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ORIGINAL PAPER

Combined effects of slip and convective boundary condition on MHD 3D stretched flow of nanofluid through porous media inspired by non-linear thermal radiation

M K Nayak[1]*, S Shaw[2], V S Pandey[3] and A J Chamkha[4]

[1]Department of Physics, Radhakrishna Institute of Technology and Engineering, Biju Patnaik University of Technology, Bhubaneswar, Odisha, India

[2]Department of Mathematics and Statistical Sciences, Botswana International University of Science and Technology, Private Bag 16, Palapye, Botswana

[3]Department of Physics, National Institute of Technology Delhi, New Delhi, India

[4]Department of Mechanical Engineering, Prince Mohammad Bin Fahd University, Al-Khobar 31952, Saudi Arabia

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Abstract: In the present study, the main concern is to investigate the magnetohydrodynamic nanofluid flow subject to porous matrix and convective heating past a permeable linear stretching sheet. In addition, the influence of velocity slip, viscous dissipation, Joule heating and non-linear thermal radiation are considered. A new micro-convection model known as the Patel model is implemented for considerable enhancement of the thermal conductivity and hence, the heat transfer capability of nanofluids. Moreover, a convective heat transfer model is introduced where the bottom surface of the sheet gets heated due to a convection mechanism from a hot fluid of particular temperature. The numerical results of the transformed governing differential equations have been obtained by using fourth-order Runge–Kutta method along with shooting approach and secant method is used for better approximation. In the present analysis, base fluids such as water and Ethylene glycol and Copper, Silver and Aluminum oxide nanoparticles are considered. Results of the present investigation show that inclusion of porous matrix contributes to slow down the fluid velocity and diminution of wall shear stress (axial as well as transverse). Drag force due to magnetic field strength, velocity slip and imposed fluid suction impede the fluid motion and upsurge the heat transfer rate from the surface. In addition, rise in viscous dissipation widens the thermal boundary layer.

Keywords: MHD 3D flow; Velocity slip; Non-linear thermal radiation; Convective boundary condition; Porous matrix

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1. Introduction

After decades of slow momentum on the research regarding the boundary layer flow of viscous/viscoelastic fluids, many researchers [1–5] have succeeded in establishing the developmental needs of the 21st century. The major advantage of magnetohydrodynamic (MHD) flow is that an applied magnetic field controls/regulates momentum and heat transfers in the boundary flow of viscous/viscoelastic fluids over a stretching surface. With the help of this principle, a controlled cooling system is developed which is very much essential for the qualities of final products in manufacturing processes involved in industrial fields.

At this moment it is not clear if this is a short- term trend or if this indicates a long-term decline of investigation regarding the heat transfer enhancement of viscous/viscoelastic fluids. But as of now, there seems to be a clear shift from traditional way of heat transfer enhancement to modern mechanism of suitable dispersion and sustainable suspension of nanoparticles of higher thermal conductivity (viz. metals, oxides, carbides, nitrides and carbon nanotubes (particles of 100 nm or less size) in conventional

*Corresponding author, E-mail: mkn2122@gmail.com

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ARTICLE

Effects of Homogenous–Heterogeneous Reactions on Radiative NaCl-CNP Nanofluid Flow Past a Convectively Heated Vertical Riga Plate

M. K. Nayak[1,*], Sachin Shaw[2], O. D. Makinde[3], and Ali J. Chamkha[4]

[1]*Department of Physics, Radhakrishna Institute of Technology and Engineering, Biju Patnaik University of Technology, Odisha 751052, India*
[2]*Department of Mathematics and Computational Sciences, Botswana International University of Science and Technology, Private Bag 16, Palapye, 10071, Botswana*
[3]*Faculty of Military Science, Stellenbosch University, Private Bag X2, Saldanha 7395, South Africa*
[4]*Department of Mechanical Engineering, Prince Mohammad Bin Fahd University, Al-Khobar 31952, Saudi Arabia*

