CHARACTERIZATION OF NANO-PARTICLE SIZE IN CONVECTIVE HEAT TRANSFER THROUGH A CYLINDRICAL ANNULUS

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ABSTRACT

We want to characterize behavior of various physical effects based on nano particle size during convective heat transfer through various geometries. It is found that the viscosity is greatly effected due to the small size of the metal particle dissolve in the fluids. The fluid convey cylindrical in general. The nano fluid flows and exhibits interesting characteristics in Heat transfer. We investigates theoretically the effect of particle size and the layer around it on heat transfer under the influence of magnetic field and heat source in porous medium. The magnitude of heat transfer decreases with increase in particle size.

***Keywords*: MHD Nano, Fluid, Annulus, Porous Material.**

I INTRODUCTION

The investigation for enhancing the heat transfer through a fluid gives birth to the nano-fluid due to the presence of metal particle in the fluid enhances the heat transfer widely. The literature is providing an excellent support for the enhancement of heat transfer.

Xuan and Li [10] presented a study on the thermal conductivity of nano-fluid comprise of copper nano-particles. The measured data showed that adding 2.5-7.5% copper oxide nano particles to the water increased its conductivity by about 24-78%. Rafee [4] had concluded that for a constant heat transfer rate, by increasing the length ratio of an annulus (L/Dh), firstly the entropy generation ratio will decrease until reaches its minimum value.

Free convection flow and heat transfer in hydro magnetic case is important in nuclear and space technology (Singh KR 1963[6], Yu CP 1969 [8], Yu CP 1970[9]). In particular, such convection flow in a vertical annulus region in the presence of radial magnetic field had been studied by Sastry and Bhadram (1978) [5].Nanda and Purushotham (1976) [2] had analyzed the free convection of a thermal conducting viscous incompressible fluid induced by traveling thermal waves on the circumference of a long vertical circular cylindrical pipe. Whitehead (1972) [7], Neeraja (1993) [3] had made a study of the fluid flow and the heat transfer in a viscous incompressible fluid confined in an annulus bounded by two rigid cylinders. The flow was generated by periodical traveling waves imposed on the outer cylinder and the inner cylinder was maintained at constant temperature.

Ali J. Chamkha [1] had studied the Heat and Mass Transfer from MHD Flow over a Moving Permeable Cylinder with Heat Generation or Absorption and destructive Chemical Reaction. He found that the diffusion decreased with increase in chemical reaction.

The above studies motivated to investigate theoretically the effects of particle size, heat source on convective heat transfer in a nano - fluid while passing through horizontal porous annulus in the presence of magnetic field.

II FORMULATION OF THE PROBLEM

We consider free and force convection flow of Cu-water nano-fluid through a porous medium in a circular cylindrical annulus in the presence of heat source, in which inner and outer walls are maintained at a constant temperature and concentration. The flow velocity, temperature and concentration in the fluid to be fully developed. The fluid region has constant physical properties and the flow is a mixed convection flow taking place under thermal and molecular buoyancies and uniform axial pressure gradient. When the momentum and energy are coupled, and also the flow is unidirectional along the axial cylindrical annulus. The boussenissque approximation is invoked so, that the density variation is confined to the thermal and the molecular buoyancy forces. By making use of the above assumptions the governing equations are:

$$\frac{\partial}{\partial r}(ru) = 0 \qquad (1)$$

$$\frac{\mu_{nf}}{\rho_{nf}}\left(\frac{\partial^2 w}{\partial r^2}+\frac{1}{r}\frac{\partial w}{\partial r}+\frac{\partial^2 w}{\partial z^2}\right)-\frac{\mu_{nf}}{\rho_{nf}k}w-\frac{\sigma B_0^2}{\rho_{nf}}w+\frac{g(\rho\beta_T)_{nf}(T-T_0)}{\rho_{nf}} = 0 \qquad (2)$$

$$w\frac{\partial T}{\partial z} = \frac{\alpha_{nf}}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)-\frac{Q}{(\rho c_p)_{nf}}(T-T_0) \qquad (3)$$

