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MHD Free convective flow of a Jeffrey fluid in a vertical channel partially filled with porous medium

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Abstract: MHD free convection flow of a Jeffrey fluid between vertical plates partially filled with porous medium is investigated. The momentum transfer in the porous medium has been described by the Brinkman extended Darcy model. The fluid flow in the free region is governed by Jeffrey model. The solution for the problem is obtained using a perturbation method. The effects of Darcy number, magnetic parameter and Jeffrey parameter on the velocity field and temperature distributions are discussed in detail through graphs.

Keywords: Convection, Darcy number, Jeffrey fluid, MHD, Porous medium.

I.INTRODUCTION

Convective flow with heat transfer under the influence of a magnetic field and chemical reaction has attracted a considerable attention of researchers because of its applications in astrophysics, geophysical fluid dynamics, and engineering. Possible applications of this type of flow can be found in many industries viz. in the chemical industry, cooling of nuclear reactors and magnetohydrodynamic (MHD) power generators. Free convection flow occurs frequently in nature. It occurs mainly due to temperature differences. Many transport processes exist in industrial applications in which the simultaneous heat and mass transfer occur as a result of combined buoyancy effects of diffusion of chemical species. Free convection flows in porous media with chemical reaction have wide applications in geothermal and oil reservoir engineering as well as in chemical reactors of porous structure.

Flow mechanism at the fluid/porous interface, was first studied by Beavers & Joseph [2] and it was observed that the velocity gradient at the interface is proportional to the slip velocity. Rudraiah and Nagaraj [12] studied the fully developed free-convection flow of a viscous fluid through a porous medium bounded by two heated vertical plates. Extensive research work has been carried out in recent years to study the effects of various solid matrix and fluid flow parameters on the free convection in channels partially filled by porous materials. Beckermann et al., [3] examined free convection flow between a fluid and a porous layer in a rectangular enclosure. Singh [15] has studied transient free convective flow between two vertical walls for asymmetric heating when one of the walls is moving with constant velocity. Using Darcy model for momentum transfer, mixed convection on a vertical cylinder embedded in a saturated porous medium is presented by Ramanaiah et al., [11] while momentum transfer based on Brinkman model in a circular cylinder is studied by Pop et al., [10]. Vajravelu et al., [19] studied combined free and forced convection in an inclined channel with permeable boundaries. Sacheti et al., [13] extended the Rudraiah and Nagaraj [12] problem in a rotating system. Convection effects are investigated in an inclined channel with porous substrates at the bounding rigid walls by Chauhan and Soni[4]. Hayat and Ali [7] investigated the peristaltic motion of a Jeffrey fluid under the effect of a magnetic field. Vajravelu et al., [20] discussed the influence of heat transfer on peristaltic transport of a Jeffrey fluid in a vertical porous stratum. Mahmoud et al., [8] studied the effect of porous medium and magnetic field on the peristaltic transport of a Jeffrey fluid in an asymmetric channel. Misra et al., [9] has investigated a mathematical modeling of blood flow in porous vessel having double stenosis in the presence of an external magnetic field. Umesh Gupta et al., [18] studied free convection flow between vertical plates moving in opposite direction and partially filled with porous medium. Turkyilmazoglu and Pop [17] have investigated the flow and heat transfer of a Jeffrey fluid near the stagnation point on a stretching/shrinking sheet with a parallel external flow. Devaki et al., [5] have considered the pulsatile flow of a Jeffrey fluid in a circular tube lined internally with porous material. Akbar et al., [1] has studied the Jeffrey fluid model for the peristaltic flow of chime in the small intestine with magnetic field. Santhosh and Radha krishnamacharya [14] studied a two-fluid model for the flow of Jeffrey fluid in tubes of small diameters. Recently Eldabe et al., [6] studied the peristaltic motion of non-Newtonian fluid with heat and mass transfer through a porous medium in the channel under the effect of magnetic field. Sinha [16] studied the magnetohydrodynamic (MHD) boundary layer flow and heat transfer of a third order fluid flowing in a channel.

