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Thermal radiation and Soret effects on natural convective flow through a porous channel with slip

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---***ABSTRACT***---
This article presents the significance of thermal radiation and Soret effect on laminar, incompressible natural convective fluid flow through a porous channel with Navier slip. The governing partial differential equations, defining the flow regime, are transformed into a system of ordinary differential equations by employing suitable transformations. Spectral Quasilinearization Method (SQLM) is applied to solve the dimensionless governing equations. The influence of emerging parameters on fluid flow velocity, temperature, and concentration are shown graphically.
KEYWORDS:-*Natural Convection, Soreteffect, Radiation effect, Navier slip, SQLM.*

I. INTRODUCTION

Heat and mass transfer by natural convection hascreated much attention in the last several decades due to its many significant engineering and geophysical applications [1, 2]. Giventhe significance, Recently, Maskaniyan et al. [3] presented natural convection and entropy generation analysis inside a channelwith a porous plate mounted as a cooling system. Most recently, Dogonchi et al. [4] analyzed the MHD free convection flow of *CuO*-water nanofluid in the complex-shapedenclosure.

The Soret effect is more significant in various physicaldevelopmentsanditseffectonthedouble-diffusive convection in porous media involved in many areas, for instance,geosciencesandchemicalengineering, etc., [5, 6]. Because of applications, Muthtamilselvanetal.[7]investigatedtheimpactofcrossdiffusions on free convection flow of double-diffusivemicropolar fluid flow in a square cavity. Most recently, Anjum and Irfan [8] studied the Soret/Dufoureffect in an irregular porouscavity.The radiation natural convection heattransfer inan inclined rectangular enclosure has been analyzedby Bouali et al. [9]. Sheikholeslami et al. [10] investigated the influence of radiation and magnetic effect on nanofluid flow usingthe two-phase model.Recently, Sheikholeslami et al. [11] presented thenanofluid MHD natural convection through a porouscomplex-shaped cavity considering thermal radiation.

In many micro and macro scales level technologieslike polishing of surfaces, the slip flow in fluids playsa very significant role. Date back to 1823 when Navier [12] introduced a slip boundary condition where the slip velocity depends linearly on the shear stress. Applications and significance of slip flow can be seen in the works of many researchers [13,14].Inviewofimportance,Zhangetal.[15]presented the unsteady flow and heat transfer of power-law nanofluid thin film over a stretching sheet with a variable magnetic field and power-law velocity slip effect. Recently, Winter et al. [16] studied the oceanproblemwithgeneralNavierboundaryconditions by applying Nitsche cut finite element method. Most recently, Alamri et al. [17] studied the influence of radiation on convective plane Poiseuille slip flow of nanofluid through a porousmedium.

In this paper, the free convection Navier slipflow in a porous channel in with thermal radiation and Soret effect is studied. A spectral quasilinearization methodisactivetosolvethesystemofequations.The quasilinearization method was suggested by Bellman etal.[18]asasimplificationoftheNewton-Raphson method. Motsa and his researchers [19, 20] have been elongated the method of the quasilinearization to a broad variety of nonlinear BVP's and shown that the method is of quadratic convergence. Recently, Goqo et al. [21] studied about the capable of entropy generation in MHD radiative viscous nanofluid flow over a porous wedge using the bivariatespectral quasi-linearization method.

II. MATHEMATICAL FORMULATION

Consider a Newtonian flow of steady, incompressible, laminar natural convection through a vertical plates channel with distance $2d$ apart. Cartesian coordinate system, temperatures, and concentrations are considered as shown in Figure 1. As the boundaries are infinitely extended in the x-direction, without loss of generality, we considered that the physical parameters are functions of y only. The properties of the fluid are presumed to be constant except for density variations in the buoyancy force term. With the above assumptions and Boussinesq approximations, the governing equations for the flow are given by

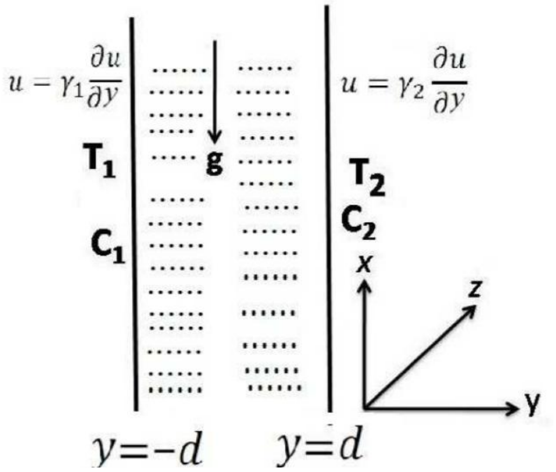

Figure 1: Physical model and coordinate system.

