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Impact of Thermal Radiation on the Heat Transfer of Squeezing Flow Between Two Parallel Disks-An Analytical Solution

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Abstract— *In this paper, the optimal homotopy Asymptotic method (OHAM) is used to solve the velocity and heat equation of magnetohydrodynamic squeezing flow under the effect of thermal radiation between two parallel disks. The nonlinear partial differential equations are transformed into nonlinear ordinary differential equations by similarity transformation. The effects of different physical parameters on velocities and fluid temperature are graphed and discussed. OHAM gives exact solutions in a single iteration, Otherwise, it provides numerical results that are very close to exact results.*

Keywords— *Squeezing flow. OHAM. Magnetic field. Thermal radiation.*

I. Introduction

Squeeze flow is a sort of flow in which a substance is forced out or deformed between two parallel plates or objects (also known as squeeze flow, squeeze flow theory, or squeezing flow). Applications for Squeeze flow include transient loading of mechanical components, food processing, polymer processing, flow through arteries, and other industrial, biological, and engineering processes. Moving pistons, squeezed film in power transmission, chocolate filler, injection modeling, and bearings with liquid metal lubrication. Under some extreme operating conditions, magnetohydrodynamic (MHD) fluid may be used as a lubricant to prevent the unexpected variation of lubricant viscosity with temperature.in (1874) Stefan studied the effect of lubrication approximation on squeezing flow. Rashidi et al. [1] Investigated the flow of a viscous, incompressible fluid caused by the regular motion of two parallel plates. Siddiqui et al [2]. used the Homotopy Perturbation method to analyze viscus squeeze flow under the effect of MHD between infinite parallel plates. Mahmood et al [3] reviewed the characteristics of the viscous fluid squeezed through a porous channel. G. Domairry and A. Aziz [4] used the Homotopy Perturbation method to analyze viscus squeeze flow under the effect of MHD between infinite parallel disks. Khaled, K. Vafai [5] studied the flow and heat transfer over a horizontal surface in an externally squeezed free stream under the effect of the MHD. Duwairi et al [6] studied the unsteady viscous fluid squeezed between parallel plates at a constant temperature. The magnetohydrodynamic squeeze flow between two parallel disks has been examined, considering the disk porosity by Joneidi et al. [7]. Muhammad et al. [8] investigated the magnetohydrodynamic (MHD) Jeffrey fluid's time-dependent squeezing flow between two parallel walls. Hayat et al [9]u sed HAM to solve the velocity and temperature of the MHD squeeze flow between two parallel disks and compare the results with G. Domairry and A. Aziz [4]. Usman et al [10] studied the flow and the heat transfer of the blood under the effect of the magnetic field through porous vessels. Çelik et al [11] solved the velocity and heat equations of MHD squeeze flow between two parallel two disks by GWCM. Ganesh Kumar et.al. [12]

made a numerical investigation of tangent hyperbolic fluid squeezed over a sensor surface with changing thermal conductivity. The impact of thermal radiation, nanoparticle type, and concentration on heat transfer flux and skin friction on each plate was examined using the numerical method. Ullah et.al [13] introduced a variety of solutions to the problem of squeezing fluid between two plates. They investigated in their study the (HPM) and (OHAM). Noor et al. [14] studied numerically the impact of the thermal radiation, chemical reactions and heat generation on the MHD Jeffery squeeze fluid. Mufti et al [15] gave an algorism for solving the system of second-order boundary value problems by OHAM.

In this study, we used the optimal homotopy Asymptotic method (OHAM) to solve the unsteady squeeze flow of viscus fluid between two parallel disks under the effect of thermal radiation and Magnetic field and compare the results with Gegenbauer Wavelet Collocation Method results.

II. Mathematical Formulation

Two parallel infinite disks between them an unsteady incompressible flow of viscous fluid and heat transfer under the effect of thermal radiation. the lower disk is permeable and fixed shown in Fig. 1. The distance between the parallel disks: $h(t) = H(1 - \xi\, t)^{\frac{1}{2}}$, H means the initial position of the upper disks from the lower disk at time $t = 0$, ξ is characteristic parameter taking the dimension of time inverse; when $\xi > 0$ the upper disk moves with velocity $v(t) = \frac{dh}{dt}$ towards the lower disk until touches it at $t \simeq \frac{1}{\xi}$, when $\xi < 0$ the upper disk moves away from the lower disk. A uniform magnetic field perpendicular to the disks relative with $B(t) = B_0(1 - \xi\, t)^{-\frac{1}{2}}$; B_0 is the initial intensity of the magnetic field. The induced magnetic field is neglected. the cylindrical coordinates system (r, φ, z) is chosen.

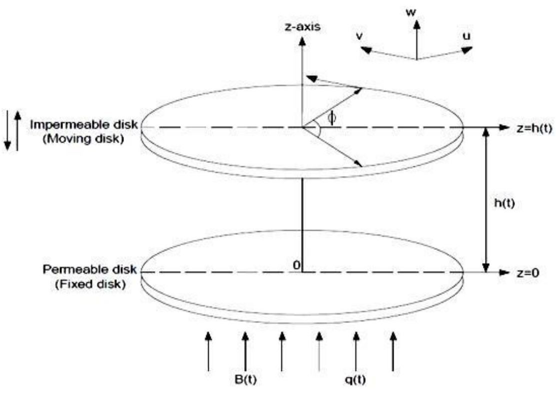

Fig. 1: physical and Geometry model of the problem

The giving equations in the cylindrical coordinates system for the two dimensional of an unsteady incompressible flow of viscous fluid and heat transfer: [11]

$$\frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial w}{\partial z} = 0 \quad (1)$$

$$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial t} + w\frac{\partial u}{\partial z}\right) = -\frac{\partial p}{\partial r} + \mu\left(\frac{\partial^2 u}{\partial r^2} + \frac{\partial^2 u}{\partial z^2} + \frac{1}{r}\frac{\partial u}{\partial r} - \frac{u}{r^2}\right) - \sigma B^2(t) u \quad (2)$$

$$\rho\left(\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial r} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left(\frac{\partial^2 w}{\partial r^2} + \frac{\partial^2 w}{\partial z^2} + \frac{1}{r}\frac{\partial w}{\partial r}\right) \quad (3)$$

