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Numerical solution for hydromagnetic boundary layer flow and heat transfer past a stretching surface embedded in non-Darcy porous medium with fluid-particle suspension

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Abstract

This paper investigates the problem of MHD boundary layer flow and heat transfer of an electrically conducting dusty fluid over an unsteady stretching surface through a non-Darcy porous medium. The flow in porous medium is described by employing the Darcy–Forchheimer based model. The unsteadiness in the flow and temperature fields are because of time-dependent stretching velocity and surface temperature. The effect of thermal radiation, viscous dissipation and non-uniform heat source/sink are also taken into account. The pertinent time-dependent equations, governing the flow and heat transfer are reduced into a set of non-linear ordinary differential equations with the aid of suitable similarity transformations. The transformed equations are numerically integrated using fourth–fifth order Runge–Kutta–Fehlberg method. The effects of various physical parameters on the velocity and temperature profiles of both phases are analyzed through several plots. Obtained numerical results are compared and found to be in good agreement with previously published results as special cases of the present investigation. It is found that, by suspending fine dust particles in the clean fluid reduces the thermal boundary layer thickness. Therefore, the dusty fluids are preferable in engineering and scientific applications, involving cooling processes.

Keywords: Non-Darcy flow; Dusty fluid; Thermal radiation; Numerical solution; Unsteady stretching sheet; Viscous dissipation

1. Introduction

Boundary layer flow and heat transfer of a fluid over a stretching surface has attracted many researchers in the last few decades. Since, it has a wide range of applications in various fields such as polymer processing industries,

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Nomenclature

a, b, c	Constants
A^*, B^*	Space and temperature dependent heat generation or absorption parameters
B	Magnetic field
B_0	Magnetic field strength
c_p	Specific heat of the fluid phase (J/kg K)
c_m	Specific heat of the dust phase (J/kg K)
C_b	Form of Drag co-efficient
C_f	Skin-friction co-efficient
D	Constant
Ec	Eckert numebr
f	Dimensionless fluid phase velocity component
F	Dimensionless dust velocity component
f_0	Suction/blowing parameter
K	Stokes drag coefficient
k	Thermal conductivity of the fluid
k_0	Porous parameter
kp	Permeability of porous medium of variable kind
k^+	Mean absorption coefficient
$k_0{}^*$	Permeability of porous medium
l	Parameter of Mass concentration of dust particles
m	Mass of dust particles
M^2	Magnetic parameter
N	Number density of dust particles
Nu	Nusselt number
Pr	Prandtl number
q_r	Radiative heat flux
q_w	Surface heat flux
q_f	Rate of heat transfer
q'''	Space and temperature dependent heat generation/absorption
R	Radiation parameter
r	Radius of dust particles
Re_x	Local Reynolds number
S	Unsteady parameter
t	Time
T	Fluid phase temperature (K)
T_p	Dust phase temperature (K)
T_w	Temperature at the wall (K)
T_∞	Ambient Temperature (K)
u, v	Fluid phase velocity components along x and y directions (m s^{-1})
u_p, v_p	Dust phase velocity components along x and y directions (m s^{-1})
U_w	Stretching sheet velocity (m s^{-1})
V_w	Suction/injection velocity (m s^{-1})
x, y	Co-ordinates (m)
ρ	Density of the fluid phase (kg/m^3)
ρ_p	Density of the dust phase (kg/m^3)
μ	Dynamic viscosity (kg m^{-1} s^{-1})
σ	Electrical conductivity of the fluid
φ	Porosity of the porous medium
ν	Kinematic viscosity of the fluid (m^2 s^{-1})