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Flow and Heat Transfer with Thermal Radiation at a General Stagnation Point in Nanofluid Under Microgravity Environment

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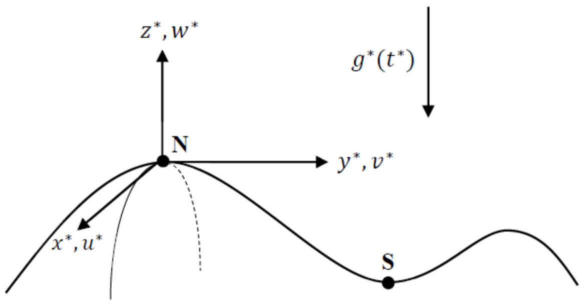
RESEARCH HIGHLIGHTS

The fundamental research near a boundary layer nanofluid flow at a stagnation point region with thermal radiation effect is conducted under microgravity environment. The mathematical formulation is modified form physical law to represent the physical characteristic of the flow and the system of the equation are solved numerically using Keller box method. The flow is analyzed in terms of physical quantities of principal interest such as skin friction and Nusset number. Parameters consider in this flow such as curvature ratio, amplitude of modulation, frequency of oscillation, nanoparticles volume friction and thermal radiation is analyzed numerically and presented graphically. From the analysis, g-jitter effect will produce a fluctuating result to the skin frictions and Nusset number indicate the singularity solution in the flow. The existing of nanoparticles and thermal radiation is found to increase the rate of heat transfer of the flow.

GRAPHICAL ABSTRACT



RESEARCH OBJECTIVES

Most of the fundamental research conducted near a boundary layer flow is focussing on flow behavior and heat transfer properties. In this research, the system of governing equation is modified from the existing study in representing the problem mathematically. The coupled equation is then solved using Keller box method numerically. The flow behavior is analyzed by physical quantities of principal interest known as skin friction and Nusset number which represent the heat transfer properties when the parameter is manipulated. The result is presented graphically and discussed briefly based on physical properties carried by the fluid.

MATHEMATICAL FORMULATION

The dimensionless governing equations which represent all the effect considered near the boundary layer flow after undergoing semi-similar transformation technique are modified from the previous study by Sharidan (1) in 2007 and presented as below.

$$C_1 f''' + C_2[(f+h)f'' - f'^2] + C_3[1+\varepsilon\cos(\pi\tau)]\theta = C_2\Omega\frac{\partial f'}{\partial\tau} \tag{1}$$

$$C_1 h''' + C_2[(f+h)h'' - h'^2] + C_3 c[1+\varepsilon\cos(\pi\tau)]\theta = C_2\Omega\frac{\partial h'}{\partial\tau} \tag{2}$$

$$\frac{1}{\Pr}\left[\frac{C_4+Nr}{C_5}\right]\theta'' + (f+h)\theta' = \Omega\frac{\partial\theta}{\partial\tau} \tag{3}$$

respect to boundary conditions

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$$f(\tau,0) = f'(\tau,0) = 0,$$
$$h(\tau,0) = h'(\tau,0) = 0, \qquad (4)$$
$$\theta(\tau,0) = 1,$$
$$f' \to 0 \quad h' \to 0 \quad \theta \to 0 \quad \text{as} \quad \eta \to \infty$$

where,

$$C_1 = \frac{1}{(1-\phi)^{2.5}},$$

$$C_2 = \left(1-\phi+\frac{\phi\rho_s}{\rho_f}\right),$$

$$C_3 = \left(1-\phi+\frac{\phi\rho\beta_s}{\rho\beta_f}\right),$$

$$C_4 = \frac{\left(k_s+2k_f\right)-2\phi\left(k_f-k_s\right)}{\left(k_s+2k_f\right)+\phi\left(k_f-k_s\right)},$$

$$C_5 = 1-\phi+\frac{\phi\left(\rho C_p\right)_s}{\left(\rho C_p\right)_f}$$

$$Nr = \frac{16\sigma^* T_\infty^3}{3k^*}$$

ε is the amplitude of the gravitational modulation and Ω is the frequency of oscillation driven from the g-jitter effect respected to time τ. c and Nr are curvature ratio from a stagnation point parameter and thermal radiation parameter while ϕ is a nanoparticles volume fraction which represent the effect of nanofluid in the flow.

