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UNDERTAKING

This is to certify that the following documents and information given in respect of the Metrix 3.3.1 **(3.3.1.1: Number of research papers in the Journals notified on UGC CARE list year wise during the last five years)** is true to the best of my knowledge and belief.

1. Number of research papers published per teacher in the Journals notified on UGC website during the last five years

2. Documents related to activities

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3.3.1 Number of research papers published per teacher in the Journals notified on UGC website during the last five years

Title of paper	Name of the author/s	Department of the teacher	Name of journal	Year of publication	ISSN number	Link to the recognition in UGC enlistment of the Journal /Digital Object Identifier (doi) number		
						Link to website of the Journal	Link to article / paper / abstract of the article	Is it listed in UGC Care list/Scopus/Web of Science/other, mention
A CRITIQUE ON THE HISTORY OF CREATION OF TRIBAL BELTS AND BLOCKS IN ASSAM	DR. KUMUD RANJAN BASUMATARY	HISTORY	Kala: The Journal of Indian Art History Congress	2020	0975-7945	-		UGC Care list
মামণি ৰয়ছম গোস্বামীৰ 'মামৰে ধৰা তৰোৱাল'ত বৰ্ণনাধৰ্মী বাগধাৰাৰ শৈলীগত বৈশিষ্ট্য	DR. POLY BORA	ASSAMESE	AJANTA	2019	2277-5730	-		UGC Care list
Cropping Patter and crop-Concentration of Kokrajhar District (B.T.A.D), Assam"	Anamika Das	Geography	Th International Journal of Analytical and Experimental Modal Analysis	2022	0886-9367			UGC Care list
Role of Selp Help Groups in Economic Empowerment of Rural Women of Kokrajhar District in Assam	Anamika Das		Journal of Interdisciplinary Cycle Research	2022	022-1945			UGC Care list
Sustainable Development, Environmental Degradation and Poverty: Exploring the Linkages	Anamika Das		Wutan Huatan Jisuan Jishu	2022	1001-1749			UGC Care List & SCOPUS

Trend of Agricultural Growth in B.T.A.D.	Anamika Das		Wutan Huatan Jisuan Jishu	2022	1001-1749			UGC Care List & SCOPUS
Growth of Fisheries and Its Significance, in BTAD Area	Anamika Das		Wutan Huatan Jisuan Jishu	2022	1001-1749			UGC Care List & SCOPUS
অসমীয়া সাহিত্যৰ বুৰঞ্জী লিখন পৰম্পৰা আৰু বুৰঞ্জীকাৰ দেবেন্দ্ৰনাথ বেজবৰুৱা	Dr. Kaneswar Baruah		Assam College Teachers' Association Journal Vol. XL	2022	229-693X			No
Hem Baruar Brahman Hahittat Kabitar Anusangha: Ati Alosona	Dr. Kaneswar Baruah		DOGO RANGSANG RESEARCH JOURNAL	2022	2347-7180			UGC Care List
Fixed Point Results on Partical Modular Metric Space	Santanu Narzary		Axioms	2022	2075-1680			SCOPUS
Some Fixed Point Results in Modular-Like Metric Spaces and Partical Modular-Like Metric Space with Its Non-Archimedean Version	Santanu Narzary		Advances and Applications in Mathematical Science	2022	0974-6803			SCOPUS
A New Characterization of Thermal Stability of Couple-Stress Fluids	Satya Ranjan Pradjani		International Journal of Recent Development in Engineering and Technology	2022	2347-6435			UGC Care List

A New Characterization of Hall Effects on Flow Through Porous Medium in a Rotating Parallel Plate Channel	Satya Ranjan Pradjani		Journal of Mathematics and Statistical Science Vol.8 Issue 12 Dec.2022	2022	2411-2518			UGC Care List

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Certificate of Publication

This is to certify that **Satya Ranjan Pradhani** had published a paper titled **"A New Characterization of Thermal Stability of Couple – Stress Fluids"** in International Journal of Recent Development in Engineering and Technology (**ISSN 2347-6435 (Online)),** Volume 11, Issue 6, June 2022.

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IJRDET Team wishes all the best for his/her bright future.

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"A New Characterization of Thermal Stability of Couple – Stress Fluids"

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Abstract-- **This paper presents the study of Thermal stability on Couple – stress Fluids. Here, we consider, the stability analysis of couple – stress fluid heated from below with magnetic field and rotation is considered. By the Linear stability theory and normal mode technique, the dispersion relation is obtained. In the case of stationary convection, dust particles are found to have a destabilizing effect on the system, where as Couple – stress and Magnetic field have dual character to its stabilizing effect in the absence of Magnetic field and rotation. The Oscillatory modes are introduced due to the presence of Magnetic field and rotation in the system. The results are presented through graphs in each case. Graphs have been plotted by giving Numerical values to the parameters to depict the stability characteristics.**

Keywords--**Magnetic field, Rotation, Couple – stress and Dust Particles.**

I. INTRODUCTION

Stability of a dynamical system is closest to real life, in the sense that realization of a dynamical system depends upon its stability. Right from the conceptualizations of turbulence, instability of fluid flows is being regarded at its root. A detailed account of the theoretical and experimental study of the onset of thermal instability (B'enard convection) in a fluid layer under varying assumption of hydrodynamics, has been discussed in detail by Chandrasekhar (1981).

As growing importance of non-Newtonian fluids in modern technology, the investigation of such fluids are desirable. The theory of couple – stress fluids is proposed by Stokes(1966). Couple –stress appear in noticeable magnitude in fluids with very large molecules.

Applications of couple- stress fluid occur in the attention of the study of the mechanism of lubrication of synovial joints, at which currently attract the attention of researchers.

A human joint is a dynamically loaded bearing that has an articular cartilage as the bearing and synovial fluid as the lubricant. Normal synovial fluid is clear or yellowish and is a non- Newtonian, viscous fluid. Walicki and Walicka (1999) Modeled synovial fluid as couple-stress fluid in human joints because of the long chain of lauronic acid molecules found as additives in synovial fluid. The problem of a couple-stress fluid heated from below in a porous medium is considered by Sharma and Sharma (2001) and Sharma and Thankur(2000).

Stokes (1987) has formulated the theory of a Couple - stress fluid. The presence of small amounts of additives in a lubricant can improve the bearing performance by increasing the lubricant viscosity and thus producing an increase in the load capacity. Joseph (1976) has given the formation and derivation of the basic equations of a layer of fluid, heated from below in porous medium, using Boussinesq approximation. The study of a layer of fluid, heated from below in porous media, is motivated both theoretically as also by its practical applications in engineering.

By spacecraft observations the dust particles play a significantrole in the dynamics of the atmosphere as well as in the diural and surface variations in the temperature.

Further, environmental pollution is the main cause of the dust to enter the human body. The metal dust which filters into the blood stream of those working near furnace causes extensive damage to the chromosomes and genetic mutation so observed are likely to breed censer as malformations in the coming progeny.

It is essential, therefore to study the presence of dust particles in astrophysical situations and fluid flow. Sunil et al.(2004) have studied the effect of suspended particles on couple- stress fluid heated and soluted from below in a porous medium and found that suspended particles have destabilizing effect on the system.

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A.K. Aggarwal and Suman Makhilja(2009) have studied the effect of thermal stability on couple-stress fluid in the presence of rotation and magnetic field and found that rotation has a stabilizing effect while Couple- Stress has stabilizing effect in the absence of rotation on the system. Kumar et al.(2004) have studied the thermal stability of Walters' B' visco-elastic fluid permeated with suspended particles in hydromagnetics in a porous medium and found that magnetic fields stabilize the system. The problem on a Rivlin-Ericksen fluid in a porous medium in the presence of uniform vertical magnetic field and rotation is also considered by Sharma et al(2001). They have found that rotation has a stabilizing effecton the system.

Sharma and Rana(2002) have studied thermosolutal instability of Walter's(Model B') visco-elastic rotation fluid permeated with suspended particles and variables gravity field in porous medium. Kumar et al.(2006) have studied the effect of magnetic field on thermal instability of a rotating Rivlin- Ericksen visco-elastic fluid Kumar et al.(2009) have studied the problem of thermalsolutal instability of couple-stress rotating fluid in the presence of magnetic field and found that magnetic field has both stabilizing and destabilizing effects on the system under certain conditions whereas rotation has a stabilizing effect on the system.

As for growing importance of Couple - Stress fluid, convection in a fluid layer heated from below, the present paper attempts to study the Stoke(1966) incompressible Couple-Stress fluid in the presence of dust particles, magnetic field and rotation .

II. Basic Equations And Mathematical Formulation Of The Problem

Consider a static in which an incompressible, Stokes couple - stress fluid layer of thickness d, is arranged, confined betweentwo infinite horizontal planes situated at z = 0 and z = d,which is acted upon by a vertical magnetic field **H**(0, 0, H), where H is a constant, uniform rotation **Ω**(0,0,Ω) , and variable gravity field **g**(0, 0, -g). The particles are assumed to be non - conducting. The fluid layer is heated from below leading to an adverse temperature gradient $\beta = \frac{T_0 - T_1}{}$, where T_0 and T_1 are the constant temperatures of the lower and upper boundaries with lower and upper boundaries with $T_0 > T_1$. Let p, ρ, T, α, v, μ^1, k_r and $\vec{q}$(u, v, w) denote respectively pressure, density, temperature, thermal, coefficient of expansion, kinematic viscosity, couple-stress viscosity, thermal diffusivity and velocity of the fluid.

$\vec{q_d}(\bar{x},t)$ and $N(\bar{x},t)$ denote the velocity and number density of particles, respectively. K = 6 πμη where η is radius of the particle, is a constant and $\bar{x}$ = (x,y,z). Then equation of motion, continuity and heat conduction of couple-stress (Stokes, 1966 and Joseph, 1976) in hydromagnetics are

$$\frac{\delta q}{\delta t} + (q.\nabla)q = -\frac{1}{\rho_0}\nabla p + g\left(1+\frac{\delta p}{\rho_0}\right) - \left(v - \frac{\mu^1}{\rho_0}\nabla^2\right)\nabla^2 q + \frac{KN}{\rho_0}(q_d - q) + 2(q \times \Omega) + \frac{\mu_e}{4\pi\rho_0}[(\nabla \times H) \times H] \quad \ldots\ldots (1)$$

$$\nabla . q = 0 \quad \ldots\ldots (2)$$

$$\frac{\partial H}{\partial t} (H.\nabla)q + \eta\nabla^2 H \quad \ldots\ldots (3)$$

and

$$\nabla . H = 0 \quad \ldots\ldots (4)$$

The equation of state for the fluid is

$$P = \rho_0[1 - \alpha(T - T_0)] \quad \ldots\ldots (5)$$

Where α is coefficient of thermal expansion and the suffix zero refers to value at the reference level z = 0.