$\frac{\partial v}{\partial y} = 0 \Rightarrow v = v_0$ (1)

$\rho v_0 \frac{\partial u}{\partial y} = \rho g^*[\beta_T(T - T_1) + \beta_C(C - C_1)] + \mu \frac{\partial^2 u}{\partial y^2} - -\frac{\mu\varepsilon}{K_f} u$(2)

$\rho C_p v_0 \frac{\partial T}{\partial y} = K_f \frac{\partial^2 T}{\partial y^2} - \frac{\partial q_r}{\partial y} + \mu(\frac{\partial u}{\partial y})^2$(3)

$v_0 \frac{\partial C}{\partial y} = D \frac{\partial^2 C}{\partial y^2} + \frac{DK_T}{T_m} \frac{\partial^2 T}{\partial y^2}$(4)

with

$y = -d: u = \gamma_1 \frac{\partial u}{\partial y}, T = T_1, C = C_1$, $y = d: u = \gamma_2 \frac{\partial u}{\partial y}, T = T_2, C = C_2$(5)

where u and v are the velocities in x and y respectively, μ is the coefficient of viscosity, g^* is the acceleration due to gravity, K_f is the coefficient of thermal conductivity, ρ is the density, C_p is the specific heat, β_T and β_C are the coefficients of thermal and solutal expansions, γ_1 and γ_2 are the slip coefficients, T_m is the mean fluid temperature, D is the mass diffusivity, K_T is the thermal diffusion ratio and ε is the porous constant.

Introducing the following transformations

$y = \eta d, u = \frac{\gamma G_r}{d} f$, $T - T_1 = (T_2 - T_1)\theta, C - C_1 = (C_2 - C_1)\phi$ (6)

Substitute in Equations (2) - (4), we obtain the governing dimensionless equations as

$f'' - Rf' + \theta + N\phi - \frac{\varepsilon}{Da} f = 0$ (7)

$\theta'' - RPr\theta' + \frac{4}{3} Rd[(C_T + \theta)^3 \theta']' + BrGr^2(f')^2 = 0$ (8)

$\phi'' - RSc\phi' + ScSr\theta'' = 0$ (9)

with

$f(-1) - \beta_1 f'(-1) = \theta(-1) = \phi(-1) = 0,\ f(1) - \beta_2 f'(1) = 0, \theta(1) = \phi(1) = 1$(10)

where the primes indicate the differentiation concerning η, $Sc = \frac{v}{D}$ is the Schmidt number, $Sr = \frac{DK_T(T_2 - T_1)}{vT_m(C_2 - C_1)}$ is thermodiffusion parameter, $R = \frac{\rho v_0 d}{\square}$ is Suction/injection number, $Gr = \frac{g^* \beta_T (T_2 - T_1) d^3}{v^2}$ is thermal Gasthof number, $Rd = \frac{4\sigma(T_2 - T_1)^3}{K_T \chi}$ is the radiation parameter, $Pr = \frac{\mu C_P}{K_f}$ is Prandtl number, $Br = \frac{\mu v^2}{K_f d^2 (T_2 - T_1)}$ is Brinkman number, N = $\frac{\beta_C(C_2 - C_1)}{\beta_T(T_2 - T_1)}$ is the buoyancy parameter, $C_T = \frac{T_1}{T_2 - T_1}$ is the temperature ratio, $\beta_1 = \frac{\gamma_1}{d}, \beta_2 = \frac{\gamma_2}{d}$ are the slip parameter and $Da = \frac{K_f}{d^2}$ is the Darcy parameter.

