Unsteady Slip Flow of Casson Fluid in Presence of Thermal Radiation and Heat Generation/Absorption with Suction/Blowing Effect

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Abstract

The numerical investigation of unsteady boundary layer slip flow and heat transfer of an incompressible Casson fluid on a vertically stretching sheet in presence of Suction and blowing. The above physical problem is represented in terms of Partial differential equations with boundary conditions. The suitable transformations are used to convert these governing partial differential to ordinary differential equations and then solved numerically by fourth order Runge-Kutta 4th order method with MAT LAB software. The impact of various governing parameters like Slip parameter (μ), Casson parameter (β), Heat generation and absorption coefficient (δ), Radiation parameter (Nr) on the velocity profile are discussed through graphs in detail. The study reveals that the variation of these parameters has erudite effect on velocity and temperature boundary layer thicknesses respectively. Also the variation of Skin friction coefficient and Heat transfer coefficient are studied numerically by increasing the values of parameters like slip parameter (μ), Unsteadiness parameter (A), and Casson parameter (β) etc. The graphs of these are plotted and discussed.

Keywords — *Slip flow, Casson fluid, Heat transfer, Suction / blowing.***

I. INTRODUCTION

Non-Newtonian fluids have vast applications in many area especially in the flow of nuclear fuel slurries, flow of liquid metal and flow of alloys, flow of plasma, and flow of lubrication with heavy oil and greases, coating of papers, polymer extrusion etc. The study of non-Newtonian fluid is very difficult, because of their complex nature and complex interactions with the flow field. The governing equations for non-Newtonian fluid flows are highly nonlinear. The study of non-Newtonian fluids has attracted much attention of the researchers because of its extensive applications in engineering and industry especially in the production of plastic materials, syrup drugs, and extraction of petroleum products from crude oil etc. Casson fluid is one type of fluid which shows Newtonian behaviour in presence of high shear rate and shows non-Newtonian behaviour with low shear rate. The Casson fluid model is a non-Newtonian fluid model which fits rheological data compare to any general viscoelastic models. Jelly, honey, tomato ketchup, soap, are examples of Casson fluid. Since human blood shows all these phenomenon, human blood can be treated as a Casson fluid. Sreenadh et al [1] studied the flow of a Casson fluid through an inclined tube of non-uniform cross section with multiple stenosis. Unsteady boundary layer flow of a Casson fluid due to an impulsive movement of the flat plate was studied by Mustafa *et al*. [2].The numerical study of electrically conducting boundary layer flow of a Casson fluid towards an exponentially shrinking sheet was carried out by Nadeem et al. [3].The boundary layer flow of a Casson Nano fluid was studied by Malik M Y et.al [4] .The effect of suction and blowing on steady boundary layer flow of Casson fluid over an exponentially stretching sheet in the presence of thermal radiation with suction and blowing effect was investigated by S.Pramanik [5]. A numerical study on Steady Mixed Convection Magneto hydrodynamic boundary layer flow and heat transfer of Casson fluid in presence of suction and blowing was carried out by B. Lakshmi et.al [6].

The Suction and blowing effects many applications in engineering activities. Suction is applied to chemical processes to remove reactants. Blowing is used to add reactant, cool the surface, in the prevention of corrosion. The boundary layer stagnation point flow and heat transfer towards a shrinking sheet in presence of suction/blowing with thermal radiation was studied by Bhattacharya and Layek [7].Suction and blowing effect on the Magneto hydro dynamic boundary layer slip flow over an exponentially sheet in presence of thermal radiation with suction and blowing was studied by

Mukhopadhyay and Swathi [8]. Mixed Convection Unsteady Stagnation-Point Flow towards a Stretching Sheet with Slip Effects was studied by Hui Chen[9].Later A.Mahdy [10] conducted a numerical computation on the Unsteady MHD slip flow of a non-Newtonian Casson fluid over a vertical stretching sheet with suction/blowing effect.

The present study spots a light on the analysis of the Magneto hydro dynamic slip flow of Casson fluid over a vertical stretching surface in presence of thermal radiation with suction and blowing effect. Variation of Skin friction coefficient- $f''(0)$ and Heat transfer coefficient- $\theta'(0)$ with respect to different parameters like slip parameter (μ), Unsteadiness parameter A, Casson parameterβ, and Permeability parameter (λ) are studied graphically and also numerical, graphical investigation of different parameters their effect on velocity and temperature profiles are carried out.

