Journal of the Egyptian Mathematical Society (2015) **23**, 429–434

Egyptian Mathematical Society
Journal of the Egyptian Mathematical Society
www.etms-eg.org
www.elsevier.com/locate/joems

SHORT COMMUNICATION

Entropy generation analysis of magneto hydrodynamic flow of a nanofluid over a stretching sheet

M. Govindaraju [a], N. Vishnu Ganesh [a], B. Ganga [b], A.K. Abdul Hakeem [a,*]

[a] *Department of Mathematics, Sri Ramakrishna Mission Vidhyalaya College of Arts and Science, Coimbatore 641 020, India*
[b] *Department of Mathematics, Providence College for Women, Coonoor 643 104, India*

Received 24 January 2014; revised 27 March 2014; accepted 14 April 2014
Available online 11 June 2014

KEYWORDS
Nanofluid;
Entropy generation;
Similarity transformation;
Magnetic field;
Stretching sheet

Abstract An analysis is carried out to study the entropy generation of an incompressible, MHD flow of water based nanofluid over a stretching sheet. The analytical solutions of the governing non-dimensional nonlinear ordinary differential equations are presented in terms of hypergeometric functions and used to compute the entropy generation number. The effects of the physical parameters on velocity and temperature profiles are already studied in our previous work [13]. This work is extended to discuss the effects of magnetic parameter, nanoparticle volume fraction, Hartmann number and the dimensionless group parameter on the entropy generation for Cu, Ag, Al_2O_3 and TiO_2 nanoparticles. The local skin friction coefficient and reduced Nusselt number are tabulated.

MATHEMATICS SUBJECT CLASSIFICATION: 76D10; 76W05; 80A20; 80A99; 82D80

© 2014 Production and hosting by Elsevier B.V. on behalf of Egyptian Mathematical Society.

1. Introduction

Entropy of a thermo dynamical system refers to the unavailability of useful work. Physically entropy generation is associated with thermo dynamical irreversibility, which is a common phenomenon in all kinds of heat transfer designs. Greater rate of entropy generation in any thermal system destroys the useful work and greatly reduces the efficiency of the system. Bejan [1,2] presented a method named Entropy Generation Minimization (EGM) to measure and optimizes the disorder or disorganization generated during a process specifically in the fields of refrigeration (cryogenics), heat transfer, storage and solar thermal power conversion. The entropy generation analysis of nanofluids investigated by several authors in different geometries [3–9].

The boundary layer flow over a continuously stretching surface finds many important applications in engineering processes, such as polymer extrusion and drawing of plastic films, and the applied magnetic field may play an important role in controlling momentum and heat transfers in the boundary layer flow of different fluids over a stretching sheet. The effect of magnetic field on nanofluids studied by the followers

* Corresponding author. Tel.: +91 9442401998.
E-mail address: abdulhakeem6@gmail.com (A.K. Abdul Hakeem).
Peer review under responsibility of Egyptian Mathematical Society.

Production and hosting by Elsevier

1110-256X © 2014 Production and hosting by Elsevier B.V. on behalf of Egyptian Mathematical Society.
http://dx.doi.org/10.1016/j.joems.2014.04.005

Nomenclature

B_0	magnetic field strength	k_f	thermal conductivity of the base fluid
Br	Brinkman number	k_s	thermal conductivity of the nanoparticles
Ha	Hartmann number	σ	electric conductivity
M	Kummer's function	Ω	dimensionless temperature difference
Mn	magnetic parameter	ϕ	the solid volume fraction
N_s	entropy generation number	ρ_{nf}	the effective density of the nanofluid
Pr	Prandtl number	ρ_f	density of the pure fluid
$Re_x^{1/2}C_f$	local skin friction coefficient	ρ_s	density of the nanoparticles
$Re_x^{-1/2}Nu_x$	reduced Nusselt number	μ_{nf}	effective dynamic viscosity of the nanofluid
S_G	local volumetric entropy generation rate	μ_f	dynamic viscosity of the basic fluid
$(S_G)_0$	characteristic entropy generation rate	η	space variable
T	local temperature of the fluid	α_{nf}	thermal diffusivity of the nanofluid
k_{nf}	thermal conductivity of the nanofluid		

[10–12]. Very recently, we investigated the effect of magnetic field on water based nanofluid over a stretching sheet numerically [13] and also we studied the MHD flow of nanofluid with thermal radiation effect both analytically and numerically [14].