II. DISCUSSION OF RESULTS

The flow equations. (7) - (9) with the boundary conditions (10) are nonlinear and coupled, hence the system of equations is solved numerically using the Spectral quasilinearization method as explained in the works of Kaladhar et.al [22].TheinfluenceofRd,Da,C_T,Sr,β_1,and$\beta_2$onflow velocity ($f(\eta)$), temperature ($\theta(\eta)$) and concentration ($\phi(\eta)$) are calculated and are explained Figs. 2to 19 by fixing *Pr*, *Br*, *Re*, *Sc*, *Gr*, *N*, ε at 0.71, 0.5,2,0.22, 2, 1, 0.1 respectively.

Figure 2 to 4 shows the impact of Darcy number (*Da*) on f , θ and $\phi$when *Rd*=0.1, *Sr*=2, C_T=0.5, β_1=0.5 and β_2=0.1. It is seen from Fig. 2 that as *Da* increases, the flow velocity increases. It can depict from Figs. 3-4 that the dimensionlesstemperaturediminishesandconcentrationenhanceswith the increase of Darcynumber.

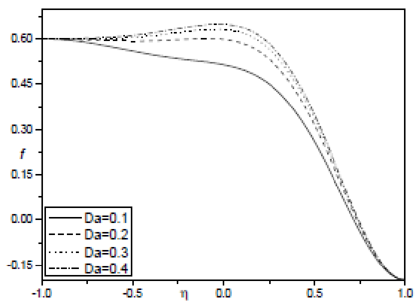

Fig 2. Effect of *Da* on $f(\eta)$

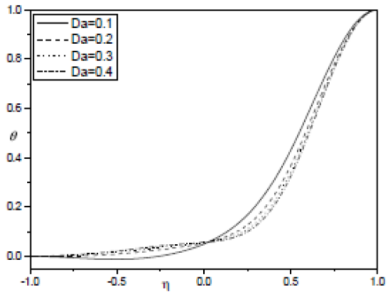

Fig 3. Effect of *Da* on $\theta(\eta)$

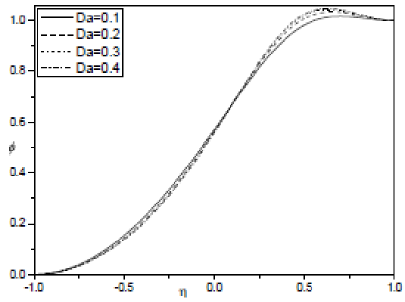

Fig 4. Effect of *Da* on $\phi(\eta)$

The influence of *Rd* on f, θ,and ϕcan be found in Fig. 5 to 7 at *Da*=0.2, *Sr*=2, C_T=0.5, β_1=0.1 and β_2=0.1.ItisnoticedfromFig.5thattheflowvelocity increasesas*Rd*magnifies.It is noted from Figs. 6-7thatthetemperatureofthefluidincreasesand the concentration of the fluid decreases as an increase in*Rd*.

Figure 8 to 10 presents the influence of Soret parameter on the flow velocity ($f(\eta)$), temperature ($\theta(\eta)$)andconcentration($\phi(\eta)$)at*Da*=0.2,*Rd*=0.1, C_T=0.5, β_1=0.5 and β_2=0.1. It is noted from Fig. 8 thattheflowvelocityincreaseswithanincrease in *Sr*. Figs. 9-10 that the temperature of the fluid decreases and the concentration of the fluid increases as an increase in Soret parameter*Sr*.