II. PROBLEM FORMULATION

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \qquad (1)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2} \qquad (2)$$

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{1}{\rho C_p}\left(k\frac{\partial^2 T}{\partial y^2}-\frac{\partial q_r}{\partial y}+Q\left(T-T_\infty\right)\right) \qquad (3)$$

Where u and v are the fluid velocity components with respect to x and y axes, υ is the kinematic viscosity, g is the gravitational field, β_t coefficient of thermal expansion, T is the fluid temperature, σ is the electrical conductivity, ρ is the density of the fluid, k is the thermal conductivity, Cp is the specific heat at constant pressure, q_r is the radiation heat flux.

The radiation heat flux is evaluated by Roseland approximation as

$$q_r=\frac{4\sigma_s}{3K}\frac{\partial T^4}{\partial y} \qquad (4)$$

Where σ_s is the Stefan-Boltzmann constant and K is the absorption coefficient, T^4 can be linearly expanded in a Taylor's series about T_∞ to get

$$T^4=4T_\infty^3T-3T_\infty^4. \qquad (5)$$

Substituting equations (4) and (5) in (3) we get

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{1}{\rho C_p}\left\{\left(k+\frac{16\sigma_s T_\infty^3}{3K}\right)\frac{\partial^2 T}{\partial y^2}+Q_0\left(T-T_\infty\right)\right\} \qquad (6)$$

In order to reduce the above Partial Differential equations to Ordinary Differential equation, we introduce the following similarity conditions

$$\eta=\sqrt{\frac{U_o}{\upsilon(1-\alpha t)}}\,y \qquad (7)$$

$$T=T_\infty+\frac{T_0x^2(1-\alpha t)^{-3/2}}{2\upsilon}\theta(\eta) \qquad (8)$$

$$\psi=\sqrt{\frac{\upsilon U_0}{1-\alpha t}}\,xf(\eta) \qquad (9)$$

A. Boundary Conditions:

The boundary conditions of the governing equations are

$$y=0,\ u=U(x,t)+Lu' \qquad (10)$$

$$V=V(x),\ T=T_w(x,t),\quad \text{and}$$

$$u'=\frac{\partial u}{\partial y}$$

$$y\to\infty;\ u\to 0,\ T\to T_\infty$$

The transformed boundary conditions are

$$\eta=0,\ f'=1+\mu f'',\quad f=S\quad \theta=1 \qquad (11)$$

$$\eta\to\infty,\ f'\to 0,\ \theta\to 0.$$

$$\left(1+\frac{1}{\beta}\right)f'''(\eta)-\left[f'(\eta)\right]^2+f(\eta)f''(\eta)-A\left(\frac{\eta}{2}f''(\eta)+f'(\eta)\right)=0 \qquad (12)$$

$$\theta''(\eta)-\frac{P_r}{1+N_r}\left[\frac{A}{2}\left(\eta\theta'+3\theta\right)+2f'(\eta)\theta(\eta)-f(\eta)\theta'(\eta)-2\delta\theta(\eta)\right]=0 \qquad (13)$$

Where $P_r=\frac{\rho\upsilon C_p}{k}$ is the Prandtl number,

$\delta=\frac{Q_o(1-\alpha t)}{U_oC_p\rho}$ is the heat generation if (δ >0), and absorption (if $\delta<0$) parameter. $N_r=\frac{16\sigma_sT^3}{3kK}$ is the thermal radiation parameter, $A=\frac{\alpha}{U_0}$ Unsteadiness parameter,

$\mu=L\left(\frac{U_0}{\upsilon(1-\alpha t)}\right)^{-1/2}$ is the dimensionless parameter

III. RESULTS AND DISCUSSION

The Partial differential ordinary equations (2) and (6) are transformed in to Ordinary differential equations(12) and (130 using the similarity transformations represented by equations (8),(9),(10) and then they are subjected to boundary conditions (11) are solved numerically using MATLAB software and the results are plotted as shown figs [1-12] to study the behaviour of velocity and temperature profiles by considering various values for the parameters A, Pr, Nr, μ ,δ.