In this paper, MHD flow and heat transfer of a Jeffrey fluid in a vertical channel partially filled with porous medium is investigated. The velocity field, the temperature distribution and skin friction at the walls are determined. Such a study may find important applications in the description of blood flow past endothelium layer in an artery and lubricant flow past cartilages which are also modeled as porous layers.

II. MATHEMATICAL FORMULATION

Let us consider the fully developed steady laminar MHD free convective flow of a Jeffrey fluid between two vertical parallel walls partially filled with porous medium and partially filled with a clear fluid when one wall is heated and other is cooled as shown in Figure 1. The *x*-axis is taken along one of the wall and *y* -axis normal to it. The flow in the porous medium is given by Brink men extended Darcy's law whereas the flow in the annulus is described by Jeffrey model. Where $\bar{U}_f$ and $\bar{U}_p$ are the velocities of free fluid region and porous region in the direction of $\bar{x}$ -axis. The temperature is also considered on the walls $\bar{y}=0$ and $\bar{y}=H$ as $\bar{T}_f=\bar{T}_c+A(\bar{T}_h-\bar{T}_c)$ and $\bar{T}_p=\bar{T}_c+B(\bar{T}_h-\bar{T}_c)$ respectively.

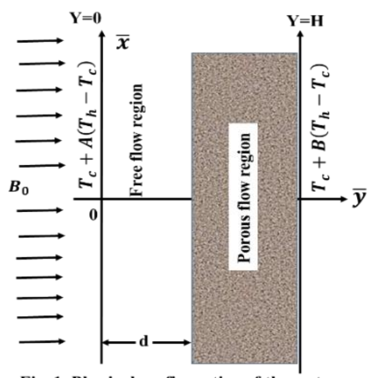

Fig .1 Physical configuration of the system

Under usual Boussinesq approximation, the flow in fluid and porous regions is governed by the following equations of motion and energy are:

Free fluid region:

$$\frac{\mu}{1+\lambda_1}\frac{d^2U_f}{dy^2}+\rho g\beta(\mathrm{T}_f-\mathrm{T}_c)-\sigma B_0^2 U_f=0 \qquad (1)$$

$$K_0\frac{\mu}{1+\lambda_1}\frac{d^2(\mathrm{T}_f-\mathrm{T}_c)}{dy^2}+\frac{\mu}{1+\lambda_1}\left(\frac{dU_f}{dy}\right)^2=0 \qquad (2)$$

Porous region:

$$\frac{\mu}{1+\lambda_1}\frac{d^2U_p}{dy^2}-\frac{\mu}{1+\lambda_1}\frac{U_p}{k}+\rho g\beta(\mathrm{T}_p-\mathrm{T}_c)-\sigma B_0^2 U_p=0 \qquad (3)$$

$$K_0\frac{d^2(\mathrm{T}_p-\mathrm{T}_c)}{dy^2}+\frac{\mu}{1+\lambda_1}\left(\frac{dU_p}{dy}\right)^2-\frac{\mu}{1+\lambda_1}\frac{\left(U_p\right)^2}{k}=0 \qquad (4)$$

The corresponding boundary conditions are

$$\left.\begin{aligned}
&y=0;\ U_f=0\ ,\ T_f=T_f+A\left(T_h-T_c\right)\\
&y=H;\ U_p=0\ ,\ T_p=T_c+B\left(T_h-T_c\right)\\
&y=d;\ U_f=U_p\ ,\ \frac{dU_f}{dy}=\frac{dU_p}{dy}\\
&y=d;\ T_f=T_p\ ,\ \frac{dT_f}{dy}=\frac{dT_p}{dy}
\end{aligned}\right\} \qquad (5)$$

Introducing following non-dimensional quantities:

$$Da=\frac{k}{H^2};\ \bar{y}=\frac{y}{H};\ \bar{\mathrm{d}}=\frac{d}{H};\ \bar{U}_f=\frac{\upsilon U_f}{g\beta H^2\left(T_h-T_c\right)};$$

$$\bar{U}_p=\frac{\upsilon U_p}{g\beta H^2\left(T_h-T_c\right)};\ \theta_f=\frac{\left(T_f-T_c\right)}{\left(T_h-T_c\right)};\ \theta_p=\frac{\left(T_p-T_c\right)}{\left(T_h-T_c\right)}; \qquad (6)$$

$$N=\frac{g^2\beta^2H^4\left(T_h-T_c\right)}{K_0\upsilon},\ M^2=\frac{\sigma B_0^2H^2}{\mu}\quad \bar{\tau}=\frac{\tau\upsilon H}{\mu g\beta H^2\left(\bar{T}_h-\bar{T}_c\right)}$$