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial r} + w\frac{\partial T}{\partial z} = \frac{k}{\rho c_p}\left(\frac{\partial^2 T}{\partial r^2} + \frac{\partial^2 T}{\partial Z^2} + \frac{1}{r}\frac{\partial T}{\partial r}\right) + \frac{\mu}{\rho c_p}\left[2\frac{u^2}{r^2} + \left(\frac{\partial u}{\partial z}\right)^2 + 2\left(\frac{\partial w}{\partial z}\right)^2 + 2\left(\frac{\partial u}{\partial r}\right)^2 + 2\left(\frac{\partial w}{\partial r}\right)^2 + 2\frac{\partial u}{\partial z}\frac{\partial w}{\partial r}\right] + \frac{1}{\rho c_p}\frac{16\sigma^* T_0^3}{3k^*}\left(\frac{\partial^2 T}{\partial r^2} + \frac{\partial^2 T}{\partial Z^2} + \frac{1}{r}\frac{\partial T}{\partial r}\right) \quad (4)$$

Where ρc_p is the heat capacity, **K** refers to thermal conductivity, **P** is the Pressure, ρ is the density. μ Refers to dynamic viscosity, **u** and **w** are the components of the velocity in r and **z** directions respectively. **T** is the temperature.

The boundary conditions of these equations:

$$u = 0, w = \frac{dh}{dt}, T = T_H, \text{at } z = h(t) \quad (5)$$

$$u = 0, w = -w_0, T = T_w, \text{at } z = 0 \quad (6)$$

Where w_0 refers to the suction or injection velocity.

The giving partial differential equations are transformed into ordinary differential equations by using dimensionless variable η and the functions $g(\eta)$, $\vartheta(\eta)$ are defined as:

$$u = \frac{\xi r}{2(1-\xi t)} g'(\eta), w = \frac{-\xi H}{H\sqrt{(1-\xi t)}} g(\eta) \quad (7)$$

$$\vartheta = \frac{T - T_H}{T_w - T_H}, \eta = \frac{z}{H\sqrt{1-\xi t}} \quad (8)$$

Substation by the above variables in the given system of equations, the given boundary conditions, and removing the Pressure gradient the following ordinary differential equations can be obtained:

$$g'''' - \gamma(\eta g''' + 3g'' - 2gg''') - (Ha)^2 g'' = 0 \quad (9)$$

$$\left(1 + \frac{4}{3}Rd\right)\vartheta'' + Pr.\gamma(2g\vartheta' - \eta.\vartheta') + Pr.Ec((g'')^2 + 12\delta^2(g')^2) = 0 \quad (10)$$

$$g(0) = A, g'(0) = 0, \vartheta(0) = 1 \quad (11)$$

$$g(1) = \frac{1}{2}, g'(1) = 0, \vartheta(1) = 0 \quad (12)$$

Where: $v = \frac{\mu}{\rho}$, $Rd = \frac{4\sigma^* T_0^3}{k^* k}$, $Ec = \frac{\xi^2 r^2}{4(1-\alpha t)^2 Cp\,(T_W - T_H)}$, $Ha = \left(\frac{\sigma}{\mu}\right)^{\frac{1}{2}} HB_0$, $Pr = \frac{\mu Cp}{k}$, $\delta = \frac{H(1-\xi t)^{\frac{1}{2}}}{r}$,

$\gamma = \frac{\xi H^2}{2v}$ is the kinematic viscosity, radiation parameter, Ecker number, Hartman number, Prandtl number, dimensionless length, and the squeeze number, respectively. When the upper disk moves toward the fixed lower disk $\gamma < 0$, the upper disk moves away from the fixed lower disk $\gamma > 0$.

III. THE OPTIMAL HOMOTOPY ASYMPTOTIC METHOD (OHAM)

A useful technique for nonlinear differential equations is the optimal homotopy asymptotic method. The convergence of the series solutions is controlled by one or more parameters in this method, which can be found by minimizing a certain function. It is employed in this work to solve the squeezing flows between two parallel disks under the effect of magnetic field and thermal radiation to estimate the solution of the velocity and heat equations. the OHAM [16] divides the main system terms into linear and nonlinear with the aid of a nonzero auxiliary function $H(P) = \sum_{k=0}^{n} p^k c_k$ which Pis the control parameter and c_k refer to the convergence controlling constants . P Take values from 0 to 1, when $P = 0$ we get the linear term, $P = 1$ the nonlinear term appears. That implies that when p changes from 0 to 1, the solution approaches creating the family equations of homotopy with the $c_k$convergence control constants. We determine these constants by resolving the problem's residual. we solved the system by using Mathematica software. The system's family equations are shown in the following equations.

Zero order

$$g0^{(4)} = 0$$
$$\vartheta0'' = 0$$
$$g0[1] = 0.5, g0'[1] = 0, g0[0] = A, g0'[0] = 0, \vartheta0[0] = 1, \vartheta0[1] = 0 \quad (11)$$

First order

$$g1^{(4)} = g0^{(4)} - C1Hag0'' - 3C1\text{Ɣ}g0'' + 2C1g0\text{Ɣ}g0^{(3)} - C1\text{Ɣ}\eta g0^{(3)} + C1\text{Ɣ}g0^{(4)}$$
$$\vartheta1'' = \vartheta0'' + \frac{36C2Ecpr\delta(g0')^2}{3+4Rd} + \frac{6C2g0pr\text{Ɣ}\vartheta0'}{3+4Rd} - \frac{3C2pr\text{Ɣ}\eta\vartheta0'}{3+4Rd} + \frac{3C2Ecpr(g0'')^2}{3+4Rd} + C2\vartheta0'' \quad (12)$$

$$g1[0] = 0, g1'[0] = 0, g1[1] = 0, g1'[1] = 0, \vartheta1[0] = 0, \vartheta1[1] = 0$$

