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H_2O based different nanofluids with unsteady condition and an external magnetic field on permeable channel heat transfer

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ABSTRACT

This paper investigates numerically the problem of unsteady magnetohydrodynamic nanofluid flow and heat transfer between parallel plates due to the normal motion of the porous upper plate. The governing equations are solved via the fourth-order Runge-Kutta method. Different kind of nanoparticles is examined. The effects of kind of nanoparticle, nanofluid volume fraction, expansion ratio, Hartmann number, Reynolds number on velocity and temperature profiles are considered. Also effect of different types of nanoparticles is examined. Results indicate that velocity decreases with increase of Hartmann number due to effect of Lorentz forces. Rate of heat transfer increase with increase of nanofluid volume fraction, Hartmann number and Reynolds number but it decreases with increase of expansion ratio. Also it can be found that choosing copper as a nanoparticle leads to highest enhancement.

Introduction

A nanofluid is a fluid containing small volumetric quantities of nanometer-sized (diameter of about 1–100 nm) particles called nanoparticles. Fluid heating and cooling are important in many industries fields such as power, manufacturing and transportation. Effective cooling techniques are absolutely needed for cooling any sort of high energy device. Common heat transfer fluids such as water, ethylene glycol, and engine oil have limited heat transfer capabilities due to their low heat transfer properties. In contrast, metals thermal conductivities are up to three times higher than the fluids, so it is naturally desirable to combine the two substances to produce a heat transfer medium that behaves like a fluid, but has the thermal conductivity of a metal. Recently several studies are investigated about nanofluid. Sheikholeslami et al. [1] studied the effect of thermal radiation on magnetohydrodynamics nanofluid flow and heat transfer. They found that found that concentration boundary layer thickness decreases with the increase of radiation parameter. Nanofluid flow and heat transfer characteristics between two horizontal parallel plates in a rotating system were investigated by Sheikholeslami et al. [2]. They proved that Nusselt number increases with increase of nanoparticle volume fraction and Reynolds number but it decreases with increase of Eckert number, magnetic and rotation

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parameters. Study of fluid flow and heat transfer in Newtonian and non-Newtonian fluids are one of the main researchers' interests [3,4]. Rahimi-Gorji et al. [5] studied nanofluids comprising of water and ethylene glycol as base fluid and Cu, Al2O3, Ag, TiO2 nanoparticles. They found out that increasing the concentration of solid nanoparticles causes reduction of temperature differences of cooling fluid and microchannel wall.

Physically, magnetic fields can induce currents in a moving electrically conductive fluid, which in turn polarizes the fluid and reciprocally changes the magnetic field itself. Such fluid was named as magnetohydrodynamics (MHD) by Alfven [6]. Since MHD flows have been found to be very useful in heat and mass transfer progresses in many industrial procedures such as polymer extrusion, drawing of copper wires, continuous stretching of plastic films and artificial fibers, hot rolling, wire drawing, glass-fiber, metal extrusion, and metal spinning, many studies [7–18] have been done towards understandings of their transport mechanisms and novel applications. It is worth mentioning that Khan and Makinde [19] conducted an investigation about the magnetic effect on nanofluid along a vertical stretching sheet. They concluded that the ratio of convective to conductive heat transfer across (normal to) the boundary decreases with the magnetic parameter increasing, while the density number of the motile microorganisms decreases with magnetic parameter enlarging. Their work indicates that the MHD flow could be used to alter the distributions of microorganisms in potential applications such as removal of microorganisms attached in a water tank. Magnetohydrodynamics (MHD) flow with heat transfer is one of the classes of flow in fluid mechanics which has received considerable attention in recent decades.

Ferrohydrodynamic and Magnetohydrodynamic effects on ferrofluid flow and convective heat transfer was studied by Sheikholeslami and Ganji [20]. They proved that Magnetic number has different effect on Nusselt number corresponding to Rayleigh number. Hatami et al. [21] simulated flow and heat transfer of a non-Newtonian third grade nanofluid in porous medium of a hollow vessel in presence of magnetic field. They found that by increasing the MHD parameter, velocity profiles decreased due to magnetic field effect. Steady magnetohydrodynamic free convection boundary layer flow past a vertical semi-infinite flat plate embedded in water filled with a nanofluid has been theoretically studied by Hamad et al. [22]. They found that Cu and Ag nanoparticles proved to have the highest cooling performance for this problem. Several recent studies on the modeling of nanofluid flow and heat transfer have been studied [23–27].