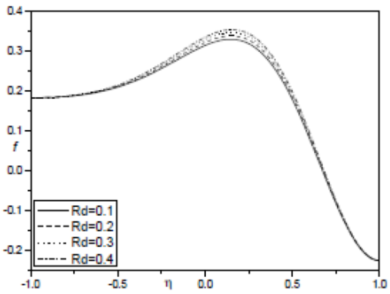

Fig 5. Effect of *Rd* on $f(\eta)$

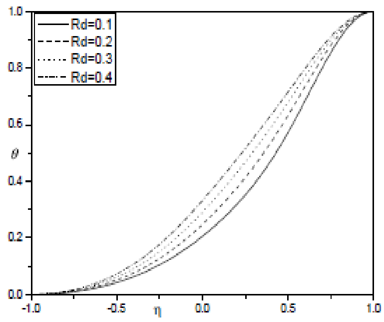

Fig 6. Effect of *Rd* on $\theta(\eta)$

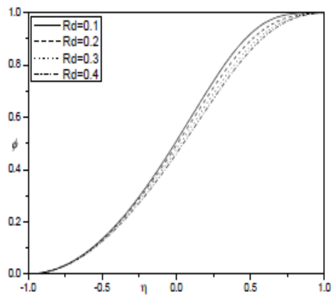

Fig 7. Effect of *Rd* on $\phi(\eta)$

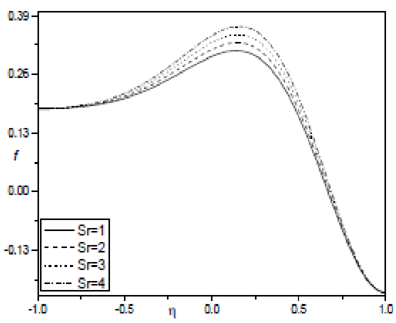

Fig 8. Effect of *Sr* on $f(\eta)$

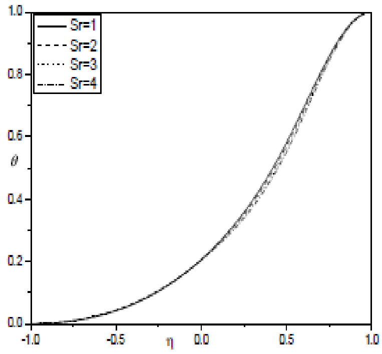

Fig 9. Effect of *Sr* on $\theta(\eta)$

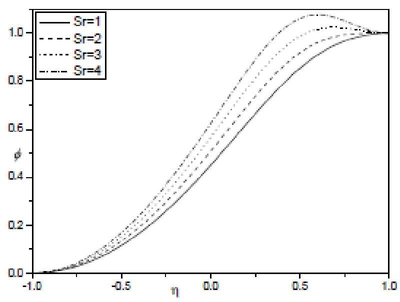

Fig 10. Effect of *Sr* on $\phi(\eta)$

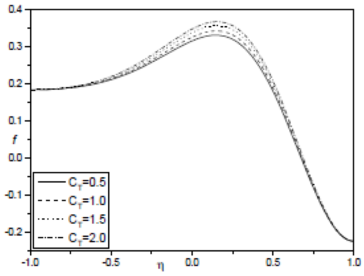

Fig11. Effect of C_T on $f(\eta)$

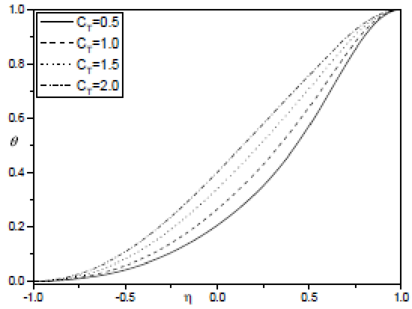

Fig12. Effect of C_T on $\theta(\eta)$

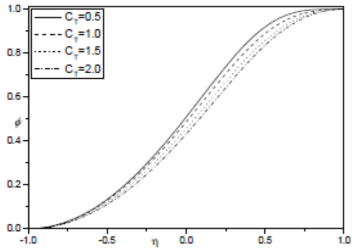

Fig13. Effect of C_T on $\phi(\eta)$

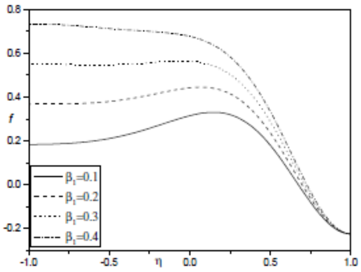

Fig14. Effect of β_1 on $f(\eta)$

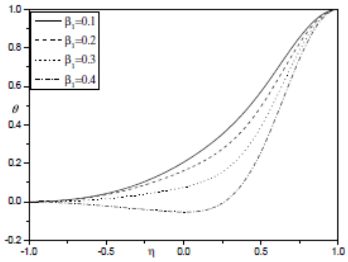

Fig15. Effect of $\beta_1$on $\theta(\eta)$

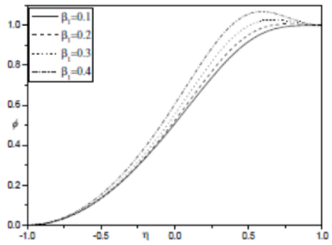

Fig16. Effect of β_1 on $\phi(\eta)$

The influence of C_T on f, θ, and ϕ can be noted in Fig.11 to 13 by fixing the other parameters at Da=0.2, Rd=0.1, Sr=2, β_1=0.5 and β_2=0.1. It is noted from Figs. 11-12 that the flow velocity and temperature of the fluid increase with an increase in C_T. Fig. 13 that the concentration of the fluid decreases as an increase in C_T.