Assume uniform particle size, spherical shape and small relative velocities between the fluid and particles. The presence of particles add an extra force term, proportional to the velocity difference between particles and fluid, appears in equation of motion (1).

Since the force exerted by the fluid on the particles is equal and opposite to the exerted by the particles on the fluid, there must be an extra force term, equal in magnitude but opposite in sign, in the equation of motion for the particles. The buoyancy force on the particles is neglected. Inter-particlereactions are not considered for we assume that the distance between particles is quite large as compared with their diameter. The equations of motion continuity for the particle, under the above approximation, are

$$mN\left[\frac{\partial q_d}{\partial t} + \frac{1}{\epsilon}(q_d.\nabla)q_d\right] = KN(q - q_d) \quad \ldots\ldots (6)$$

and

$$\frac{\partial N}{\partial t} + \nabla(N.q_d) = 0 \quad \ldots\ldots (7)$$

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Here mN is represent the mass of the particles per unit volume. Let C_v, C_{pt} denote the heat capacity of the fluid at constant volume and the heat capacity of the particles. Assuming that the particles and fluids are in thermal equilibrium, then the equation of heat conduction given by

$$\frac{\partial T}{\partial t} + (q.\nabla)T + \frac{mNC_{pt}}{\rho_0 C_v}\left(\frac{\partial}{\partial t} + q_d.\nabla\right)T = K_T\nabla^2 T \quad \text{……………………………(8)}$$

Where v is kinematic viscosity v, μ' is couple-stress viscosity, kT is thermal diffusivity and α is coefficient of thermal expansion which are assumed to be constants.

III. Various Analytical Dicussion Related To The Variables

Stationary Convection

At stationary convection, when the instability sets, the marginal state will be characterized by $\sigma = 0$. Thus, putting $\sigma = 0$ in the equation, we get

$$R_1 = \frac{1+X}{XB}\left[\{F_1(1+x)+1\}(1+x)^2 + Q_1 + \frac{TA_1(1+x)}{[\{F_1(1+x)+1\}(1+x)^2+Q_1]}\right. \quad \text{……………………….(9)}$$

Which expresses the modified Rayleigh number R_1 as a function of the parameters B,F_1, T_{A_1} ,Q_1 and dimensionless wave number x.

To study the stability nature, effect of dust particles, couple-stress and magnetic fields, we examine the behavior of $\frac{dR_1}{dB}$, $\frac{dR_1}{dF_1}$, $\frac{dR_1}{dT_{A_1}}$, and $\frac{dR_1}{dQ_1}$ analytically.

From equation (09), we have

$$\frac{dR_1}{dB} = \frac{1+X}{XB^2}\left[\{F_1(1+x)+1\}(1+x)^2 + Q_1 + \frac{TA_1(1+x)}{[\{F_1(1+x)+1\}(1+x)^2+Q_1]}\right. \quad \text{……………………………………….(10)}$$

This confirms that dust particles have a destabilizing effect on a couple - stress rotating dusty fluid on the thermal convection.

From equation (09), we have

$$\frac{dR_1}{dF_1} = \frac{(1+x)^4}{xB^2}\left[1 - \frac{TA_1(1+x)}{[\{F_1(1+x)+1\}(1+x)^2+Q_1]^2}\right] \quad \text{……….(11)}$$

Which shows that Couple - Stress has a stabilizing or destabilizing effect on the thermal convection under the restrictions

T_{A1} (1 + x) > or < [{ F1(1 + x) + 1}$(1+x)^2$ + Q1$]^2$

But, for the accepted values of various parameters, the said effect is stabilizing only if

T_{A_1} (1+x) < [{ F1(1 + x) + 1}$(1+x)^2$ + Q1$]^2$

In the absence of rotation and magnetic field, equation (11) becomes

$$\frac{dR_1}{dF_1} = \frac{(1+x)^4}{xB} \quad \text{…………………………….. (12)}$$

Which confirms that couple-stress has a stabilizing effect on the thermal convection in the absence of rotation and magnetic field as derived by Sharma and Sharma (2004).

Again from equation (09), we have

$$\frac{dR_1}{dT_{A_1}} = \frac{(1+x)^2}{xB[\{F_1(1+x)+1\}(1+x)^2+Q_1]} \quad \text{…………………… (13)}$$

Which shows that rotation has a stabilizing effect on the system.

In the absence of magnetic field, equation (13) becomes

$$\frac{dR_1}{dT_{A_1}} = \frac{1}{xB[\{F_1(1+x)+1\}]} \quad \text{………………………… (14)}$$

Which clearly shows that rotation has a stabilizing effect onthe thermal convection of couple-stress rotating fluid in the absence of magnetic field as derived by Sharma and Sharma (2004).

Again from equation (09), we have

$$\frac{dR_1}{dQ_1} = \frac{(1+x)}{xB}\left[1 - \frac{TA_1(1+x)}{[\{F_1(1+x)+1\}(1+x)^2+Q_1]^2}\right] \quad \text{..………… (15)}$$

T_{A_1} (1+ x) < or > [{ F1(1 + x) + 1}$(1 + x)^2$ + Q1$]^2$

But, for the permissible values of various parameters, theabove effect is stabilizing only if

T_{A_1} (1+x) < [{ F1(1 + x) + 1}$(1+x)^2$ + Q1$]^2$

In the absence of rotation (T_{A_1}= 0), equation (15) becomes

$$\frac{dR_1}{dQ_1} = \frac{(1+x)}{xB} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(16)$$

Which clearly shows that in the absence of rotation, magnetic field has a stabilizing effect on a couple-stress rotating dusty fluid on the thermal convection.

Oscillatory Convection

Using equations (1) to (8) with the boundary condition, we get

$$\sigma\left(1+\frac{M}{1+\sigma\tau_1}\right) I_1 + I_2 + FI_3 - \frac{g\alpha kTa^2}{v\beta}\left(\frac{1+\sigma^*\tau_1}{B+\sigma^*\tau_1}\right)[I_4 + \sigma^* Bp_1 I_5] + \frac{\mu_e\eta}{4\pi\rho_0 v}[I_6 + \sigma^* p_2 I_7] + d^2\left[\sigma^*\left(1+\frac{M}{1+\sigma^*\tau_1}\right)I_8 + F\, I_9 + I_{10}\right] + \frac{\mu_e\eta d^2}{4\pi\rho_0 v} + [\, I_{11} + \sigma p_2 I_{12}] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(17)$$

Where

$I_1 = \int(\,|DW|^2 + a^2\,|W|^2)dz$

$I_2 = \int(\,|D^2W|^2 + 2a^2\,|DW|^2 + a^4\,|W|^2)dz$

$I_3 = \int(\,|D^3W|^2 + 3a^2\,|D^2W|^2 + 3a^4\,|DW|^2 + a^6\,|W|^2)dz$

$I_4 = \int(\,|DQ|^2 + a^2\,|Q|^2)dz$

$I_5 = \int(\,|Q|^2)dz$

$I_6 = \int(\,|D^2K|^2 + 2a^2\,|DK|^2 + a^4\,|K|^2)dz$

$I_7 = \int(\,|DK|^2 + a^2\,|K|^2)dz$

$I_8 = \int(\,|Z|^2)dz$

$I_9 = \int(\,|D^2Z|^2 + 2a^2\,|DZ|^2 + a^4\,|Z|^2)dz$

$I_{10} = \int(\,|DZ|^2 + a^2\,|Z|^2)dz$

$I_{11} = \int(\,|DX|^2 + a^2\,|X|^2)dz$, and $I_{12} = \int(\,|X|^2)dz$,

Where σ* is the complex conjugate of σ. All the integrals I_1 to I_{12} are positive definite, putting σ = iσ, in equation andequating the imaginary parts, we obtain

$$\sigma_I\left[\sigma\left(1+\frac{M}{1+\sigma_i^2\tau_1^2}\right)I_1 + \frac{g\propto k_T a^2}{v\beta}\left\{\frac{\tau_1(B-1)}{B^2+\sigma_i^2\tau_1^2}\, I_4 + \frac{B+\sigma_i^2\tau_1^2}{B^2+\sigma_i^2\tau_1^2}\, Bp_1 I_5\right\} - \frac{\mu_e\eta}{4\pi\rho_0 v}\, p_2 I_7 - d^2\left\{1+\frac{M}{1+\sigma_i^2\tau_1^2}\right\} I_8 + \frac{\mu_e d^2\eta}{4\pi\rho_0 v}\, p_2 I_{12} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(18)$$

In absence of magnetic field and rotation, equation (18) becomes

$$\sigma_I\left[\left(1+\frac{M}{1+\sigma_i^2\tau_1^2}\right)I_1 + \frac{g\propto k_T a^2}{v\beta}\left\{\frac{\tau_1(B-1)}{B^2+\sigma_i^2\tau_1^2}\, I_4 + \frac{B+\sigma_i^2\tau_1^2}{B^2+\sigma_i^2\tau_1^2}\, Bp_1 I_5\right\}\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(19)$$

It may be inferred from equation (19), it is obvious that all terms in the bracket are positive definite. Thus $\sigma_i = 0$, which means that oscillatory modes are not allowed in the system and Principle of Exchange of Stabilities (PES) is satisfied in the absence of magnetic field and rotation. It is evident form equation (18) that presence of magnetic field and rotation brings oscillatory modes (as, σ_i may not be zero) which were non-existent in their absence.

IV. Discussion On Numerical Computations

The critical thermal Rayleigh number for the onset of instability is determined for critical wave number obtained by using Newton - Raphson method, by means of the condition $\frac{dR_1}{dx}$=0

The numerical values of critical thermal Rayleigh number R1 and critical wave number x determined for various values of dust particles B, magnetic field Q1, couple - stress F1, and rotation T_{A_1}, Graphs have been potted between critical Rayleigh number R_1 and Parameters B, Q_1, F_1 and $T_{A_1}$by substituting some numerical values to them.

