Applied Thermal Engineering 98 (2016) 850–861

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research Paper

# Stagnation electrical MHD nanofluid mixed convection with slip boundary on a stretching sheet

Kai-Long Hsiao *

*Department of the Digital Recreation and Game Design, Taiwan Shoufu University, 168, Nansh Li, Madou District, Tainan City, Taiwan, China*

## HIGHLIGHTS

- Stagnation EMHD nano energy conversion for extrusion stretching sheet processing.
- Conjugate heat conduction, convection and mass transfer problems have been solved.
- Flow and heat mass transfer of nanofluids' important parameters have been examined.
- Excellent calculation results have been achieved and compared with others' studies.

## ARTICLE INFO

*Article history:*
Received 10 October 2015
Accepted 31 December 2015
Available online 11 January 2016

*Keywords:*
EMHD
Stagnation
Nanofluid
Mixed convection
Heat source/sink

## ABSTRACT

In this study, the stagnation nano energy conversion problems have been completed for conjugate mixed convection heat and mass transfer with electrical magneto hydrodynamic (EMHD) and heat source/sink effects nanofluid flow field over a slip boundary stretching sheet surface. The physical phenomena varied which depended on different factors. All of the important nano energy conversion parameters $S_0$, M, E, Gt, Gc, λ, Pr, Sc, Ncc, S and δ have represented the dominance of the magnetic energy effect, electric effect, mixed convection effect, heat generation/absorption energy effect, heat transfer effect, mass diffusion effect, heat conduction–convection effect and slip boundary effects, respectively. The similarity transformation and a modified Finite-Difference method are used to analyze the present nano energy conversion system's thermal energy conversion problem. The non-linear ordinary equations of the corresponding flow field momentum, temperature, concentration equations and plate sheet heat conduction equation are derived by employing the similarity transformation technology. The dimensionless non-linear ordinary equations are composed of momentum, temperature, concentration and plate sheet heat conduction equations which have been solved numerically by an improved finite difference technique.
© 2015 The Author. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

## 1. Introduction

Stagnation nano energy conversion problem about nanofluids passing a slip stretching sheet has been of increasing importance over the last few years. Qualitative analyses of studies have significant bearing on several industrial applications, such as polymer sheet extrusion from a dye, drawing of plastic films, etc. It needs cooling of the stretching sheet during the process manufacturing at very high temperature. There are some ways of cooling the stretching surface; the present study chose nano fluid as necessary for more effective cooling of the stretching surface. Maybe it is not easily available, but for specific requirement it is still important for using. Also, the fluids have yielded many types of effects (i.e. magnetic energy, electrical energy, buoyancy energy and heat generation/absorption energy) into the problem. At first, there are some applied energy applications for related heat and mass transfer aspect. Hsiao [1,2] studied about heat and mass mixed convection for MHD viscoelastic fluid past a stretching sheet with Ohmic dissipation. Hsiao [3] investigated conjugate heat transfer for mixed convection and Maxwell fluid on a stagnation Point problem. Hsiao [4] provided for energy conversion conjugate conduction–convection and radiation over non-linearly extrusion stretching sheet with physical multimedia effects. Hayat et al. [5] studied about inclined magnetic field effect in stratified stagnation point flow over an inclined cylinder problem; it is considered for an inclined cylinder thermal energy system application to industry application.

The study of non-Newtonian fluid flowing past stretching sheet was provided by Hartnett [6]. Aman and Ishak [7] studied the problem of mixed convection boundary layer flow adjacent to a stretching vertical sheet in an incompressible electrically conducting fluid. These are related studies to the present investigation about nanofluid flow. There were some studies about similar boundary

* Tel.: +886911864791; fax: +88662896139.
*E-mail address:* hsiao.kailong@msa.hinet.net.

http://dx.doi.org/10.1016/j.applthermaleng.2015.12.138
1359-4311/© 2015 The Author. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

layer problem, the non-liner stretching sheet heat and fluid energy conversion system investigation. Vajravelu and Soewono [8] had solved the fourth order non-linear systems arising in combined free and forced convection flow over a stretching sheet. Afify [9] studied heat and mass transfer of a viscous, incompressible and electrically conducting fluid over a stretching surface. Cortell [10] studied effects of radiation on the thermal boundary layer over a nonlinearly stretching sheet. Awang Kechil and Hashim [11] studied series solution of flow over non-linearly stretching sheet with chemical reaction and magnetic field. Cortell [12] studied viscous flow and heat transfer over a nonlinearly stretching sheet. Vajravelu [13] investigated viscous flow over a nonlinearly stretching sheet. Liu and Liu [14] studied stokes' second problem with arbitrary initial phase flow. Recently, the slip boundary layer problems for flow passing the sheet were studied by some researchers. Vajravelu et al. [15] studied second order slip flow and heat transfer over a stretching sheet with non-linear Navier boundary condition problem. Ibrahim and Shankar [16] studied MHD boundary layer flow and heat transfer of a nanofluid past a permeable stretching sheet with velocity, thermal and slip boundary conditions. Roşca and Pop [17] investigated flow and heat transfer over a vertical permeable stretching/shrinking sheet with a second order slip. Das [18] studied slip flow and convective heat transfer of nanofluids over a permeable stretching surface. Turkyilmazoglu [19] investigated heat and mass transfer of MHD second order slip flow. Turkyilmazoglu [20] studied dual and triple solutions for MHD slip flow of non-Newtonian fluid over a shrinking surface. Raftari and Vajravelu [21] solved the problem for homotopy analysis method for MHD viscoelastic fluid flow and heat transfer in a channel with a stretching wall. Hayat et al. [22] studied about slip flow and heat transfer of a second grade fluid past a stretching sheet through a porous space. Khan and Pop [23] investigated boundary-layer flow of a nano fluid past a stretching sheet problem. All of above studies [15–23] are not considered for the conjugate heat transfer problem, but towards the slip boundary layers fluid flow for many kinds of features. There are some related boundary layer studies for the exponentially shrinking sheet. Bhattacharyya and Vajravelu [24] investigated stagnation-point flow and heat transfer over an exponentially shrinking sheet. Sajid and Hayat [25] studied influence of thermal radiation on the boundary layer flow due to an exponentially stretching sheet. Pop et al. [26] studied boundary layer flow and heat transfer over an exponentially shrinking vertical sheet. For nanofluid flow, Khan and Pop [23] studied boundary-layer flow of a nanofluid past a stretching sheet. For applied energy fields, some of studies about latent-heat storage and photo catalytic effectiveness problems were provided by Chai et al. [27] Jiang et al. [28] designed magnetic microcapsules based on n-eicosane core and Fe3O4/SiO2 hybrid shell for dual-functional phase change materials. Jiang et al. [29] studied about thermal properties of paraffin microcapsules modified with nano-Al2O3. Yu et al. [30] investigated calcium carbonate shell for enhancement of thermal conductivity problems.

