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RESEARCH ARTICLE

HEAT AND MASS TRANSFER OF AN UNSTEADY MHD PERISTALTIC FLOW IN A POROUS MEDIUM WITH CROSS DIFFUSION EFFECT

Panneerselvi, R.*, Selvameena, N. and Sheebarani, N.

Department of Mathematics, PSGR Krishnammal College for Women,Coimbatore, Tamil Nadu.

ABSTRACT

In this work the significance of Cross Diffusion effect on unsteady MHD peristaltic flow in a porous medium with heat and mass transfer is investigated. The governing partial differential equations are transformed into dimensionless equations by using dimensionless quantities. Stream function, velocity, temperature, concentration, skin friction, Nusselt number and Sherwood number are obtained. The results are discussed for various emerging parameters encountered in the problem under investigation. The importance of main parameters on the present study is explained graphically.

Keywords: Cross diffusion, Reynolds number, Peristaltic flow, Stream function, Eckert number.

1. INTRODUCTION

The heat and mass transfer of an unsteady MHD flow attracted by the researchers, because it is most useful to many fields such as production process, chemical-engineering application of a physical and the peristaltic flow used in pump and other mechanical systems.The most important mechanism of fluid transport is peristalsis and it is formed by the propagation of a peristaltic wave on the channel walls.

Influence of wall flexibility and cross diffusion on the peristaltic transport of a MHD dissipative fluid in the presence of Joule heating are presented by Sucharitha, G. et al [1]. The effects of MHD couple stress fluid in peristaltic flow with the porous medium under the impact of slip, heat transfer and wall properties attempted by Sankad, G. C. and Nagathan, P.S. [2]. The heat and mass transfer effects on MHD flow of a steady viscous incompressible and electrically conducting fluid through a non-isothermal parallel flat wall the presence of Soret effect is investigated by Panneerselvi, R. and Subhasree, D. [3]. Raju, C.S.K.et al [4] analyzed the steady two dimen- sional flow over a vertical stretching surface in presence of aligned magnetic field, cross diffussion and radiation effect.

The influence of heat transfer on the peristaltic flow of a conducting PHAN-THIEN-TANNER fluid in an asymmetric channel with porous medium is studied by Vajravelu, K. et al [5]. Jayachandra Babu, M. and Sandeep, N.[6] studied the presence of cross-diffusion effects on MHD non-newtonian fluid flow over a slandering sheet by viewing velocity slip. The effect of heat transfer and elasticity of flexible walls in swallowing food bolus through the oesophasus supposed to be jeffrey fluid is analyzed by Arun Kumar, M. et al [7]. Dheia, G. and Salih Al-Khafajy [8] constructed a mathematical model is constructed to study the effect of heat transfer and elasticity of flexible walls with the porous medium. The effect of heat transfer and inclined magnetic field on the peristaltic flow of williamson fluid in an asymmetric channel through porous medium is investigated by Ramesh, K. and Devakar, M. [9]. The effects of both wall slip conditions and heat transfer on the MHD peristaltic flow of a Maxwell fluid in a porous planar channel with elastic wall properties have been studied by Kalidas Das, [10].

Keeping in mind the importance of heat and mass transfer of an MHD Peristaltic fluid with cross diffusion effects in porous medium under the influence of inclined magnetic field, we have gone for a detailed study. The stream function is used to solve governing coupled non-liner partial differential equations.

2. MODELLING OF THE PROBLEM

In this, the peristaltic transport of a viscous fluid in a two dimensional porous channel between two elastic walls is considered. The flow is generated by a peristaltic wave propagated along the elastic walls of the channel with a

*Correspondence: Panneerselvi, R., Department of Mathematics, PSGR Krishnammal College for Women, Coimbatore, Tamil Nadu,India.

constant speed c. Here, Joule heating diffusion and dissipation effects are considered. The dimensional of the uniform channel flow in a porous medium is given as the width of the uniform channel 2d, wave amplitude a. the angle of inclined magnetic field is taken as α, $\bar{x}$ is the axial coordinate and $\bar{y}$ is normal to it.

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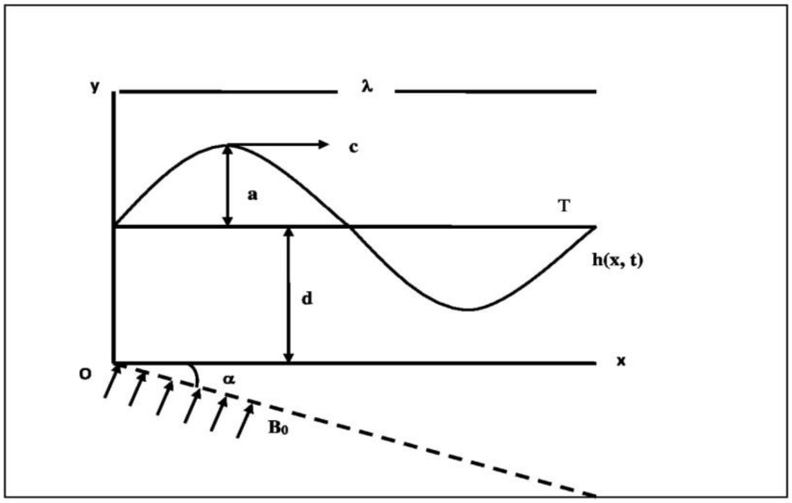


Fig. 1.Configuration of the Problem

The geometry of the surface wall is given as,

$$\bar{h}(\bar{x},\bar{t}) = a \sin \frac{2\pi}{\lambda}(\bar{x} - c\bar{t}) + d \quad (1)$$

Consider the motion of the elastic wall as,

$$L(\eta) = p - p_0 \quad (2)$$

Here L denotes the flexible wall motion with viscosity damping force is given by,

$$L = -\tau \frac{\partial^3 \eta}{\partial x^3} + m \frac{\partial^3 \eta}{\partial x \partial t^2} + C \frac{\partial^2 \eta}{\partial x \partial t} \quad (3)$$