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In Figure 1. The critical Rayleigh number R_1 decreases with increase in dust particles parameter B which shows that have dust particles have destabilizing effect on the system that indicates when the critical Rayleigh number R_1 is plotted against dust particles B for fixed value of $F_1 = 10$, $T_{A_1} = 100$ and $Q_1 = 100, 300, 500$.

In Figure 2. The critical Rayleigh number R_1increses with increase in rotation parameter T_{A_1} which shows that rotation has a stabilizing effect on the system whenever the critical Rayleigh number R_1 is potted against rotation parameter T_{A_1} for fixed value of $F_1 = 10$, $B = 20$ and $Q_1 = 100, 400, 700$.

In Figure 3. The critical Rayleigh number R_1 increases with increase in rotation parameter T_{A_1} which shows that rotation has a stabilizing effect on the system when critical Rayleigh number R_1 is potted against rotation parameter T_{A_1} for fixed value of $F_1 = 10$, $Q_1 = 500$, and $B = 5,10, 15$.

In Figure 4. The critical Rayleigh number R_1 increases with increase in magnetic field Q_1 which shows that magnetic field has a stabilizing effect on the system which indicates the critical Rayleigh number R_1 is potted against magnetic field Q_1 for fixed value of $F_1 = 10$, $B = 20$ and $T_{A_1} = 100, 500,1000$.

V. Discussion Through Graphs

Dispersion relation governing the effects of dust particles, couple-stress, rotation and magnetic field is derived. The main results from the analysis are depicted graphically and summarized as follows:

(i) For the case of stationary convection, dust particles have a destabilizing effect on the system as can be seen from equation (10), and graphically from Figure 1.

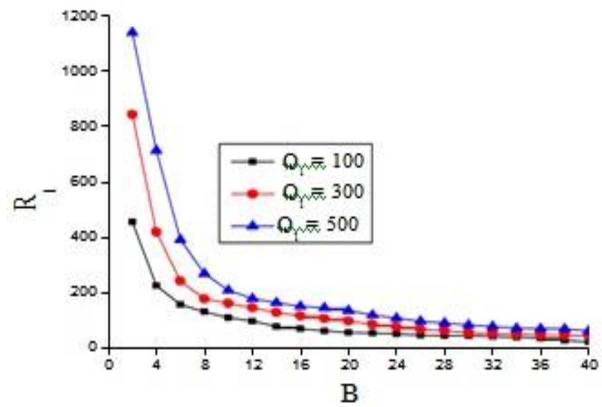

Figure 1: Variation of critical Rayleigh number R_1 with dust particles B for fixed value of $F_1 = 10$, $T_{A_1} = 100$ and $Q_1 = 100,300,500$.

(ii) Couple-stress has stabilizing /destabilizing effects on the system for the permissible values of various parameters which can be seen from equation (11). In the absence of rotation, couple-stress clearly has a stabilizing effect on the system as can be seen from equation (12) as derived by Sharma and Sharma (2004).

(iii) For the case of stationary convection, the rotation has a stabilizing effect on the system as can be seen from equation (13), and graphically, from Figure 2 and Figure 3.

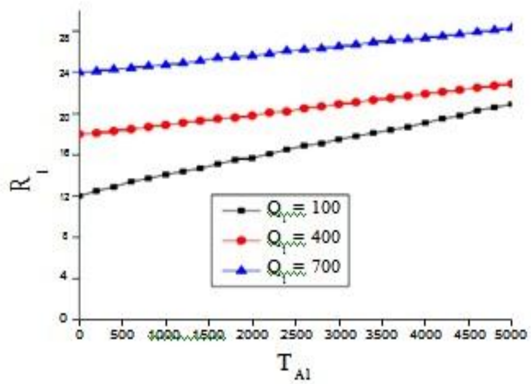

Figure 2: Variation of critical Rayleigh number R_1 with rotation T_{A_1} for fixed value of $F_1 = 10$, $B = 20$ and $Q_1 = 100, 400, 700$

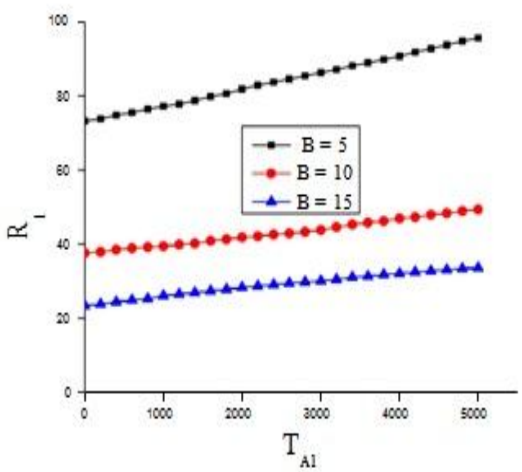

Figure 3: Variation of critical Rayleigh number R_1 with rotation T_{A1} for fixed value of $F_1 = 10$, $Q_1 = 500$, and $B = 5, 10, 15$.

(iv) Magnetic field has stabilizing/destabilizing effect on the system for the permissible values of various parameters as can be seen from equation (15), and graphically from Figure 4.

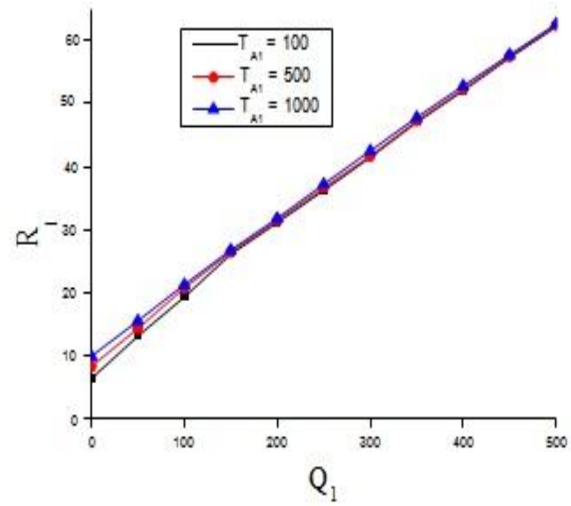

Figure 4: Variation of critical Rayleigh number R_1 with magnetic field Q_1 for fixed value of $F_1 = 10$, $B = 20$ and $T_{A_1} = 100, 500, 1000$.

(v) The Principle of Exchange of Stabilities (PES) is found to hold true in the absence of magnetic field and rotation. It is evident from equation (18) that presence of magnetic field and rotation brings oscillatory modes (as σ_i may not be zero) which were non-existent in their absence.

VI. Conclusion

In this paper, the combined effect of dust particles, on a couple - stress rotating dusty fluid heated from below in hydromagnetics is considered. In this analysis, we have investigated the effect of various parameters like dust particles, couple- stress, rotation and magnetic field on the onset of convection through numerical computations and graphs. The main results from the above analysis are listed as

i) Dust particles have destabilizing effect on a couple - stress rotating dusty fluid on the thermal convection.
ii) Couple - Stress has a stabilizing or destabilizing effect on the thermal convection under the restrictions of permissible values of various parameters.

iii) Rotation has a stabilizing effect on the thermal convection of dusty couple-stress rotating fluid.

iv) Magnetic field has a stabilizing/destabilizing effect on the system for the permissible values of various parameters and in the absence of rotation, magnetic field has a stabilizing effect on a couple-stress rotating dusty fluid on the thermal convection.

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A New Characterization of Hall Effects on Flow Through Porous Medium in a Rotating Parallel Plate Channel

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Abstract

This paper presents the study of unsteady flow of an incompressible electrically conducting viscous fluid in a rotating porous media, with a variable pressure gradient and in the presence of hall current. Here we consider three different cases, like impulsive change, cosine and sine oscillations of pressure gradient. Here, it is proved in this paper that, the rotational and Lorenz forces are having significant effect on velocity profile in the presence of pressure gradient and hall current.

Keywords: Unsteady flows, rotating channels, Hall current effects, pressure gradient, impulsive change, Cosine Oscillations and Sine Oscillations.

Introduction

We assess and calculate the positions and velocities with respect to a fixed frame of reference, applying its magnetic field. The dynamics of geophysics as a field of study has become a vital branch of fluid dynamics owing to the enormous work being carried to explore the atmosphere. Hall effects have extended its influence even on the studies launched in the area of astrophysics, where it is used to study the celestial occurrences like solar storms or even the dynamics working on the stellar, solar structures and the matter present between one planets and the other and between one star and the other. Hide and Roberts [1], gave an explanation for the observed continuation and secular variation of the geomagnetic field. Also Dieke [2] discussed an important in the solar physics mixed up in the sunspot development. A phenomenon (It was discovered by Edwin Hall in 1879) that occurs when an electric current moving through a conductor is exposed to an external magnetic field applied at a right angle, in which an electric potential develops in the conductor at a right angle to both the direction of current and the magnetic field. The Hall effect was a direct result of Lorentz forces acting on the charges in the current, and was named after American physicist Edwin Herbert Hall (1855- 1938). Hall current effect is also indispensable when the fluid is an ionized gas with low density or we are applying the high range of magnetic field. Because the electrical conductivity of the fluid will then be a tensor and a Hall current is provoked. Which is likely to be central in many engineering situations has been discussed by Sutton and Sherman [3]. The Hall effects on the flow of ionized gas between parallel plates under uniform transverse magnetic field have been premeditated by Sato [4]. Nanda and Mohanty [5] considered the hydromagnetic rotating channel flows. Datta and Jana [6] presented the Hall effects on unsteady Couette flow.

Hall effects on hydromagnetic convective flow through a channel with conducting walls is given by Datta and Jana [7], they discussed the flow nature with non-dimensional parameters. Mandal et al. [8] have studied the combined effects of rotation and Hall current on steady flow. Mandal et al. [9] discussed the effects of Hall current on flow between thick arbitrarily conducting plates. Ghosh [10] has analysed the unsteady hydromagnetic flow in a rotating channel with oscillating pressure gradient. Nagy et al. [11] discussed the effects of Hall currents and rotational force on Hartmann flow under general wall conditions. Kanch et al. [12] discussed the Hall Effect on unsteady Couette flow under boundary layer approximations.