In this paper, the boundary layer flow and heat transfer of sodium chloride (NaCl)-carbon nanopowder (CNP) nanofluid over a Riga-plate with homogeneous–heterogeneous quartic autocatalysis chemical reaction in the presence of convective heating and thermal radiation is investigated. The similarity transformed nonlinear governing equations are obtained and tackled numerically using shooting technique. Effects of thermo-physical parameters on the nanofluid velocity, temperature, chemical species concentration, skin friction, and local Nusselt number are discussed quantitatively. It is found that momentum, thermal and concentration boundary layer thicknesses diminished due to Lorentz force effects. An enhancement in values of Biot number, nanoparticle volume fraction and thermal radiation parameter upsurges nanofluid temperature causing diminution in thermal boundary layer thickness. The skin friction coefficient exhibits increasing trend in the order of nanoparticles (carbon nanopowder (CNP) < graphite < carbon black (CB)) at the relatively higher values of strength of heterogeneous reaction.

KEYWORDS: CNP Nanofliud, Convective Boundary Condition, Thermal Radiation, Homogenous–Heterogeneous Reactions, Vertical Riga Plate.

1. INTRODUCTION

Researchers have made considerable progress in universalizing the investigations regarding the boundary layer flow of nanofluid safer an investigation that is perpetuated by Choi et al.[1] who reported that the nanofluids (nanoparticles suspended fluids) are able to change their own physical properties from their base fluid. The unflagging attention has brought to the investigations related to boundary layer flow of nanofluids by the dedicated work of persons like Khan and Pop[2] and others.[3–10] We valued their contributions which consistently brought to light the investigations. The foresightedness of their investigations led to the further enormous developments in the related areas and huge inevitable applications include nanofluids as coolants in cancer therapy, safer surgery, and effective heat exchange performance to cater the growing demands of modern technology include power station, chemical production and microelectronics heat exchangers. In addition, magneto-nanofluids contribute their applications in optical modulators, magneto-optical wavelength filters, tunable optical fibre filters and optical switches and bio-medical applications viz drug delivery, magnetic cell separation and contrast enhancement in magnetic resonance imaging.

Carbon nanopowder (CNP) is a carbon based material which is having a nominal diameter of 100 nm. CNP nanofluids enhance its own thermal conductivity by approximately 19% with particle volume fraction 1.5% which is outstandingly higher than that of nanofluids developed yet. This is the nanoparticle geometry (particle non-sphericity) which contributes to enhance its own thermal conductivity. Further, the effective specific heat CNP nanofluid decreases with increase in the particle volume fraction.[11]

Riga-plate arrangement develops Lorentz force parallel to the array which has a unique characteristic that is exponentially decaying with distance normal to the plate.

*Author to whom correspondence should be addressed.
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Principal
Radhakrishna Institute of Technology and Engineering, Bhubaneswar

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ARTICLE

Free Convective 3D Stretched Radiative Flow of Nanofluid in Presence of Variable Magnetic Field and Internal Heating

M. K. Nayak[1,*], Sachin Shaw[2], and Ali J. Chamkha[3]

[1]Department of Physics, Radhakrishna Institute of Technology and Engineering, Biju Patnaik University of Technology, Odisha 751052, India
[2]Department of Mathematics and Statistical Sciences, Botswana International University of Science and Technology, Private Bag 16, Palapye, 10071, Botswana
[3]Department of Mechanical Engineering, Prince Mohammad Bin Fahd University, Al-Khobar 31952, Saudi Arabia

The current paper investigated in detail the effects of variable magnetic field and thermal radiation on free convective flow of an electrical conducting incompressible nanofluid over an exponential stretching sheet with internal heating. In the present study, a micro-convection model (Patel model) is introduced. The present model has great influence on heat transfer mechanism in the sense that it significantly enriches the thermal conductivity and hence more heat transfer capability of nanofluids. The governing boundary layer partial differential equations are transformed into a set of ordinary non-linear differential equations by using suitable similarity transformation. The transformed equations are then solved numerically using fourth-order Runge-Kutta method along with shooting technique. The major outcome of the present study is that the presence of a magnetic field under the influence of thermal buoyancy and thermal radiation impedes the fluid motion associated with a diminution of axial and radial velocity gradients at the wall. It experiences an enhancement in the thermal resistance leading to a deterioration in the rate of heat transfer from the stretching sheet within the boundary layer.