Where

τ – the elastic tension in the wall

m – the mass per unit area

C – the coefficient of the viscous damping force

As per the assumption for this work, the governing equations and boundary conditions can be obtained as

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (4)$$

$$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y}\right) = -\frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) - \mu\frac{u}{k} - \sigma u B_0^2 \cos^2 \alpha$$
$$+ \rho g \beta (T - T_0) + \rho g \beta' (C - C_0) \quad (5)$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right) \quad (6)$$

$$\rho\phi\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=\mu\left(\frac{\partial u}{\partial y}\right)^2+k\left(\frac{\partial^2 T}{\partial y^2}\right)+\frac{D_m k_T}{C_s C_p}\left(\frac{\partial^2 C}{\partial y^2}\right)+\sigma B^2 u^2\cos^2\alpha \quad (7)$$

$$\left(\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}\right)=D_m\left(\frac{\partial^2 C}{\partial y^2}\right)+\frac{D_m K_T}{C_p}\left(\frac{\partial^2 T}{\partial y^2}\right) \quad (8)$$

Here, the fluid velocities are u and v along x and y axis. As the plane is symmetrical, the normal velocity is zero. Here ρ,μ denotesthefluiddensityandthecoefficient of viscosity of the fluid. Also p, T, C, σ represents the pressure, the temperature of the fluid, the concentration of the fluid and the electrical conductivity of the fluid.

Appropriate boundary conditions are given as follows,

$$\frac{\partial u}{\partial y}=0,\quad \frac{\partial^3 u}{\partial y^3}=0,\frac{\partial T}{\partial y}=0,\frac{\partial C}{\partial y}=0,\text{ at y=0} \quad (9)$$

$$\frac{\partial^2 u}{\partial y^2}=0,\quad T=T_0,\ C=C_0,\text{ at y=h} \quad (10)$$

$$\frac{\partial^2 u}{\partial y^2}-\left(M^2\cos^2\alpha+\frac{1}{k}\right)u-\left(E_1\frac{\partial^3\eta}{\partial x^3}+E_2\frac{\partial^3\eta}{\partial x\partial t^2}+E_3\frac{\partial^2\eta}{\partial x\partial t}\right)=0\text{ ,at y=}\eta(x,t) \quad (11)$$

From Mittra and Prasad [5], the dynamic boundary conditions are given as,

$$\frac{\partial}{\partial x}L(\eta)=-\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)-\frac{\sigma u B_0^2\cos^2\alpha}{1+m^2\cos^2\alpha}\text{ , at y= }\eta(x,t) \quad (12)$$

Where $\frac{\partial}{\partial x}L(\eta)=\frac{\partial p}{\partial x}=-\tau\frac{\partial^3\eta}{\partial x^3}+m\frac{\partial^3\eta}{\partial x^3}+C\frac{\partial^3\eta}{\partial x\partial t}$

The dimensionless parameters used are,

$x\lambda=\bar{x}$, $yd=\bar{y}$, $\psi cd=\bar{\psi}$, $uc=\bar{u}$, $vc=\bar{v}$, $p=\frac{\partial^2\bar{p}}{\mu c\lambda}$, $\tau_{xy}=\frac{d\bar{\tau}_{xy}}{\mu c}$, $\frac{c\bar{t}}{\lambda}$, $\delta=\frac{d}{\lambda}$,

$$\varepsilon=\frac{a}{d},\ \mathrm{Re}=\frac{\rho cd}{\mu},\ \theta=\frac{T-T_0}{T-T_0},\phi=\frac{C-C_0}{C-C_0},Sc=\frac{v}{D_m},Sr=\frac{D_m K_T(C_1-C_0)}{\mu C_p C_s(T_1-T_0)},M=\sqrt{\frac{\sigma}{\mu}}B_0,$$

$$\Pr=\frac{\rho v c_f}{K_0},Ec=\frac{c^2}{c_f(T_1-T_0)},Du=\frac{D_m K_T(C_1-C_0)}{\mu C_p C_s(T_1-T_0)},E_1=\frac{-\tau d^3}{\lambda^3\mu c},E2=\frac{mcd^3}{\lambda^3\mu},E_3=\frac{cd^3}{\lambda^2\mu},$$

$$h=\frac{\bar{h}}{d}=(\varepsilon\sin 2\pi(x-t)+1),Gr=\frac{vg\beta(T_w-T_\infty)}{c^2},Gm=\frac{vg\beta(C_w-C_\infty)}{c^2}$$

Non-dimensional variables are introduced in the equations (4) – (8), after dropping the primes, we get,

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{14}$$

$$\operatorname{Re}\delta\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial p}{\partial x}+\left(\delta^2\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)-\frac{u}{k}-M^2\cos^2\alpha u+\operatorname{Re}Gr\theta+Gm\phi \tag{15}$$

$$\operatorname{Re}\delta\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial p}{\partial y}+\delta^2\left(\delta^2\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right) \tag{16}$$

$$\operatorname{Re}\delta\left(\frac{C_1-C_0}{C_1-C_0}\right)\Pr\left(v\frac{\partial\theta}{\partial y}\right)=Ec\Pr\left(\frac{\partial u}{\partial y}\right)^2+\left(\frac{\partial^2\theta}{\partial y^2}\right)+Du\Pr\left(\frac{\partial^2\phi}{\partial y^2}\right)+M^2\cos^2\alpha u\Pr Ec \tag{17}$$

$$\operatorname{Re}\delta\left(v\frac{\partial\phi}{\partial y}\right)=\frac{1}{sc}\left(\frac{\partial^2\phi}{\partial y^2}\right)+Sr\left(\frac{\partial^2\theta}{\partial y^2}\right) \tag{18}$$

