



Entropy generation in a micropolar fluid flow through an inclined channel with slip and convective boundary conditions



D. Srinivasacharya*, K. Hima Bindu

Department of Mathematics, National Institute of Technology, Warangal 506004, India

ARTICLE INFO

Article history:

Received 4 June 2015

Received in revised form

5 August 2015

Accepted 8 August 2015

Available online xxx

Keywords:

Slip flow

Micropolar fluid

Convective boundary condition

Inclined channel

Entropy

Bejan number

ABSTRACT

The present paper studies the entropy generation in a micropolar fluid flow through an inclined channel with slip and convective boundary conditions. The governing equations are linearized using quasi-linearization and then solved using Chebyshev spectral collocation method. The velocity, micro-rotation and temperature profiles are obtained and utilized to compute entropy generation and Bejan number. The effects of the angle of inclination, coupling number, slip parameter, Biot number and Brinkman number on the velocity, microrotation, temperature, entropy generation and Bejan number are studied and presented graphically. The results reveal that the entropy generation number increases with the increase of angle of inclination and Brinkman number while the increase of coupling number and Reynolds number causes the entropy generation to reduce. It is observed that the heat transfer irreversibility dominates at the centre of the channel.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The optimal design criteria for thermal systems by minimizing their entropy generation have recently been a topic of great interest. Efficient utilization of energy is the main objective in the design of thermal devices. The performance of thermal devices is always affected by irreversible losses that lead to an increase of entropy and reduce the thermal efficiency. Therefore, in the energy optimization problems and design of many traditional heat removal engineering devices, it is necessary to minimize the entropy generation or destruction of available work due to heat transfer and fluid friction as a function of the design variables selected for the optimization analysis. The entropy generation is encountered in many energy related applications, such as solar power collectors, geothermal energy systems and the cooling of modern electronic systems. Entropy generation analysis provides a useful tool to identify the irreversibilities in any thermal system as well as to determine the optimum condition for any process. A variety of fluid flow systems have been analyzed and optimized using the EGM (entropy generation minimization) method. Several investigations

([1–6]) were carried on entropy generation under various flow configurations.

Fluid flow and heat transfer inside channels with simple geometry and different boundary conditions is one of the fundamental areas of research in engineering. It has wide range of thermal engineering applications in electronics cooling, thermal insulation engineering, water movement in geothermal reservoirs, heat pipes and thermal insulation. Recently, a wide literature on fluid flow and entropy generation in various channels has been developed. Havzali et al. [7] investigated the effect of entropy generation on a laminar, viscous, incompressible flow between two inclined, parallel, isothermal plates. They observed that the entropy generation in a small section is dominant on the total entropy production. Kamisli and Oztop [8] examined the entropy generation in two immiscible incompressible fluid flows under the influence of pressure difference in thin slit of constant wall heat fluxes. Cimpean and Pop [9] studied the entropy generation for a mixed convection flow of a fluid saturated porous medium through an inclined channel with uniform heated walls. Komurgoz et al. [10] investigated the magnetic effect on heat-fluid and entropy generation interactions in an inclined channel consisting of two regions: one filled with clear fluid and the second with porous medium. Damseh et al. [11] studied the local entropy generation due to steady fully developed laminar forced convection channel flow in the presence of a transverse magnetic field. Eegunjobi and Makinde

* Corresponding author.

E-mail addresses: dsc@nitw.ac.in, dsrinivasacharya@yahoo.com (D. Srinivasacharya).

Nomenclature

a_j	microinertia parameter
B_e	Bejan number
Bi	Biot number
B_r	Brinkman number
C_p	specific heat
f	dimensionless velocity
Gr	Grashof number
$2h$	channel width
K_f	thermal conductivity
m^2	micropolar parameter
N	coupling number
N_h	entropy generation due to heat transfer
N_θ	entropy generation due to viscous dissipation
N_s	dimensionless entropy generation number
Re	Reynolds number

T	Dimensional Temperature
T_1	ambient Temperature
T_2	fluid Temperature
u	dimensional axial velocity
X	horizontal axis (direction of flow)
Y	coordinate perpendicular to the plate

Greek Symbols

α	inclined angle
α_1	slip parameter
β, γ	gyration viscosity coefficients
θ	dimensionless temperature
κ	vortex viscosity
μ	viscosity of the fluid
ρ	density of the fluid
σ	dimensionless microrotational component

