EAST EUROPEAN JOURNAL OF PHYSICS. 2. 51-62 (2023)
DOI:10.26565/2312-4334-2023-2-02 ISSN 2312-4334

NUMERICAL ANALYSIS ON MHD MIXED CONVECTION FLOW OF Al_2O_3/H_2O (ALUMINUM-WATER) NANOFLUIDS IN A VERTICAL SQUARE DUCT[†]

Bishnu Ram Das[‡], P.N. Deka[§], Shiva Rao*

Department of Mathematics, Dibrugarh University, Dibrugarh-786004, Assam, India
[‡]*e-mail: bishnuram.das84@gmail.com*, [§]*e-mail: pndeka@dibru.ac.in*
**Corresponding Author e-mail: shivarao374@gmail.com*
Received February 9, 2023; revised March 6, 2023; accepted March 9, 2023

In this work, we have considered steady laminar magnetohydrodynamics (MHD) mixed convection flow of an electrically conducting fluid in presence of Al_2O_3 nanoparticle while water is the base fluid in a vertical square duct. The walls of the duct are thermally insulated. In the energy equation, the effect of viscous dissipation and Joule heat are also considered. In this case, the walls of the duct are kept at a constant temperature. By using dimensionless quantities, the governing equations of momentum, induction, and energy are first transformed into dimensionless equations and then the reduced equations are solved using an explicit finite difference approach. The velocity, temperature, and induced magnetic field profiles are plotted graphically to analyze the effect of different flow parameters. It is observed that the nanofluid motion expedites with the increase of the value of the magnetic parameter, Reynolds number, and Prandtl number. The current research may find its application in the numerous industrial as well as cooling sectors. This study observed its importance with the view to increasing the heat transfer efficiency for practical applications relevant to industry and engineering issues. The issues discussed in this study have not been included in the earlier investigation for steady nanofluid flow due to a square duct.
Keywords: *Nanofluids; Explicit finite-difference numerical method (EFDM); MHD flow; Buoyancy force; Mixed convection; square duct; Heat transfer; Magnetic field*
PACS: 44.20.+b, 44.40.+a, 44.30.+v, 47.11.-j, 47.11.Bc

1. INTRODUCTION

Nanofluids which have a wide range of applications in industry are defined as suspensions of solid nanoparticles in some form of organic or inorganic materials in basic fluids which are mainly utilized for heat transfer applications. These nanoparticles improve the heat transfer performance by raising conduction and convection coefficients which enables them to be more effective in various applications. The currently available heat transfer fluids which are used for these purposes including water, ethylene glycol mixture, engine oil, etc., possess poor heat transfer capability. In recent times, the consideration of nanofluids in engineering and industrial applications has drawn a lot of attention from scientists due to their improved thermal properties and advantageous heat transfer characteristics without any pressure drop. As a result of their large thermal conductivity, nanofluids are used in place of base fluids as working fluids nowadays. Mixed convection flow is the combination of forced and natural convection flows. Further, mixed convection flow in a channel or duct is encountered in the Dual-Coolant Lead-Lithium (DDCL) flow for fusion power as a tritium breeder and many industrial applications and engineering devices such as a cooling systems for electronic components and reactors. Choi and Eastman [1] introduced the concept of nanofluids and presented impressive results with many possibilities for usage. Nanofluids are new classes of nano-technology-based materials concerning nanoparticles (1nm to 100 nm) dispersed in base fluids. These heat transfer fluids have promoted great interest among researchers in the last few years, mainly due to their potential applications. The nanofluids have higher thermal conductivities in comparison to the base fluids, which could result in higher heat transfer rates.

Convection process in a square duct is relevant to certain heat transfer engineering applications acting as electronic equipment, food drying, heat exchangers, cooling, and nuclear reactors. Experimentally and numerically in recent years, many researchers have studied natural convection and mixed convection in a square duct under a wide range. The mixed convection of $\mathbf{Al_2O_3/water}$ nano fluid interior of a square duct accommodates boiling quadrilaterals obstacles on its bottom wall considered by Doustdar and Yekani [2]. Mixed convection flows in a square duct partially heated from below using nanofluid were studied by Mansour et al. [3]. The results of a numerical study on the mixed convection in a square duct filled with a $\mathbf{Al_2O_3/water}$ nanofluid was investigated by Ghasemi and Aminossadati [4]. They concluded that the heat transfer rate can be reduced by adding a considerable amount of nanoparticles into the distilled water cases of upward and downward sliding walls. Abu-Nada and Oztop [5] investigated the effect in natural convection processes with nanofluid which are enclosed in containers. Hemmat Esfe et al. [6] studied the heat transfer and Mixed-convection fluid flow of an $\mathbf{Al_2O_3/water}$ nanofluid with effective thermal conductivity and viscosity is dependent on temperature and nanoparticle concentration core of a square duct. Their results stipulated that adding $\mathbf{Al_2O_3}$ nanoparticle produces an extraordinary enhancement of heat transfer concerning that of the unmixed fluid. The effect of the Prandtl number and Reynolds number for laminar mixed convection in a top wall moving, the bottom heated square duct was discussed by Moallemi and Jang [7]. They investigated that when Reynolds number and Grashof numbers were kept constant, increment of Prandtl number enhanced the heat transfer rate. The mixed convection in a square duct having a side wall

[†] ***Cite as:*** B.R. Das, P.N. Deka, and Shiva Rao, East Eur. J. Phys. **2**, 51 (2023), https://doi.org/10.26565/2312-4334-2023-2-02