In view of the above non-dimensional quantities, the basic equations (1) to (4) and the boundary conditions equation (5) can be expressed in non-dimensional form, dropping bars, as

Fluid region:

$$\frac{1}{1+\lambda_1}\frac{d^2U_f}{dy^2}+\theta_f-M^2U_f=0 \qquad (7)$$

$$\frac{d^2\theta_f}{dy^2}+\frac{N}{\left(1+\lambda_1\right)}\left(\frac{dU_f}{dy}\right)^2=0 \qquad (8)$$

Porous region:

$$\frac{1}{1+\lambda_1}\frac{d^2U_p}{dy^2}-\frac{U_p}{Da\left(1+\lambda_1\right)}+\theta_p-M^2U_p=0 \qquad (9)$$

$$\frac{d^2\theta_p}{dy^2}+\frac{N}{\left(1+\lambda_1\right)}\left(\frac{dU_p}{dy}\right)^2+\frac{N}{Da\left(1+\lambda_1\right)}\left(U_p\right)^2=0 \qquad (10)$$

In equation (9), the momentum transfer in porous domain is described based on Brinkman extended Darcy model, where Da is the Darcy number, d the distance of interface from the plate, g the acceleration due to gravity, H the distance between vertical plates, k the permeability of the porous matrix, K the thermal conductivity, N the buoyancy parameter, β the coefficient of thermal expansion, μ the dynamic viscosity, υ the kinematic viscosity, ρ the density, τ the shear stress and θ is the temperature. The subscripts f represent fluid layer, p the porous layer, h hot plate and c the cold plate.

The boundary and matching conditions (5) in dimensionless form are:

$$\left.\begin{array}{l} y=0\,;U_f=0\,,\ \theta_f=A \\ y=d;U_f=U_p\,,\ \dfrac{dU_f}{dy}=\dfrac{dU_p}{dy} \\ y=1;\quad U_p=0\,,\quad \theta_p=B \\ y=d;\theta_f=\theta_p\,,\ \dfrac{d\theta_f}{dy}=\dfrac{d\theta_p}{dy} \end{array}\right\} \quad (11)$$

where, the matching conditions for velocity are due to continuity of velocity and shear stress at the interface. The continuity of temperature and heat flux at the inter-face has been considered as matching conditions for temperature.

III. SOLUTION OF THE PROBLEM

The governing momentum and energy equations (7) to (10) are coupled partial differential equations that cannot be solved in closed form. It can be observed that problem is non-linear due to viscous and Darcy dissipation terms. This problem can be tackled by using a perturbation method as N is small in most of the practical problems. Accordingly, we assume, for small N, the expansions:

$$\left.\begin{array}{l} U_f=U_{0f}+NU_{1f}+0(\mathrm{N}^2) \\ U_p=U_{0p}+NU_{1p}+0(\mathrm{N}^2) \\ \theta_f=\theta_{0f}+N\theta_{1f}+0(\mathrm{N}^2) \\ \theta_p=\theta_{0p}+N\theta_{1p}+0(\mathrm{N}^2) \end{array}\right\} \quad (12)$$

Substituting (12) in the Equations (7) to (10) gives the quantities $U_{0f}, U_{0P}, \theta_{0f}$ and θ_{0p} are the solutions for N equal to zero i.e., when the viscous and Darcy dissipations are neglected whereas U_{1f}, U_{1p}, θ_{1f}, θ_{1p} are perturbed quantities relative to $U_{0f}, U_{0P}, \theta_{0f}$ and θ_{0p} respectively when the viscous and Darcy dissipations are taken into account.