Chauhan and Agrawal [13] studied the Hall effects on flow in a channel partially filled with a porousmedium into a rotating system. Sarkar et al. [14] have examined the combined effects of Hall currents and rotation on steady hydromagnetic flow. Nadeem et al. [15] discussed the numerical solutions of peristaltic flow of a Newtonian fluid under the effects of magnetic field and heat transfer in a porous concentric tubes. Nadeem and Akbar [16] discussed the influence of heat transfer and variable viscosity in vertical porous annulus with peristalsis. Nadeem et al. [17] have investigated the influence of heat and mass transfer on Newtonian bio-magnetic fluid of blood flow throughout a tapered porous artery with a stenosis.

The heat generation/absorption and thermo-diffusion on an unsteady free convective flow of radiating and chemically reactive second grade fluid near an infinite vertical plate through a porous medium and taking the Hall current into account have been studied by Veera Krishna and Chamkha [19].

Motivated from the above studies, in this paper, we have considered the unsteady flow of an incompressible electrically conducting viscous fluid in the course of porous medium in a rotating system with pressure gradient as a variable and taking hall current into account.

Formulation and Solution of the Problem

We have consider the unsteady flow of an incompressible electrically conducting viscous fluid in the course of porous medium in a rotating system between two infinitely long horizontal parallel walls separated by a distance h with pressure gradient as a variable and taking hall current into account. We choose a Cartesian frame of reference with the x-axis along the channel wall at y = 0. The configuration of the problem given in Fig.2. A uniform transverse magnetic field H_0 is applied perpendicular to the channel walls. Since the channel walls are infinite in extent and the flow is unsteady, the physical variables are the function of y and t only.

The unsteady boundary layer equations for the flow through a loosely porous medium along x and z-directions in a rotating frame of reference using Brinkman model are

$$\frac{\partial u}{\partial t} - v_0 \frac{\partial u}{\partial y} + 2\Omega w = -\frac{1}{\rho}\frac{\partial p}{\partial x} + v\frac{\partial^2 u}{\partial y^2} - \frac{\mu_e J_z H_o}{\rho} - \frac{v}{k}u \quad \text{-----(1)}$$

$$\frac{\partial w}{\partial t} - v_0 \frac{\partial w}{\partial y} - 2\Omega w = v\frac{\partial^2 w}{\partial y^2} - \frac{\mu_e J_z H_o}{\rho} - \frac{v}{k}u \quad \text{------ (2)}$$

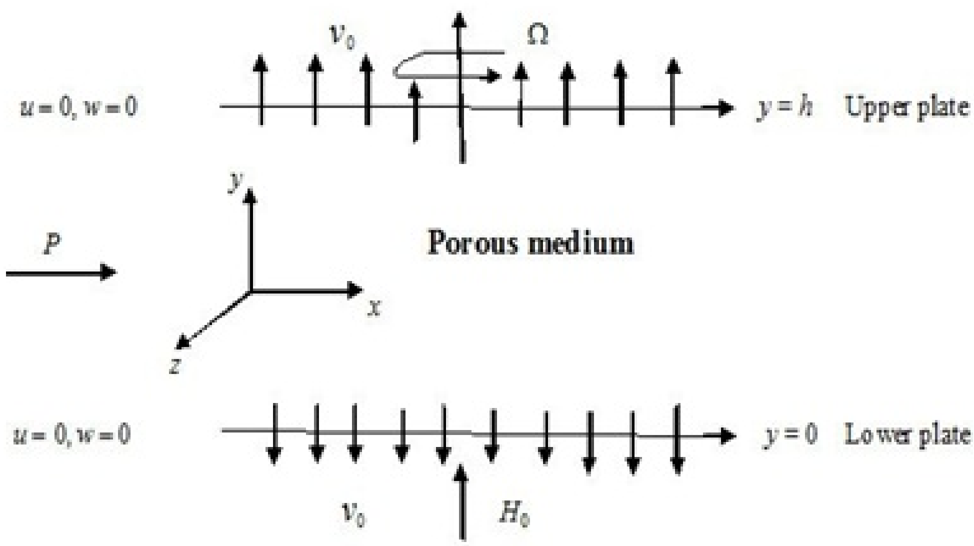


Figure 1: Physical Geometry of the problem

The initial and boundary conditions are

u = 0, w = 0, *t ≤ 0,* *0 ≤ y ≤ h* ---------- (3)

u = 0, w = 0, *v = v₀,* *t > 0, y = 0 and y = h* ------------*(4)*

The generalized Ohm's law comes essentially from the momentum equation of motion for the electron fluid. Its derivation can be found in some plasma physics books. It can be written, on taking Hall currents into account and neglecting ion-slip and thermo-electric effect, as (Cowling [18])

$$J + \frac{\omega_e \tau_e}{H_0}(J \times H) = \sigma(E + \mu_e q \times H) \quad \text{--------------- (5)}$$

The right hand side is the electric field in the moving frame, The first term on the left hand side comes from the electron drag on the ions. The second term is the Hall term and has to do with the idea that electrons and ions can decouple and move separately, The magnetic Reynolds number assumed small, so that the induced magnetic field effect is negligible in comparison with applied magnetic field. The electron atom collision frequency is relatively high as compared to the ion collision frequency, due to this the electron pressure gradient is neglected but, Hall Effect remains present. The relation $\Delta . H = 0$ for magnetic field implies $H_y = H_0 = constant$, everywhere in the fluid. Further, the equation of the conservation of the current density is $\nabla . J = 0, gives\, J_y = constant.$ This constant is zero since $J_y = 0$ at the places which are electrically non-conducting. Thus $J_y = 0$ everywhere in the flow, Since the induced magnetic field is neglected, Maxwell's equation becomes $\nabla \times E = 0$ which implies $\frac{\partial E_x}{\partial y} = 0$ and $\frac{\partial E_z}{\partial y} = 0$. That is E_x = constant everywhere in the flow. In view of the above assumption, the equation (5) gives

$$J_x - m J_z = - \sigma\mu_e H_0 w \quad \text{------------(6)}$$

$$J_z + m J_x = - \sigma\mu_e H_0 u \quad \text{------------(7)}$$

We solve the equations (6) and (7), we get

$$J_x = \frac{\sigma\mu_e H_0}{1+m^2} (mu - w) \quad \text{------------ (8)}$$

$$J_z = \frac{\sigma\mu_e H_0}{1+m^2} (u + mw) \quad \text{-------------(9)}$$

On making use of (8) and (9), the momentum equation (1) and (2) along x- and z- directions become

$$\frac{\partial u}{\partial t} - v_0 \frac{\partial u}{\partial y} + 2\Omega w = -\frac{1}{\rho}\frac{\partial \rho}{\partial x} + v\frac{\partial^2 w}{\partial y^2} + \frac{\sigma\mu_e^2 H_0^2}{\rho(1+m^2)}(u + mw) - \frac{v}{k}u \text{ --- } (10)$$

$$\frac{\partial w}{\partial t} - v_0 \frac{\partial w}{\partial y} - 2\Omega \mathrm{u} = v\frac{\partial^2 w}{\partial y^2} - \frac{\sigma\mu_e^2 H_0^2}{\rho(1+m^2)}(w - mu) - \frac{v}{k}w \quad \text{---(11)}$$

We introduce the non-dimensional variables

$x^* = \frac{x}{h}$, $y^* = \frac{y}{h}$, $u^* = \frac{uh}{v}$, $w^* = \frac{wh}{v}$, $q^* = \frac{qh}{v}$,

$t^* = \frac{tv}{h^2}$, $\omega^* = \frac{\omega h^2}{v}$, $p^* = \frac{ph^2}{\rho v^2}$

making use of non-dimensional variables, the equations (10) and (11) becomes to (dropping asterisks)

$\frac{\partial u}{\partial t} - Re\frac{\partial u}{\partial y} + 2K^2 w = f(t) + \frac{\partial^2 u}{\partial y^2} - \frac{M^2}{1+m^2}(u + mw) - Du$ -------(12)

$\frac{\partial w}{\partial t} - Re\frac{\partial w}{\partial y} + 2K^2 u = \frac{\partial^2 w}{\partial y^2} - \frac{M^2}{1+m^2}(w - mu) - Dw$ -------(13)

Where, $M^2 = \frac{\sigma\mu_e^2 H_0^2 h^2}{\rho v}$ is the Hartmann number, $m = \tau_e\omega_e$ is the hall parameter, $D = \frac{k}{h^2}$ is the Darcy parameter (Permeability parameter), $K^2 = \frac{\Omega^2 h^2}{v}$ the rotation parameter, Re = $\frac{v_0 h}{v}$ the Reynolds number and $f(t) = -\frac{1}{\rho}\frac{\partial p}{\partial x}$ is the non-dimensional pressure gradient.

Corresponding non-dimensional initial and boundary conditions are

u = 0, w = 0, t ≤ 0, 0 ≤ y ≤ 1 --------- (14)

u = 0, w = 0, t > 0, y = 0 and y = 1 --------- (15)

Combining equations (12) and (13), Let q = u + iw and i = $\sqrt{-1}$, we get the momentum equation in terms of complex velocity q where, u is the velocity along the x-direction and w is the velocity along the z-direction, is given as –

$\frac{\partial q}{\partial t} - Re\frac{\partial q}{\partial y} = f(t) + \frac{\partial^2 q}{\partial y} - \left(\frac{M^2}{1+im}\ 2iK^2 + D\right)q$ ------- (16)

The initial and boundary conditions are -

q = 0, t ≤ 0, 0 ≤ y ≤ 1 ----------- (17)

q = 0, t > 0, y = 0 and y = 1 ----------- (18)

Taking the Laplace transform of the equation (16), we have

$\frac{\partial^2 \bar{q}}{\partial y^2} - Re\frac{\partial \bar{q}}{\partial y} - \left(\frac{M^2}{1+im} - 2iK^2 + D\right)\bar{q} = \bar{f}$ (s) ---------- (19)

The transformed boundary conditions are

$\bar{q}(0,s) = 0$, and $\bar{q}(1,s) = 0$ --------(20)

The solution of the equation (19) subjected to the boundary condition (20) are given by -

$$\bar{q}(\text{y, s}) = \frac{\bar{f}(s)}{\lambda_1+s}\left[1 - e^{-\frac{1}{2}Rey}\,\frac{\sinh\sqrt{\lambda_2+s(1-y)}}{\sinh\sqrt{\lambda_2+s}} - e^{-\frac{1}{2}Re(1-y)}\,\frac{\sinh\sqrt{\lambda_2+s(y)}}{\sinh\sqrt{\lambda_2+s}}\right] \text{------- (21)}$$