The relevant boundary conditions are,

$$\frac{\partial u}{\partial y}=0,\frac{\partial^3 u}{\partial y^3}=0, \quad \text{at y=0} \tag{19}$$

$$\frac{\partial^2 u}{\partial y^2}=0, \quad \text{at } y=\eta(x,t)=(1+\varepsilon\sin 2\pi(x-t)) \tag{20}$$

$$-\operatorname{Re}\delta\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)+\left(\delta^2\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)-\frac{u}{k}-M^2\cos^2\alpha u+\operatorname{Re}Gr\theta+\operatorname{Re}Gm\phi$$

$$=\left(E_1\frac{\partial^3\eta}{\partial x^3}+E_2\frac{\partial^3\eta}{\partial x\partial t^2}+E_3\frac{\partial^2\eta}{\partial x\partial t}\right), \text{at } y=\eta(x,t) \tag{21}$$

3. METHOD OF SOLVING THE PROBLEM

Considering the wavelength of the peristaltic wave to be large and the Reynolds number to be small, equation (14) – (18) reduces to the form

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{22}$$

$$\frac{\partial p}{\partial x}=\frac{\partial^2 u}{\partial y^2}-\left(\frac{1}{k}+M^2\cos^2\alpha\right)u \tag{23}$$

$$\frac{\partial p}{\partial y}=0 \tag{24}$$

$$\frac{\partial^2\theta}{\partial y^2}+Br\left(\left(\frac{\partial u}{\partial y}\right)^2+M^2u^2\cos^2\alpha\right)+\Pr Du\left(\frac{\partial^2\phi}{\partial y^2}\right)=0 \tag{25}$$

$$\frac{\partial^2 \phi}{\partial y^2} + ScSr\left(\frac{\partial^2 \theta}{\partial y^2}\right) = 0 \qquad (26)$$

By introducing the stream function,

$$u = \frac{\partial \psi}{\partial y}, v = -\frac{\partial \psi}{\partial x}$$

The equations (22) – (26) becomes,

$$\frac{\partial p}{\partial x} = \frac{\partial^3 \psi}{\partial y^3} - \left(\frac{1}{k} + M^2 \cos^2 \alpha\right)\frac{\partial \psi}{\partial y} \qquad (27)$$

$$\frac{\partial p}{\partial y} = 0 \qquad (28)$$

$$\frac{\partial^2 \theta}{\partial y^2} + Br\left(\left(\frac{\partial^2 \psi}{\partial y^2}\right)^2 + M^2 \cos^2 \alpha \left(\frac{\partial \psi}{\partial y}\right)^2\right) + \Pr Du\left(\frac{\partial^2 \phi}{\partial y^2}\right) = 0 \qquad (29)$$

$$\frac{\partial^2 \phi}{\partial y^2} + ScSr\left(\frac{\partial^2 \theta}{\partial y^2}\right) = 0 \qquad (30)$$

and the corresponding boundary conditions are obtained as,

$$\frac{\partial^2 \psi}{\partial y^2} = \frac{\partial \theta}{\partial y} = \frac{\partial \phi}{\partial y} = 0, \text{ at } y=0 \qquad (31)$$

$$\frac{\partial \psi}{\partial y} = 0, \theta = 0, \phi = 1, \text{ at } h = (\varepsilon \sin 2\pi(x-t)+1) \qquad (32)$$

$$\frac{\partial^3 \psi}{\partial y^3} - \left(\frac{1}{k} + M^2 \cos^2 \alpha\right)\frac{\partial \psi}{\partial y} - \left(E_1 \frac{\partial^3 h}{\partial x^3} + E_2 \frac{\partial^3 h}{\partial x \partial t^2} + E_3 \frac{\partial^2 h}{\partial x \partial t}\right) = 0, \text{ at } y = h \qquad (33)$$

∂y $\quad 3\,\overline{\partial x \partial t}$

By differentiating equation (27) with respect to y, weget,

$$\frac{\partial^4 \psi}{\partial y^4} - \left(\frac{1}{k} + \frac{M^2 \cos^2 \alpha}{1 + m^2 \cos^2 \alpha}\right)\frac{\partial^2 \psi}{\partial y^2} = 0, \qquad (34)$$

By solving the equations (29), (30) and (34), with boundary conditions (31), (32) and (33). We attain the stream function and the velocity, the temperature and the concentration,

$$\psi = \frac{c_1}{p}\left(\frac{\sinh\left(\sqrt{p}\,y\right)}{\sqrt{p}\cosh\left(\sqrt{p}\,h\right)}\right) - y \qquad (35)$$

$$u = \frac{\partial \psi}{\partial y} = \frac{c_1}{p}\left(\frac{\cosh\left(\sqrt{p}\,y\right)}{\cosh\left(\sqrt{p}\,h\right)} - 1\right) \qquad (36)$$

$$\theta = \frac{-Brc_1^2}{(1 - SrSc\Pr Du)p\left(\cosh\sqrt{p}h\right)^2}\left(\frac{\left(\cosh\sqrt{p}y\right)^2}{4p}\left(\frac{M^2}{p}+1\right)+\frac{y^2}{4}\left(\frac{M^2}{p}-1\right)\right)$$

$$+\frac{M^2}{p}\left(\frac{\left(\cosh\sqrt{p}h\right)^2 y^2}{2}\right)-\frac{2\cosh\sqrt{p}h}{p}\left(\cosh\sqrt{p}y\right)+A \qquad (37)$$

$$\phi = \frac{ScSrBrc_1^2}{(1 - SrSc\Pr Du)p\left(\cosh\sqrt{p}h\right)^2}\left(\frac{\left(\cosh\sqrt{p}y\right)^2}{4p}\left(\frac{M^2}{p}+1\right)+\frac{y^2}{4}\left(\frac{M^2}{p}-1\right)\right)$$

$$+\frac{M^2}{p}\left(\frac{\left(\cosh\sqrt{p}h\right)^2 y^2}{2}\right)-\frac{2\cosh\sqrt{p}h}{p}\left(\cosh\sqrt{p}y\right)+B \qquad (38)$$