$$\frac{1}{1+\lambda_1}\frac{d^2U_{0f}}{dy^2}+\theta_{0f}-M^2U_{0f}=0 \quad (13)$$

$$\frac{d^2\theta_{0f}}{dy^2}=0 \quad (14)$$

$$\frac{1}{1+\lambda_1}\frac{d^2U_{1f}}{dy^2}+\theta_{1f}-M^2U_{1f}=0 \quad (15)$$

$$\frac{d^2\theta_{1f}}{dy^2}+\frac{1}{(1+\lambda_1)}\left(\frac{dU_{0f}}{dy}\right)^2=0 \quad (16)$$

$$\frac{1}{1+\lambda_1}\frac{d^2U_{0p}}{dy^2}-\frac{1}{Da(1+\lambda_1)}U_{0p}+\theta_{0p}-M^2U_{0p}=0 \quad (17)$$

$$\frac{d^2\theta_{0p}}{dy^2}=0 \quad (18)$$

$$\frac{1}{1+\lambda_1}\frac{d^2U_{1p}}{dy^2}-\frac{1}{Da(1+\lambda_1)}U_{1p}+\theta_{1p}-M^2U_{1p}=0 \quad (19)$$

$$\frac{d^2\theta_{1p}}{dy^2}+\frac{1}{(1+\lambda_1)}\left(\frac{dU_{0p}}{dy}\right)^2+\frac{1}{Da(1+\lambda_1)}\left(U_{0p}\right)^2=0 \quad (20)$$

The corresponding boundary conditions are

$$\left.\begin{array}{ll} U_{0f}=0 & \theta_{0f}=A \\ U_{1f}=0 & \theta_{1f}=0 \end{array}\right\} \text{ at } y=0$$

$$\left.\begin{array}{ll} U_{0p}=0 & \theta_{0p}=A \\ U_{1p}=0 & \theta_{1p}=0 \end{array}\right\} \text{ at } y=1$$

$$\left.\begin{array}{ll} U_{0f}=U_{0p} & \dfrac{dU_{0f}}{dy}=\dfrac{dU_{0p}}{dy} \\ U_{1f}=U_{1p} & \dfrac{dU_{1f}}{dy}=\dfrac{dU_{1p}}{dy} \end{array}\right\} \text{ at } y=d \quad (21)$$

$$\left.\begin{array}{ll} \theta_{0f}=\theta_{0p} & \dfrac{d\theta_{0f}}{dy}=\dfrac{d\theta_{0p}}{dy} \\ \theta_{1f}=\theta_{1p} & \dfrac{d\theta_{1f}}{dy}=\dfrac{d\theta_{1p}}{dy} \end{array}\right\} \text{ at } y=d$$

Solving the equations (13) to (20) using boundary conditions (21) gives the following velocity and temperature components

$$U_{0f}=c_3e^{b_1y}+c_4e^{-b_1y}+b_2y+b_3\,;$$

$$U_{0p}=a_3e^{b_4y}+a_4e^{-b_4y}+b_5y+b_6\,;$$

$$\theta_{0f}=c_1y+c_2\,;$$

$$\theta_{0p}=a_1y+a_2\,;$$

$$\theta_{1f}=b_{30}e^{2b_1y}+b_{31}e^{-2b_1y}+b_{32}e^{b_1y}+b_{33}e^{-b_1y}+b_{34}y^2+a_5y+a_6 \quad (22)$$

$$U_{1f}=c_5e^{n_1y}+c_6e^{-n_1y}+b_{60}e^{2b_1y}+b_{61}e^{-2b_1y}+b_{62}ye^{b_1y}+b_{63}ye^{-b_1y}+b_{64}y^2+b_{65}y+b_{66}$$

$$U_f=U_{0f}+NU_{1f}$$

$$U_p=U_{0p}+NU_{1p}$$

$$\theta_f=\theta_{0f}+N\theta_{1f}$$

$$\theta_p=\theta_{0p}+N\theta_{1p}$$

IV. SKIN FRICTION

$$\bar{\tau}_f=\mu\frac{dU_f}{dy}\bigg]_{y=0} \quad \text{and} \quad \bar{\tau}_p=\mu\frac{dU_p}{dy}\bigg]_{y=H}$$

