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ORIGINAL ARTICLE

Boundary layer flow and heat transfer analysis on Cu-water nanofluid flow over a stretching cylinder with slip

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Abstract Investigation of heat transfer effect on Cu-water nanofluid flow past a stretching cylinder is focused in the recent article. The numerical method of nonlinear known as RKF 4–5th has been taken into account along with shooting process to obtain the solution of required ODEs with supplementary boundary conditions. The influence of thermal radiation parameter on non-dimensional skin friction and Nusselt number along with convection parameter, solid particle volume fraction and heat generation/absorption parameter are represented in the tabular and graphical way. The volume fraction of nanofluid is considered as 0–6% with an increment of 2%. The thermal radiation parameter lies in the domain of $[0.3, 5]$. Moreover, the values of porosity parameter (λ) and heat generation/absorption parameter (Q) are varied as $0.5 \leqslant \lambda \leqslant 2.5$ and $-2 \leqslant Q \leqslant 2$, respectively. The data of authors declared that augmentation is perceived in temperature curves with the volume fraction of solid particles; moreover, momentum boundary layer depreciates with boost in volume fraction parameter of copper (Cu) particles. The obtained data are distinguished with earlier study and admirable agreement has been noted.

1. Introduction

There is a significant role of thermal radiation effects on flow and heat transfer in the field of Engineering and Physics, mainly space technology, high-temperature processes and also it plays a vital role to improve the heat transfer characteristics in polymer processing industry. Wang [1] has planed the steady flow of fluid over a stretching cylinder as of outer surface. The leading problem is a third order ODEs that lead to perfect similitude solutions of the Navier-Stocks equations. The simultaneous influences of MHD and entropy generation flow over a stretching cylinder in the existence of porous medium were purposed by Butt et al. [2] and they investigated that as accelerated in magnetic parameter and permeability parameter momentum boundary layer reduces. Ishak et al. [3] have described suction/injection effect on steady flow of an incompressible fluid due to a permeable stretching tube. They noticed that that Reynolds number climbs as growing in the numerical

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Nomenclature

A	constant
A_1	constant
B	constant
c	constant
C_f	skin-friction coefficient
C_p	heat capacity (J/kg K)
Ec	Eckert number
f	non-dimensional stream function
g	acceleration due to gravity (m/s^{-2})
K	permeability of the porous medium
K^*	Rosseland mean absorption coefficient
L	velocity slip factor
l	thermal slip factor
Nr	thermal radiation parameter
Nu	Nusselt number
Pr	Prandtl number
q_r	thermal radiative heat flux
Q_0	heat generation/absorption coefficient
Q	heat generation/absorption parameter
Re	Reynolds number
s	velocity slip parameter
T	temperature of the fluid (K)
T_w	temperature of the surface of tube (K)
T_∞	temperature of fluid far from the tube
t	thermal slip parameter
u, w	velocity along r and z direction (m/s)
z	cylindrical coordinate in axial direction (m)

Greek symbols

α_{nf}	thermal diffusivity of nanofluid (m^2/s)
β_{bf}	thermal expansion coefficient of base fluid (K^{-1})
β_{nf}	thermal expansion coefficient of nanofluid (K^{-1})
β_{sp}	thermal expansion coefficient of solid particle
κ_{bf}	thermal conductivity (W/mK)
κ_{nf}	thermal conductivity (W/mK)
κ_{sp}	thermal conductivity (W/mK)
ϕ	solid volume fraction (%)
λ	porosity parameter
$(\rho C_p)_{nf}$	heat capacitance of nanofluid
ρ_{bf}	density of base fluid (kg/m^3)
ρ_{nf}	density of nanofluid (kg/m^3)
ρ_{sp}	density of solid particle (kg/m^3)
σ^*	Stefan-Boltzmann constant (W/m^2 K^4)
μ_{bf}	dynamic viscosity of base fluid (kg/ms)
μ_{nf}	dynamic viscosity of nanofluid fluid (kg/ms)
v_{bf}	kinematic viscosity of base fluid (m^2/s)
θ	non-dimensional temperature
γ	natural convection parameter
η	similarity variable

Superscripts

$*$	asterisk
$\prime$	derivative with respect to η

Subscripts

bf	base fluid
nf	nanofluid
sp	solid particle fluid
∞	free stream condition

values of skin friction coefficient. Ashorynejad et al. [4] have purposed the influence of magnetohydrodynamic flow over a stretching tube utilizing nanofluid. They established that on escalating the values of both magnetic parameter and Reynolds number, shear stress rate is amplified. Ahmed et al. [5] have examined the mutual influences of heat source/sink, thermal conductivity and dynamic viscosity with the existence of stretching permeable tube utilizing nanofluid. Majeed et al. [6] have analyzed the synchronized influence of partial slip and heat transfer on steady non-Newtonian Casson fluid flow outside stretching tube with arranged heat flux. They found that as amplified in Casson fluid parameter, the heat transfer rate moderates. Hayat et al. [7] have described magnetohydrodynamic third grade fluid flow past a stretching cylinder. They set up that Reynolds number is decreasing function of radial velocity. The influence of mixed convection steady flow past a stretching tube has been projected by Wang [8]. Si et al. [9] have studied the heat transfer influence on unsteady viscous flow past a stretching porous tube. Wang and Ng [10] considered viscous fluid flow outside stretching cylinder in the incidence of slip. They established that unsteady parameter is an escalating function of temperature profiles of nanoparticles. Ishak and Nazar [11] have purposed the laminar and incompressible viscous fluid flow past a stretching cylinder. Naramgari and Sulochana [12] have examined the effects of flow and heat transfer on nanofluid flow due to a stretching surface with MHD. Sk et al. [13] studied the grouped effect of MHD and slip on permeable stretching surface utilizing nanofluid. The various studies were visualized to analyze the thermal radiation influence on nanofluid flow over a stretching/shrinking sheet [14–17]. Similarly, the several attempts have been made to examine the influence of natural convection during nanofluid flow under different conditions (see [18–24]). Ganga et al. [25] describe the viscous and Ohmic dissipation influences on MHD flow due to a vertical plate with heat generation/absorption in the existence of nanofluid. They depicted that heat transfer coefficient is a decreasing function of Eckert number. Recently, Pandey and Kumar have [26] investigated the influence of viscous dissipation and suction/injection on nanofluid flow due to a porous wedge with slip and MHD. The boundary layer flow of Sisko fluid due to different geometry has been studied by [27–30]. Khan et al. [31] have used both analytical and numerical methods to find the solution of Sisko nanofluid flow over a stretching surface in the presence of convective boundary conditions. Again, the heat transfer characteristics of Sisko nanofluid flow past a stretching cylinder are studied by Khan and Malik [32]. The current work deals with the influence of thermal radiation with, porosity parameter, heat source/sink and slip on nanofluid steady flow over a stretching cylinder. The solution of the study is obtained

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