Second order

$$g2^{(4)} = g1^{(4)} - C1Hag1'' - 3C1\text{Ɣ}g1'' + 2C1f1\text{Ɣ}g0^{(3)} + 2C1g0\text{Ɣ}g1^{(3)} - C1\text{Ɣ}\eta g1^{(3)} + C1g1^{(4)}$$
$$\vartheta2'' = \vartheta1'' + \frac{72C2Ecpr\delta g0'g1'}{3+4Rd} + \frac{6C2g1pr\text{Ɣ}\vartheta0'}{3+4Rd} + \frac{6C2g0pr\text{Ɣ}\vartheta1'}{3+4Rd} - \frac{3C2pr\text{Ɣ}\eta\vartheta1'}{3+4Rd} + \frac{6C2Ecprg0''g1''}{3+4Rd} + C2\vartheta1'' \quad (13)$$
$$g2[0] = 0,\ g2'[0] = 0,\ g2[1] = 0,\ g2'[1] = 0, \vartheta2[0] = 0, \vartheta2[1] = 0$$

And so, on the general solution of the given system

$$g(\eta, c1) = g0 + g1 + g2 + g3 + \cdots$$
$$\vartheta(\eta, c2) = \vartheta0 + \vartheta1 + \vartheta2 + \cdots$$

By solving the problem's residual, we get the constants

$c1 = -0.99909263, c2 = -1.0008509,\ g''(1) = -1.80863751, \vartheta'(1) = -1.02408506$ for $pr = 0.7, A = 0.2, \text{Ɣ} = 0.2, Ha = 0.2, Ec = 0.1, \delta = 0.1, Rd = 0.1$

IV. RESULTS AND DISCUSSION

In this work, OHAM is used to get the solution of the velocity and heat equation for the MHD squeezing flow of viscous fluid under the effect of thermal radiation. The comparison between the OHAM results of calculation skin friction coefficient $g''(1)$ Nusselt number$-\vartheta'(1)$ and GWCM results [11] by using the same values of parameters in TABLE I. It is noted that the OHAM results convergent with the GWCM results. The impact of the different parameters (squeeze parameter, squeeze number, Ecker number, Prandtl number, Hartman number) on the velocity components and the fluid temperature was studied for two cases suction at $A = 1$ and injection at $A = -1$. From equation (5) w and u are identified as vertical and axial velocities proportional to $g(\eta)$ and $g'(\eta)$ respectively. Vertical and axial velocities depend on A, Ɣ and Ha parameters. The temperature of the fluid $\vartheta(\eta)$ depends on parameters such as (Ɣ , Ha , Pr, Ec, $\delta$and Rd).in all Figures of $\vartheta(\eta)$ the solid line indicates to $Rd = 0$, and the dash line indicates to $Rd = 0.5$.

TABLE I. The comparison between the OHAM results and GWCM results [11]

A	S	Ha	$-g''(1)$ (OHAM)	$-f''(1)$ Çelik et.al. [12]	Error	$-\vartheta'(1)$ (OHAM)	$-\theta'(1)$ Çelik et .al. [11]	Error
-0.2	0.1	0.2	4.232052057	4.232066555	1.44983E-05	1.18024009	1.180239671	-4.19E-07
-0.1	0.1	0.2	3.623050609	3.623059462	8.85279E-06	1.13169656	1.131697331	7.71E-07
0	0.1	0.2	3.01552641	3.015530801	4.39093E-06	1.09056039	1.090561491	1.101E-06
0.1	0.1	0.2	2.409477638	2.40947877	1.13212E-06	1.05680287	1.056804157	1.287E-06
0.2	0.1	0.2	1.80490246	1.80490152	-9.40323E-07	1.03039624	1.030397406	1.166E-06
-0.2	-0.3	0.2	4.113706822	4.113667297	-3.9525E-05	1.17342666	1.173427934	1.274E-06
-0.2	-0.2	0.2	4.14362952	4.14360339	-2.613E-05	1.17510981	1.17511035	5.4E-07
-0.2	0	0.2	4.2027984	4.2027992	8.00004E-07	1.17851678	1.178516632	-1.48E-07
-0.2	0.2	0.2	4.261090175	4.261118482	2.8307E-05	1.18197688	1.181975445	-1.435E-06
-0.2	0.3	0.2	4.289916492	4.289958577	4.2085E-05	1.18372687	1.183723576	-3.294E-06
0.1	0.01	0.2	2.402387209	2.402387735	5.25921E-07	1.05814235	1.058142397	4.7E-08
0.1	0.2	0.2	2.417349989	2.417351783	1.79364E-06	1.05531361	1.05531828	4.67E-06
0.1	0.3	0.2	2.42521576	2.425218223	2.46316E-06	1.05382339	1.053833551	1.0161E-05
0.1	0.1	0.01	2.407886732	2.407886734	2.26159E-09	1.05680282	1.056803864	1.044E-06
0.1	0.1	0.1	2.408281637	2.408281835	1.97709E-07	1.05680283	1.056803935	1.105E-06
0.1	0.1	0.2	2.409477638	2.40947877	1.13212E-06	1.05680287	1.056804157	1.287E-06

Fig. 2, and 3: illustrate the changes of the vertical and radial velocities $g(\eta), g'(\eta)$ with the changes of $A > 0$ (the suction parameter). there is a direct relationship between the suction parameter and vertical velocity where both of them increase, and there is an inverse relation between the suction parameter and radial velocity, by increasing the suction parameter the radial velocity decreases. Fig.4:illustrates the increase of fluid temperature by increasing A (direct relation) with considering the effect of thermal radiation Rd. Fig 5,6,and 7:show the impact of $A > 0$ (the injection parameter) on velocities $g(\eta), g'(\eta)$ where the opposite happened with respect to the suction case ,and the fluid temperature was still the same in both cases .Fig.8,and 9 : illustration of the changes of the vertical, radial velocities with the changes of Ɣ (squeezing parameter); we obtain that by increasing Ɣ the vertical velocity decreases; as same as the radial velocity near the fixed lower disk but increasing occurs near the moving upper disk zone.fig.10:describes the changes in fluid temperature which decreases by increasing Ɣ with considering the effect of thermal radiation Rd. The opposite happened in the case of injection for the vertical, radial velocities and fluid temperature as shown in Fig. 11,12, and 13.