Its non-dimensional form, dropping bars

$$\tau_f=\mu\frac{dU_f}{dy}\bigg]_{y=0}=b_{104}+Nb_{105} \text{ and}$$

$$\tau_p=\mu\frac{dU_p}{dy}\bigg]_{y=1}=b_{97}+Nb_{98} \quad (23)$$

V. RATE OF HEAT TRANSFER

Apart from the velocity and temperature distribution in the channel, it is important to determine rate of heat transfer between the plates and the fluid. The rate of heat transfer through the channel wall to the fluid is given by

$$Q = k\left[\frac{dT}{dy}\right]_{y=0,\ y=H}$$

The rate of heat transfer in dimensional form can be written as

$$q = \left[\frac{d\theta}{dy}\right]_{y=0,\ y=1}$$

Based on the analytical solutions reported above, the rate of heat transfer at the walls *y* =0 and y =1 is given by

$$q_f = \left[\frac{d\theta_f}{dy}\right]_{y=0} = a_1 + N\,b_{99} \text{ and}$$

$$q_p = \left[\frac{d\theta_p}{dy}\right]_{y=1} = a_1 + N\,b_{100} \qquad (24)$$

VI. GRAPHICAL RESULTS AND DISCUSSION:

In this paper, the fully developed steady laminar MHD free convective flow of a Jeffrey fluid between two vertical parallel walls partially filled with porous medium and partially filled with a clear fluid when one wall is heated and other is cooled as shown in Figure 1. The governing equations having non- linear nature have been solved by analytical method. Different types of interfacial conditions between a porous medium and fluid layer are analyzed in detail. Three primary regions were found likewise, fluid region (near wall y=*0*), interface region and porous region (near the wall y=1), for the cases when *A*=1, B =0 (plate y=0 is heated and plate *y*=1 is cooled) and A=0, B=1 (plate y=0 is cooled and y=1 is heated). The effect of Darcy number on the flow has been discussed. The effect of Darcy number on the flow has been discussed. The variation of velocity and temperature with y is calculated, from equations (22), for different parameters Da, M and λ_1 for different cases and is shown in Figures (2)-(11) and Table-1.

The variation of velocity and temperature with y is calculated, from equations (13) to (20) and using (21), for different parameters M , Da, λ_1 for different cases, A=1, B=0 and A=0, B=1 and also different width (d=0.3, d=0.5, d=0.7)is shown in Figures. The variation of velocity ($U_f\ or U_p$) with y is calculated, for different values of λ_1 in the case of $A=1, B=0$ for $d=0.3, d=0.5, d=0.7$ is shown in Figure2, for fixed $Da=0.1$ and $M=0.1$, we observe that the velocity increases with the increasing of $\lambda_1 (=0.1, 0.5, 1)$ .The variation of velocity ($U_f\ or U_p$)with y is calculated, for different values of λ_1 in the case of $A=0, B=1$ for $d=0.3$, $d=0.5$, $d=0.7$ is shown in Figure 5, for fixed $Da=0.1$ and $M=0.1$, we observe that the velocity increases with the increasing of $\lambda_1 (=0.1, 0.5, 1)$ .The variation of velocity ($U_f\ or U_p$) with y is calculated, for different values of Da in the case of $A=1, B=0$ for $d=0.3$, $d=0.5$, $d=0.7$ is shown in Figure 3, for fixed $\lambda_1=0.1$ and $M=0.1$, we observe that the velocity increases with the increasing of $Da(=0.1, 0.01, 0.001)$ .The variation of velocity ($U_f\ or U_p$) with y is calculated, for different values of Da in the case of $A=0,\ B=1$ for $d=0.3,\ d=0.5,\ d=0.7$ is shown in Figure 6, for fixed $\lambda_1=0.1$ and $M=0.1$, we observe that the velocity increases with the increasing of Da $(=0.1, 0.01, 0.001)$ .The variation of velocity ($U_f\ or U_p$) with y is calculated, for different values of M in the case of $A=1,\ B=0$ for $d=0.3, d=0.5, d=0.7$ is shown in Figure 4, for fixed $\lambda_1=0.1$ and $Da=0.1$, we observe that the velocity increases with the decreasing of $M(=0.1, 0.12, 0.14)$ .The variation of velocity ($U_f\ or U_p$) with y is calculated, for different values of M in the case of $A=0,\ B=1$ for $d=0.3, d=0.5, d=0.7$ is shown in Figure 7, for fixed $\lambda_1=0.1$ and $Da=0.1$, we observe that the velocity increases with the decreasing of $M(=0.1, 0.12, 0.14)$ .The variation of temperature ($\theta_f\ or\ \theta_p$) with y is calculated, for different values of λ_1 in the case of $A=1, B=0$ for $d=0.3, d=0.5, d=0.7$ is shown in Figure8,for fixed $Da=0.1$ and $M=0.1$, weobservethat the temperature increases with the increasing of $\lambda_1\ (=0.1, 0.5, 1)$ .The variation of temperature ($\theta_f\ or\ \theta_p$) with y is calculated, for different values of λ_1 in the case of $A=0, B=1$ for $d=0.3, d=0.5, d=0.7$ is shown in Figure10, for fixed $Da=0.1$ and $M=0.1$, we observe that the temperature increases with the increasing of $\lambda_1\ (=0.1, 0.5, 1)$ .The variation of temperature (θ) with y is calculated, for different values of M in the case of $A=1, B=0$ for $d=0.3, d=0.5, d=0.7$ is shown in Figure9, for fixed $Da=0.1$ and $\lambda_1=0.1$, we observe that the temperature increases with the decreasing of $M\ (=0.1, 0.12, 0.14)$ .The variation of temperature ($\theta_f\ or\ \theta_p$) with y is calculated, for different values of M in the case of $A=0, B=1$ for $d=0.3, d=0.5, d=0.7$ is shown in Figure9, for fixed $Da=0.1$ and $\lambda_1=0.1$, we observe that the temperature increases with the decreasing of $M\ (=0.1, 0.12, 0.14)$.