Skin friction, Nusselt number and Sherwood number at the wall are defined by,

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=h}$$

$$\tau = \frac{c_1}{\sqrt{p}}\left(\frac{\sinh\sqrt{p}h}{\cosh\sqrt{p}h}\right)$$

$$Nu = -\left(\frac{d\theta}{dy}\right)_{y=h}$$

$$Nu = \frac{Brc_1^2}{(1 - ScSr\Pr Du)p\left(\cosh\sqrt{p}h\right)^2}\left(\frac{\left(\sinh\sqrt{p}h\right)^2}{2\sqrt{p}}\left(1+\frac{M^2\cos^2\alpha}{p}\right)+\frac{h}{2}\left(\frac{M^2\cos^2\alpha}{p}-1\right)\right)$$

$$+\frac{M^2\cos^2\alpha}{p}\left(\left(\cosh\sqrt{p}h\right)^2 h-\frac{2\cosh\sqrt{p}h}{\sqrt{p}}\sinh\sqrt{p}h\right)$$

$$Sh = -\left(\frac{d\phi}{dy}\right)_{y=h}$$

$$Sh = -\frac{SrScBrc_1^2}{(1 - ScSr\Pr Du)p\left(\cosh\sqrt{p}h\right)^2}\left(\frac{\left(\sinh\sqrt{p}h\right)^2}{2\sqrt{p}}\left(1+\frac{M^2\cos^2\alpha}{p}\right)+\frac{h}{2}\left(\frac{M^2\cos^2\alpha}{p}-1\right)\right)$$

$$+\frac{M^2\cos^2\alpha}{p}\left(\left(\cosh\sqrt{p}h\right)^2 h-\frac{2\cosh\sqrt{p}h}{\sqrt{p}}\sinh\sqrt{p}h\right)$$

Where,

$$c_1 = -8\varepsilon\pi^3\left((E_1+E_2)\cos 2\pi(x-t) - \frac{E_3}{2\pi}\sin 2\pi[x-t]\right)$$

$$p = \frac{1}{k} + M^2\cos^2\alpha$$

$$A = 1 + \frac{-Brc_1^2}{(1-SrSc\Pr Du)p(\cosh\sqrt{p}h)^2}\left(\frac{(\cosh\sqrt{p}y)^2}{4p}\left(\frac{M^2}{p}+1\right) + \frac{y^2}{4}\left(\frac{M^2}{p}-1\right)\right)$$

$$+\frac{M^2}{p}\left(\frac{(\cosh\sqrt{p}h)^2 y^2}{2}\right) - \frac{2\cosh\sqrt{p}h}{p}(\cosh\sqrt{p}y)$$

$$B = 1 - \frac{ScSrBrc_1^2}{(1-SrSc\Pr Du)p(\cosh\sqrt{p}h)^2}\left(\frac{(\cosh\sqrt{p}y)^2}{4p}\left(\frac{M^2}{p}+1\right) + \frac{y^2}{4}\left(\frac{M^2}{p}-1\right)\right)$$

$$+\frac{M^2}{p}\left(\frac{(\cosh\sqrt{p}h)^2 y^2}{2}\right) - \frac{2\cosh\sqrt{p}h}{p}(\cosh\sqrt{p}y)$$

4. RESULTS AND DISCUSSION

Theimpactofrelevantparameterontheflowcharacteristicsareproduced withthehelpofgraphs.Inthisstudy,weusedthefixedvaluesofvariousparameters as x = 0.01, t = 0.01, s = 0.2, E_1 = 0.2, E_2 = 0.2, E_3 = 0.1, Pr = 0.71, Br = 0.2,Sc= 0.22, Sr = 0.2, Du = 0.2, m = 0.2, n = 0.5.

Thevelocityprofilefordifferentamplitudeparameters(s)isshowninfigure 2. It is clear from the figure that the velocity profile increases in (s) has increasing function andthevelocityprofileforvariousmagneticparameters(M)isshown in figure3.ItisnoticedthevelocityprofileisdecreasingwithincreasingMagneticparameter(M).

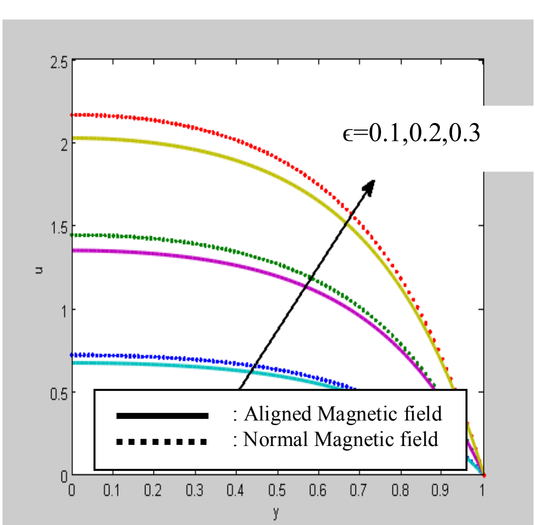


Fig. 2. Velocity Profiles for different ε

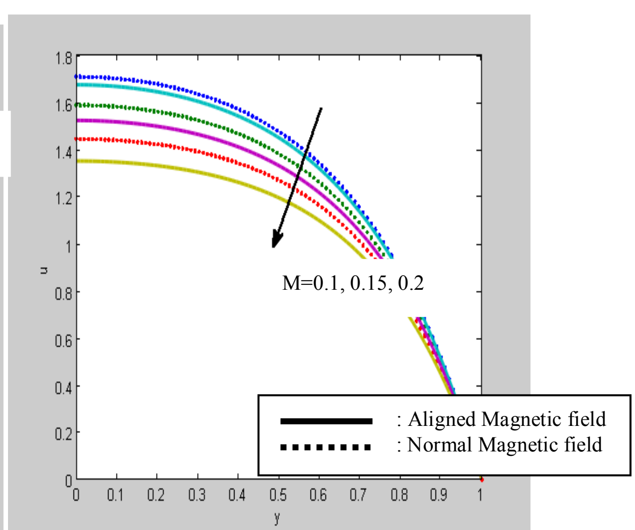
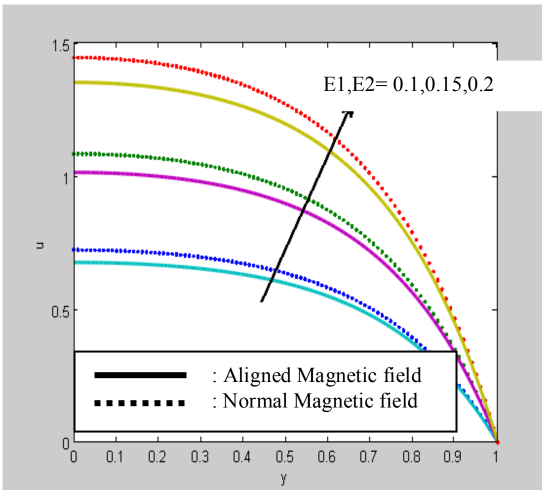


Fig. 3. Velocity Profiles for various M

Thevelocityprofilefordistinct Elasticityparameters(E_1,E_2)isshown infigure4anditisalsoclearthatthevelocityprofileincreaseswithincreasingwall tension(E_1)andmasscharacterization(E_2).