KEYWORDS: MHD 3D Flow, Nanofluid, Free Convection, Thermal Radiation, Internal Heating.

1. INTRODUCTION

In recent times, many theoretical and experimental studies comprehend about the improvement of thermo-physical properties of nanofluids mainly the enhancement of intrinsic thermal conductivities through suspension of nanoparticles in base fluids.[1–5] In reality, the study of nanofluids reveals that heat transfer performance of nanofluid is superior to its base fluid. The heat transfer properties vary subject to the particle size, the concentration of the particles, and on the particle material.[6–10]

Mabood et al.[11] studied the effect of variable magnetic field on stagnation point flow of nanofluids in a porous medium wherein they observed that the Al_2O_3-water nanofluid developed a thicker momentum boundary layer compared to Cu-water nanofluid in the absence as well as presence of magnetic field. Hayat et al.[12] investigated the non-linear thermal radiation effects on silver and copper nanoparticles with water as base fluid in association with mixed convection. In their study, it is observed that introduction of radiation parameter reduces mean absorption coefficient which enhanced heat transfer rate indicating more cooling in both Cu-water and Ag-water nanofluids. This study implicates that the heat transfer rate increases with rise in temperature and thermal radiation parameter.

Significant applications in the manufacturing processes, broad range of biomedical applications including wound treatment, gastric medications, asthma treatment, targeted drug release, elimination of tumors with hyperthermia etc. have motivated many researchers to investigate magnetohydrodynamic nanofluid flow and heat transfer properties of various fluids under different boundary conditions of motion. The effect of magnetic field in the flow and heat transfer of nanofluid in a rotating system was investigated by Sheikholeslami et al.[13] Reddy and Chamkha[14] investigated the Soret and Dufour effects in presence of magnetic field of a convective flow of Al_2O_3-water and

*Author to whom correspondence should be addressed.
Email: mkn2122@gmail.com
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Principal
Radhakrishna Institute of Technology and Engineering, Bhubaneswar

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Research Article

Heat Transfer Effects on MHD 3D Flow of Nanofluid by a Shrinking Surface

K. P. Priyadarsan[1], M. K. Nayak[2*], and S. Panda[3]

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Abstract

In this paper, heat transfer analysis associated with thermal radiation as well as viscous dissipation accompanied by internal heat generation/absorption on three dimensional MHD flow of nanofluid over a shrinking surface has been investigated. Some suitable transformations are employed to convert the partial differential equations corresponding to momentum and energy equations into highly non-linear ordinary differential equations. Series solutions of these equations are obtained by employing Homotopy analysis method (HAM). Results for velocities, temperature and Nusselt number are displayed and discussed in rich detail. It is found that magnetic field impedes the fluid motion leading to thinner momentum boundary layer. Increase in thermal radiation as well as viscous dissipation reduces the heat transfer rate from the shrinking surface. It is remarkable to note that heat generation and heat absorption alters the heat transfer rate and there by changes the structure of thermal boundary layer.

Keywords: MHD; 3D flow; Nanofluid; Thermal radiation; Viscous dissipation; Heat generation

1. Introduction

The study of three dimensional magnetohydrodynamic flow of an electrically conducting nanofluid has attracted the immense interest from many researchers around the world because of their fascinating thermo-physical properties and heat transfer performance as well as enormous potential applications. Such applications include coolants for computers and nuclear reactors, cancer therapy, safer surgery by cooling, lubricants, heat exchangers, micro-channel heat sinks, and different electronic devices for use in Defence sectors, cooling of vehicles and transformers, in

*Corresponding e-mail: mkn2122@gmail.com (M. K. Nayak)
1. Department of Mathematics, National Institute of Technology Calicut, Calicut, Kerala – 673601, India.
2. Department of Physics, Radhakrishna Institute of Technology and Engineering, Biju Patnaik University of Technology, Bhubaneswar, Odisha, India.
3. Department of Mathematics, National Institute of Technology Calicut, Calicut, Kerala – 673601, India.

