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G-JITTER INDUCED MIXED CONVECTION FLOW BETWEEN TWO PARALLEL PLATES WITH NEWTONIAN HEATING

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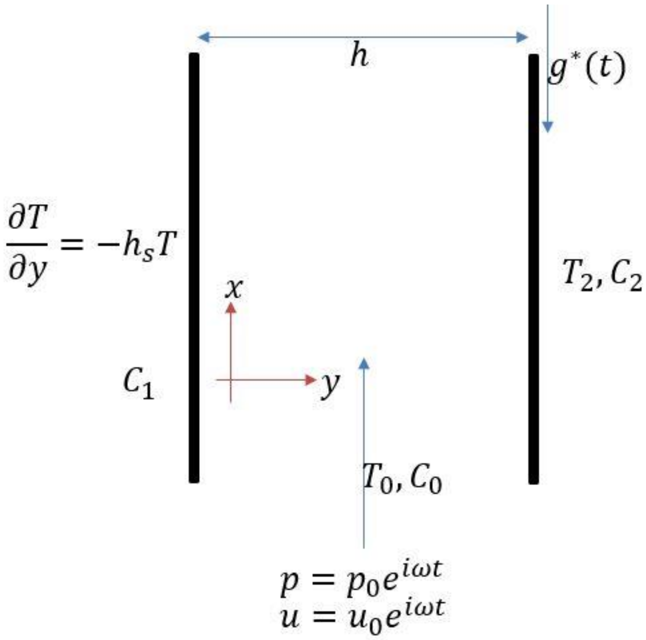
RESEARCH HIGHLIGHTS

This article deals with the mixed convection flow between two vertical parallel plates with the effect of g-jitter. Newtonian heating is considered on the left wall of the plate. The governing equations of heat and mass transfer are modelled in the Cartesian coordinate system with the effect of g-jitter. Non-dimensional variables are used to transform the governing equations together with the boundary layer condition. Separation of variables method are applied to provide the exact analytical solutions for the velocity, temperature and concentration profiles. The obtained solutions are computed to produce the graphical results. It is showed that due to an increasing value of wall temperature and thermal conjugate parameter, the fluid temperature increased. As wall concentration increases, the fluid concentration also increased. Meanwhile, the velocity increasing as mixed convection and thermal conjugate parameter increased. Contradict, the velocity decreasing as the value of buoyancy ratio and frequency increased.

GRAPHICAL ABSTRACT



RESEARCH OBJECTIVES

Space experiments have revealed unknown effect on earth which is g-jitter or residual acceleration phenomena associated with the microgravity environment. g-Jitter is the inertia effects due to quasi steady, oscillatory or transient accelerations arising from crew motions and machinery vibrations in parabolic aircrafts, space shuttles or other microgravity environments (1). g-Jitter gives additional effect on material processing in microgravity environment which interact the density gradient and result in both fluid flow. It is important to understand the effect of g-jitter to design and maintaining the cooling board of a system to prevent such overheating cause problem like explosion in practical application (2).

Therefore, the main objective of this research is to investigate the effect of Newtonian heating and g-jitter towards mixed convection flow between two parallel vertical plates motivated by Hayat (3). In particular, this research is being proposed to expand the following works by Sharidan (4) which investigate analytically the effect of g-jitter on mixed convection flow in two vertical parallel plates with constant wall temperature boundary condition. Therefore, on

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the present study, this project mainly focused on the analytical study of the g-jitter effect of heat and mass transfer by mixed convection flow between two parallel plates.

Materials and Methods

An incompressible fluid which unsteadily flows between two vertical parallel plates with width, h is considered. Assuming at time $t=0$, the flow is at the constant temperature and concentration, T_0 and C_0 and has the mean velocity, u_0 and pressure, p_0. The axial velocity u, and the fluid temperature and concentration, T and C are assumed to be functions of y plus function of time t. Based on the assumptions, the initial and boundary layer conditions governing the mixed convection flow containing the equation of motion, energy and mass equations. It is then being transformed using appropriate non-dimensional variables and turned into the following forms.