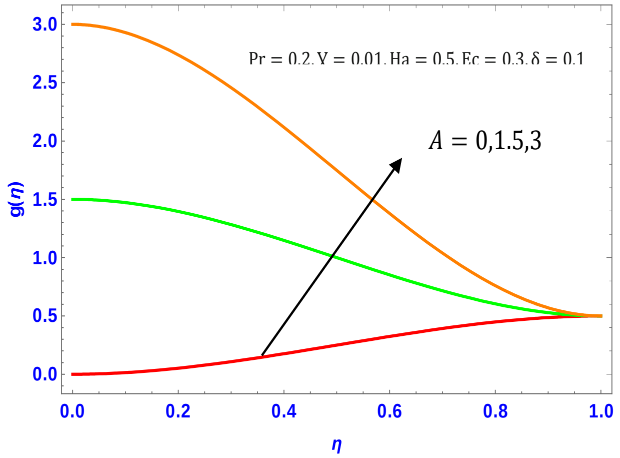

Fig. 2: the impact of suction parameter on the vertical velocity

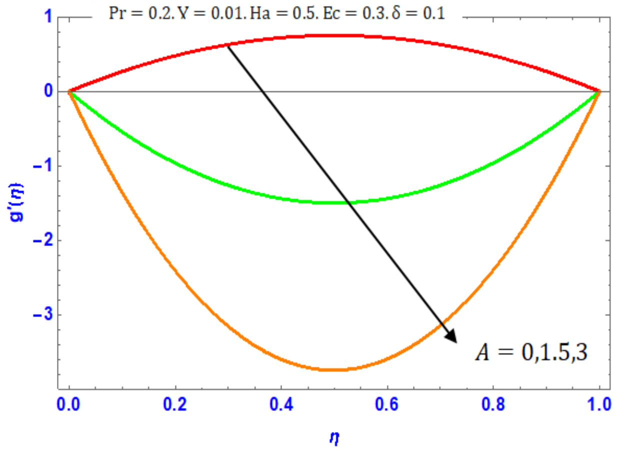

Fig. 3: the impact of suction parameter on the radial velocity

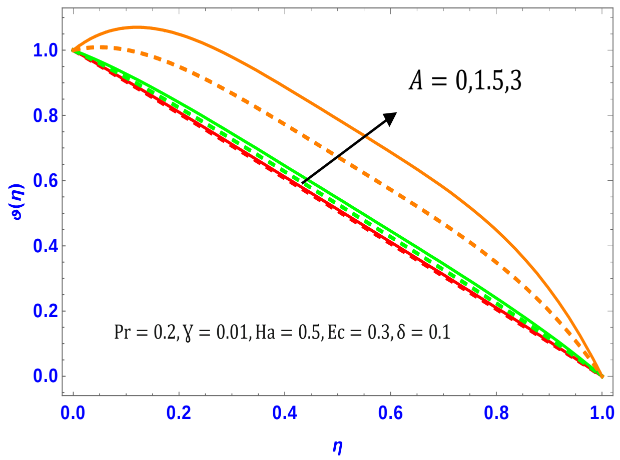

Fig. 4: the impact of suction parameter on the fluid temperature

The fluid temperature is direct proportional with physical parameters $(Ec, \mathrm{Pr}, \delta)$ in both cases (suction/injection) in Fig.14,15,16,17,18, and 19. The vertical and radial velocities are slightly affected with the change of Ha parameter in cases (suction/injection) in Fig.20,21,23, and 24. The temperature of the fluid is inversely proportional to Ha parameter in both cases (suction /injection) in Fig.22, and 25