[12] presented combined effects of variable viscosity and asymmetric convective boundary conditions on the entropy generation rate in MHD porous channel flow. Das and Jana [13] investigated the combined effects of magnetic field, suction/injection and Navier slips on entropy generation in an MHD flow through a porous channel under a constant pressure gradient. Mahdavi et al. [14] investigated the entropy generation and convective heat transfer of a pipe partially filled with a porous material by numerical simulation. Torbabi et al. [15] studied the heat transfer and entropy generation in a channel partially filled with porous media using local thermal non-equilibrium model. They discussed about the effects of many thermophysical parameters on the velocity, temperature, Nusselt number and entropy generation rates. Torabi and Zhang [16] analyzed the local and total entropy generation in MHD porous channel with thick walls.

The fluids with slip velocity have many applications at both macro and micro scales in technology such as polishing of surfaces and in micro devices. Navier [17] proposed a slip boundary condition where the slip velocity depends linearly on the shear stress. At macro level, wall slip is encountered in polymer extrusion processes where it is caused by instabilities at high stress levels [18]. Denn [19] presented a review of mechanisms of slip in non-Newtonian fluids and also explores the relation between slip and extrusion instabilities. Also the study of convective heat transfer has much importance in high-temperature processes like gas turbines, nuclear plants, thermal energy storage, etc. The effects of slip velocity and convective heat transfer on entropy generation for any fluid flow of different geometries have been studied by several authors. Iman [20] investigated the importance of thermal boundary conditions of the heated/cooled walls in the development of flow, heat transfer, and observed the characteristics of entropy generation in a porous enclosure. Hooman [21] presented the effect of velocity slip, temperature jump, and duct geometry on heat transfer and entropy generation through a micro duct of rectangular cross-section. Butt et al. [22] presented the effects of hydrodynamic slip on entropy generation in a viscous flow over a vertical plate with convective boundary condition. Chinyoka and Makinde [23] investigated the entropy generation rate in an unsteady porous channel flow with Navier slip subjected to asymmetrical convective boundary conditions. Anand [24] discussed the effect of slip on the entropy generation and heat transfer characteristics of the fully developed flows of power law fluids in a micro channel. Mostafa and Ali [25] presented the analytical solution for non-Newtonian fluid flows between parallel-plates in micro scale

subject to iso-flux and isothermal wall boundary conditions, while taking the effects of wall slip and viscous dissipation into consideration. Ibanez [26] studied the combined effects of hydrodynamic slip, magnetic field and suction/injection Reynolds number on the global entropy generation rate under convective boundary conditions.

Most of the researchers have reported their study on entropy generation pertaining to viscous fluid. The study of viscous fluid does not adequately describe the flow properties of polymeric fluids, animal blood, coal slurries, Mine tailings and mineral suspensions. Such properties are described in non-Newtonian fluid flow model. Many fluids in nature and industrial processes show a non-Newtonian fluid behavior. One among those models is micropolar fluid introduced by Eringen [27] which exhibit certain microscopic effects arising from the local structure and microrotations of fluid elements. The Micropolar fluids have been shown to accurately simulate the flow characteristics of polymeric additives, geomorphological sediments, colloidal suspensions, haematological suspensions, liquid crystals, lubricants, etc. The main advantage of using micropolar fluid model compared to other non-Newtonian fluids is that it takes care of the rotation of fluid particles by means of an independent kinematic vector called the microrotation vector.

The majority of the studies reported in the literature on entropy generation analysis for micropolar fluid flows deal with horizontal channel subject to thermal and/or wall flux boundary conditions. However, in the present analysis an attempt is made to analyze the effect of angle of inclination of the channel, slip velocity and convective boundary conditions on entropy generation in a micropolar fluid flow through an inclined channel. The velocity, microrotation and the temperature distribution are determined by solving the momentum, angular momentum and energy equations with Spectral Quasi linearization method. The obtained velocity, microrotation and the temperature distribution are utilized to compute the entropy generation and Bejan number.

2. Mathematical formulation

Consider a steady laminar incompressible fully developed micropolar fluid flow bounded by two infinite inclined parallel plates separated by a distance $2h$. The channel is inclined at an angle α . Choose the cartesian coordinate system with x -axis aligned at the center of the channel in the direction of the flow and the y -axis perpendicular to the plates (as shown in Fig. 1). Since the

Download English Version:

<https://daneshyari.com/en/article/1731472>

Download Persian Version:

<https://daneshyari.com/article/1731472>

[Daneshyari.com](https://daneshyari.com)