RESULTS

The system of equation (1)-(3) is solved numerically using Keller box method together with boundary condition in (4). An analysis is conducted by considering all the effects in this problem and presented graphically as Fig. 1-Fig. 6

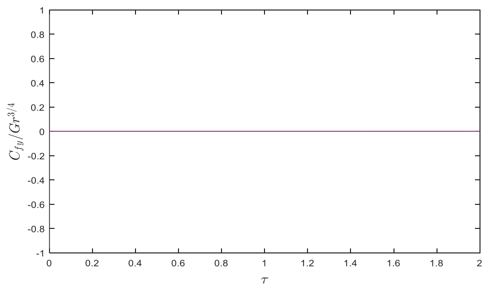

Fig. 1: Effect of stagnation point parameter when $c = 0$ on skin friction.

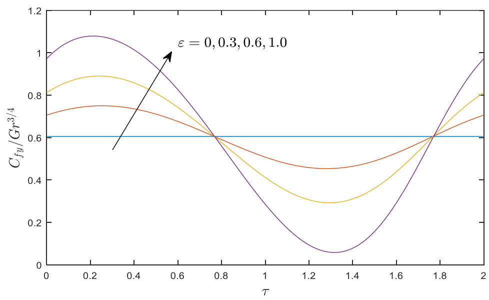

Fig. 2: Effect of stagnation point parameter when $c = 1$ on skin frictions.

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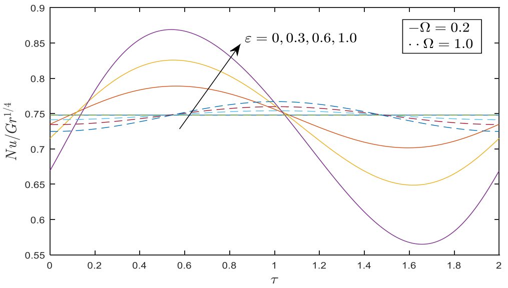

Fig. 3: Effect of g-jitter parameters on the Nusset number

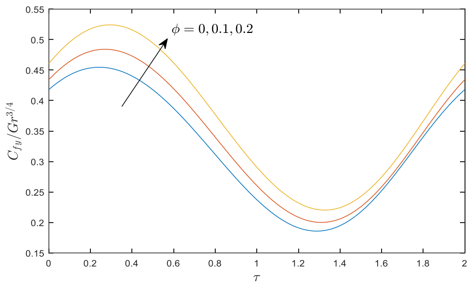

Fig. 4: Effect of nanoparticle volume fraction on the skin friction.

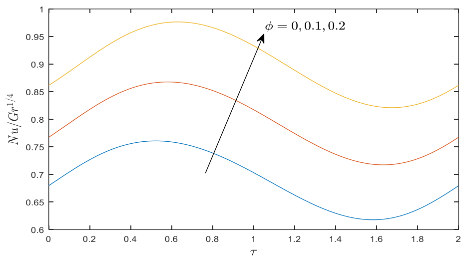

Fig. 5: Effect of nanoparticle volume fraction on the Nusset number.

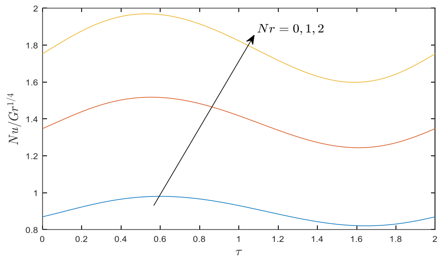

Fig. 6: Effect of thermal radiation parameter on the Nusset number.

Fig. 1 and Fig. 2 shows the effect of stagnation point parameter on the fluid flow behavior. The value is chosen for the curvature ratio will produce a special stagnation-point case flow such as plane stagnation case flow on Fig. 1 and axisymmetry case flow on Fig. 2 as also found in (2). As for the g-jitter effect in Fig. 3, ε is found producing a fluctuanting result of Nusset number same as (3) correspond to there are a singularity solution happen on the flow. The larger value of Ω also found reduce the peak values of the Nusset number and converge faster than a small value of Ω. Effect of volume nanoparticle volume fraction is studies on Fig. 4 and 5 and the increases values of ϕ increase both skin friction and the Nusset number same as found by (4). Lastly, Fig. 6 analyzed effect of thermal radiation on the Nusset number and the behaviour show a good agreement with the previous study conducted in (5).

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