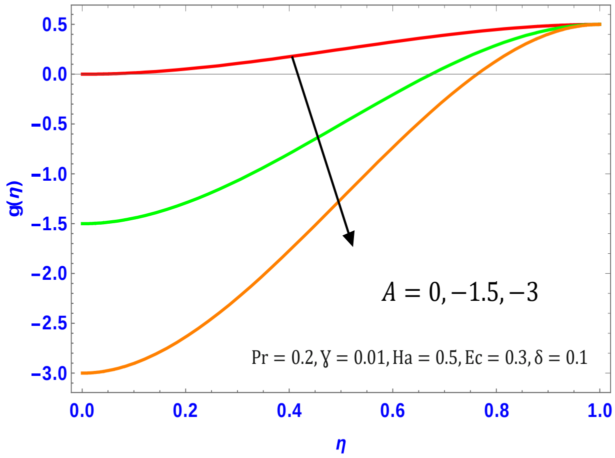

Fig. 5: the impact of injection parameter on the vertical velocity

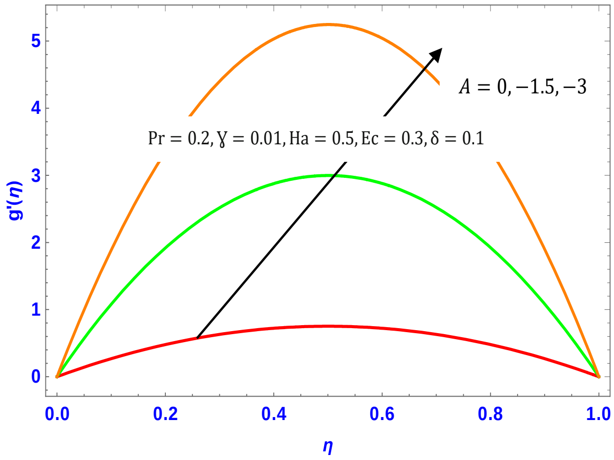

Fig. 6 the impact of injection parameter on the radial velocity

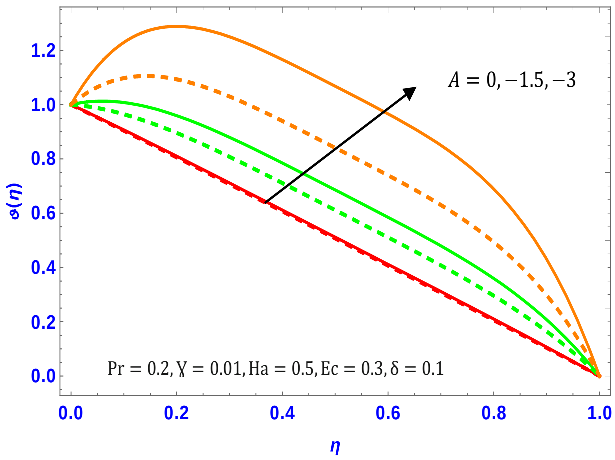

Fig. 7: the impact of injection parameter on the fluid temperature

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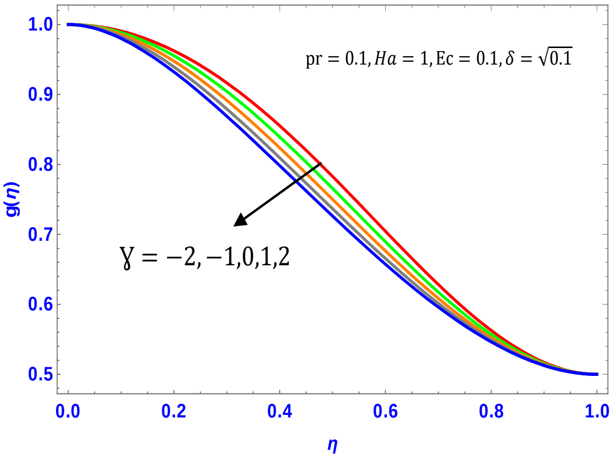