The appropriate initial and boundary conditions for the problem are given by

$$\begin{aligned} T &= T_0, \quad w = 0 \quad \text{on} \quad r = a \\ T &= T_m, \quad w = 0 \quad \text{on} \quad r = a+s \end{aligned} \qquad (4)$$

Thermo-Physical properties are related as follows:

$$\rho_{nf} = (1-\phi)\rho_f + \phi\rho_s, \quad \alpha_{nf} = \frac{k_{nf}}{(\rho c_p)_{nf}}$$

$$(\rho c_p)_{nf} = (1-\phi)(\rho c_p)_f + \phi(\rho c_p)_s$$

$$(\rho\beta)_{nf} = (1-\phi)(\rho\beta)_f + \phi(\rho\beta)_s$$

$$\frac{\mu_{nf}}{\mu_f} = 1 + 2.5\phi + 4.5\left[\frac{1}{\frac{h}{d_p}\left(2+\frac{h}{d_p}\right)\left(1+\frac{h}{d_p}\right)^2}\right]$$

$$k_{nf} = k_f\left(1-\phi\right) + \beta_1 k_p \phi + c_1 \frac{d_f}{d_p} k_p \, Re^2 d_p \, pr \, \phi \qquad (5)$$

where $\beta_1 = 0.01$ is a constant for considering the kapitza resistance per unit area

$c_1 = 18 \times 10^6$ is a proportionality constant

$$Re\, d_p = \frac{d_p}{\gamma_f}\frac{\kappa T}{3\pi\mu_f d_p l_f} = \frac{1.381\times 10^{23} T}{\gamma_f \, 3\pi\mu_f \left(0.738\right)}$$

$d_f = 0.384$ nm for water, pr = Prandtl number $= \frac{\nu_f}{\alpha_f}$

l_f = Mean free path $= 0.738$, κ = Boltzmann constant, $T = 300k$

We introduce the following dimensionless variables:

$$R = \frac{r}{a},\quad Z = \frac{z}{a},\quad W = \frac{w}{\nu_f},\quad U = \frac{u}{\nu_f},\quad \theta = \frac{T - T_0}{T_m - T_0} \qquad (6)$$

Using equations 4, 5, 6 and the thermo-physical properties than the Equation 2 & 3 can be written in the following dimensionless form:

$$\left(1 + 2.5\phi + 4.5\left[\frac{1}{\frac{h}{d_p}\left(2+\frac{h}{d_p}\right)\left(1+\frac{h}{d_p}\right)^2}\right]\right)\left(\frac{\partial^2 W}{\partial R^2} + \frac{1}{R}\frac{\partial W}{\partial R}\right)\frac{1}{\left(1-\phi+\phi\frac{\rho_s}{\rho_f}\right)} - \frac{1}{D}\left(1 + 2.5\phi + 4.5\left[\frac{1}{\frac{h}{d_p}\left(2+\frac{h}{d_p}\right)\left(1+\frac{h}{d_p}\right)^2}\right]\right)\frac{1}{\left(1-\phi+\phi\frac{\rho_s}{\rho_f}\right)}W$$
$$- \frac{1}{\left(1-\phi+\phi\frac{\rho_s}{\rho_f}\right)} M W + \frac{1}{\left(1-\phi+\phi\frac{\rho_s}{\rho_f}\right)} Gr\,\theta = 0$$

$$W\frac{\partial\theta}{\partial z}=\frac{1}{Pr}\left[\left(1-\phi+0.01\phi\frac{k_p}{k_f}+\frac{k_p}{k_f^{2}}\phi\frac{\rho_f^{2}c_{pf}}{d_p\mu_f^{3}}28632.9991\times10^{-52}\right)\frac{1}{\left(1-\phi+\phi\frac{(\rho c_p)_s}{(\rho c_p)_f}\right)}\right]\left[\frac{\partial^2\theta}{\partial R^2}+\frac{1}{R}\frac{\partial\theta}{\partial R}\right]-\frac{1}{Pr}Q_H\left[\frac{1}{1-\phi+\phi\frac{(\rho c_p)_s}{(\rho c_p)_f}}\right]\theta$$