Radiative flow of nano fluid over a stretching/shrinking sheet with second order slip boundary condition was investigated by Hakeem [28]. They used Lie group transformation and solved the resulting equation analytically by hyper geometric function and numerically by a fourth order Runge–Kutta method with the shooting technique. Using long wavelength and low Reynolds number assumptions Akbar and Butt [29] first time developed equations for the Cu–water nano fluid. In this investigation it is found that the velocity field rises due to high electromagnetic forces and buoyancy forces as compared to viscous forces. Misra et al. [30] discussed the steady flow of an incompressible viscoelastic and electrically conducting fluid through parallel plate channel in the presence of uniform magnetic field taking into account the application in cardiovascular system dynamics.

The incompressible fluid flow and heat transfer over rotating bodies have many industrial and engineering applications such as gas turbine engines and electronic devices having rotary parts and have been studied in many industrial, geothermal, geophysical, technological and engineering fields. Originally Von Kármán [31] discussed the steady flow of Newtonian fluid over a rotating disk, who introduced an elegant transformation that enabled the Navier–Stokes equations for an isothermal, impermeable rotating disk to be reduced to a system of coupled ordinary differential equations. Using momentum integral method, he obtained an approximate solution to the ordinary differential equations (ODEs). Hydromagnetic flow between two horizontal plates in a rotating system, where the lower plate is a stretching sheet and the upper is a porous solid plate, was analyzed by Sheikholeslami et al. [32]. They reported that increasing magnetic parameter or viscosity parameter leads to decreasing Nu, while with increasing the rotation parameter, blowing velocity parameter, and Pr, the Nusselt number increases. Sibanda and Makinde [33] investigated the hydromagnetic steady flow and heat transfer characteristics of an incompressible viscous electrically conducting fluid past a rotating disk in a porous medium with the ohmic heating and viscous dissipation, they found that magnetic field retards the fluid motion due to the opposing Lorentz force generated by the magnetic field and the magnetic field and Eckert number tend to enhance the heat transfer efficiency.

In this study, laminar nanofluid flow and heat transfer between two contacting and rotating plates is investigated. New model is used in simulation of nanofluid. Programming software was used to study heat transfer in presence of magnetic field. Nanofluid thermophysical properties were taken from the obtainable formulations in literature. The focus of this study was on the heat transfer of water-based nanofluids with various volume fractions of solid nanoparticles and effects of active parameters on hydrothermal behavior. The findings can be applied to the use in many industries.

Governing equations

The unsteady flow between two parallel flat plates is considered as shown in Fig. 1. The wall, which coincides with the x

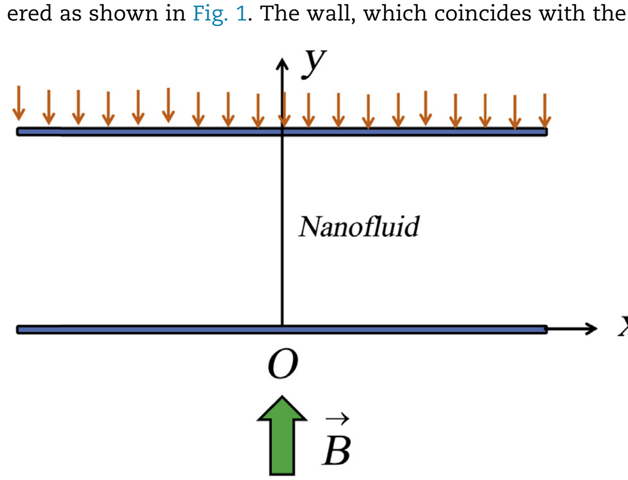

Fig. 1 – Geometry of problem.

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