Fig. 8: the impact of the squeezing parameter on the vertical velocity at A=1

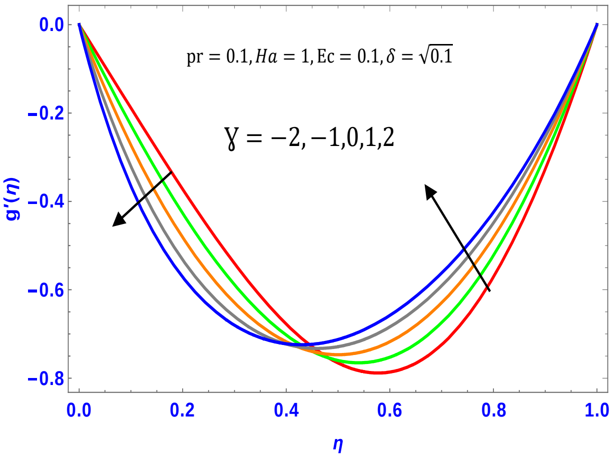

Fig. 9: the impact of the squeezing parameter on the radial velocity at A=1

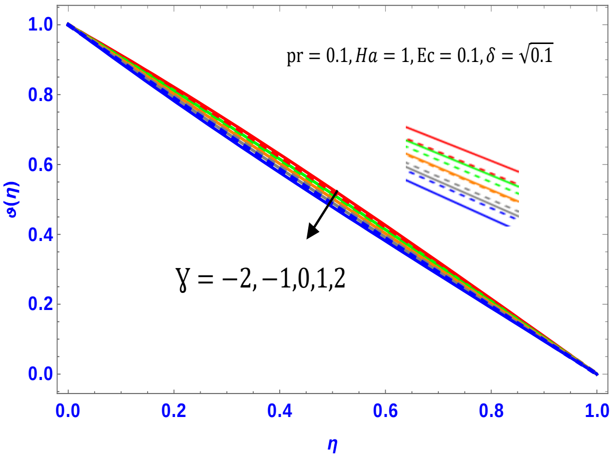

Fig. 10: the impact the squeezing parameter on the fluid temperature at A=1

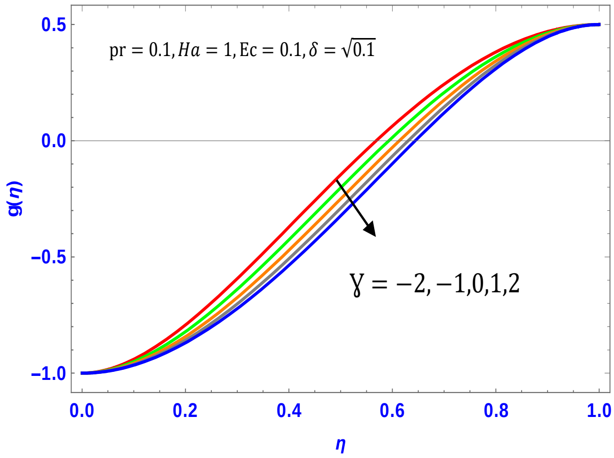

Fig. 11: the impact of the squeezing parameter on the vertical velocity at A= -1

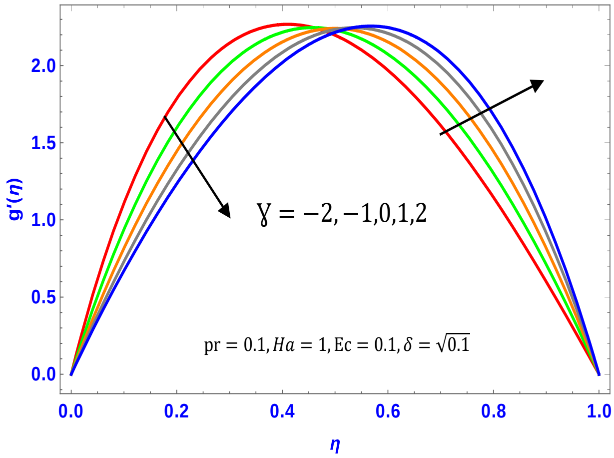

Fig. 12: the impact of the squeezing parameter on the radial velocity at A= -1

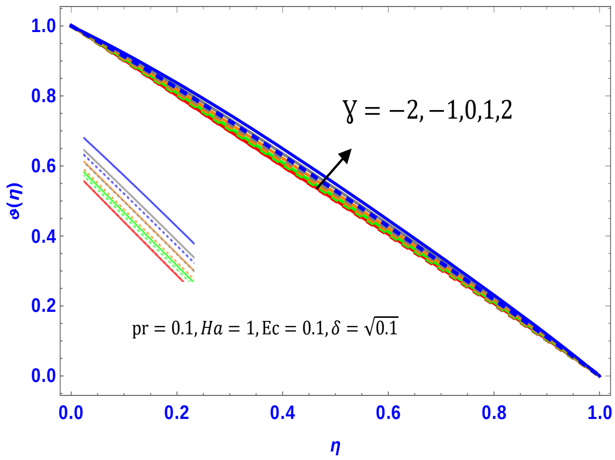

Fig. 13: the impact the squeezing parameter on the fluid temperature at A= -1

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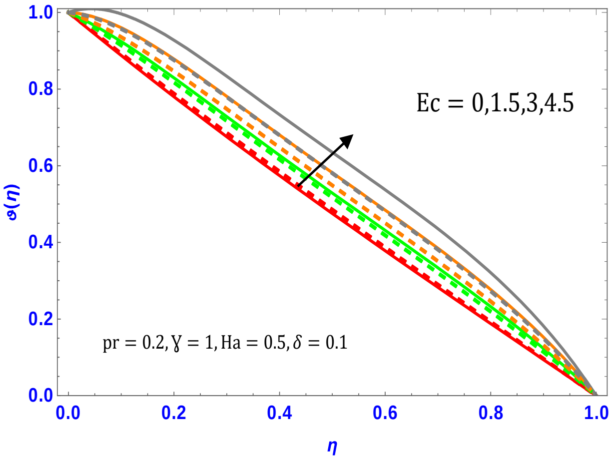