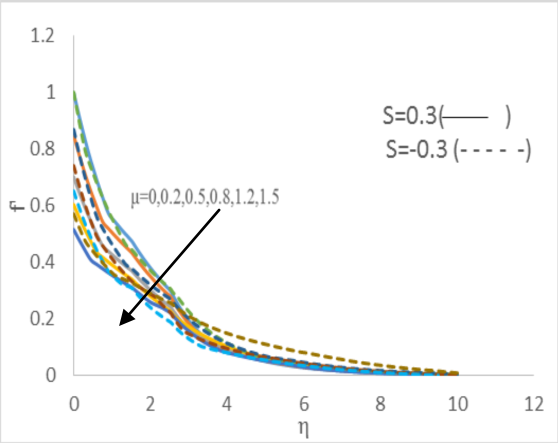

Fig 1.Velocity Profile for various values of Slip parameter (μ) With A=0.1, β=0.5, Pr=0.72, Nr =3.

Figures 1 gives the velocity profiles for various values of the slip parameter (μ) with suction/blowing effect. The slip parameter μ measures the magnitude of slip takes place at the surface. Fig 1 shows clearly that as the value of the slip parameter varies the velocity distribution of the fluid drops, because as the value of μ increases this permits more fluid to flow over the surface due to which the flow retards near the stretching surface this declines fluid velocity which leads to the thinning of velocity boundary layer.

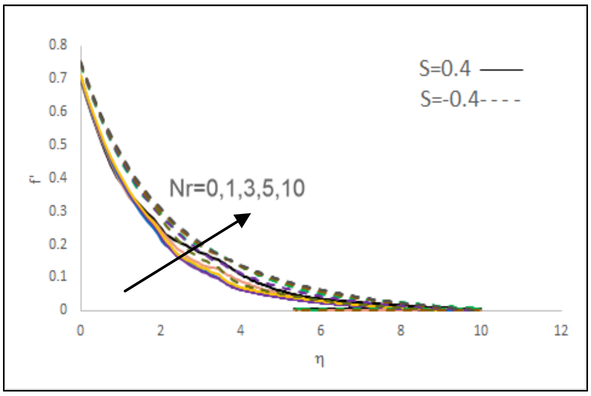

Fig 2. Velocity Profile for various values of Radiation Parameter (Nr) with δ=-0.5, A=0.7, β=0.5, Pr=0.6, μ=0.7.

The above figs 2 defines the effect of thermal radiation (Nr) on velocity profiles. It is noted that when the value of thermal radiation parameter Nr is increased the velocity profile increases.

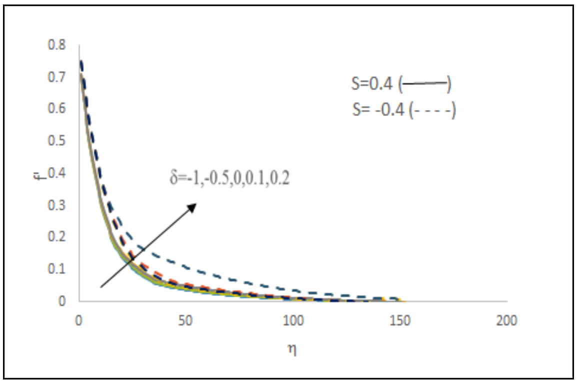

Fig 3. Velocity Profile for various values of heat generation/absorption coefficient (δ) with β=0.5, Pr=0.72, Nr =5, μ=0.7.

The velocity for various values of heat generation and absorption coefficient is as shown in the fig 3. it has been observed that the fluid velocity increases with increases in the value of δ.

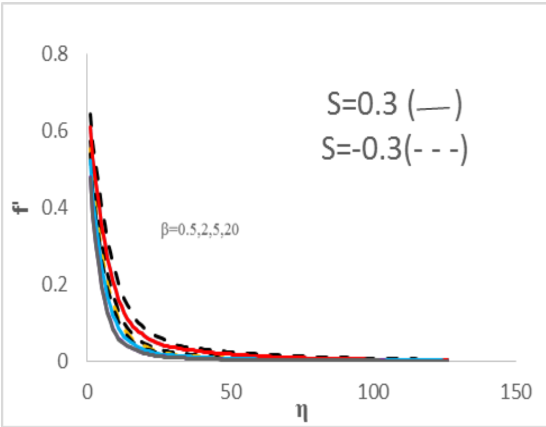

Fig 3. Velocity Profile for various values of Casson parameter (β) with A=0,1. Pr=0.72, Nr =5, μ=0.7.

