue. To solve the resulting eigenvalue problem, Galerkin method is used. According, the variables are written in a series of trial functions as

$$W_i=\left(z^2-\frac{1}{4}\right)^{i+1},\ \ \theta_i=\left(z^2-\frac{1}{4}\right)^{i},\ \ \phi_i=z^{2i-1} \tag{15}$$

W_i, θ_i and ϕ_i will be represented by the power series satisfying the respective boundary conditions.

RESULTS AND DISCUSSION

The research concerns the effects of MFD viscosity on Darcy-Brinkman ferromagnetic instability with the Maxwell-Cattaneo heat conduction law. The non-classical Maxwell-Cattaneo heat flux law includes a wave type heat transfer and does not suffer from the physically unacceptable drawback of infinite heat propagation speed. The eigenvalues are obtained for rigid-rigid, isothermal boundary conditions. The thermal Rayleigh number R, describing the stability of the system, is taken as a function of the different parameters of the study. The fixed values of C, M_3, Da^{-1}, V, χ, Λ are taken to be 0.001, 5, 5, 0.5, 3 and 3 respectively. The numerical implementation package MATHEMATICA is used to define the eigenvalue expressions and the associated critical numbers. The numerical values are given in tables 1 and 2 respectively.

Fig. 2 depicts the dependency of the critical thermal Rayleigh number R_c on the magnetic Rayleigh number N for varying values of C and fixed values of M_3, Da^{-1}, V, χ and Λ respectively. The ratio of the magnetic and dissipative forces is known as the magnetic Rayleigh number. It is shown that R_c reduces monotonically as N and C levels rise, illustrating that N and C both enhance ferroconvection at lower values of R_c. As a result, the two physical mechanisms, second sound and magnetic mechanism destabilize the system. In other words, the existence of a magnetic field and second sound improves heat transport and hence speeds up the commencement of Darcy-Brinkman ferroconvection. It is important to note that the effect of C enhances the destabilizing effect of N simultaneously. The destabilizing effect of C is due to the fact that the energy equation under consideration is functionally a damped wave equation and so hyperbolic rather than parabolic.

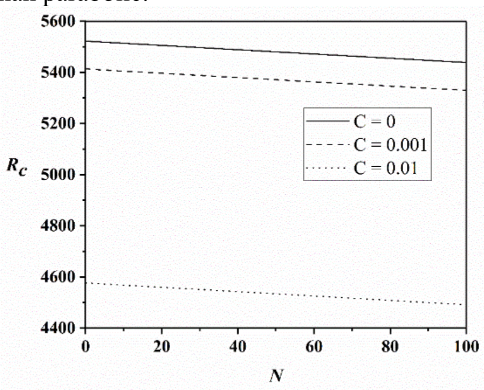

Figure 2. Variation of R_c with N for different values of the Cattaneo number C

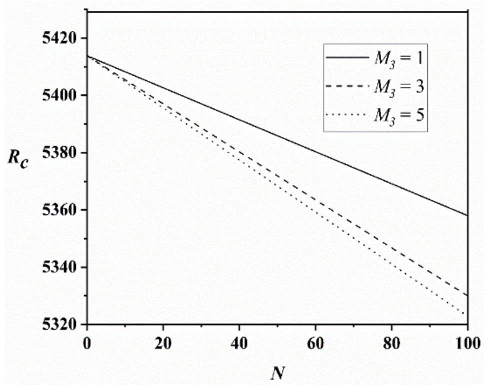

Figure 3. Variation of R_c with N for different values of the magnetization parameter M_3

The magnetic equation of state's departure from linearity is represented by the parameter M_3 (See Fig. 3). We observe that when M_3 increases, R_c monotonically decreases. As the magnetic equation of state gets more nonlinear, the threshold of ferroconvection in a porous layer with second sound advances. Furthermore, when N is small, the destabilizing effect of M_3 is almost minor.

Figs. 4 and 5 show how porosity factors Da^{-1} and Λ affect the start of ferroconvection. When both Da^{-1} and Λ are raised, the onset of ferroconvection is significantly inhibited. It could be attributable to the fact that increasing Da^{-1} reduces the permeability of the porous material, which slows fluid movement. However, it is important to emphasize that the Brinkman model is based on an effective viscosity $\bar{\mu}_f$ that differs from the fluid viscosity μ_f denoted by the Brinkman number. As a result, increasing Λ increases the viscous effect, which slows fluid movement. Therefore, in the presence of a Darcy-Brinkman porous medium, greater heating is necessary to initiate ferroconvection. It is worth noting that when both Da^{-1} and Λ are large, the ferrofluid layer is slightly destabilized by the magnetic process.