Thevelocityprofileforvariouspermeability parameter (k) increases and is shown in figure5.



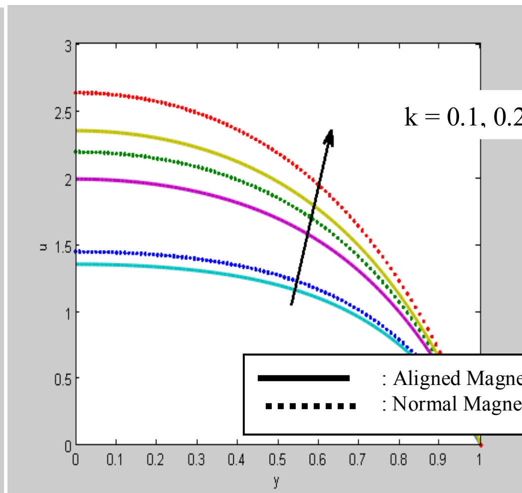
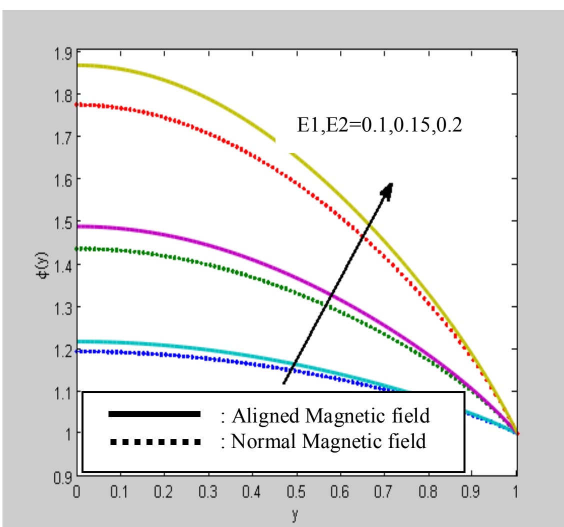


Fig.4. Velocity Profiles for distinct E1,E2Fig. 5. Velocity Profiles for different k

ThetemperatureprofilefordifferentElasticityparameters(E_1,E_2)isshown infigure6andthisfigureshowsthatenhancesofwalltension(E_1)andmasscharacterization(E_2)increasesthetemperatureprofile.Thetemperatureprofilefordistinct Dufour number (Du) is shown in figure 7. It describes that, the rising values of crossdiffusionbooststhethermalfield.



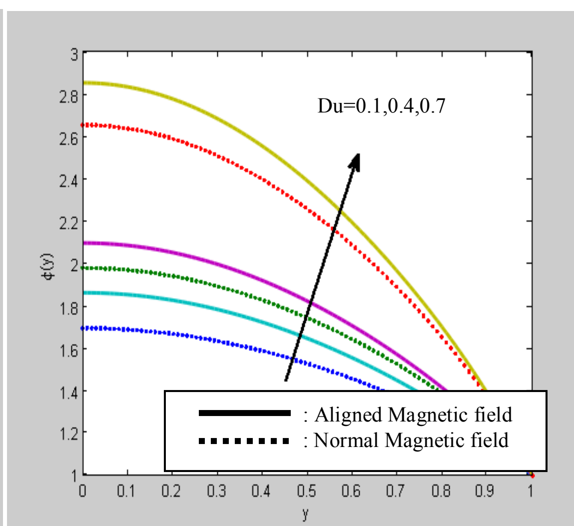
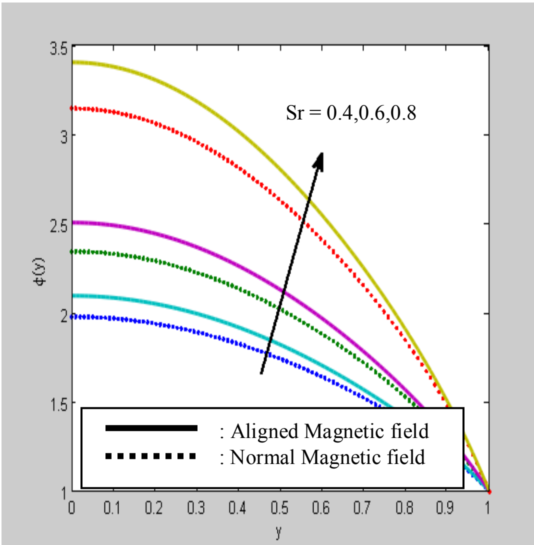


Fig.6. Temperature Profiles E1,E2Fig. 7. Temperature Profiles for distinct Du

Thetemperatureprofilefordifferentvalues ofSoretnumber(Sr)andBrinkmannnumber(Br)areshownthroughfigures8and 9. It is explained clearly from the figure that temperature profile is enhanced with the increase in these two parameters.



