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ORIGINAL ARTICLE

Steady nanofluid flow with variable fluid possessions over a linearly extending surface: A Lie group exploration

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Abstract The temperament of stream characteristic, heat and mass transfer of MHD forced convective flow over a linearly expanding porous medium has been scrutinized in the progress exploration. The germane possessions of the liquid like viscosity along with thermal conductivity are believed to be variable in nature, directly influenced by the temperature of flow. As soon as gaining the system of leading equations of the stream, Lie symmetric group transformations have been employed to come across the fitting parallel conversions to alter the central PDEs into a suit of ODEs. The renovated system of ODE with appropriate boundary conditions is numerically solved with the assistance of illustrative software MAPLE 17. The consequences of the relevant factors of the system have been exemplified through charts and graphs. An analogous qualified survey has been prepared among present inquiry and subsisting reads and achieved an admirable accord between them. The variable viscosity parameter has more significant effect on nanofluid velocity than regular fluid and temporal profile as well as nanoparticle concentration is also influenced with variable viscosity.

1. Introduction

The MHD Nano liquid flow induced by an elongating surface has attracted the concentration of countless intellectuals owing to its noticeably eminent significance in the fabrication of sheeting material of both metal and polymer sheets, extending of optical fiber. Following the pioneering effort of Sakiadis [1], Crane [2] inspected the stable incompressible Newtonian liquid surge over an elongating sheet. Further, Weidman and Magyari [3] have explored assorted flow challenges over an extending sheet under diverse borderline conditions. Noghrehabadi et al. [4] argued the flow of thermal energy within nanofluids induced by extending sheet with partial slip border conditions. Influence of Magnetic force over a Nano liquid stream induced by extending plane nonlinearly is perceived by Sk et al. [5]. When thermal energy and mass are surged concurrently in a moving gush, the associations between the fluxes and the dynamic potentials are noteworthy. So the thermal energy flux

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Nomenclature

u, v	velocity components along x, y-axis
v_w	suction/injection velocity
T	temperature variable
C	nanoparticle volumetric fraction
c_p	specific heat at constant pressure
Pr	Prandtl number
D_T	thermophoretic diffusion coefficient
Shr	local Sherwood number
U	free stream velocity of the flow
Nur	local Nusselt number
f_w	suction/injection parameter
M	magnetic field parameter
Re_x	local Reynold's number
Nt	thermophoresis parameter
Nb	Brownian motion parameter
B_0	magnetic field flux
C_fr	local skin friction coefficient
K	permeability parameter of porous medium

Greek symbols

τ	ratio between effective heat capacity of the nanoparticle and the fluid
φ	dimensionless nanoparticle concentration
σ	electrical conductivity
ν	kinematic viscosity
ψ	stream function
η	similarity variable
ε	thermal conductivity parameter
θ_r	variable viscosity parameter

Subscript

$'$	differentiation with respect to η
∞	condition far away from the plate
w	condition on the sheet

is able to be produced by temperature gradients in addition to concentration gradients as well. Alam et al. [6] explored the upshot of Soret and Dufour impression on trembling MHD mass transfer course past a vertical permeable plane in a permeable medium. Layek et al. [7] deliberate the stagnation point stream flowing over a hot widening plate entrenched in a porous medium and conferred the flow of thermal energy and mass toward. An inconstant course induced by a porous drawing out surface with prescribed fence temperature has been measured by Ishak et al. [8]. Hamad [9] acquired analytical resolution of free convection stream over an enlarging sheet with the influence of outer magnetic flux. Elbashbeshy et al. [10] equipped a precise solution of boundary layer nanofluid course flowing with magnetic influence and suction or injection factor. Nanofluid stream along with gyrotactic microorganisms is investigated and several slip effects on the course have been discussed by Sk et al. [11]. Zeeshan et al. [12] considered a nonlinearly enlarging surface to explore the flow property and heat transmission of viscous Ferro-fluid in application of magnetic dipole. Many researchers show interests in nanoparticle to enhance the heat transfer capacity of the fluid to meet the energy efficient eco-friendly planet. For this purpose scholars like Ellahi et al. [13] investigated the influence of various shapes of Cu nanoparticle on enhancement of heat transmission capacity and thermal conductivity of water. Also Ellahi et al. [14] analyzed natural convection of single and multi-walled carbon nanotubes in salt water nanofluid. Sk et al. [15] use TiO_2 as nanoparticle in water and kerosene nanofluid to get more efficient heat movement vehicle.

Most of the mentioned efforts are accomplished considering the fluid possessions independent on time, flow temperature, etc. But the substantial belongings of the liquids may amend drastically with temperature, pressure or distance. In case of lubricating solutions, mount in heat attributable to the internal resistance concerns the liquid viscosity and accordingly it cannot be treated as invariable. Amplifying of the drift temperature escorts to a local enlargement in the convey incident by dropping the viscosity crossways the boundary layer and so the heat relocation pace at the wall is also distressed greatly. In industrialized construction systems, liquids frequently endure tremendous circumstances such as soaring temperature, incredible pressure, towering shear rates and external heating and each of these aspects may guide to uneven fluid assets. The participation of irregular liquid property must bear in mind for scrutinizing nanofluid stream further more precisely and accurate estimation of transmission of thermal energy and mass. Researchers such as Batchelor [16], Ling and Dybbs [17], Chiam [18], Mukhopadhyay et al. [19], Myers et al. [20], had provided evidenced in their exertion that the thermal conductivity and viscosity are for the most part receptive to thermal ascending. Prasad et al. [21] examined the consequences of viscosity and thermal conductivity reliant on temperature on heat and mass relocation surge over a nonlinearly elongated sheet. Das [22] thrashed out the encouragement of variable fluid assets on micro polar fluid stream with accompany of thermophoresis effect and chemical reaction. Mukhopadhyay [23] implemented Batchelor's model [16] of fluid viscosity reliant on temperature to scrutinize the influence of thermal energy emission on heat reassign alongside a symmetric wedge. Recently, Animasaun [24] deliberated the consequences of uneven fluid belongings on free convective Casson liquid current. Intellectuals such as Sheikholeslami and Ellahi [25], and Akbar et al. [26] investigated the effect of magnetic force field on the nanofluid embedded in various media. Rashidi et al. [27] studied transverse magnetic field over a fluid flow with diamond shaped porous obstacle. Kandelousi and Ellahi [28] applied non-constant magnetic field to study the effect on Ferro nanofluid in a vessel as drug transport vehicle using lattice Boltzmann method.

The symmetries of differential equations, which arise frequently in Lie group analysis, are the suite of alterations for which partial differential equations become ordinary differential equations but the solutions linger unaffected [29–31]. The scheme is extensively employed in nonlinear dynamical struc-

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