Principal
Radhakrishna Institute of Technology and Engineering, Bhubaneswar

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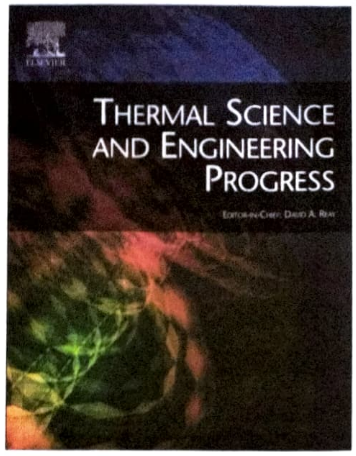

Three dimensional MHD flow of nanofluid over an exponential porous stretching sheet with convective boundary conditions

M.K. Nayak, N.S. Akbar, D. Tripathi, V.S. Pandey

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Three dimensional MHD flow of nanofluid over an exponential porous stretching sheet with convective boundary conditions

[1]M.K. Nayak, [2]N.S. Akbar, [#3]D. Tripathi, and [4]V.S. Pandey

[1]Department of Physics, Radhakrishna Institute of Technology and Engineering, Bhubaneswar, India

[2]DBS&H CEME National University of Sciences and Technology, Islamabad, Pakistan

[3]Department of Mechanical Engineering, Manipal University Jaipur, Rajasthan-303007, India

[4]Department of Physics, National Institute of Technology Delhi, New Delhi, India

Corresponding Author: D Tripathi (dharmendra.tripathi@jaipur.manipal.edu)

Abstract

A numerical simulation for three dimensional steady flow of nanofluids passing through an exponential stretching sheet in presence of magnetohydrodymaics is presented. The surface of stretching sheet is considered as pervious. Buongiorno model associated with Brownian motion and thermophoretic diffusion is also employed. Well known similarity transformations are used to convert the governing equations into a set of ordinary differential equations. The transformed equations are then solved numerically using fourth order Runge-Kutta method. The effects of transverse magnetic field and permiability on dimensionless fluid velocity, fluid temperature, skin friction,Nusselt number and Sherwood number are examined. The numerical results accomplished in the present study are validated and felt to be in good agreement with the previously published results. The numerical computations reveal that that the Lorentz force due to presence of magnetic field impinges its resistance on fluid motion and enhances the thermal resistance. As a consequence, heat transfer rate from the sheet gets reduced in association with the porosity of the medium.

Keywords: *Magnetohydrodynamics; Three dimensional analysis; Nanofluid; Porosity; Brownian motion; Thermophoretic diffusion.*

1. Introduction

Avalanche of significant engineering applications of nanofluids in emerging diversified fields such as better coolants in computers and nuclear reactors, cancer therapy, safer surgery, heat exchangers, micro-channel heat sinks, and several electronic devices for use in military sectors, vehicles and transformers, in designing the waste heat removal equipment, major manufacturing industries including materials and chemicals, oil and gas, food and drink, paper and printing, polymer extrusion, glass blowing, rapid spray cooling, cooling of microelectronics, wire drawing

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Original Research Paper

MHD 3D free convective flow of nanofluid over an exponentially stretching sheet with chemical reaction

M.K. Nayak [a], Noreen Sher Akbar [b], D. Tripathi [c,*], Z.H. Khan [d], V.S. Pandey [e]

[a] Department of Physics, Radhakrishna Institute of Technology and Engineering, Biju Patnaik University of Technology, Bhubaneswar, Odisha, India
[b] DBS&H CEME, National University of Sciences and Technology, Islamabad, Pakistan
[c] Department of Mechanical Engineering, Manipal University, Jaipur, Rajasthan 303007, India
[d] Department of Mathematics, University of Malakand Dir (lower), Khyber Pakhtunkhwa, Pakistan
[e] Department of Physics, National Institute of Technology Delhi, New Delhi, India