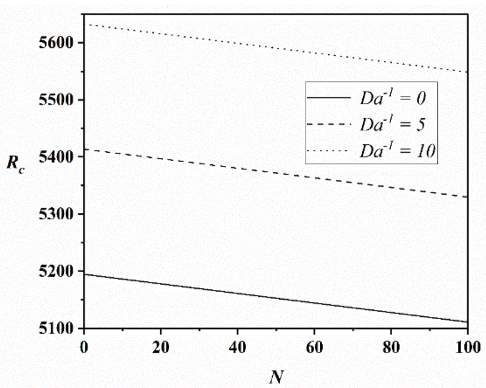

Figure 4. Variation of R_c with N for different values of inverse Darcy number Da^{-1}.

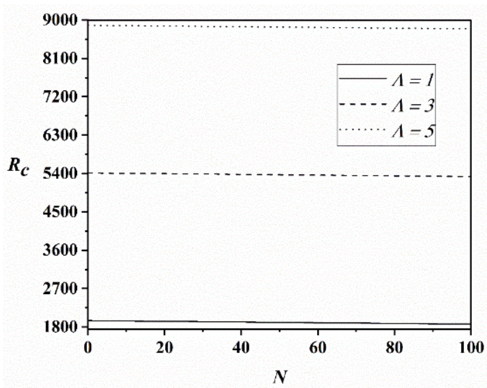

Figure 5. Variation of R_c with N for different values of Brinkman Number Λ.

Fig. 6 demonstrates that an increase in the magnetic susceptibility χ results in the same trend for R_c, indicating that the stabilizing effects confining nature is minimal. Computations also show that the convection cell size is more sensitive to the porous parameters Λ and Da^{-1}, while the magnetic parameters M_3 and χ are the inverse.

In Fig. 7, the magnetic field dependent variable viscosity parameter increases from 0 to 1, it stabilizes the system. If we increase the variable viscosity, the critical thermal Rayleigh number also increases. This is because the magnetization of the magnetic fluid increases as the strength of the magnetic field increases.

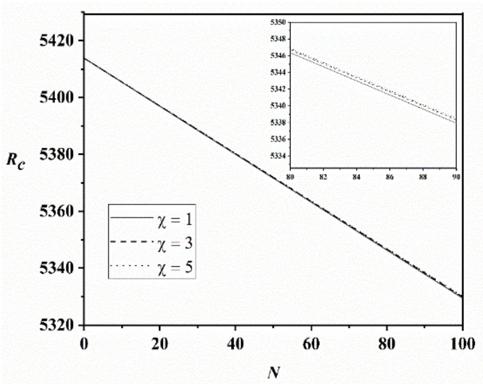

Figure 6. Variation of R_c with N for different values of magnetic susceptibility χ.

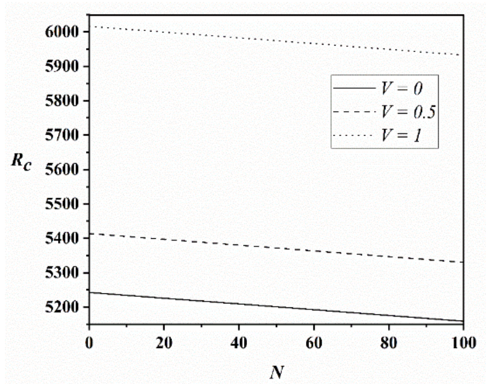

Figure 7. Variation of R_c with N for different values of variable viscosity V.