The effect of β_1 on f, θ, and ϕ can be noted in Fig.14 to 16 by fixing the other parameters at Da=0.2, Rd=0.1, Sr=2, C_T=0.5 and β_2=0.1. It is noted from Fig. 14 that the flow velocity increases with an increase in β_1. Figs. 15-16 that the temperature of the fluid decreases and the concentration of the fluid increases as an increase in β_1.

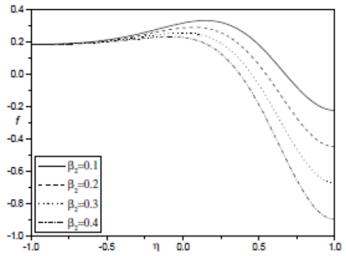

Fig17. Effect of β_2 on $f(\eta)$

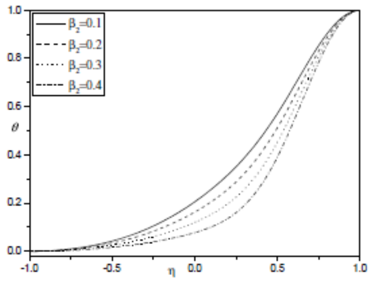

Fig18. Effect of $\beta_2$on $\theta(\eta)$

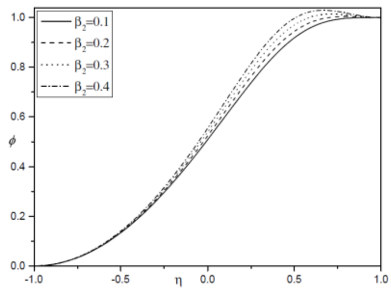

Fig19. Effect of β_2 on $\phi(\eta)$

The effect of β_2 on f, θ, and ϕ can be noted in Fig.17 to 19 by fixing the other parameters at Da=0.2, Rd=0.1, Sr=2, C_T=0.5 and β_1=0.5. It is noted from Fig.17 that the flow velocity with an increase in β_2. Figs. 18-19 that the temperature of the fluid decreases and the concentration of the fluid increases as an increase in β_2.

III. CONCLUSION

This article investigates the steady magnetohydrodynamic flow of Newtonian fluid in a porous channel in presence of Radiation and Soret effects. Spectral Quasilinearization Method is used to solve the final dimensionless governing equations. The main findings are:

- Flow velocity and concentration profiles amplify whereas the temperature profile decreases with an increase in Darcy number (Da), Soret parameter (Sr), and slip parameter (β_1).
- Fluid flow velocity and temperature profiles amplify whereas the concentration profile decreases with an increase in radiation parameter (Rd) and temperature ratio (C_T).
- The flow velocity and temperature profiles are decreasing whereas the concentration of the fluid increases

with the increase of slip parameter(β_2).

REFERENCES

[1] T. Fujii and H. Imura, Natural-convection heat transfer from a plate with arbitrary inclination. *International Journal of Heat and Mass Transfer*, 15(4), 1972, pp.755–767.

[2] D.S. Chauhan and P. Rastogi, Radiation effectsonnaturalconvectionMHDflowinarotating vertical porous channel partially filled with a porous medium. *Applied Mathematical Sciences*, 4(13), 2010, pp. 643–655.

[3] M. Maskaniyan, M. Nazari, S. Rashidiand o. Mahian, Natural convection and entropygeneration analysis inside a channel with a porous platemountedasacoolingsystem.*ThermalScience and Engineering Progress*, 6, 2018, pp. 186–193.

[4] A.S. Dogonchi, F. Selimefendigiland D.D. Ganji, Magneto-hydrodynamic natural convection of *CuO*-water nanofluid in complex shaped enclosure considering various nanoparticle shapes. *International Journal of Numerical Methods for Heat and Fluid Flow*, 29(5), 2019, pp. 1663–1679.

[5] J. Wang, M. Yang and Y. Zhang, Onset of double diffusive convection in horizontal cavity with Soret and Dufour effects. *International Journal of Heat and Mass Transfer*, 78, 2014, pp.1023–1031.