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ABSTRACT

This paper deals with a problem where the effect of variable magnetic field and chemical reaction on free convective flow of an electrically conducting incompressible water based nanofluid over an exponentially stretching sheet has been investigated. In the present study, Buongiorno model associated with Brownian motion and thermophoretic diffusion is employed to describe the heat transfer enhancement of nanofluids. Some suitable similarity transformations reduced the governing boundary layer non-linear partial differential equations into a set of ordinary non-linear differential equations. The transformed equations are then solved numerically using fourth order Runga-Kutta method along with Shooting technique. The major outcomes of the present study is that the magnetic field impedes the fluid motion while thermal as well as mass buoyancy forces accelerate it, the thermophoretic diffusion enhances dimensionless fluid temperature as well as concentration leading to thicker thermal and concentration boundary layers. On the other hand, concentration exponent, Brownian motion parameter and chemical reaction parameter exhibit reverse trend on temperature and concentration. In addition, the presence of magnetic field under the influence of thermal as well as mass buoyancies supports to reduce the rate of heat transfer as well as wall shear stress while the first order chemical reaction develops a thinner concentration boundary layer.

1. Introduction

Over the decades, the study of flow and heat transfer over a stretching surface has motivated many researchers because of its numerous significant engineering applications include polymer extrusion, glass blowing, rapid spray cooling, cooling of microelectronics, wire drawing and quenching in metal foundries, etc. Crane [1] was the first pioneer who theoretically studied the boundary layer flow over stretching surfaces. Since then, many researchers [2–4] came forward and provided their research contributions in several aspects of flow and heat transfer problems involving stretching surfaces.

Nanofluids are the fluids that possess 100 nm or less size of nanoparticles such as metals, oxides, carbides and nitrides along with conventional base fluids such as water, kerosene, engine oil, toluene, ethylene and tri-ethylene glycol. Because of higher thermal conductivity of nanoparticles compared to base fluids, nanofluids are served as better coolants in computers and nuclear reactors, cancer therapy, safer surgery, lubricants, heat exchangers, micro-channel heat sinks and several electronic devices for use in military sectors, vehicles and transformers, in designing the waste heat removal equipment, major manufacturing industries including materials and chemicals, oil and gas, food and drink, paper and printing, etc. It was an ironic beginning by Choi [5] to study experimentally and revealed to the society about the enhancement of thermal conductivity of fluids with nanoparticle. Later on, Buongiorno [6] established a non-homogeneous equilibrium model to describe the heat transfer enhancement of nanofluids due to Brownian motion and thermophoretic diffusion of nanoparticles. Khan and Pop [7] developed the boundary- layer flow of nanofluids over stretching sheet. Makinde and Aziz [8] implemented the convective boundary condition in exhibiting boundary-layer flow of a nanofluid over a stretching surface. Recently, studies taking realistic factor into account such as the three-dimensional magnetohydrodynamic flow of nanofluid over a permeable linear stretching

* Corresponding author.
E-mail address: dharmtri@gmail.com (D. Tripathi).

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Radiative non linear heat transfer analysis on wire coating from a bath of third-grade fluid

M.K. Nayak[a,*], Sachin Shaw[b], Ali J. Chamkha[c,d]

[a] Department of Physics, Radhakrishna Institute of Technology and Engineering, BijuPatnaik University of Technology, Odisha, India
[b] Department of Mathematics and Statistical Sciences, Botswana International University of Science and Technology, Private Bag 16, Palapye, Botswana
[c] Department of Mechanical Engineering, Prince Mohammad Bin Fahd University, Al-Khobar 31952, Saudi Arabia
[d] Prince Sultan Endowment for Energy and Environment, Prince Mohammad Bin Fahd University, Al-Khobar 31952, Saudi Arabia