From the above graph it is clear that the velocity of the fluid decreases with increase in the value of the Casson parameter (β).This is because when Casson parameter (β) is increased the fluid shows Newtonian characteristic with increased yield stress and this intern slowdowns the fluid flow.

The following graphs [4-10] shows the variation in the skin friction coefficient $-f''(0)$ and heat transfer coefficient $-\theta'(0)$ for various values of slip parameter (μ),Unsteadiness parameter A, Casson parameterβ,and Permeability parameter(λ).

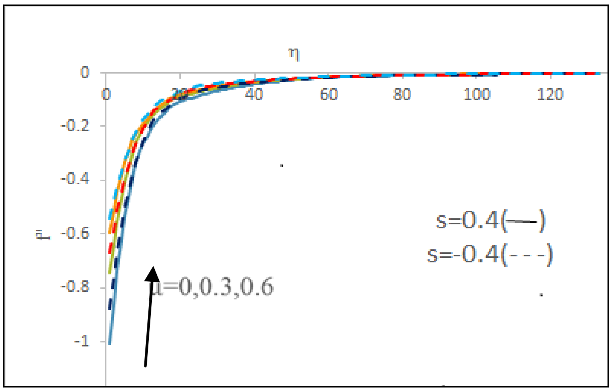

Fig.4 .Variation of $-f''(0)$ for μ=0.0.3, 0.6, M=0.6, A=0.1,β=0.5, Pr=6.2 Nr=5.

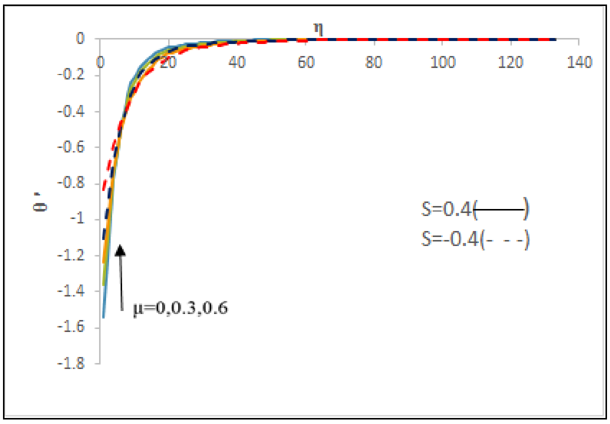

Fig.5.Variation of $-\theta'(0)$ for μ=0.0.3, 0.6, M=0.6, A=0. β=0.5, Pr=6.2 Nr=5.

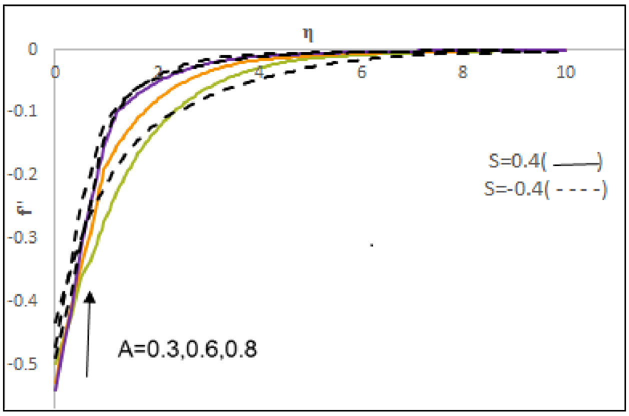

Fig.6 .Variation of $-f''(0)$ for A=0.3, 0.6, 0.8, λ=0.4, μ= δ =0.7, β=0.5, Pr=6.2 Nr=5.

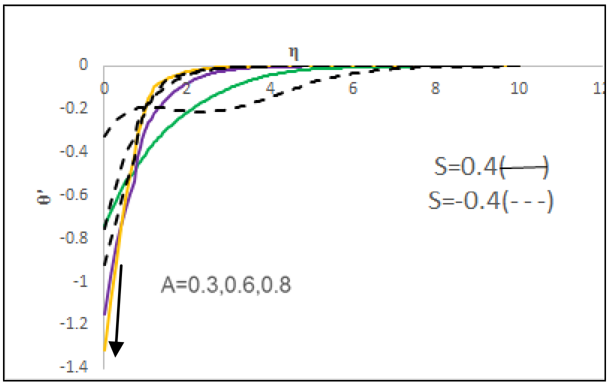

Fig.7 .Variation of $-\theta'(0)$ for A=0.3, 0.6, 0.8, λ=0.4, μ= δ =0.7, β=0.5, Pr=6.2 Nr=5.