Becoming of importance were the many energy conversion problems about fins; Shi and Dong [31] investigated entropy generation and optimization of laminar convective heat transfer in a micro channel with staggered arrays of pin fin structure problem. Elsafi and Gandhidasan [32] studied about comparative study of double-pass flat and compound parabolic concentrated photovoltaic–thermal systems with and without fins and obtained a good result for different conditions. Syed et al. [33] numerically studied an innovative design of a finned double-pipe heat exchanger with variable fin-tip thickness and found a good effect. Hazarika et al. [34] analytically studied the solution to predict performance and optimum design parameters of a constructed T-shaped fin with simultaneous heat and mass transfer. Turkyilmazoglu [35] studied about stretching/shrinking longitudinal fins of rectangular profile and heat transfer and related parameter effects. From references 31–35 were investigation of the energy conversion problems about the fins, but the present study was an extension work and application to an extrusion slip stretching sheet energy conversion problem. For the heat source/sink feature studies, Nandeppanavar et al. [36] investigated heat transfer over a nonlinearly stretching sheet with non-uniform heat source and variable wall temperature. Nandeppanavar et al. [37] investigated and studied heat transfer in MHD viscoelastic boundary layer flow over a stretching sheet with thermal radiation and non-uniform heat source/sink problems. For the nanofluid heat transfer problems, Noghrehabadi et al. [38] studied and analyzed fluid flow and heat transfer of nanofluids over a stretching sheet near the extrusion slit. Hsiao [39] investigated a nofluid flow with multimedia physical features for conjugate mixed convection and radiation. For the thermal energy conversion problems, Cortell [40] studied magneto-hydrodynamic flow and radiative nonlinear heat transfer of a viscoelastic fluid over a stretching sheet with heat generation/absorption, a very complex heat energy conversion problem in a non-Newtonian flow field. López de Haro et al. [41] investigated about heat transfer and entropy generation in the parallel plate flow of a power-law fluid with asymmetric convective cooling related energy conversion problem. Hachicha et al. [42] considered wind speed effect on the flow field and heat transfer around a parabolic trough solar collector couple energy conversion problem. Vajravelu et al. [43] investigated about flow and heat transfer of nanofluids at a stagnation point flow over a stretching/shrinking surface in a porous medium with thermal radiation related energy conversion heat transfer problem. Hayat et al. [44] studied boundary layer flow of Carreau fluid over a convectively heated stretching sheet energy conversion related problems; it is also a novel non-Newtonian fluid flow couple with thermal boundary layer heat transfer problems. Liu and Andersson [45] investigated heat transfer over a bidirectional stretching sheet with variable thermal conditions; it is mainly focused on the thermal energy conversion related problems at the couple boundary layer fluid flow system. Recently, there are some of studies about the nano energy heat transfer problems. Hayat et al. [46] investigated Soret and Dufour effects in peristaltic transport of physiological fluids with chemical reaction problems.

In the present investigation, a novel stagnation nanofluid nano energy conversion study for conjugate conduction–convection and heat source/sink problem has been performed. The term "nanofluid" refers to a liquid containing a suspension of submicron solid particles (nanoparticles). There are different models to handle such kinds of problems. The nanoparticles used in nanofuids are typically made of nano metals (Al, Cu), carbides (SiC), nitrides (AlN, SiN), etc. The suspended particles are able to increase the thermal conductivity and heat transfer performance. In this study, Brownian motion model to nanofluid and its properties used Eqs. (10) and (14) to solve the problem. All of the properties have been divided into fluid parts, for example $\frac{k_f}{(\rho c_p)_f}$, and nanoparticle parts, for example $(\rho c_p)_p$. A conjugate mixed convection heat and mass transfer problem with the magnetic energy effect, electrical conductivity effect and heat source/sink energy effects passing a slip stretching surface have been processed. From the results, finding some better heat transfer effects which were made by some important parameters, such as $S_0$, M, Gc, Gt, Pr, Sc, Nt, Nc, λ and Ncc.

## 2. Theory and analysis

### 2.1. Flow field analysis

In this study, consider an incompressible nanofluid past a slip boundary stretching sheet. The generalized continuity equation, momentum equation, fluid energy equation, fluid concentration equation and sheet conduction equation in three dimensions are formed on the basis of Ohm's law and Maxwell's equation with study of Electrical Magneto Fluid Dynamics (EMHD). The steady EMHD

Download English Version:

https://daneshyari.com/en/article/7048658

Download Persian Version:

https://daneshyari.com/article/7048658

Daneshyari.com