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ABSTRACT

Wire coating as an industrial process coats bare conducting wires for primary insulation so as to accomplish mechanical strength and provide protection for aggressive environments. In the present study, we have investigated and discussed the influence of radiative linear as well as non-linear heat transfer on wire coating with melt polymer as a coating fluid in response to a third-grade fluid model subject to Joule heating. In our analysis, we deal with (i) Reynolds model and (ii) Vogel's model to implement the temperature-dependent viscosity. The governing equations characterizing the flow and heat transfer are solved numerically by the fourth-order Runge-Kutta method. It is heartening to note that the temperature parameter Θ_R is an indicator of the small/large temperature difference between the surface and the ambient fluid, which has a remarkable effect on the heat transfer characteristics and the temperature distributions in the flow region within the die. It is visualized that an increase in Θ_R and the radiation parameter R decrease the fluid temperature of the coating fluid, thereby enhancing the rate of heat transfer associated with a thinner thermal boundary layer.

1. Introduction

At the beginning of the 20th century, due to enormous applications in industries and technological processes such as polymeric extrusion, drawing of wires, petroleum drilling, manufacturing of food and papers, etc., many investigators have been motivated in the study of viscoelastic fluid flow and heat transfer in the wire coating process. In fact, the most efficient process used for wire coating is the coaxial extrusion process.

The co-extrusion process is an operation in which either molten polymer is extruded continuously on an axially moving wire or the bare preheated wire is dragged inside a die filled with molten polymer. In this process of coating, the velocity of continuum as well as the melt polymer (third grade fluid) develops high pressure in a specific region. This high pressure generates strong bonding between the melt polymer and the wire and hence provides fast coating. Wire-coating in pressure-type die for Newtonian as well as non-Newtonian fluids were carried out by pioneer researchers, namely Bernhardt [1], Bagley and Storey [2], Han and Rao [3], Carley et al. [4], and Wagner and Mitsoulis [5] in the beginning. The analysis of wire coating for pressure-type die for Newtonian and non-Newtonian fluids is presented in the books of Middleman [6], Tadmor and Gogos [7], and Mckelvey [8].

A series of studies were undertaken by many researchers, notably Fata et al. [9], Hayat et al. [10] and Nayak and Dash [11], where they analyzed wire coating using third grade fluid in various situations. Regarding wire coating, third-grade fluid was considered as it itself a viscoelastic fluid of industrial importance. A third-grade fluid was used because it exhibits features such as shear thickening and shear thinning. In addition, researchers viz. Ali and Javed [12], Ali et al. [13], Javed et al. [14] performed studies investigating wire coating associated with different kinds of fluids such as FENE-P fluid, Giesekus viscoelastic fluid and Phan-Thien-Tanner fluid.

Nayak et al. [15] in their study explored the influence of transverse magnetic field in wire coating using third grade fluid as coating material. This is one of the major 20th century contributions, regarding flow as well as heat transfer of third grade fluid on wire coating, to the development of a better quality final product (coated wire), due to better controlled rate of cooling. However, they did not investigate the influence of linear as well as non-linear thermal radiation in their study. The objective of the present study is to analyze the influence of linear as well as non-linear thermal radiation in the wire coating process, wherein a coating material is modeled as third grade fluid viz. melt

* Corresponding author.
E-mail address: mkn2122@gmail.com (M.K. Nayak).

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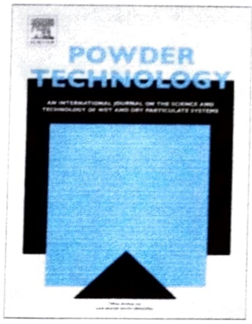

3D free convective MHD flow of nanofluid over permeable linear stretching sheet with thermal radiation

M.K. Nayak, Noreen Sher Akbar, V.S. Pandey, Zafar Hayat Khan, Dharmendra Tripathi

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3D free convective MHD flow of nanofluid over permeable linear stretching sheet with thermal radiation