Fig. 14: the impact the Ecker number on the fluid temperature at A=1

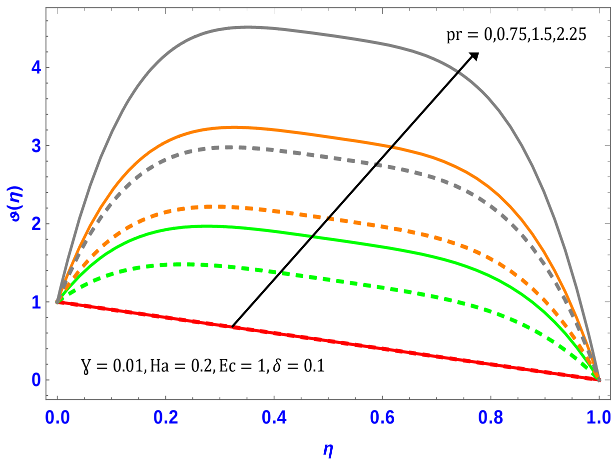

Fig. 17: the impact Prandtl number on the fluid temperature at A=-1

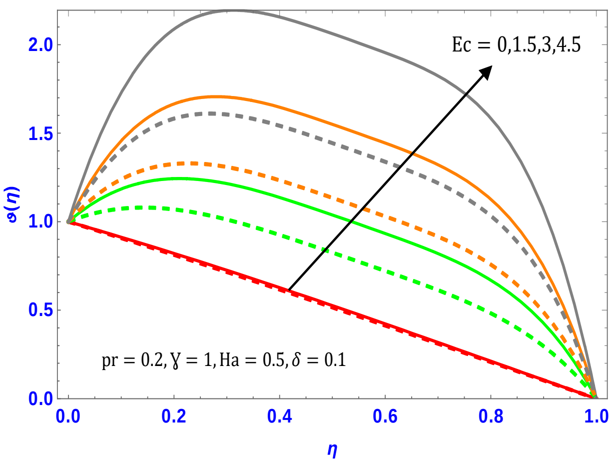

Fig. 15: the impact the Ecker number on the fluid temperature at A=-1

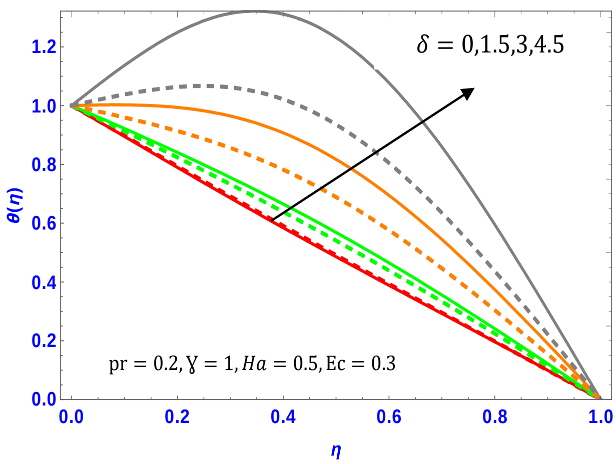

Fig. 18: the impact δ on the fluid temperature at A = 1

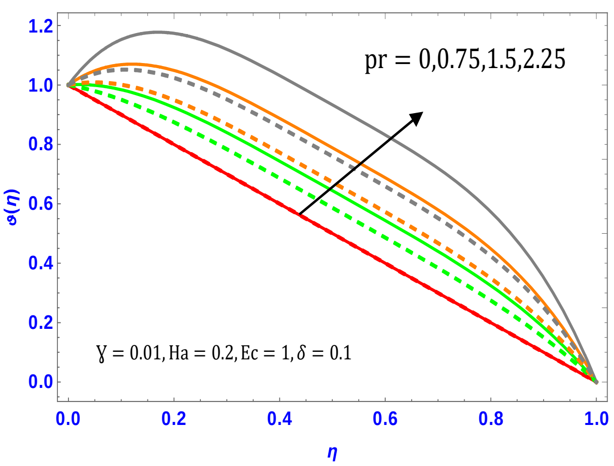

Fig. 16: the impact Prandtl number on the fluid temperature at A=1

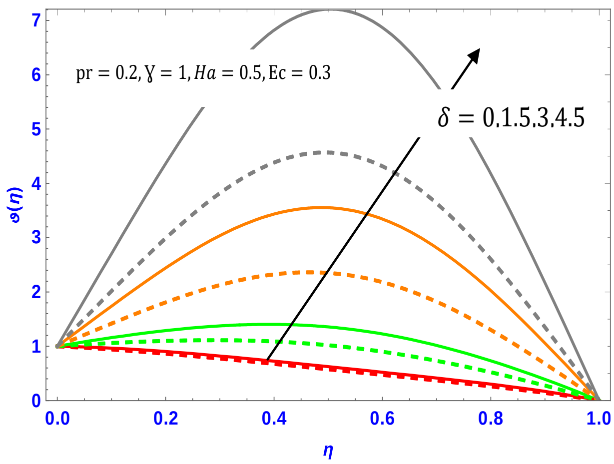

Fig. 19: the impact δ on the fluid temperature at A=-1

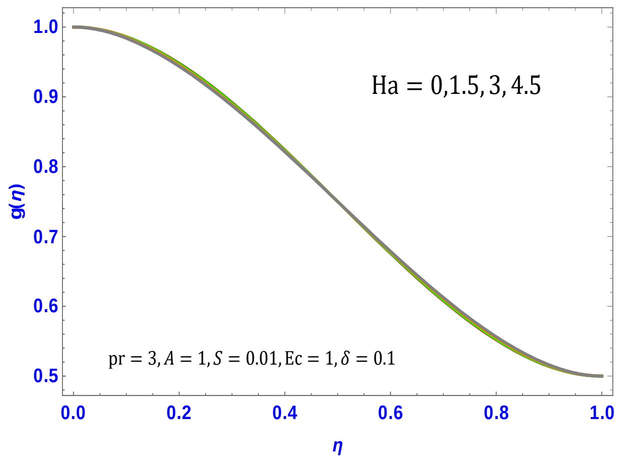

Fig. 20: the impact of Hartman number on the vertical velocity at A=1

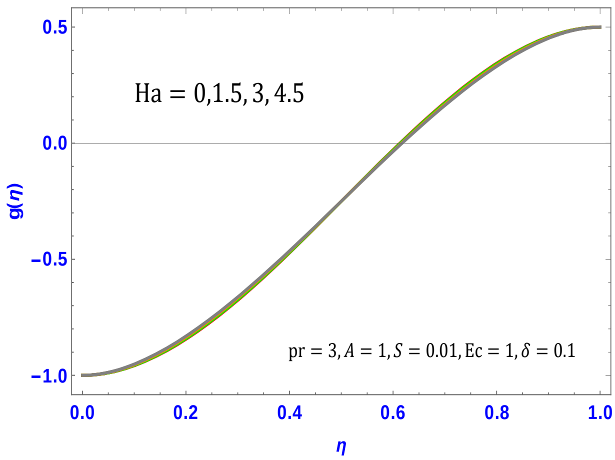

Fig. 23: the impact of Hartman number on the vertical velocity at A=-1

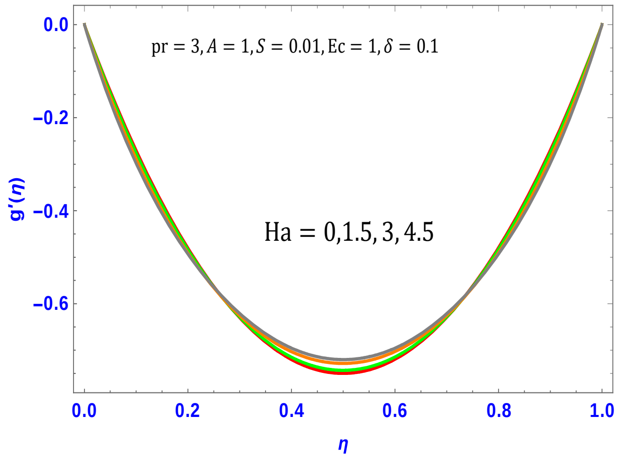

Fig. 21: the impact of Hartman number on the radial velocity at A=1

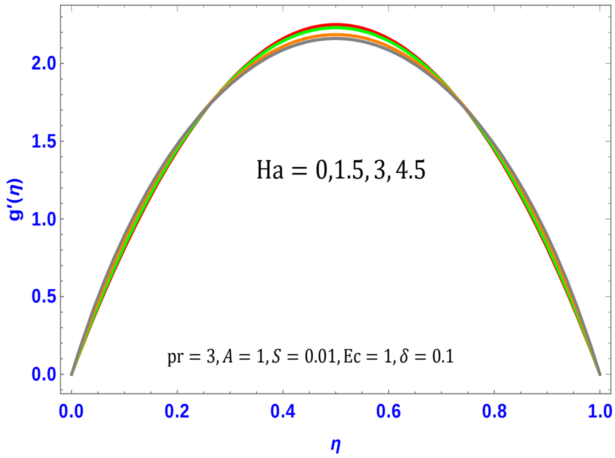

Fig. 24: the impact of Hartman number on the axial velocity at A=-1

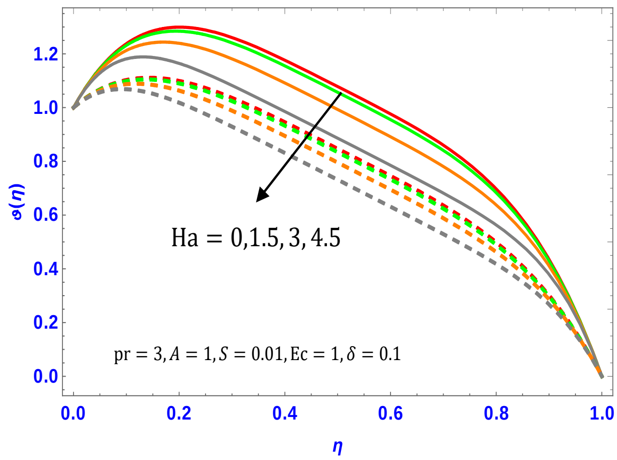

Fig. 22: the impact of Hartman number on the fluid temperature at A=1

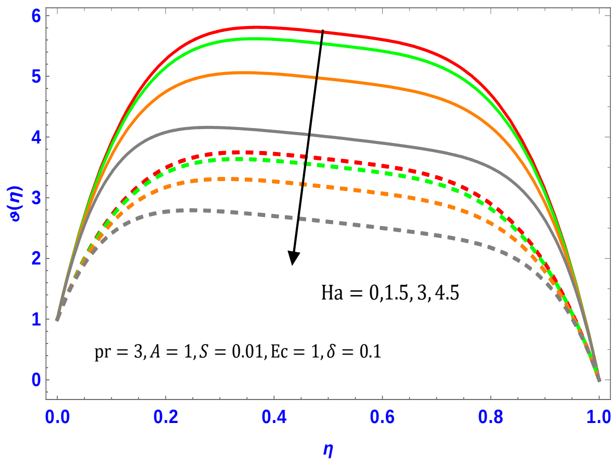

Fig. 25: the impact of Hartman number on the fluid temperature at A=-1

V. CONCLUSION

In this work, it is clear that the optimal homotopy asymptotic method can be successfully used to solve the system of the fourth order of nonlinear ordinary differential equations. This method is very simple to get the exact solution without the need for the discretization of the variables. The results of this study were convergent with the Gegenbauer Wavelet Collocation Method results. It is clear that from all temperature graphs, increasing thermal radiation cause decreasing in the temperature of the fluid, and does not affect the velocities graphs.

REFERENCES

[1] M. M. Rashidi, H. Shahmohamadi, and S. Dinarvand, "Analytic Approximate Solutions for Unsteady Two-Dimensional and Axisymmetric Squeezing Flows between Parallel Plates," Math. Probl. Eng., vol. 2008, pp. 1–13, 2008, doi: 10.1155/2008/935095.

[2] S. I. & A. R. A. A. M. Siddiqui and To, "Unsteady squeezing flow of a viscous MHD fluid between parallel plates, a solution using the homotopy perturbation method", doi: 10.3846/1392-6292.2008.13.565-576.

[3] M. Mahmood, S. Asghar, and M. A. Hossain, "Squeezed flow and heat transfer over a porous surface for viscous fluid," Heat Mass Transf., vol. 44, no. 2, pp. 165–173, Oct. 2007, doi: 10.1007/s00231-006-0218-3.

[4] G. D. and A. Aziz2, "Approximate Analysis of MHD Squeeze Flow between Two Parallel Disks with Suction or Injection by Homotopy Perturbation Method", doi: 10.3846/1392-6292.2008.13.565-576.

[5] A.-R. A. Khaled and K. Vafai, "Hydromagnetic squeezed flow and heat transfer over a sensor surface," Int. J. Eng. Sci., vol. 42, no. 5–6, pp. 509–519, Mar. 2004, doi: 10.1016/j.ijengsci.2003.08.005.