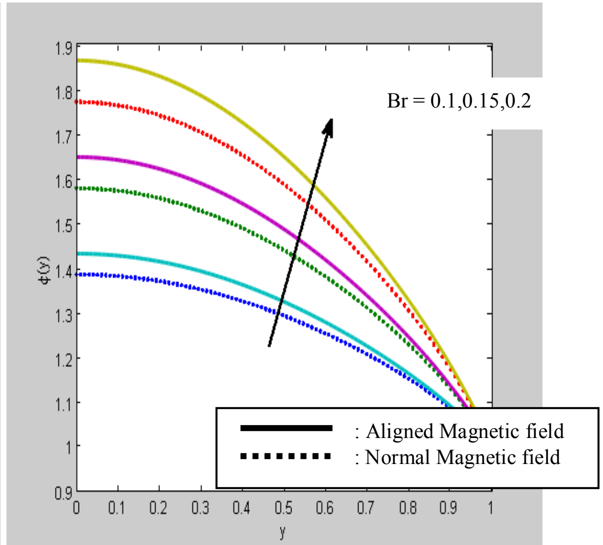
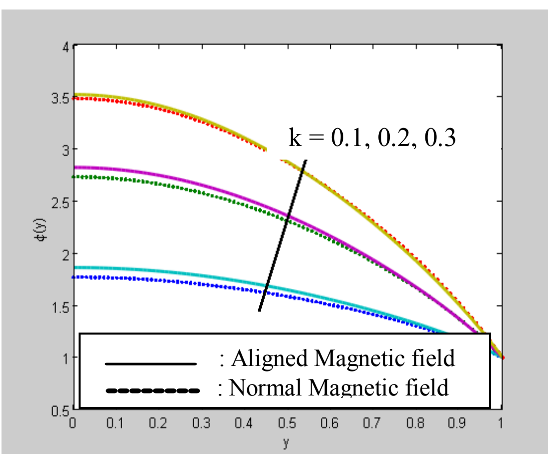


Fig. 8. Temperature Profiles for different SrFig.9. Temperature Profiles for Br

The temperature profile for different permeability parameter (k) is shown in figure 10 respectively. It is clear that raising the values of k increases the temperatureprofile.The concentration profiles for various Elasticity parameters (E_1, E_2) is showninfigure11andisshowsthatincreasingwalltension(E_1)andmasscharacterization(E_2)reducestheconcentrationprofile.



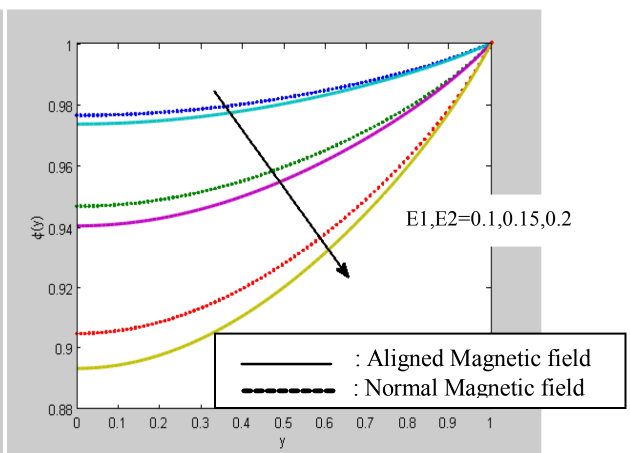
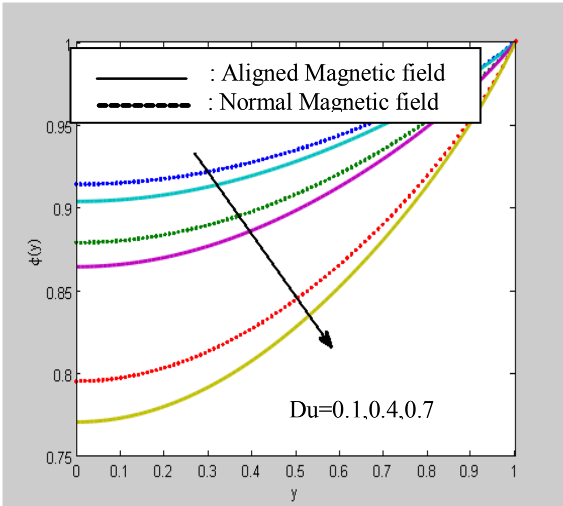


Fig.10. Temperature profiles for distinct k **Fig.11. Concentration Profiles for E1,E2**

Theconcentrationprofileforvarious Dufournumber(Du)isshowninfigure12.Itisclearthattheconcentrationprofile suppresses the filed with the increase in Dufour number. The concentration profile forvariousSoretnumber(Sr)isshowninfigure13.Itisunderstoodfromthefigure that,theconcentrationprofiledecreaseswiththeincreaseinSoretnumber.



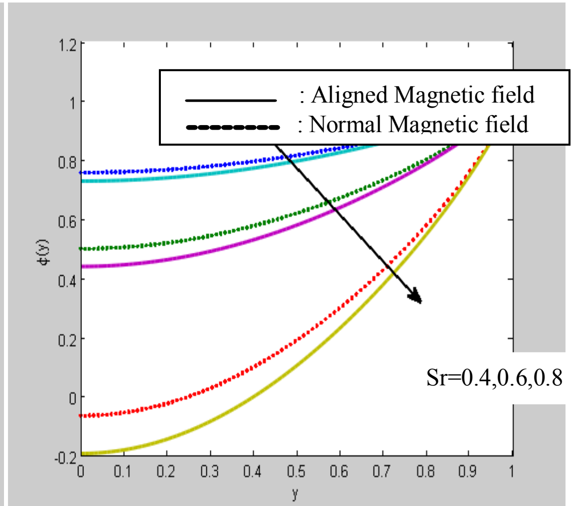
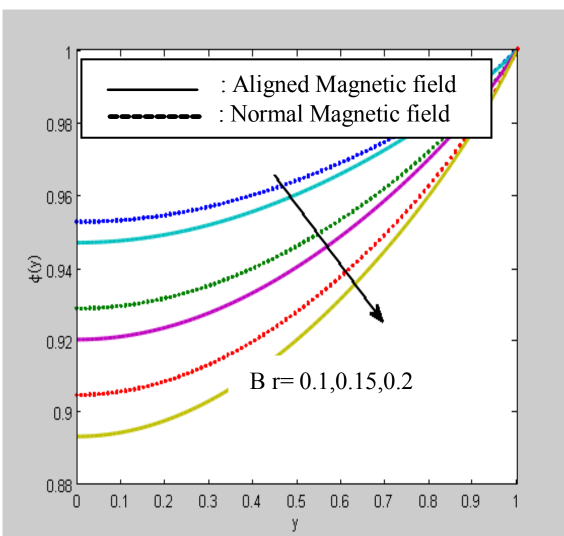


Fig. 12. Concentration Profiles for Du Fig. 13. Concentration Profiles for Sr

Inconcentrationprofile,decreasingvaluesofBrinkmannumber(Br)declinestheconcentration profileandshownthroughfigure14.Theconcentrationprofilefordifferentpermeability parameter (k) is shown through figure 15. It is noticed that, for bothcases concentration profiledecreases.