Where the corresponding boundary conditions (4) can be written in the dimensionless form as:

$W = 0, \theta = 0$ on $R = 1$

$W = 0, \theta = 1$ on $R = 1 + s$

Here Pr is the Prandtl number, M is the magnetic parameter (Hartmann number), Q_H is the heat source parameter, D^{-1} is the Darcy number, Gr is the Grashof number, which are defined as:

$$Pr=\frac{\nu_f}{\alpha_f},\ M=\frac{\sigma B_0^{2}}{\mu_f}a,\ Q_H=\frac{Q}{k_f}a,\ \frac{1}{D}=\frac{a}{k},Gr=\frac{g(\rho\beta_T)(T_m-T_0)}{\nu_f^{2}}$$

The local Nusselt number Nu in dimension less form:

$$Nu=-\frac{k_{nf}}{k_f}\theta'(1+s)$$

III SOLUTION OF THE PROBLEM

The cross section of the cylinder which considers and appears in the annulus form for numerical computations. The governing equations are solved for momentum (w) and temperature (θ) by using method of lines with the help of Mathematical package across the cylindrical annulus subject to the boundary conditions.

IV RESULTS

The profiles of momentum and temperature are drawn at Pr = 7 for constant axial temperature and axial concentration gradients.

From Figs. 1 - 8 the flow is maximum in the mid region of the annulus. The momentum decreases with solid volume fraction (ϕ). If the amount of Cu nano-particles increases, the momentum decreases due to Brownian motion. The width of an annulus affects the flow very much. The flow is maximum for width of an annulus (s). The velocity enhances with increase of the thickness of the layer (h) around the nano-particle due to increase in friction. The velocity is maximum for 10nm or more and almost constant for 2nm or less thickness. The flow has obstructed by the Cu nano-particle very much.

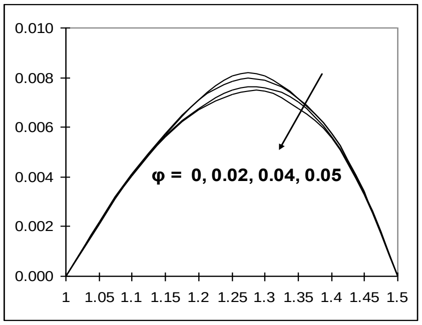

Fig.1 Variation of w with ϕ

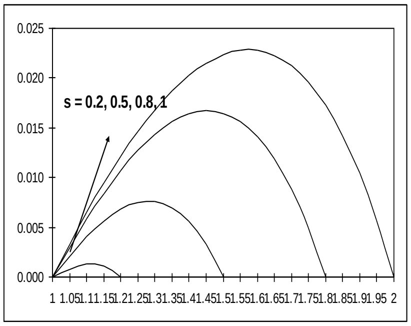

Fig.2 Variation of w with S

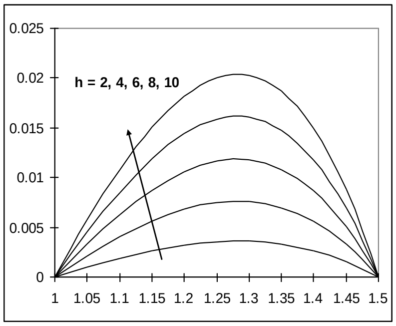

Fig.3 Variation of w with h

As the Particle size (d_p) increases from 20nm to 100nm the velocity is decreased due to low Brownian motion. The velocity is maximum for small particles at about 20nm and the velocity is almost constant at about 100nm or more. The velocity increases with increase in thermal Grashof numbers (Gr). The velocity decreases with increase in the Hartmann number (M) and the velocity found maximum in the absence of the magnetic field. The velocity decreases with increase in heat source (Q_H). The flow increases with increase in the porosity (D^{-1}).