Where $\lambda_1 = \frac{M^2}{1+im} - 2iK^2 + D$ and $\lambda_2 = \frac{Re^2}{4} + \frac{M^2}{1+im} - 2iK^2 + D$ and we assume

$$f(t) = P_0 + P_1 e^{i\omega t} + P_2 e^{-i\omega t} \quad \text{-------------} \quad (22)$$

Where ω is the frequency of oscillation ; $P_0, P_1, and\ P_2$ are real constants. Taking the inverse Laplace transforms to the equation (21), and we obtain the solution for the complex velocity q as,

$$q(y,t) = \frac{P_0}{\lambda_1}\left[1 - e^{-\frac{1}{2}Re\,y}\,\frac{\sinh(a-ib)(1-y)}{\sinh\,(a-ib)} - e^{\frac{1}{2}Re(1-y)}\,\frac{\sinh(a-ib)(y)}{\sinh\,(a-ib)}\right] +$$

$$\frac{P_1}{\lambda_1+i\omega}\left[1 - e^{-\frac{1}{2}Re\,y}\,\frac{\sinh(a_1 \pm ib_1)(1-y)}{\sinh(a_1 \pm ib_1)} - e^{\frac{1}{2}Re(1-y)}\,\frac{\sinh(a_1 \pm ib_1)(y)}{\sinh(a_1 \pm ib_1)}\right] e^{i\omega t} +$$

$$\frac{P_1}{\lambda_1-i\omega}\left[1 - e^{-\frac{1}{2}Re\,y}\,\frac{\sinh(a_2-ib_2)(1-y)}{\sinh(a_2-ib_2)} - e^{-\frac{1}{2}Re(1-y)}\,\frac{\sinh(a_2-ib_2)(y)}{\sinh(a_2-ib_2)}\right] e^{i\omega t} -$$

$$\left(\frac{P_0}{\lambda_1} + \frac{P_1}{\lambda_1+i\omega} + \frac{P_1}{\lambda_1-i\omega}\right)*\left[1 - e^{-\frac{1}{2}Re\,y}\,\frac{\sinh(1/2)(1-y)}{\sinh(1/2)Re} - e^{\frac{1}{2}Re(1-y)}\,\frac{\sinh(1/2)Re(y)}{\sinh(1/2)Re}\right] e^{-\lambda_1 t}$$

$$+\ 2\sum_{n=1}^{\infty} n\pi\left[(-1)^n e^{\frac{1}{2}Re(1-y)} - e^{-\frac{1}{2}Re\,y}\right]\left(\frac{P_0}{S_1} + \frac{P_1}{S_1+i\omega} + \frac{P_2}{S_1-i\omega}\right)\frac{\sin n\pi y}{\lambda_1+S_1} e^{S_1 t} \quad \text{-----(23)}$$

In the equation (23), the lower sign is valid for $2K^2 + \frac{mM^2}{1+m^2} + mD > \omega$ and the upper sign is valid for $2K^2 + \frac{mM^2}{1+m^2} + mD < \omega$. The equation (23) represents the velocity of the fluid in the general case. Now we shall consider the following special cases.

Case – 1. Velocity distribution for impulsive pressure gradient :

In this case $P_1 = P_2 = 0$, then the equation (23) reduces to

$$q(y,t) = \frac{P_0}{\lambda_1}\left[1 - e^{-\frac{1}{2}Re\,y}\,\frac{\sinh(a-ib)(1-y)}{\sinh\,(a-ib)} - e^{\frac{1}{2}Re(1-y)}\,\frac{\sinh(a-ib)(y)}{\sinh\,(a-ib)}\right] +$$

$$-\ \frac{P_0}{\lambda_1}\left[1 - e^{-\frac{1}{2}Re\,y}\,\frac{\sinh(1/2)(1-y)}{\sinh(1/2)Re} - e^{\frac{1}{2}Re(1-y)}\,\frac{\sinh(1/2)Re(y)}{\sinh(1/2)Re}\right] e^{-\lambda_1 t} +$$

$$+ 2\sum_{n=1}^{\infty} n\pi \left[(-1)^n e^{\frac{1}{2}Re(1-y)} - e^{-\frac{1}{2}Re\, y}\right]\left(\frac{P_0}{S_1}\right)\frac{\sin n\pi y}{\lambda_1+S_1} e^{S_1 t} \quad \text{------------ (24)}$$

Case – 2. Velocity distribution for cosine oscillations of pressure gradient :

In this case $P_0 = 0\ and\ P_1 = P_2 = \frac{P}{2}$, then the equation (23) reduce to

$$q(y,t) = \frac{P}{2}\left\{\left[1 - e^{-\frac{1}{2}Re\, y}\frac{\sinh(a_1 \pm ib_1)(1-y)}{\sinh(a_1 \pm ib_1)} - e^{\frac{1}{2}Re(1-y)}\frac{\sinh(a_1 \pm ib_1)(y)}{\sinh(a_1 \pm ib_1)}\right]\frac{e^{i\omega t}}{\lambda_1 + i\omega}\right.$$

$$\left. + \left[1 - e^{-\frac{1}{2}Re\, y}\frac{\sinh(a_2 - ib_2)(1-y)}{\sinh(a_2 - ib_2)} - e^{-\frac{1}{2}Re(1-y)}\frac{\sinh(a_2 - ib_2)(y)}{\sinh(a_2 - ib_2)}\right]\frac{e^{i\omega t}}{\lambda_1 - i\omega}\right\}$$

-

$$\frac{P}{2}\left(\frac{1}{\lambda_1+i\omega} + \frac{1}{\lambda_1-i\omega}\right) * \left[1 - e^{-\frac{1}{2}Re\, y}\frac{\sinh(1/2)(1-y)}{\sinh(1/2)Re} - e^{\frac{1}{2}Re(1-y)}\frac{\sinh(1/2)Re(y)}{\sinh(1/2)Re}\right] e^{-\lambda_1 t}$$

$$+ 2\sum_{n=1}^{\infty} n\pi P\left[(-1)^n e^{\frac{1}{2}Re(1-y)} - e^{-\frac{1}{2}Re(y)}\right]\left(\frac{1}{S_1+i\omega} + \frac{1}{S_1-i\omega}\right)\frac{\sin n\pi y}{\lambda_1+S_1} e^{S_1 t} \quad \text{---(25)}$$

Case – 3. Velocity distribution for sine oscillations of pressure gradient : In this case $P_0 = 0\ and\ P_1 = P_2 = \frac{P}{2i}$, then the equation (23) reduce to

$$q(y,t) = \frac{P}{2i}\left\{\left[1 - e^{-\frac{1}{2}Re\, y}\frac{\sinh(a_1 \pm ib_1)(1-y)}{\sinh(a_1 \pm ib_1)} - e^{\frac{1}{2}Re(1-y)}\frac{\sinh(a_1 \pm ib_1)(y)}{\sinh(a_1 \pm ib_1)}\right]\frac{e^{i\omega t}}{\lambda_1 + i\omega}\right.$$

$$\left. + \left[1 - e^{-\frac{1}{2}Re\, y}\frac{\sinh(a_2 - ib_2)(1-y)}{\sinh(a_2 - ib_2)} - e^{-\frac{1}{2}Re(1-y)}\frac{\sinh(a_2 - ib_2)(y)}{\sinh(a_2 - ib_2)}\right]\frac{e^{i\omega t}}{\lambda_1 - i\omega}\right\}$$

-

$$\frac{P}{2i}\left(\frac{1}{\lambda_1+i\omega} + \frac{1}{\lambda_1-i\omega}\right) * \left[1 - e^{-\frac{1}{2}Re\, y}\frac{\sinh(1/2)(1-y)}{\sinh(1/2)Re} - e^{\frac{1}{2}Re(1-y)}\frac{\sinh(1/2)Re(y)}{\sinh(1/2)Re}\right] e^{-\lambda_1 t}$$

$$+ 2\sum_{n=1}^{\infty} n\pi P_i\left[(-1)^n e^{\frac{1}{2}Re(1-y)} - e^{-\frac{1}{2}Re(y)}\right]\left(\frac{1}{S_1+i\omega} + \frac{1}{S_1-i\omega}\right)\frac{\sin n\pi y}{\lambda_1+S_1} e^{S_1 t} \text{---(26)}$$

for the impulsive change of pressure gradient, the non-dimensional shear stresses at the wall y = 0 are given by

$$\tau_x + i\tau_z = \left(\frac{\partial q}{\partial y}\right)_{y=0} = \frac{P_0}{\lambda_1}\left[\left\{\left(\frac{1}{2}\right)Re + (a - ib)\right\}\coth(a - ib) + \frac{\left(\frac{1}{2}\right)Re + (a-ib)}{\sinh(a-ib)} e^{\frac{1}{2}Re}\right] -$$

$$\frac{P_0 Re}{\lambda_1}\coth\frac{Re}{2} e^{-\lambda_1 t} + 2\pi^2\ P_0\sum_{n=1}^{\infty}\left[(-1)^n e^{\frac{1}{2}Re} - 1\right]\left(\frac{n^2}{s_1}\right)\frac{1}{\lambda_1+s_1} e^{s_1 t} \quad \text{----(27)}$$

for the cosine oscillations of pressure gradient, the non-dimensional shear stresses at the wall y = 0 are given by

$$\tau_x + i\tau_z = \left(\frac{\partial q}{\partial y}\right)_{y=0} = \frac{P}{2}\left[\left\{\left(\frac{1}{2}\right)Re + (a_1 \pm ib_1)\right\}\coth(a_1 \pm ib_1) + \frac{\left(\frac{1}{2}\right)Re + (a_1 \pm ib_1)}{\sinh(a_1 \pm ib_1)} e^{\frac{1}{2}Re}\right]$$

$$\frac{e^{i\omega t}}{\lambda_1+i\omega} + \left[\left\{\left(\frac{1}{2}\right)Re + (a_2 - ib_2)\right\}\coth(a_2 - ib_2) + \frac{\left(\frac{1}{2}\right)Re + (a_2 - ib_2)}{\sinh(a_2 - ib_2)} e^{\frac{1}{2}Re}\right]\frac{e^{-i\omega t}}{\lambda_1-i\omega}$$