The values of skin-friction and rate of heat transfer on the walls y=0 and y=1are given in TABLE.1. It is clear that skin-friction increases on the both walls with increasing magnetic parameter, non-Newtonian Jeffrey parameter, width *d* and Darcy number. The interchange of temperatures at the walls also expresses the same behavior with respect to skin-friction on both the walls. Further it is clear that rate of heat transfer increases on both the walls with increasing non-Newtonian Jeffrey parameter, Darcy number and width *d*. We infer that the increase impermeability, width of the porous layer and Darcy number enhances rate of heat transfer in the channel. The interchange of temperatures at the walls expresses the same behavior with respect to rate of heat transfer on both the walls.

TABLE.1: Values of skin-friction $\left(|\tau_f|, |\tau_p|\right)$ and rate of heat transfer $\left(|q_f|, |q_p|\right)$ for different values of magnetic parameter (M) non-Newtonian Jeffrey parameter (λ_1) and Darcy parameter *Da* with effect of width of the channel *d* and interchange of walls temperature (*A* =1, *B* =0 and *A* =0, *B* =1)

				A=1 B=0			
M	λ_1	**Da**	**d**	$\|\tau_f\|$	$\|\tau_p\|$	$\|q_f\|$	$\|q_p\|$
0.1	0.1	0.1	0.3	0.749	0.2852	12.835	3.4416
			0.5	1.4877	0.7071	19.363	7.7877
			0.7	2.2932	1.4897	23.721	14.311
0.12	0.5	0.01	0.3	0.4812	0.0368	7.0851	2.4268
			0.5	1.0241	0.0841	10.922	4.9742
			0.7	1.7482	0.2705	13.498	8.807
0.14	1	0.001	0.3	0.4182	0.0037	3.8414	1.8544
			0.5	0.8749	0.0068	6.1605	3.3868
			0.7	1.4835	0.0116	7.7285	5.6999
				A=0 B=1			
M	λ_1	**Da**	**d**	$\|\tau_f\|$	$\|\tau_p\|$	$\|q_f\|$	$\|q_p\|$
0.1	0.1	0.1	0.3	0.5685	0.4424	14.880	1.4495
			0.5	1.2987	0.8615	21.399	5.7999
			0.7	2.1055	1.6475	25.736	12.319
0.12	0.5	0.01	0.3	0.2626	0.1569	9.1868	0.4447
			0.5	0.7636	0.2036	13.022	3.0074
			0.7	1.4788	0.3897	15.558	6.8392
0.14	1	0.001	0.3	0.1623	0.0634	5.971	0.1228
			0.5	0.5402	0.0661	8.2939	1.4313
			0.7	1.1197	0.071	9.8208	3.7497