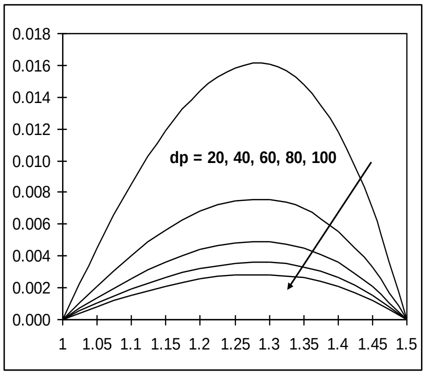

Fig.4 Variation of w with d_p

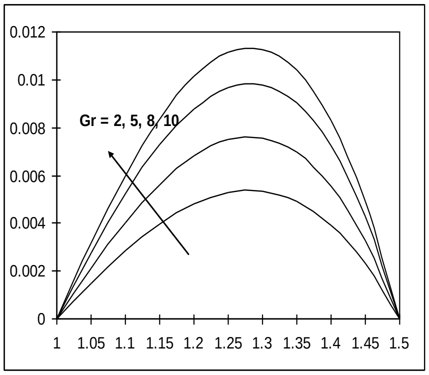

Fig.5 Variation of w with Gr

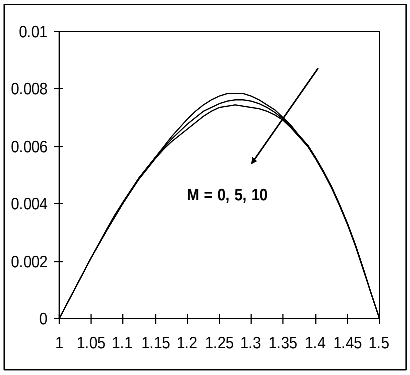

Fig.6 Variation of w with M

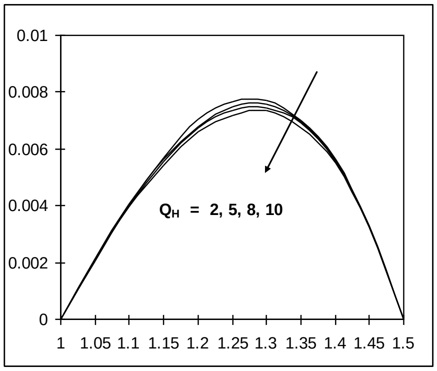

Fig.7 Variation of w with Q_H

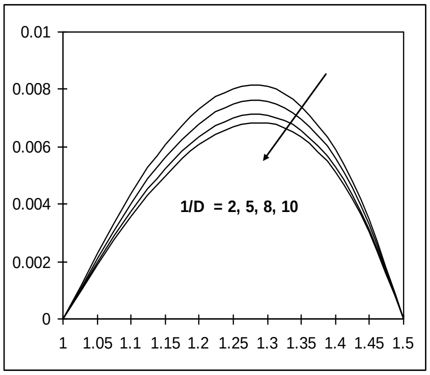

Fig.8 Variation of w with D^{-1}

From Figs. 9 – 14 the heat transfer takes place from inner cylinder to outer cylinder linearly for all variations of φ, s, h, d_p, Q_H and D^{-1}. The temperature enhances with increase in volume fraction (ϕ) of Cu particles. The temperature increases rapidly with increase of the width (s) of an annulus. The temperature is maximum in an annulus when the inner and outer cylinders are of the same radius. The layer (h) around the nano-particle reduces the temperature due to less thermal conductivity of CuOH when compared with Cu. The temperature enhances with increase in size of the particle (d_p). The temperature decreases with increase in heat source (Q_H). The temperature reduces with the increase in porosity (D^{-1})