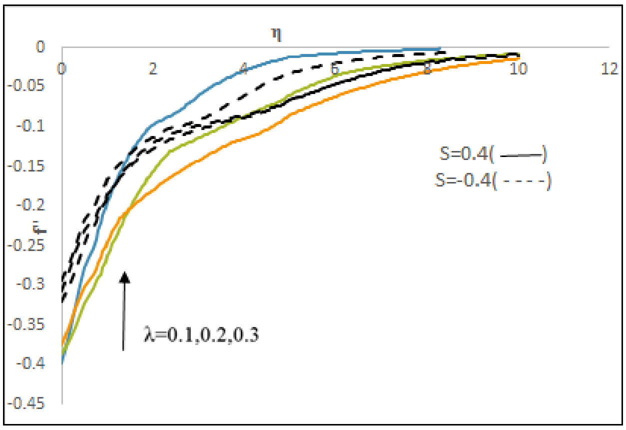

Fig.8 .Variation of $-f''(0)$ for λ=0.1, 0.2, 0.3. M=0.6, λ=0.4, μ= δ =0.7, β=0.5, Pr=6.2 Nr=5.

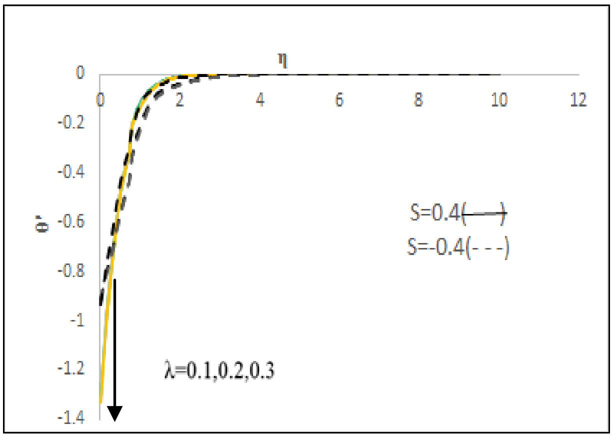

Fig.9 .Variation of for $-\theta'(0)$ λ=0.1, 0.2, 0.3. M=0.6, λ=0.4,μ= δ =0.7, β=0.5, Pr=6.2 Nr=5.

From the graphs [4-9] it is observed that the skin friction coefficient $f''(0)$ and heat transfer coefficient $\theta'(0)$ increases with increases in the value of the μ and δ in presence of suction and blowing. But the value of $f''(0)$ and $\theta'(0)$ decreases with the increases in the value of unsteadiness parameter (A) when S=0.4(Suction) and S=-0.4(blowing).

As the value of the Casson parameter is increased in presence of suction and blowing, the value of $f''(0)$ and $\theta'(0)$ increases. Also with the increase in the permeability parameter (λ) the skin friction coefficient $f''(0)$ increases but heat transfer coefficient $\theta'(0)$ decreases.

IV. CONCLUSIONS

The conclusions of the above work can be outlined as follows.

- The Skin friction coefficient increases with increases in the values of Slip parameter (μ), Casson parameter (β), Permeability parameter (λ) in presence of suction and blowing. While with the increases in the Unsteadiness parameter (A) the Skin friction coefficient decreases.
- The Heat transfer coefficient increases with increases in the values of Slip parameter (μ), Casson parameter (β) in presence of suction and blowing. But with the rise in the value of Unsteadiness parameter (A) and Permeability parameter (λ) the Heat transfer coefficient diminishes.
- With increase in slip parameter (μ) the thickness in velocity boundary layer diminishes in presence of suction/blowing.
- With increases in Radiation parameter (Nr), velocity boundary layer thicknesses increases.
- Fluid velocity increases with increases in heat generation and absorption coefficient (δ).

ACKNOWLEDGEMENTS

The authors would like to thank Dr. A.R Manjunath, Professor, Department of Aerospace Engineering, and Jain University for his timely help and guidance in solving differential equations in Mat lab to obtain results.

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