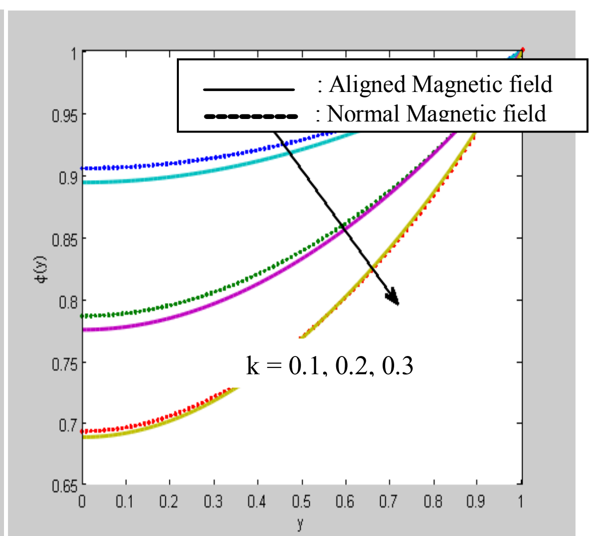
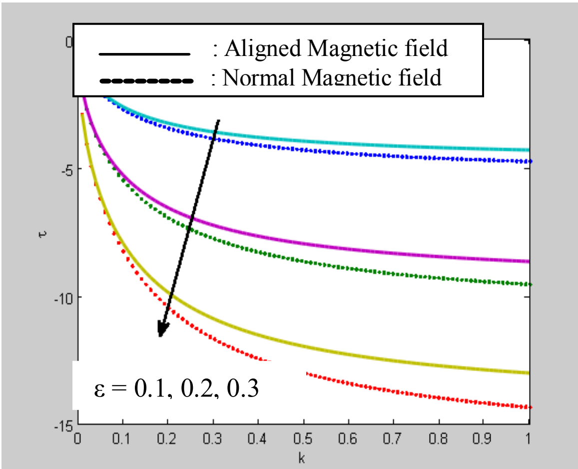


Fig. 14. Concentration Profiles for BrFig. 15. Concentration profiles for different k

TheSkinfrictioncoefficientforvarious(s)isshowninfigure16.Itisclear tonoticethattheriseoftheseparametersdecreasestheSkinfrictioncoefficient. The nature of Nusselt number for distinct values of Du, Sr, Br and m is shownthroughfigure17tofigure19.Itisnoticedthat,increaseintheseparameters enhances Nusseltnumber.



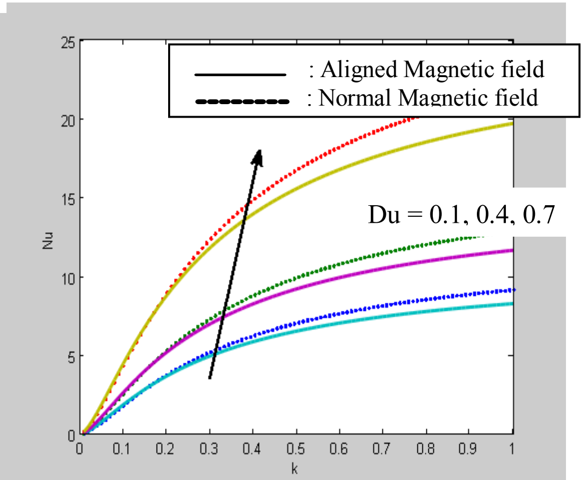
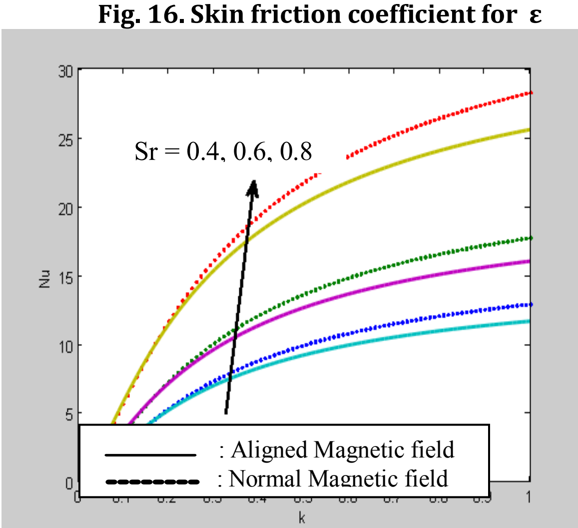


Fig. 16. Skin friction coefficient for ε **Fig. 17. Nusselt number for various Du**