Table 1. Dependence of a_c with N and C

N	a_c		
	$C = 0$	$C = 0.001$	$C = 0.01$
0	3.1267	3.1485	3.3324
20	3.1278	3.1496	3.3337
40	3.1288	3.1507	3.3349
60	3.1299	3.1517	3.3363
80	3.1309	3.1528	3.3377
100	3.132	3.1539	3.3389

Table 2. Dependence of a_c with N and V

N	a_c		
	$V = 0$	$V = 0.5$	$V = 1$
0	3.1443	3.1485	3.1653
20	3.1454	3.1496	3.1663
40	3.1466	3.1506	3.1673
60	3.1477	3.1517	3.1683
80	3.1488	3.1528	3.1693
100	3.1499	3.1539	3.1703

CONCLUSIONS

The effect of variable viscosity in non-classical heat conduction on the onset of Rayleigh-Bénard instability in a horizontal layer of Darcy-Brinkman porous medium saturated with a Boussinesq-Cattaneo-ferromagnetic liquid and subjected to the simultaneous action of a vertical magnetic field and a vertical temperature gradient is studied analytically using the small perturbation method. A linearized convective instability analysis is performed since both the magnetic and buoyancy mechanisms are operative. Because the principle of exchange of stabilities applies to the current investigation, instability criteria are derived in terms of the stationary Rayleigh number R, wavenumber a, Cattaneo number C and magnetic and porous properties. The following conclusions have been reached:

- In a sparsely dispersed porous layer, the Cattaneo heat flow equation has a significant effect on ferroconvection. For a Maxwell-Cattaneo ferromagnetic fluid, the Rayleigh-Bénard problem is always less stable than for a Fourier magnetic fluid.
- The flow is significantly influenced by magnetic and porous effects in the presence of a second sound.
- As the magnetic field strength and Cattaneo number increase, the threshold of the stationary instability drops. Thus, magnetic forces and second sound destabilize the system, causing convective motion to occur at shorter wavelengths.
- The inverse Darcy number and the Brinkman number are increased, which strengthens the ferromagnetic fluid's stability.
- The aspect ratio of the convection cell is particularly sensitive to the porous medium influence.
- The onset of convection is always advanced due to the presence of variable viscosity.