[1]M. K. Nayak, [2]Noreen Sher Akbar, [3]V. S. Pandey, [4]Zafar Hayat Khan, [#5]Dharmendra Tripathi

[1]Department of Physics, Radhakrishna Institute of Technology and Engineering, Biju Patnaik University of Technology, Odisha, India

[2]DBS&H CEME National University of Sciences and Technology, Islamabad, Pakistan

[3]Department of Physics, National Institute of Technology Delhi, New Delhi, India

[4]Department of Mathematics, University of Malakand Dir (lower) Khyber Pakhtunkhwa, Pakistan

[5]Department of Mechanical Engineering, Manipal University, Jaipur, Rajasthan-303007, India

Corresponding Author: D Tripathi (dharmtri@gmail.com)

Abstract

This paper mainly focuses on the influence of transverse magnetic field as well as thermal radiation on three-dimensional free convective flow of nanofluid over a linear stretching sheet. One remarkable aspect of this study is that a new micro-convection model namely Patel model has been introduced in view of enhancement of thermal conductivity and hence more heat transfer capability of nanofluid. The non-linear partial differential equations have been converted into strong non-linear ordinary differential equations by employing suitable transformations and these transformed equations are solved by Runga-Kutta method of fourth order along with Shooting technique as well as Secant method for better approximation. From this study, it is found that the presence of magnetic field slows down the fluid motion while it enhances the fluid temperature leading to a reduction in heat transfer rate from the surface. It is also found that enhancing thermal radiation parameter causes a reduction in heat transfer rate.

Keywords: MHD; 3D flow; Nanofluid; Free convection; Thermal radiation.

1. Introduction

Over the last decade, many researchers have been attracted the interests of doing research on nanofluids in view of their fascinating and significant engineering focus with respect to usefulness and applications that include cooling involved in cancer therapy, safer surgery, vehicles, transformers, solid state lighting, super powerful computers, nuclear reactors, electronic devices used in military sectors, biomedicine, various process industries involving materials and

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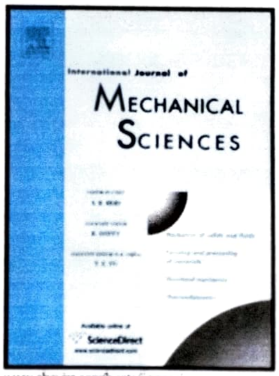
MHD 3D flow and heat transfer analysis of nanofluid by shrinking surface inspired by thermal radiation and viscous dissipation

M.K. Nayak



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MHD 3D flow and heat transfer analysis of nanofluid by shrinking surface inspired by thermal radiation and viscous dissipation

M. K. Nayak

Department of Physics, Radhakrishna Institute of Technology and Engineering, Biju Patnaik University and Technology, Bhubaneswar, India.

E-mail: mkn2122@gmail.com

Abstract

In the present paper three dimensional magnetohydrodynamic (MHD) flow and heat transfer analysis associated with thermal radiation as well as viscous dissipation of nanofluid over a shrinking surface has been investigated. The developed governing equations are transformed employing suitable transformations which are then solved by Homotpy analysis method (HAM). The study of all governing parameters such as magnetic, permeability, wall mass transfer, radiation, nanoparticle volume fraction and shrinking parameters along with Eckert and Biot's numbers is carried out and the representative results are provided to explore the effect of these pertinent parameters on the fluid velocity and temperature as well as the local skin friction and local Nusselt number. The major outcome of the present study is that the magnetic field and porous matrix both impede the fluid motion, along with reduction in the velocity gradient at the wall thereby reducing local skin friction and thermal radiation as well as viscous dissipation effects show a reduction in the rate of heat transfer from the shrinking surface.

Keywords

MHD; 3D flow; Nanofluid; Thermal radiation; Viscous dissipation.