$$- \frac{PRe}{2}\left(\frac{1}{\lambda_1+i\omega} + \frac{1}{\lambda_1-i\omega}\right)\coth\left[\frac{1}{2}Re\right] e^{\lambda_1 t} + \pi^2 P\sum_{n=1}^{\infty}\left[(-1)^n e^{\frac{1}{2}Re} - 1\right]$$

$$\left(\frac{1}{s_1+i\omega}+\frac{1}{s_1-i\omega}\right)\frac{1}{\lambda_1+s_1}e^{s_1 t} \quad \text{----------(28)}$$

for the sine oscillation of pressure gradient, the non-dimensional shear stresses at the wall y = 0 are given by

$$\tau_x + i\tau_z = \left(\frac{\partial q}{\partial y}\right)_{y=0} = \frac{P}{2i}\left\{\left[\left\{\left(\frac{1}{2}\right)Re+(a_1 \pm ib_1)\right\}\coth(a_1 \pm ib_1)+\frac{\left(\frac{1}{2}\right)Re-(a_1 \pm ib_1)}{\sinh(a_1 \pm ib_1)}e^{\frac{1}{2}Re}\right]\right.$$

$$\frac{e^{i\omega t}}{\lambda_1+i\omega}+\left[\left\{\left(\frac{1}{2}\right)Re+(a_2-ib_2)\right\}\coth(a_2-ib_2)+\frac{\left(\frac{1}{2}\right)Re-(a_2-ib_2)}{\sinh(a_2-ib_2)}e^{\frac{1}{2}Re}\right]\left.\frac{e^{-i\omega t}}{\lambda_1-i\omega}\right\}$$

$$-\quad \frac{PRe}{2i}\left(\frac{1}{\lambda_1+i\omega}+\frac{1}{\lambda_1-i\omega}\right)\coth\left[\frac{1}{2}Re\right]e^{-\lambda_1 t}+\pi^2 P\sum_{n=1}^{\infty}\left[(-1)^n e^{\frac{1}{2}Re}-1\right]$$

$$\left(\frac{1}{s_1+i\omega}+\frac{1}{s_1-i\omega}\right)\frac{1}{\lambda_1+s_1}e^{s_1 t} \quad \text{----------(29)}$$

Results and Discussion

We have considered the unsteady flow of an incompressible electrically conducting viscous fluid in the course of porous medium in a rotating system with pressure gradient as a variable and taking hall current into account. We have computed three different cases based on our study of impulsive change, cosine and sine oscillations of pressure gradient. In this aspect, we have analytically and computationally solved the decisive equations by applying Laplace transform technique. It has been successfully established that the flow behavior is determined owing to the mutual influence of Coriolis force and hydro-magnetic force on each other under the purview or monitoring of pressure gradient and hall current. The flow governed by the non-dimensional parameters for the velocity components u and w with different values of magnetic parameter M, Hall parameter m, rotation parameter K, Reynolds number Re, D the permeability parameter, frequency parameter ω and phage angle ωt in Figures (1,12). Figures (1,4) represent the velocity profiles for impulsive pressure gradient; (5,8) represent the velocity profiles for cosine oscillations of pressure gradient, where as the Figures (9,12) represent the velocity profiles for sine oscillations of pressure gradient. Here we observe that, all the profiles are on negative sides for w. Negative velocity just means velocity in the opposite direction than what would be positive. This will attained only with effect pressure gradient in pertinent directions of the flow field.

We have perceive from Figures (1, 5 & 9) that the velocity component u enhances with add to Hartmann number M with the impulsive change of pressure gradient, and The velocity component w less for the cosine oscillations of while it raises with impulsive change and sine oscillations with an augment in magnetic parameter M, given in Figures (2, 6 & 10).As expected due to the fact that the application of transverse magnetic field results to a resistive type force (called Lorentz force) similar to drag force and upon increasing the values of magnetic parameter, the drag force increases which leads to the deceleration of the flow. It is seen from Figures (3, 7 & 11) that the primary velocity *u* increases with an increase in Hall parameter *m* for sine oscillations of the pressure gradient while it reduces for the impulsive change and cosine oscillations of the pressure gradient. Hence, we conclude that an increase in Hall parameter reduces the Lorentz force in *x*- direction and motion of the fluid particles is reinforced in that direction.

VELOCITY PROFILES WITH IMPULSIVE PRESSURE GRADIENT:

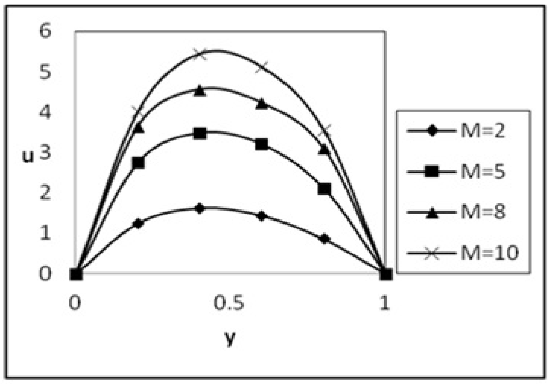
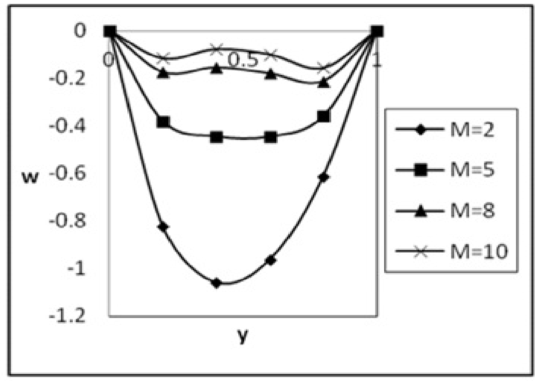


Fig. 1



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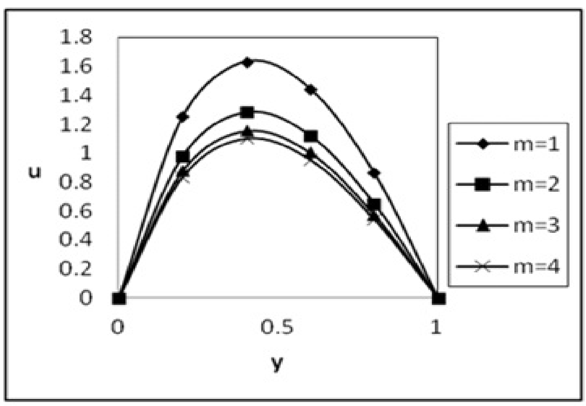

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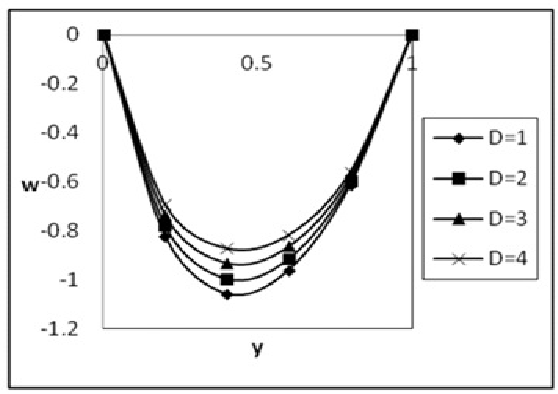


Fig. 4

I. **Velocity Profiles with Cosine Oscillations of Pressure Gradient:**

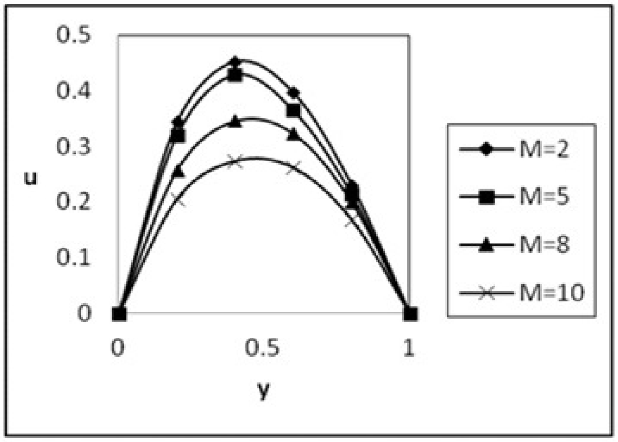
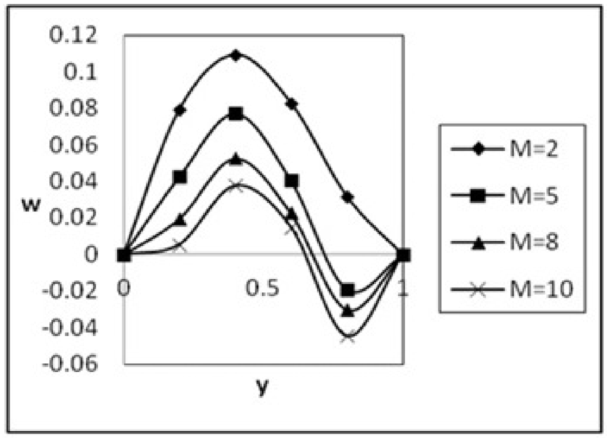


Fig. 5



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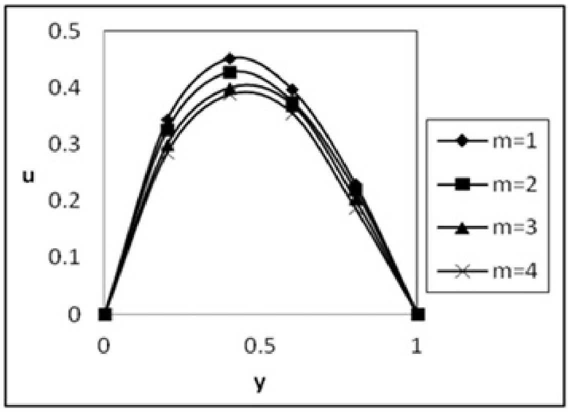