[6] H. M. Duwairi, B. Tashtoush, and R. Damseh, "On heat transfer effects of a viscous fluid squeezed and extruded between two parallel plates," Heat Mass Transf., Aug. 2004, doi: 10.1007/s00231-004-0525-5.

[7] A. A. Joneidi, G. Domairry, and M. Babaelahi, "Effect of Mass Transfer On A Flow In The Magnetohydrodynamic Squeeze Film Between Two Parallel Disks with One Porous Disk," Chem. Eng. Commun., vol. 198, no. 3, pp. 299–311, Nov. 2010, doi: 10.1080/00986445.2010.512533.

[8] T. Muhammad, T. Hayat, A. Alsaedi, and A. Qayyum, "Hydromagnetic unsteady squeezing flow of Jeffrey fluid between two parallel plates," Chinese J. Phys., vol. 55, no. 4, pp. 1511–1522, Aug. 2017, doi: 10.1016/j.cjph.2017.05.008.

[9] T. Hayat, A. Yousaf, M. Mustafa, and S. Asghar, "Influence Of Heat Transfer In The Squeezing Flow Between Parallel Disks," Chem. Eng. Commun., vol. 199, no. 8, pp. 1044–1062, Aug. 2012, doi: 10.1080/00986445.2011.631203.

[10] M. Usman, S. T. Mohyud Din, T. Zubair, M. Hamid, and W. Wang, "Fluid flow and heat transfer investigation of blood with nanoparticles through porous vessels in the presence of magnetic field," J. Algorithm. Comput. Technol., vol. 13, p. 174830181878866, Jan. 2019, doi: 10.1177/1748301818788661.

[11] İ. Çelik and H. K. Öztürk, "Heat transfer and velocity in the squeezing flow between two parallel disks by Gegenbauer Wavelet Collocation Method," Arch. Appl. Mech., vol. 91, no. 1, pp. 443–461, Jan. 2021, doi: 10.1007/s00419-020-01782-4.

[12] K. Ganesh Kumar, B. J. Gireesha, M. R. Krishanamurthy, and N. G. Rudraswamy, "An unsteady squeezed flow of a tangent hyperbolic fluid over a sensor surface in the presence of variable thermal conductivity," Results Phys., vol. 7, pp. 3031–3036, 2017, doi: 10.1016/j.rinp.2017.08.021.

[13] I. Ullah, M. T. Rahim, H. Khan, and M. Qayyum, "Analysis of various semi-numerical schemes for magnetohydrodynamic (MHD) squeezing fluid flow in porous medium," Propuls. Power Res., vol. 8, no. 1, pp. 69–78, Mar. 2019, doi: 10.1016/j.jppr.2019.01.003.

[14] N. A. M. Noor, S. Shafie, and M. A. Admon, "Slip effects on mhd squeezing flow of jeffrey nanofluid in horizontal channel with chemical reaction," Mathematics, vol. 9, no. 11. 2021. doi: 10.3390/math9111215.

[15] M. R. Mufti, M. I. Qureshi, S. Alkhalaf, and S. Iqbal, "An Algorithm: Optimal Homotopy Asymptotic Method for Solutions of Systems of Second-Order Boundary Value Problems," Math. Probl. Eng., vol. 2017, pp. 1–11, 2017, doi: 10.1155/2017/8013164.

[16] M. Abdel-Wahed and E. El-Said, "Magnetohydrodynamic flow and heat transfer over a moving cylinder in a nanofluid under convective boundary conditions and heat generation," Therm. Sci., vol. 23, no. 6 Part B, pp. 3785–3796, 2019, doi: 10.2298/TSCI170911279A.