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REFERENCES

[1] B.A. Finlayson, "Convective instability of ferromagnetic fluids", J. Fluid Mech. **40**(4), 753 (1970). https://doi.org/10.1017/S0022112070000423
[2] K. Gotoh, and M. Yamada, "Thermal Convection in a Horizontal Layer of Magnetic Fluids", Journal of the Physical Society of Japan, **51**(9), 3042 (1982). https://doi.org/10.1143/JPSJ.51.3042
[3] P.J. Stiles, and M. Kagan, "Thermoconvective instability of a horizontal layer of ferrofluid in a strong vertical magnetic field", Journal of Magnetism and Magnetic Materials, **85**, 196 (1990). https://doi.org/10.1016/0304-8853(90)90050-Z
[4] S. Venkatasubramanian, and P.N. Kaloni, "Effects of rotation on the thermoconvective instability of a horizontal layer of ferrofluids", Int. J. Eng. Sci. **32**(2), 237 (1994). https://doi.org/10.1016/0020-7225(94)90004-3
[5] R. Sekar, G. Vaidyanathan, and A. Ramanathan, "Effect of rotation on ferro thermohaline convection", Journal of Magnetism and Magnetic Materials, **218**(2), 266 (2000). https://doi.org/10.1016/S0304-8853(00)00358-9
[6] E.R. Lapwood, "Convection of a fluid in a porous medium", Math. Proc. Cambridge Philos. Soc. **44**(4), 508 (1948). https://doi.org/10.1017/S030500410002452X
[7] R.A. Wooding, "Rayleigh instability of a thermal boundary layer in flow through a porous medium", J. Fluid Mech. **9**(2), 183 (1960). https://doi.org/10.1017/S0022112060001031
[8] K. Kordylewski, "Convection effect on thermal ignition in porous medium", Chem. Eng. Sci. **39**(3), 610 (1983).
[9] G. Vaidyanathan, A. Ramanathan, and S. Maruthamanikandan, "Effect of magnetic field dependent viscosity on ferroconvection in sparsely distributed porous medium", Indian Journal of Pure and Applied Physics, **40**, 166 (2001).
[10] A. Ramanathan, and G. Suresh, "Effect of magnetic field dependent viscosity and anisotropy of porous medium on ferroconvection", Int. J. Eng. Sci. **42**(1-3), 411 (2004). https://doi.org/10.1016/S0020-7225(02)00273-2
[11] N.M. Thomas, and S. Maruthamanikandan, "Effect of Gravity Modulation on the Onset of Ferroconvection in a Densely Packed Porous Layer", IOSR Journal of Applied Physics (IOSR-JAP), **3**(2278-4861), 30 (2013). https://doi.org/10.1016/s0020-7225(97)80002-x
[12] G.N. Sekhar, P.G. Siddheshwar, G. Jayalatha, and R. Prakash, "Throughflow Effects on Thermal Convection in Variable Viscosity Ferromagnetic Liquids", International Journal of Mechanical and Mechatronics Engineering, **11**(6), (2017). https://doi.org/10.5281/zenodo.1131971
[13] S. Mathew, and S. Maruthamanikandan, "Darcy-Brinkman Ferro convection with temperature dependent viscosity", J. Phys. Conf. Ser. **1139**(1), (2018). https://doi.org/10.1088/1742-6596/1139/1/012023.
[14] V. Vidya Shree, C. Rudresha, C. Balaji, and S. Maruthamanikandan, "Effect of MFD viscosity on ferroconvection in a fluid saturated porous medium with variable gravity", Journal of Mines, Metals and Fuels (JMMF), **70**(3A), 98 (2022). https://doi.org/10.18311/jmmf/2022/30675
[15] M.E. Gurtin, and A.C. Pipkin, "A general theory of heat conduction with finite wave speeds", Arch. Ration. Mech. Anal., **31**(2), 113 (1968). https://doi.org/10.1007/BF00281373
[16] B. Straughan and F. Franchi, "Benard convection and the cattaneo law of heat conduction", Proc. R. Soc. Edinburgh Sect. A Math. **96**(1–2), 175 (1984). https://doi.org/10.1017/S0308210500020564
[17] P. C. Dauby, M. Nélis, and G. Lebon, "Generalized Fourier equations and thermoconvective instabilities", Revista Mexicana de Fisica, **48**(1), 57 (2002).
[18] B. Straughan, "Oscillatory convection and the Cattaneo law of heat conduction", Ricerche Mat. **58,** 157 (2008). https://doi.org/10.1007/s11587-009-0055-z.
[19] S. Mathew, S. Maruthamanikandan, S.S. Nagouda, "Gravitational Instability in a Ferromagnetic Fluid Saturated Porous Medium with Non-Classical Heat Conduction", IOSR J. Math. **6**(1), 7 (2013). https://doi.org/10.9790/5728-0610718
[20] R. Keerthi, B. Mahanthesh, and S.S. Nagouda, "Rayleigh–Bénard convection in a non-Newtonian dielectric fluid with Maxwell–Cattaneo law under the effect of internal heat generation/consumption", Multidiscip. Model. Mater. Struct. **16**(5), 1175 (2020). https://doi.org/10.1108/MMMS-09-2019-0174
[21] S. Mathew, and S. Maruthamanikandan, "Oscillatory porous medium ferroconvection with Maxwell-Cattaneo law of heat conduction", J. Phys. Conf. Ser. **1850**(1), 2021. https://doi.org/10.1088/1742-6596/1850/1/012024

ВПЛИВ ЗАЛЕЖНОЇ ВІД МАГНІТНОГО ПОЛЯ В'ЯЗКОСТІ НА ФЕРОКОНВЕКЦІЮ ДАРСІ-БРІНКМАНА З ДРУГИМ ЗВУКОМ

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Методом малого збурення досліджено задачу про конвекцію під дією плавучості в насиченому феромагнітною рідиною пористому середовищі з законом Максвелла-Каттанео та МФД в'язкістю. Рух рідини описується за допомогою моделі Брінкмана. Передбачається, що рідка і тверда матриці знаходяться в локальній тепловій рівновазі. Для спрощених граничних умов проблема власних значень розв'язується точно й отримані розв'язки замкнутої форми для стаціонарної нестійкості. Було виявлено, що магнітні сили та другий звук підсилюють початок фероконвекції Брінкмана. Однак фероконвекція ускладнюється при збільшенні параметрів пористості. Результати показують, що в'язкість MFD гальмує початок фероконвекції Дарсі-Брінкмана і що ефект стабілізації в'язкості MFD зменшується, коли магнітне число Релея є значним. Крім того, показано, що коливальна нестійкість виникає перед стаціонарною нестійкістю, за припущення, що числа Прандтля і Каттанео є достатньо великими.

Ключові слова: феррорідина, в'язкість МФД, пористе середовище, магнітне поле, другий звук