Fig. 7

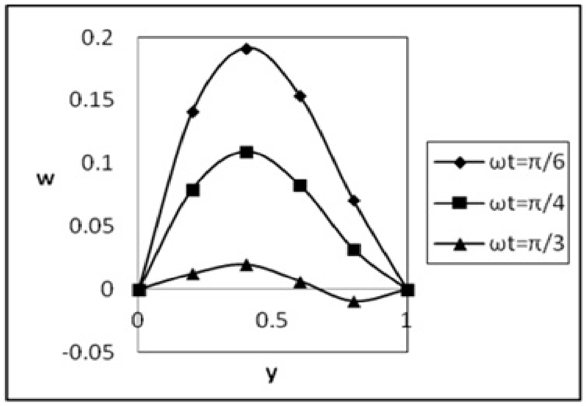


Fig. 8

II. **Velocity Profiles with Sine Oscillations of Pressure Gradient:**

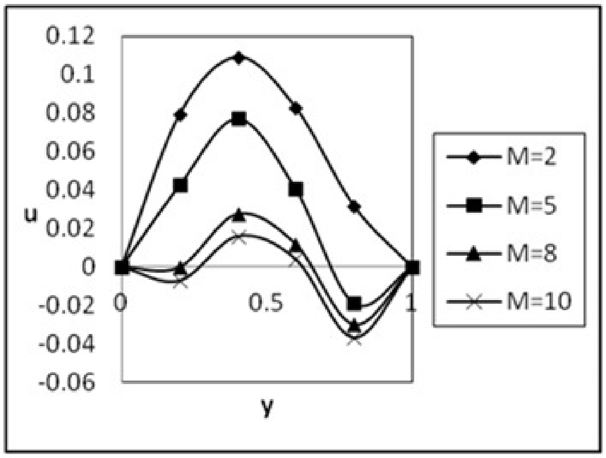


Fig. 9

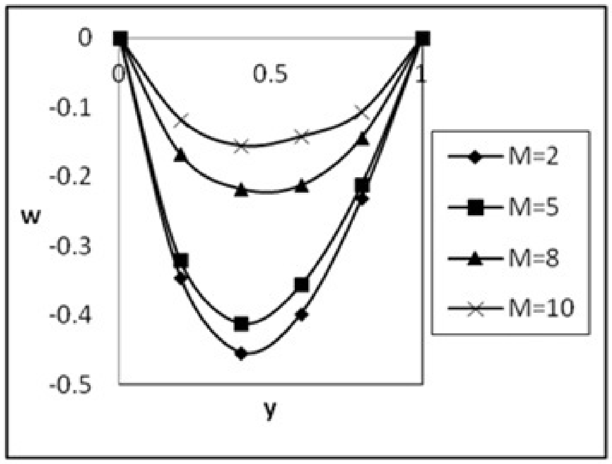
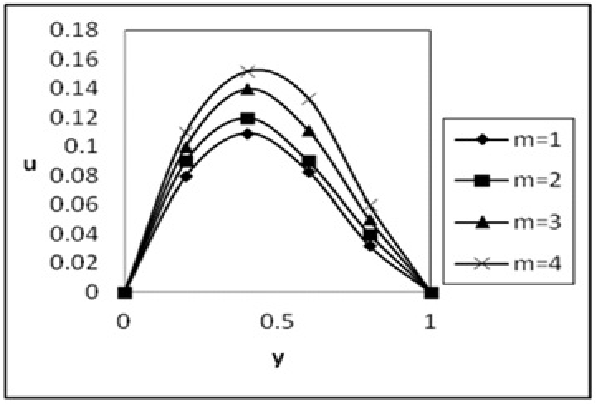


Fig. 10



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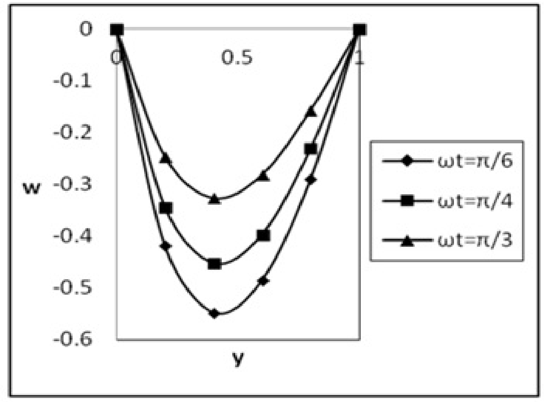

Fig. 12

Conclusions

We have considered the unsteady flow of an incompressible electrically conducting viscous fluid in the course of porous medium in a rotating system with pressure gradient as a variable and taking hall current into account. The conclusions are made as follows.

1. The velocity component for primary flow enhances with increasing M, K and D, and reduces with m, Re for the impulsive change of pressure gradient.

2. The velocity component for secondary flow enhances with increasing M, Re and D, and reduces with m and K for the impulsive change of pressure gradient.

3. The velocity component for primary flow increases with increasing Re, D and ω, and reduces with M, m, K and phase angle ωt for the cosine oscillations of pressure gradient.

4. The velocity for primary flow increases with increasing m and D, and reduces with M, K and phase angle ωt for the sine oscillations of pressure gradient.

5. The magnitude of the velocity for primary flow and for secondary flow enhances initially and then gradually reduces with an increase in Reynolds number Re for sine and cosine oscillations of the pressure gradient respectively.

6. The velocity for secondary flow enhances with increasing M, m, K and phase angle ωt , and reduces with increase in Re, D and frequency of oscillation ω for the impulsive change of pressure gradient.

7. The magnitude of τ_x due to the primary flow decreases for the impulsive change and cosine oscillations with increment in M, m, Re, K and D. For secondary flow it reduces for K and M and increases for m, Re and D.

8. Both the stresses enhance with increase in m, K and D; and reduce with increase in M or Re for sine of the pressure gradient.

9. The shear stress τ_x increases for petite values of M and then it reduces for cosine and sine oscillations of the pressure gradient with an increase in frequency parameter ω

10. The stress τ_z enhances and then it reduces for cosine oscillations. Whereas it initially decreases and then boosts for sine oscillations of the pressure gradient with an increase in ω

11. Finally, the rotational and Lorentz forces are having significant effect on velocity profile in the presence of pressure gradient and hall current.

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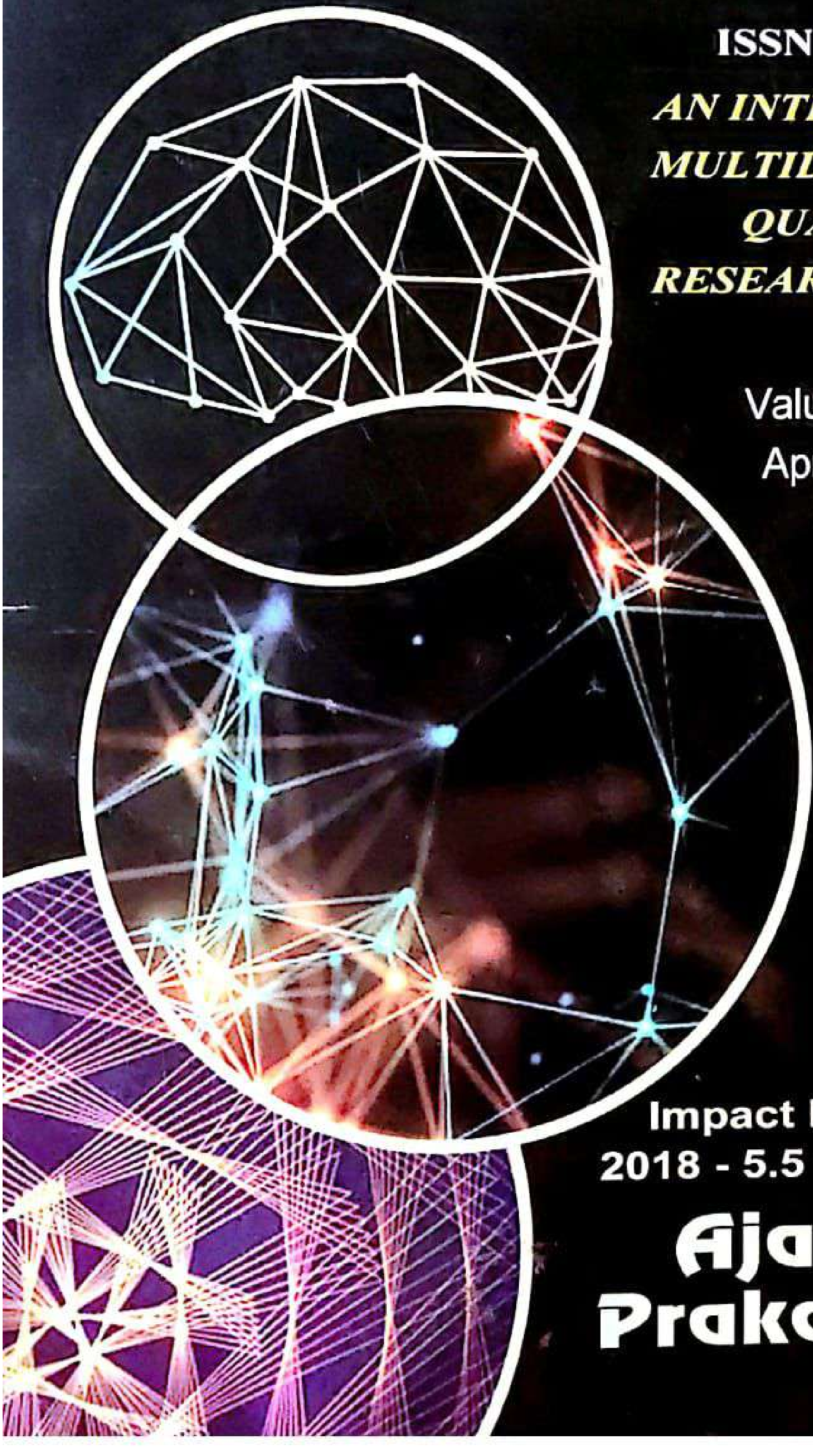

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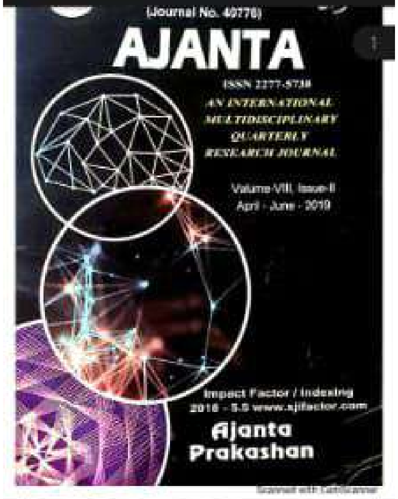

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Fixed Point Results on Partial Modular Metric Space

Dipankar Das [1], Santanu Narzary [1], Yumnam Mahendra Singh [2], Mohammad Saeed Khan [3] and Salvatore Sessa [4,*]

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Abstract: In the present paper, we refine the notion of the partial modular metric defined by Hosseinzadeh and Parvaneh to eliminate the occurrence of discrepancies in the non-zero self-distance and triangular inequality. In support of this, we discuss non-trivial examples. Finally, we prove a common fixed-point theorem for four self-mappings in partial modular metric space and an application to our result; the existence of a solution for a system of Volterra integral equations is discussed.