Nomenclature

(u, v, w) fluid velocity components along (x, y, z) directions (m/s)

υ_{nf} kinematic viscosity of nanofluid (m^2/s)

σ fluid electrical conductivity $\left(s^3 A^2 Kg^{-1} m^{-3}\right)$

B_0 strength of uniform magnetic field (Kg/s^2.A)

f_w suction parameter

ρ_{nf} density of nanofluid (Kg/m^3)

K_p^* permeability parameter

α_{nf} thermal diffusivity of nanofluid (m^2/s)

$(\rho c_p)_{nf}$ heat capacitance of nanofluid (J/m^3.K)

W suction velocity (m/s)

Impact of Disruptive Technology in Academic Libraries

Brundaban Nahak
Librarian,
Radhakrishna Institute of Technology & Engineering (RITE),
Bhubaneswar, Odisha
E-mail : bnahak@gmail.com

Abstract

With the development of digital technologies, various disruptive innovations have emerged that are gradually replacing academic libraries in the information-seeking process. Revolutionary change, the challenges of new technologies, a paradigm shift—these are words used to bring one's attention to the need for adaptation and innovation by academic libraries. Disruptive technologies that have driven the transition from the automated to the electronic library "require new service models…that challenge established organizations and the interests and expertise of the individuals within them." These changes are occurring in an environment of decreasing resources (human and financial) and increasing demands of users. The traditional roles of libraries are being challenged by disruptive technologies such as e-books, Amazon and social media. As fast information and to-the-door delivery become the norm, how we ensure the continued validity of the library. Libraries have had a place in society for almost as long as human societies have existed. Yet you may now feel that our profession is threatened by the digital era and that we might well be trying to sell scythes to 21st century farmers. The traditional roles and functions of libraries are being challenged by disruptive technologies. These new products and services have created their own demand and found their way into everyday lives – e-books and search engines, Amazon and social media. Clay Christensen, often credited with coining the term 'disruptive technology', identifies how they are 'typically cheaper, simpler, smaller and frequently more convenient to use'. Convenience is a veritable byword for the digital age: people have become accustomed to fast information and to-the-door delivery. So how do we ensure the continued validity of library services in the face of such upheaval? Everything discussed so far has a tone of inevitability. Time marches on, the wheel keeps turning and things will change. Yet there is only one thing inevitable about the fate of a disrupted sector: evolve or fail. The old adage or traditional saying that every challenge is both a threat and an opportunity is most true when it comes to business strategy. Disruptive technologies require a response: turn disruptions into competence-enhancing influences. This is easier said than done. Information Systems Professor Hank Lucas of the Robert H. Smith School of Business at the University of Maryland, outlines the primary inhibiting factors that cause businesses (like Borders, Kodak and Blockbuster) to fail to react in a positive way to new technologies. We also recommend that academic libraries involve their users and build partnerships with other libraries and with commercial communities to bring about service innovation necessary to respond to disruption.

Key Words : Disruptive innovation, Library, Business Models, Disruptive Technology

Introduction

Academic libraries have a pivotal role in the transmission of information and knowledge in higher educational institutions. They are to facilitate the teaching, learning and research functions of their respective institutions. Academic libraries managers they are expected to acquire preserve and disseminate information resources that would satisfy the needs of both present and future users. The Traditional way in which libraries have operated has been for users to visit the library and for the staff to get to know the needs of their users. This is no longer the case. This Business Model is now dead. It is dead because the ways in which libraries, publishers and education operate are being totally disrupted. Libraries are no longer the archivists of content, Publishers are; Libraries are no longer the centre of the community; the Internet is; Library catalogues no longer provide access to the collections, Google does. It is vital to understand disruption, to see examples of disruption at work and to learn ways in which it can be used to our advantage. Failing to do so will see the library being eliminated from the information chain and being made redundant. It is not always easy for libraries to position themselves in the best interests of their institution's users. The use of imagination and creativity will strongly help the library work with its users and administration to gain agreed direction and resources for the library into the future.

The Library world has been hugely impacted by the Disruptive Technology phenomenon. The arrival and huge growth of digital content has fundamentally changed the way in which content is made available to library users. Libraries will vary in the percentage