The purpose of this attempt is to analyse the entropy generation of magneto hydrodynamic flow of an incompressible viscous nanofluid over a stretching sheet analytically. The analytical solutions of dimensionless governing equations are presented in terms of hypergeometric function. The entropy generation is calculated using the entropy relation by substituting the velocity and temperature fields obtained from the momentum and entropy equations.

2. Formulation of the problem

The entropy analysis for a steady laminar two-dimensional flow of an incompressible viscous nanofluid past a linearly semi-infinite stretching sheet is studied with magnetic field effect. We also consider influence of a constant magnetic field of strength B_0 which is applied normally to the sheet. The temperature at the stretching surface takes the constant value T_w, while the ambient value, attained as y tends to infinity, takes the constant value T_∞. It is further assumed that the induced magnetic field is negligible in comparison to the applied magnetic field (as the magnetic Reynolds number is small). The fluid is a water based nanofluid containing different types of nanoparticles: Copper (Cu), Aluminium (Al_2O_3), Silver (Ag) and Titanium Oxide (TiO_2). It is also assumed that the base fluid water and the nanoparticles are in thermal equilibrium and no slip occurs between them. The thermo physical properties of the nanofluid are considered as in [13]. Under the above assumptions, the governing equations can be written in non-dimensional (see [13]) form as

$$F''' + (1-\phi)^{2.5}\{[1-\phi+\phi(\rho_s/\rho_f)](FF''-F'^2) - Mn\,F'\} = 0 \tag{1}$$

$$\theta'' + \frac{Prk_f[1-\phi+\phi(\rho C_p)_s/(\rho C_p)_f]}{k_{nf}}F\theta' = 0 \tag{2}$$

with the corresponding boundary conditions

$$\begin{aligned} &F=0 \quad F'=1 \quad \text{at} \quad \eta=0,\\ &F'\to 0 \quad \text{as} \quad \eta\to\infty \end{aligned} \tag{3}$$

$$\theta(0)=1 \qquad \text{and} \qquad \theta(\infty)=0 \tag{4}$$

where ϕ is the solid volume fraction, ρ_f and ρ_s are the densities of the base fluid and nanoparticles, $(\rho C_p)_f$ and $(\rho C_p)_s$ are the specific heat parameters of the base fluid and nanoparticles, k_f is the thermal conductivity of the base fluid, k_{nf} the thermal conductivity of the nanofluid, Pr is the Prandtl number and Mn is the magnetic parameter.

3. Analytical solutions of the flow field and the heat transfer

The exact solution to differential Eq. (1) satisfying the boundary condition (3) is obtained as (see Anjali Devi and Ganga [15])

$$F(\eta) = \frac{1-e^{-m\eta}}{m} \tag{5}$$

where m is the parameter associated with the nanoparticle volume fraction, the magnetic field parameter, the fluid density and the nanoparticle density as follow

$$m = \sqrt{(1-\phi)^{2.5}[Mn+1-\phi+\phi(\rho_s/\rho_f)]} \tag{6}$$

The analytical solution of (2) satisfying (4) interms of η is obtained as

$$\theta(\eta) = e^{-ma_0\eta}\frac{M[a_0, a_0+1, -a_0e^{-m\eta}]}{M[a_0, a_0+1, -a_0]} \tag{7}$$

where M is the Kummer's function ([15]), $\alpha = \frac{k_{nf}}{k_f(1-\phi+\phi\frac{(\rho Cp)_s}{(\rho Cp)_f})}$ and $a_0 = \frac{Pr}{\alpha m^2}$.

The skin friction can be written as

$$\begin{aligned} Re_x^{1/2}C_f &= -\frac{2F''(0)}{(1-\phi)^{2.5}}\\ &= -\frac{2}{(1-\phi)^{2.5}}\sqrt{(1-\phi)^{2.5}[Mn+1-\phi+\phi(\rho_s/\rho_f)]} \end{aligned} \tag{8}$$

The non-dimensional wall temperature gradient derived from Eq. (7) reads as

Download English Version:

https://daneshyari.com/en/article/483462

Download Persian Version:

https://daneshyari.com/article/483462

Daneshyari.com