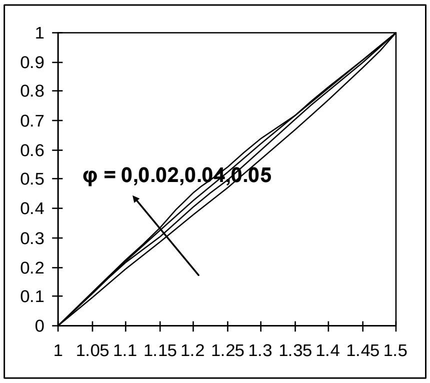

Fig.9 Variation of θ with ϕ

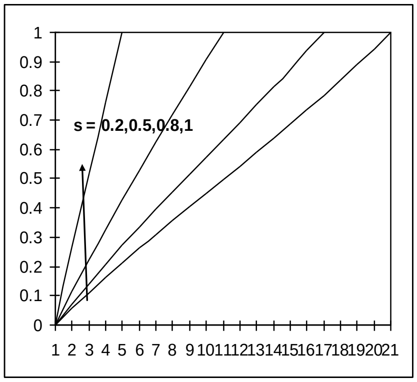

Fig.10 Variation of θ with S

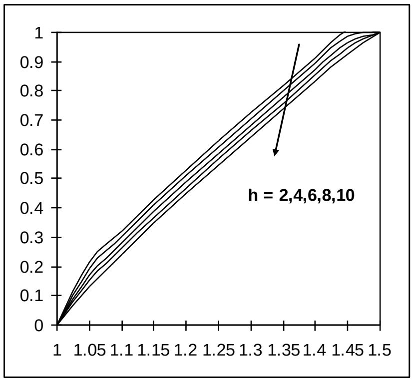

Fig.11 Variation of θ with h

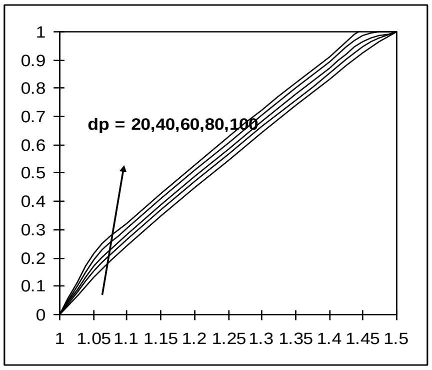

Fig.12 Variation of θ with d_p

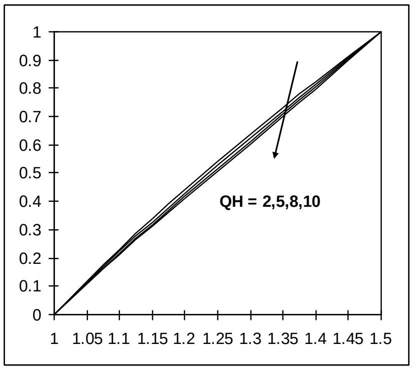

Fig.13 Variation of θ with Q_H

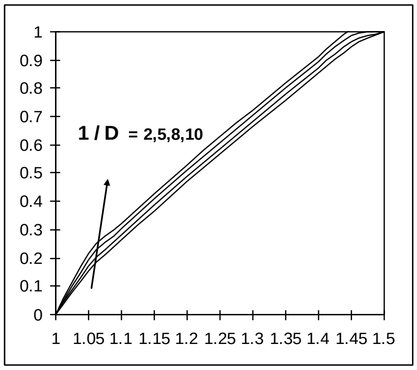

Fig.14 Variation of θ with D^{-1}

Nusselt Number:

$s = 0.5,\ h = 4,\ Gr = 5,\ M = 5,\ D^{-1} = 5$

ϕ	$d_p = 40,$ $Q_H = 0$	$d_p = 40,$ $Q_H = 5$	$d_p = 40,$ $Q_H = 10$	$d_p = 20,$ $Q_H = 5$	$d_p = 100,$ $Q_H = 5$
0.02	-1.64838	-2.35051	-2.96791	-2.35512	-2.34821
0.04	-1.64798	-2.29046	-2.86112	-2.29467	-2.28836
0.05	-1.64781	-2.26412	-2.81397	-2.26814	-2.2621

The variation of Nusselt number for different values of volume fraction (ϕ), d_p and Q_H are depicted in the surface of the outer cylinder. The magnitude of heat transfer decreases as the volume fraction increases on the surface of the outer cylinder. The magnitude of heat transfer increases as the heat source increases. The magnitude of heat transfer decreases with increase in particle size.

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