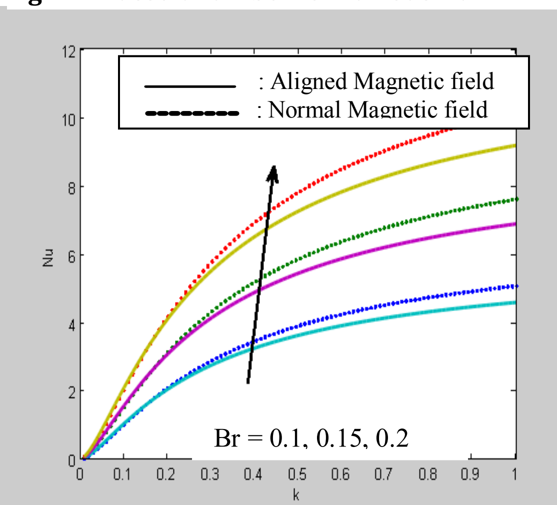
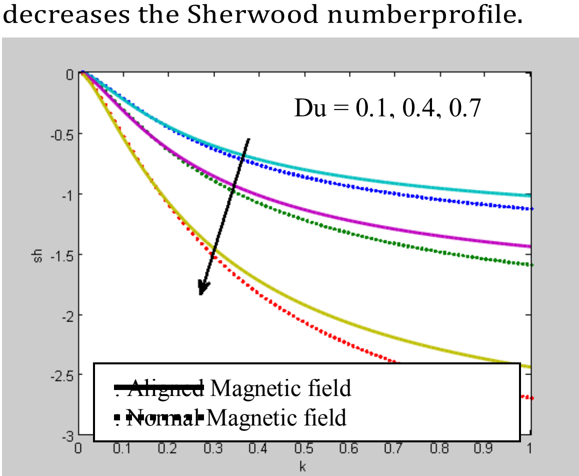


Fig. 18. Nusselt number for different Sr Fig. 19. Nusselt number for various Br

ThenatureofSherwoodnumberfordistinctvaluesofDu,Sr,Brandmis shownin throughfigure20tofigure22.Itisclearfromthefiguresthat, increase of these parameters decreases the Sherwood numberprofile.



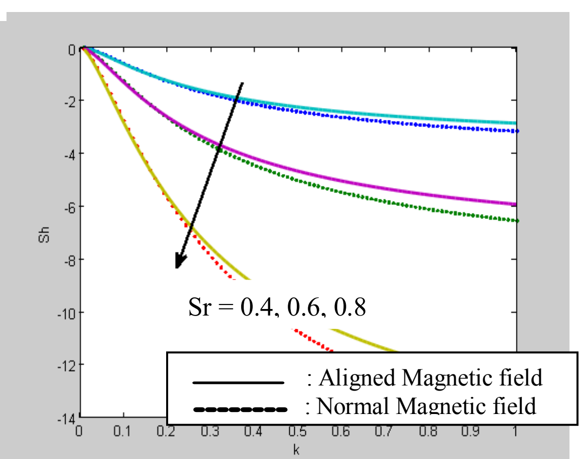


Fig.20. Sherwood number for different DuFig. 21. Sherwood number for Sr

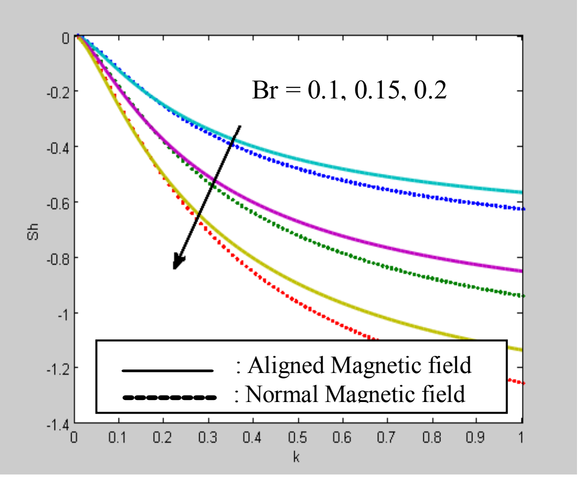


Fig. 22. Sherwood number for Br

5. CONCLUSION

In this study, exact solution for the stream function, the velocity profile, thetemperatureprofileandtheconcentrationprofileintheexistenceofCrossdiffusioneffect,andPermeabilityparameteronanunsteadyMHDflowareconstructed. TheeffectofheatandmasstransferonCrossdiffusionofanunsteadyMHDflowis analyzed in detail. Graphical results reveal the consequence of the variousdimensionless parameters which exists in the problem underanalysis.

The succeeding results are made based on the results and discussion:

* As amplitude ratio (s) increases, the mean velocity profile also increases andsameresultsariseforwalltension(E_1)andmasscharacterization(E_2).
* WiththeincreaseinPermeabilityparameter(k),themeanvelocityprofile alsoincreases.
* Withtheincreaseinwalltension(E_1)andmasscharacterization(E_2),the temperatureprofileincreases.ThesameresultsareobtainedforDufournumber(Du), Soret number (Sr) and Brinkman number(Br).
* AsPermeabilityparameter(k)increases,thetemperatureprofileincreases.
* Increaseinwalltension(E_1)andmasscharacterization(E_2),decreases the concentrationprofile.Thesameresultsappearfor Dufournumber(Du),Soretnum- ber (Sr) and Brinkman number(Br).
* IncreaseinPermeabilityparameter(k),decreasestheconcentrationprofile.
* Increase in (s), the skin friction (τ)decreases.
* WiththeincreaseinDufournumber(Du),Soretnumber(Sr)andBrinkman number (Br), the Nusselt number (Nu)increases.
* With the increase in Dufour number (Du), Soret number (Sr) and Brinkman number (Br), the Sherwood number (Sh)decreases.

Nomenclature:

x, y - Cartesian co-ordinates
u, v - Fluid velocity
μ - pressure, viscosity
d, a - mean width of the channel, amplitude
λ, c - wavelength, wave speed
σ, υ - electrical conductivity, kinematic viscosity
T, s - temperature, amplitude ratio
ρ, t - density of the fluid, time
CB - coefficient of volume expansion
θ, φ - Non-dimensional temperature, Non-dimensional concentration
M, G - Magnetic parameter, gravitational force
Cp - specific heat
Cs - concentration viscosity
Bo - magnetic field
KT - diffusion ratio
Dm - mass diffusion coefficient
Sr - Soret parameter
Sc - Schmidt number
Du - Dufour parameter
Br - Brinkman number
Gr - Grashof number for heat transfer
Gm - Mass Grashof number
Pr - Prandtl number
Re - Reynolds number
E1, E2, E3 - Elasticity temperature
To, T1 - concentration fluid at lower and upper walls
Co, C1 - temperature of fluid at lower and upper walls

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