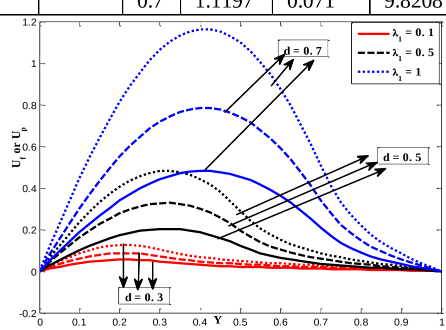

Figure 2: Velocity profiles (U_f *or* U_p) for different values of λ_1 , with the difference of width of the flow region, at walls temperature A=1 and B=0.

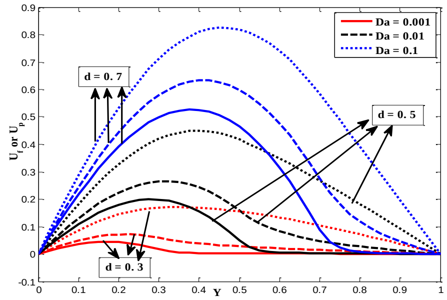

Figure 3: Velocity profiles (U_f *or* U_p) for different values of Da , with the difference of width of the flow region, at walls temperature A=1 and B=0.

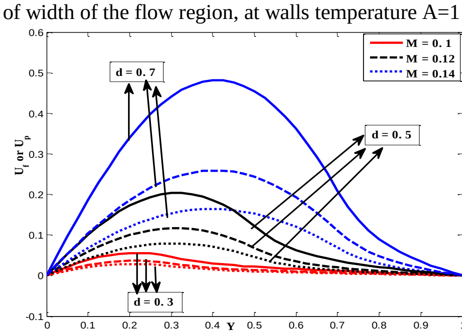

Figure 4: Velocity profiles (U_f *or* U_p) for different values of M , with the difference of width of the flow region, at walls temperature A=1 and B=0.

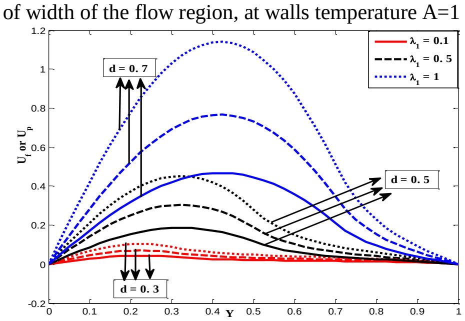

Figure 5: Velocity profiles (U_f *or* U_p) for different values of λ_1 , with the difference of width of the flow region, at walls temperature A=0 and B=1.

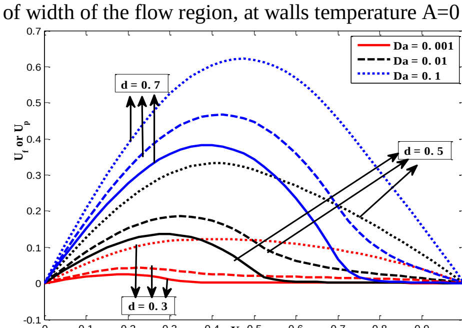

Figure 6: Velocity profiles (U_f *or* U_p) for different values of Da , with the difference of width of the flow region, at walls temperature A=0 and B=1.

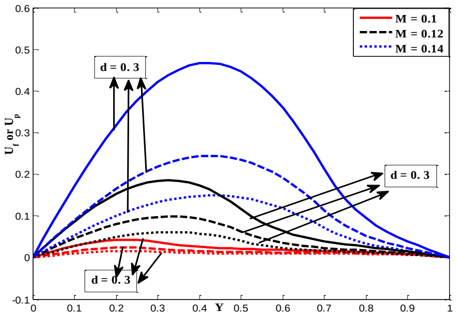

Figure 7: Velocity profiles (U_f or U_p) for different values of M , with the difference of width of the flow region, at walls temperature A=0 and B=1.