[6] N.A. Khan and F. Sultan, On the double diffusive convection flow of Eyring-Powell fluiddue toconethroughaporousmediumwithSoretand Dufour effects. *AIP advances*, 5(5), 2015, pp. 057140.

[7] M. Muthtamilselvan, K. Periyaduraiand D.H. Doh, Impact of nonuniform heated plate on double-diffusive natural convection of micropolar fluid in a square cavity with Soret and Dufour effects. *Advanced Powder Technology*, 29(1), 2018, pp. 66–77.

[8] I. Anjum Badruddin, Heat and Mass Transfer with Soret/Dufour Effect in IrregularPorous Cavity. *Journal of Thermophysics and Heat Transfer*, 2019, pp. 1–16 .

[9] H. Bouali, A. Mezrhab, H. Amaoui,and M. Bouzidi, Radiation-natural convection heat transfer in an inclined rectangular enclosure.*International Journal of Thermal Sciences*, 45(6), 2006, pp. 553–566.

[10] M. Sheikholeslami,D.D. Ganji, M.Y. Javedand R. Ellahi, Effect of thermal radiation on magnetohydrodynamics nanofluid flow and heattransfer by means of two phase model. *Journal of Magnetism and Magnetic Materials*, 374, 2015, pp.36–43.

[11] M. Sheikholeslami, Z. Li and M. Shamlooei, Nanofluid MHD natural convection through a porous complex shaped cavity considering thermal radiation. *Physics Letters A*, 382(24), 2018, pp.1615–1632.

[12] C.L.M.H.Navier,Memoiresurlesloisdumovement des fluids. *Memoires de l'Academie Royale des Sciences de l'Institut de France*, 6(1823), 1823, pp.389–440.

[13] D.IftimieandF.Sueur,Viscousboundarylayers for the Navier-Stokes equations with the Navier slip conditions. *Archive for rational mechanics and analysis*, 199(1),2011, pp. 145–175.

[14] W.A. Khan, O.D. Makinde and Z.H. Khan, MHD boundary layer flow of a nanofluid containing gyrotactic microorganisms past a vertical plate with Navier slip. *International journal ofheatandmasstransfer*,74,2014,pp.285–291.

[15] Y. Zhang, M. Zhang and Y. Bai, Unsteady flow and heat transfer of power-law nanofluid thin film over a stretching sheet with variable magneticfieldandpower-lawvelocityslipeffect. *Journal of the Taiwan Institute of Chemical Engineers*, 70, 2017, pp. 104–110.

[16] M. Winter, B. Schott, A. MassingandW.A. Wall, ANitsche cut finite element method for the Oseenproblem with general Navierboundary conditions. *Computer Methods in Applied Mechanics and Engineering*, 330, 2018, pp. 220–252.

[17] S.Z. Alamri, R. Ellahi, N. Shehzad, and A. Zee- shan, Convective radiative plane Poiseuille flow of nanofluid through porous medium with slip: an application of Stefan blowing. *Journal of Molecular Liquids*,273, 2019,pp. 292–304.

[18] R.Bellman,H.KagiwadaandR.Kalaba,Quasi- linearization, system identification andprediction. *International Journal of Engineering Science*, 3(3), 1965, pp. 327–334 .

[19] Z.Makukula,P.SibandaandS.Motsa,Anoteon the solution of the von Karman equations using series and Chebyshev spectral methods. *Boundary Value Problems*, 2010(1), 2010, pp.471793

[20] Ch. RamReddy and T. Pradeepa, Spectral quasi-linearization method forhomogeneous *Open Engineering*, 6(1), 2016.

[21] S.P. Goqo, S.D. oloniiju,H. Mondal, P. Sibanda and S.S. Motsa, Entropy generation in MHD radiative viscous nanofluid flow over a porous wedge using the bivariate spectral quasi- linearization method. *Case studies in thermal engineering*, 12, 2018, pp. 774–788

[22] K. Kaladhar, K. Madhusudhan Reddy and D. Srinivasacharya, Inclined magnetic field, thermal radiation andHall current effects on Mixedconvectionflowbetweenverticalparallelplates, *ASME.J.HeatTransfer*,141, 2019,pp.102501- 102507.