Keywords: fixed point; partial metric space; modular space; partial modular space; weakly compatible mappings; C-class function; Volterra integral equation

MSC: 47H10; 54H25

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1. Introduction

In 1992, Matthews [1] initiated the idea of non-zero self-distance by introducing the notion of the partial metric as a part of the study of the denotational semantics of data flow programming languages in a topological model in computer sciences and also extended Banach's contraction principle [2] in such space. Subsequently, many authors have begun to report its topological properties and obtained many fixed-point theorems in this space (for more details and references, we refer to [3–8]). On the other hand, in 1950, Nakano [9] introduced the concept of the modular in connection with the theory of order spaces, which was later developed by Musielak and Orlicz [10], Khamsi [11] and Kozlowski [12] as modular function space.

In 2006, Chistyakov [13] introduced the notion of the metric modular on an arbitrary set and the corresponding modular space, which is more general than a metric space, and, based on this, he further studied Lipschitz continuity and a class of superposition (or Nemytskii) operators on modular metric space (see also [14,15]). Recently, Hosseinzadeh and Parvaneh [16] introduced the notion of partial modular metric spaces as a generalization partial metric space and gave some fixed-point results.

In this paper, we refine the concept of the partial modular metric to eliminate the occurrence of discrepancies in the non-zero self-distance and triangular inequality and prove a common fixed-point theorem for four self-mappings with a suitable example. As an application of our result, the existence of a solution for a system of Volterra integral equations is discussed.

2. Preliminaries

In this section, we recall some definitions and properties to use in our result.

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SOME FIXED POINT RESULTS IN MODULAR-LIKE METRIC SPACES AND PARTIAL MODULAR-LIKE METRIC SPACES WITH ITS NON-ARCHIMEDEAN VERSION

DIPANKAR DAS[1], SANTANU NARZARY[2*] and NIRANJAN BORA[2]

Department of Mathematical Sciences
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Abstract

In this paper, the notion of partial modular-like metric space from partial modular metric spaces with some properties and examples, and observed that the restriction of partial modular-like metric space to equivalent to dislocated (modular-like) metric space is self distance axiom. All the results are also study in non-Archimedean modular sense. Some fixed point results via C-class function are introduced with suitable examples to validate the results. As an application for the existence and uniqueness of solutions for a system of Volterra integral equations is given.

1. Introduction

In [13], Matthews introduced partial metric space which is a generalization of metric space as self-distance is nonzero. In [3], Amini-Harandi introduced metric like space as generalization of partial metric space. In [6], Chistyakov introduced modular metric space which generalizes metric space. For some nonlinear contraction fixed point theorem in modular spaces is not possible, to remove this difficulty, in ([15], [16]) Paknazar et al. introduced non-Archimedean modular metric spaces by changing its triangular property. In [8], Hosseinzadeh and Paryaneh, introduced partial

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Role of Self Help Groups in Economic Empowerment of Rural Women of Kokrajhar District in Assam

Anamika Das.

Abstract:

Women are integral part of the society as well as indispensable for building up a good society they are always relegated to the background. Women empowerments means women have the capacity to explore them self in every sector of the society. They have the power to carry on daily livelihood, engaged in all social, economical and political affairs. Indian government have also announced the year 2001 as women's empowerment year focusing on the subject "where women are equal partners like men'. So need of the hour is to empowered rural women for sustaining better future and creating brighter nation

Self Help Groups (SHGs) and micro finance is taken as an instrument for empowering rural women. Generally SHGs consist of 10 rural poor women. They contributed small saving to build up a fund for their own use. The ultimate objective behind the creation of SHGs is to enable them to enjoy financial freedom for themselves at the same time all the members who belong to SHGs can lead a meaningful life in a hassle free society. In present study the investigation try to focus the role of SHGs in socio-economic development of rural women with special reference to Gossaigaon sub-division under Kokrajhar district of Assam.

Keywords: *Self Help Groups, Socio-economic development, rural women.*

Introduction:

One of the most important factors for the success of any enterprises is the timely and sufficiently availability of institutional finance. The problem of unemployment is increasing by leaps and bounds in our society. The economic needs of family are increasing day by day compelling women to take up gainful employment outside the home. Self Help Groups work for the upliftment of the women. This study can be considered as an important contribution towards the development and growth of micro enterprises in Gossaigaon Sub-division.

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সংক্ষিপ্তসাৰ ঃ *দেশ বা ঠাই ভ্ৰমণত অৰ্জন কৰা অভিজ্ঞতাসমূহৰ এক সুকীয়া আবেদন আৰু গুৰুত্ব আছে। দেশ ভ্ৰমণৰ পৰা আমেজ লোৱাটো সাধাৰণ লোকৰ কাম। আনহাতে আবেগ আৰু গুৰুত্ব দুয়োটাকে আবেদনশীলভাৱে সাহিত্যত সংস্থাপন কৰাটো সাহিত্যিকৰ ধৰ্ম। ইয়াতেই সাধাৰণ লোক আৰু সাহিত্যিকৰ মাজৰ প্ৰধান পাৰ্থক্য। মন কৰিবলগীয়া কথা এইটোৱে যে ভ্ৰমণ সাহিত্যৰ বাবে ভ্ৰমণ অভিজ্ঞতাই প্ৰথম পৃষ্ঠভূমি হ'লেও একেবাৰে পৰা সেইসমূহ অভিজ্ঞতাক লৈয়ে গঢ়ি উঠা সি ভ্ৰমণ সাহিত্য হৈ নুঠে, যি হয়তো হ'ব পাৰে দিনলিপিৰ আকাৰ। গতিকে লেখকে তাত সাহিত্যৰ উপাদান সংযোগ কৰিবই লাগিব, যিটো আকৌ বিষয়বস্তুৰ বৰ্ণনা শৈলীত [illegible]। এয়া সহজেই জানিব পাৰি। তথাপি দুই-এজন গ্ৰন্থকাৰে তথ্য নিৰ্ভৰ বৰ্ণনাৰ মাজতো সাহিত্যৰ ধৰ্ম ৰক্ষা কৰি এইবিধ সাহিত্যক আগবঢ়াই নিয়াৰ চেষ্টা কৰি আহিছে। সেইসকলৰ ভিতৰত স্বাধীনতাৰ পৰবৰ্তী সময়ছোৱাৰ গ্ৰন্থকাৰ হেম বৰুৱা অন্যতম। লেখক হেম বৰুৱাৰ সাহিত্যৰ বৰ্ণনাই তথ্য নিৰ্ভৰ। সেইবুলি লেখকে গ্ৰন্থসমূহত তথ্যকে যে কেৱল যোগান ধৰিছে তেনে নহয়। সেইসমূহ তথ্যক কলাত্মক ৰূপ দিবলৈ সাহিত্যৰ কেতবোৰ অনুষংগ গ্ৰহণ কৰাৰ চেষ্টা কৰিছে। অনুষংগসমূহৰ ভিতৰত 'কবিতা' অন্যতম। আমাৰ এই আলোচনাত লেখক হেম বৰুৱাই তেওঁৰ ভ্ৰমণ গ্ৰন্থবোৰত কেনেকৈ কেনেবোৰ প্ৰসংগত প্ৰাসংগিক কৰি তুলিবলৈ কবিতাৰ আশ্ৰয়ত ভ্ৰমণ অভিজ্ঞতাক সাহিত্যত ৰূপায়ণৰ চেষ্টা কৰিছে তাৰে এটি বিৱৰণ দাঙি ধৰাৰ প্ৰয়াস কৰা হৈছে।*

বীজ শব্দ ঃ ভ্ৰমণ অভিজ্ঞতা, ভ্ৰমণ সাহিত্য, কবিতা, কাব্যধৰ্মী গদ্য।

অৱতৰণিকা ঃ

আধুনিক কালৰ এক উল্লেখযোগ্য সাহিত্যৰ শাখা হ'ল ভ্ৰমণ সাহিত্য। ভ্ৰমণ সাহিত্য এনে এবিধ সাহিত্য [illegible] লেখকৰ বিষয়বস্তু পৰিৱেশনত সীমাবদ্ধতা আন সাহিত্য শাখাসমূহতকৈ কিছু কম। এইবিধ সাহিত্য [illegible] হেতুকে সীমাবদ্ধতা যে কিছু পৰিমাণে কম সেই কথা উল্লেখ কৰিব পাৰি। কিন্তু সেইবুলি ভ্ৰমণ সাহিত্যৰ [illegible] মুক্ত ক্ষেত্ৰও নহয় যে লেখকৰ ইচ্ছানুযায়ী যিকোনো বিষয় অপৰিকল্পিতভাৱে একেবাৰে পৰা [illegible] কৰি যাব। ভ্ৰমণ সাহিত্যও সাহিত্য। গতিকে সাহিত্যৰ চৰিত্ৰ ইয়াতো চিত্ৰায়ণ হ'ব লাগিব।

ভ্ৰমণ সাহিত্যৰ আধাৰ হ'ল ভ্ৰমণ অভিজ্ঞতা। লেখকে তেওঁৰ ভ্ৰমণ কালত বহু অভিজ্ঞতাই লাভ কৰে। [illegible] সকলো অভিজ্ঞতাকে যে একেবাৰে পৰা লিপিবদ্ধ কৰি যাব তেনেও নহয়। লেখকে কেনেকৈ [illegible] বাছনি কৰিব সেয়া তেওঁ নিজেই সিদ্ধান্ত ল'ব। অনুপৰি লেখকজনৰ নিজেও সেয়া নিজা অভিজ্ঞতা, [illegible] অভিজ্ঞতাক পাঠকে আন্তৰিকভাৱে গ্ৰহণ নকৰিবও পাৰে। অথবা লেখকৰ বাবে ভাল লগা কোনো অভিজ্ঞতা [illegible]

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