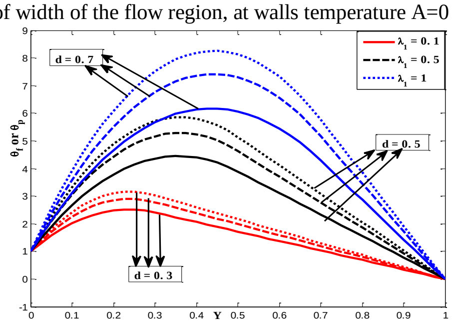

Figure 8: Temperature profiles (θ_f or θ_p) for different values of λ_1 , with the difference of width of the flow region,atwalls temperature A=1 and B=0.

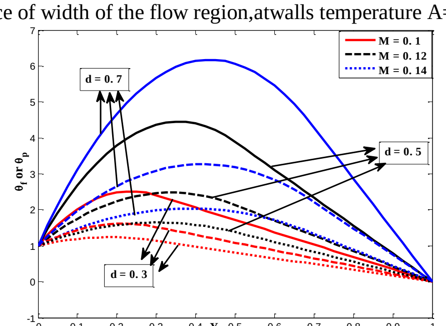

Figure 9: Temperature profiles (θ_f or θ_p) for different valuesof M , with the difference of width of the flow region,at walls temperature A=1 and B=0.

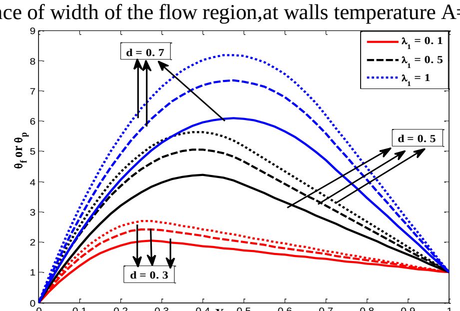

Figure 10: Temperature profiles (θ_f or θ_p) for different values of λ_1 , with the difference of width of the flow region,at walls temperature A=0 and B=1.

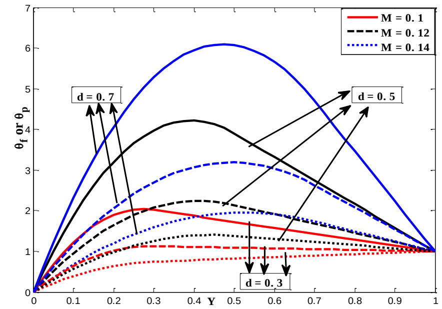

Figure 11: Temperature profiles (θ_f or θ_p) for different values of M , with the difference of width of the flow region,at walls temperature A=0 and B=1.

VII. CONCLUSIONS

Analytical investigate laminar MHD free convective flow of a Jeffrey fluid between two vertical parallel walls partially filled with porous medium and partially filled with a clear fluid when one wall is heated and other is cooled. . The momentum transfer in the porous medium has been described by the Brinkman extended Darcy model. The fluid flow in the free region is governed by Jeffrey model.

- The governing equations having non- linear nature have been solved by analytical method and different types of interfacial conditions between a porous medium and free fluid layer are used.
- We conclude that the velocity increases with increase of λ_1, *Da*, for the cases when *A*=1, B =0 (plate y=0 is heated and plate *y*=1 is cooled) and A=0, B=1 (plate y=0 is cooled and y=1 is heated).
- It is noticed that the velocity increases with decrease of M , for the cases when *A*=1, B =0 (plate y=0 is heated and plate *y*=1 is cooled) and A=0, B=1 (plate y=0 is cooled and y=1 is heated).
- It is obtained that the temperature increases with increasing of λ_1 and the opposite behavior is observed for the parameter value of M for the both the cases when *A*=1, B =0 (plate y=0 is heated and plate *y*=1 is cooled) and A=0, B=1 (plate y=0 is cooled and y=1 is heated).

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