$$\frac{\partial U}{\partial \tau}=-\frac{\partial P}{\partial X}+\frac{\partial^2 U}{\partial Y^2}+\frac{Gr}{Re}\cdot g(\tau)\cdot[\theta+N\varphi], \tag{1}$$

$$\frac{\partial \theta}{\partial \tau}=\frac{1}{Pr}\frac{\partial^2 \theta}{\partial Y^2}, \tag{2}$$

$$\frac{\partial \varphi}{\partial \tau}=\frac{1}{Sc}\frac{\partial^2 \varphi}{\partial Y^2} \tag{3}$$

$$\begin{aligned}
&\tau<0: && U=0,\theta=0, && \varphi=\varphi_0 && \text{for} && 0<Y<1\\
&\tau\geq 0: && U=0,\frac{\partial\theta}{\partial y}=-\gamma(\theta+1), && \varphi=r_C && \text{at} && Y=0\\
& && U=0,\theta=0, && \varphi=\varphi_2 && \text{at} && Y=1
\end{aligned} \tag{4}$$

Seperation of variables method is used to solve the equations. Equations (1) to (3) have the solution of Equation (5), (6) and (7).

$$\varphi(Y,\tau)=r_C+(1-r_C)Y \tag{5}$$

$$\theta(Y,\tau)\ =\frac{r_T\ (1-\gamma Y)+\gamma(1-Y)}{1-\gamma} \tag{6}$$

$$Imag\left(U=\Phi e^{i\Omega\tau}\right)=Real(\Phi)\sin(\Omega\tau)+Imag(\Phi)\cos(\Omega\tau). \tag{7}$$

$$\begin{aligned}\Phi(Y)=\frac{1}{\beta^2}\Bigg\{&\left(\frac{\partial F}{\partial X}-\frac{Gr}{Re}\left[\frac{r_T+\gamma}{1-\gamma}+Nr_C\right]\right)\frac{\sinh(\beta(1-Y))}{\sinh\beta}\\
&+\left(\frac{\sinh\beta Y}{\sinh\beta}\left\{\frac{\partial F}{\partial X}-\frac{Gr}{Re}(r_T+N)\right\}\right)+\frac{Gr}{Re}\Big[\frac{r_T\ (1-\gamma Y)+\gamma(1-Y)}{1-\gamma}\\
&+N(r_C+Y(1-r_C))\Big]-\frac{\partial F}{\partial X}\Bigg\}\end{aligned} \tag{8}$$

where $\beta^2=i\Omega$ with $\partial F/\partial X$ is given by

$$\frac{\partial F}{\partial X}=\frac{\beta^3\sinh\beta}{2\cosh\beta-\beta\sinh\beta-2}+\frac{Gr}{Re}\left[\frac{2\cdot r_T+\gamma(1-r_T)}{2(1-\gamma)}+\frac{N(1+r_C)}{2}\right]. \tag{9}$$

The results are then being computed into mathematical software named MATLAB and generated.

Results

Results shown that the concentration and temperature increased with the increasing value of wall concentration r_C, wall temperature r_T and thermal conjugate γ. Physically, as r_T increases, more hot fluid is carried through the vertical plates due to the increasing fluid temperature

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which consequently results in higher wall temperature gradient. This analysis allows the simulation of heat transfer between wall and fluid domains by exchanging the thermal energy at the interfaces between them (5).
For velocity profiles, as γ and $\mathrm{Gr/Re}$ increased, the velocity increased. The increasing value of γ imply that as the heat is exchange between fluid and the wall, it enhances the heat transfer process. The increment of $\mathrm{Gr/Re}$ is due to the fact that the buoyancy forces are much more effective rather than the viscous forces. Further, as frequency Ω and buoyancy ratio N increasing, the fluid velocity decreased. Velocity incresed due to the pressure and associated upward force on the bottom of the vertical plates are lesser than the upward force on the top of the vertical plates. This allows the fluid to move slower in upward direction of vertical plates because of the pressure.

FINDINGS

The unsteady mixed convection flow under the influence of g-jitter between two parallel vertical plates together with Newtonian heating is discussed. The exact analytical solutions for the non-linear system is developed via separation of variables method. The results showed that as temperature ratio r_T and thermal conjugate γ increased, the temperature increased. Similarly, as concentration ratio r_C increases, the concentration of the fluid increased. For velocity distribution, the velocity U is increased as mixed convection parameter $\mathrm{Gr/Re}$ thermal conjugate γ increased. Contradict with that, the fluid decelerates with an increment in the buoyancy ratio N and frequency Ω.

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