Abstract

Title: Modelling of flow and heat transfer of nanofluids

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The present thesis is devoted to the study of heat and mass transfer phenomena in nanofluid flow process by applying semi-analytic and purely analytical methods. A significant part of this thesis is centered around the study of electroosmotic nanofluid flow in a micro-nano channel. The study considers the presence of an external magnetic field with an aim to analyze entropy generation. The semi-analytical methods such as differential transform method and homotopy analysis method have been utilised to solve the fluid flow problems. The selected problems in the thesis bear potential applications in plastic extrusion process and building microfluidic devices. The entire thesis is divided into eight chapters as described below:

The **Chapter 1** is an introductory section that briefly discusses the numerical methods and topics concerned with the problems considered in subsequent chapters in this thesis. This chapter also defines and presents an overview of the properties and terminology used in this thesis such as heat and mass transfer phenomena, electroosmosis, magneto-hydrodynamic flow and basic ideas on entropy generation.

The **Chapter 2** presents the effects of ion diffusion coefficient on steady electroosmotic couple stress nanofluid flow and heat transfer in a porous microchannel bounded by two permeable beds. The study considers the nanofluid injection process through porous beds. The combined effects of ion diffusivity and injected nanofluid velocity on EDL (Electric double layer) thickness are analytically expressed. The differential transform method (DTM) is used to solve the flow equations. The DTM solution is then compared with the exact analytical solution of velocity, Zeta potential function. Moreover, a square averaged residual analysis is conducted. The bulk nanofluid flow rate is found to follow a quadratic like relationship with the couple stress parameter. The nanofluid temperature is found to increase with an enhancement of ion diffusion coefficient, which is related with experimental results observed by Kong et al. (Phys. Chem. Chem. Phys. 19 (2017) 7678) for NaCl electrolyte solution confined in a graphene nanochannel. Moreover, the nanofluid temperature decreases with enhancement of both porous permeability of the medium and couple stress parameter.

The **Chapter 3** aims to study the electroosmotic nanofluid flow and heat transfer phenomena in a microchannel with porous walls by paying due attention to the interaction of the injected fluid velocity and the net charge density in the base fluid on the development of Zeta potential and electroosmotic slip velocity. The novelty of this study is to obtain the integral expression for electroosmotic slip velocity which is found to converge to Smoluchowski velocity when the injected fluid velocity is low and porous permeability of the channel wall becomes negligible. Under a weak electric field condition, the enhancement of pressure gradient is found to increase the normalized temperature and decrease the normalized nanoparticle concentration. The bulk

nanofluid temperature is found to follow an almost quadratic relationship with applied pressure gradient. Additionally, in the absence of injection velocity, we observed a new expression for Soret number as a ratio of the cross sectional nanoparticle concentration to the Joule heating parameter.

In **Chapter 4**, we examine the pulsating electroosmotic nanofluid flow phenomena in a microchannel with porous walls. The combined effects of injected nanofluid velocity and ion diffusion coefficients on the Zeta potential formation is considered. The novel boundary condition is introduced so as to examine the effects of electroosmotic parameters and frictional forces on thermal profiles as well as nanoparticle volume fractions present in the nanofluid.

In **Chapter 5**, we study the magnetohydrodynamic graphene-(PDMS) nanofluid flow between two squeezing parallel plates in the presence of thermal radiation effects. The energy efficiency of the system via the Bejan number is studied extensively. The entropy generation in terms of the Bejan number, the coefficient of skin-friction, and the heat transfer rate is furthermore investigated under the effects of various physical parameters of interest. The present study shows that the entropy generation due to frictional forces is higher than that of due to thermal effects. Thus, the study bears the potential application in powder technology as well as in biomedical engineering.

The **Chapter 6** examines the energy efficiency of the squeezing Cu-water nanofluid flow that takes place within two parallel plates having externally applied magnetic field. The effects of thermal radiation are taken into account. The non-linear partial differential equations are converted into a set of coupled ordinary differential equations by the self-similarity transformations. The differential transform method (DTM) is used to solve the set of coupled differential equations, which gives rise to a series solution. The convergence analysis has been made and two theorems are presented to confirm the validity of the obtained series solution.

The **Chapter 7** investigates the unsteady Maxwell nanofluid flow past a stretching surface, embedded in a porous medium, in the presence of magnetic field and thermal radiation effects. The Navier's slip boundary condition is considered at the nanofluid-surface interface. Entropy analysis for the energy efficiency of the system in terms of the Bejan number is carried out extensively. By employing suitable similarity transformations on the set of partial differential equations; describing the flow regimes, we have transformed them into a set of coupled ordinary differential equations. These transformed equations are then solved by using the homotopy analysis method (HAM). The findings show that the rise in time relaxation parameter has adverse effects on nanofluid velocity but enhances the entropy generation in the system.

Finally, the **Chapter 8** summarizes the overall important findings of the thesis and discusses the future scope of research in this direction.

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