Journal of the Taiwan Institute of Chemical Engineers 000 (2018) 1–12

Contents lists available at ScienceDirect

Journal of the Taiwan Institute of Chemical Engineers

journal homepage: www.elsevier.com/locate/jtice

# Rheological behaviour of various metal-based nano-fluids between rotating discs: a new insight

O. Pourmehran[a,*], M.M. Sarafraz[a], M. Rahimi-Gorji[b], D.D. Ganji[c]

[a] Department of Mechanical Engineering, The University of Adelaide, South Australia, Australia
[b] Department of Mechanical Engineering, Technical and Vocational University of Iran, Behshahr, Mazandaran, Iran
[c] Department of Mechanical Engineering, Babol Noshirvani University of Technology, Mazandaran, Iran

ARTICLE INFO

*Article history:*
Received 15 January 2018
Revised 25 March 2018
Accepted 1 April 2018
Available online xxx

*Keywords:*
Nanofluid flow
Brownian motion
Permeable channel
Heat transfer
Cylindrical coordinate

ABSTRACT

In this study, nanofluid flow and heat transfer between two contracting and rotating disks are investigated. Brownian motion is considered to simulate viscosity of nanofluid and Patel model is used to predict the behavior of thermal conductivity of nanofluid. The governing equations are solved via the fourthorder Runge–Kutta method. Different kinds of nanoparticles are examined. Effects of active parameters such as nanoparticle volume fraction, rotational Reynolds number, injection Reynolds number, and expansion ratio are considered. Results indicate that Nusselt number is a decreasing function of expansion ratio while it is increasing function of other parameters such as nanoparticle volume fraction, rotational Reynolds number, and injection Reynolds number. Also, it can be found that maximum value of heat transfer enhancement is obtained by selecting the silver (Ag) as nanoparticle.

© 2018 Taiwan Institute of Chemical Engineers. Published by Elsevier B.V. All rights reserved.

## 1. Introduction

Fluid heating and cooling are important in many industrial 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 so 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, while has the thermal conductivity of a metal. Recently several studies are investigated about nanofluid. Ellahi et al. [1] proposed a model for investigating the behavior of ferro-nanofluid upon a stretchable rotating disc under the influence of low oscillations. Analytic results were attained by homotopic analysis method. Shirvan et al. [2] considered two phase mixture model and Response Surface Methodology for sensitivity analysis of heat exchanger containing nanofluid with aluminum-oxide nanoparticles. They found that Reynold number caused enhancement in Nusselt number. When it comes to biologically produced nanofluids and magnetohydrodynamic two-phase systems, still higher thermal performance is seen. 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. [3]. 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 [4,5]. Ellahi [6] discussed about the recent developments of danofluids An analytical investigation is applied for unsteady flow of a nanofluid squeezing between two parallel plates studied by Pourmehran et al. [7] recently. The results demonstrate that when the two plates move toward together, the Nusselt number has a direct relationship with nanoparticle volume fraction and Eckert number while it has a reverse relationship with the squeeze number.

Esfahani et al. [8] performed an entropy generation analysis for the flow of nanoliquid in a wavy channel upon a heat exchanger plate. Entropy generation was assumed as a function of temperature and velocity. It was concluded that viscous entropy generation improved with dimensionless amplitude. Rashidi et al. [9] developed a discrete phase model in order to track the discrete nature of $Al_2O_3$ particles in an obstructed duct with two side-by-side obstacles. Results indicated that particles with smaller diameter diffused with streamlines. A theoretical examination of nanoparticles shapes influence on heat and mass flow of ferrofluid over a disk with rotation in presence of low magnetic field was done by Hassan et al. Moreover, Rahimi-Gorji et al. [10] studied an analytical investigation of the heat transfer for the microchannel heat sink (MCHS) cooled by different nanofluids (Cu, $Al_2O_3$, Ag,

* Corresponding author.
*E-mail addresses:* oveis.pourmehran@adelaide.edu.au, oveis87@yahoo.com (O. Pourmehran).

https://doi.org/10.1016/j.jtice.2018.04.004
1876-1070/© 2018 Taiwan Institute of Chemical Engineers. Published by Elsevier B.V. All rights reserved.

Please cite this article as: O. Pourmehran et al., Rheological behaviour of various metal-based nano-fluids between rotating discs: a new insight, Journal of the Taiwan Institute of Chemical Engineers (2018), https://doi.org/10.1016/j.jtice.2018.04.004

**Nomenclatures**

| | |
|---|---|
| $C$ | nanofluid concentration |
| $C_p$ | specific heat at constant pressure |
| $G$, $F$ | dimensionless velocity |
| $k$ | thermal conductivity |
| $Nu$ | Nusselt number |
| $Pr$ | Prandtl number |
| $N_b$ | Brownian motion parameter |
| $V_B$ | Brownian velocity |
| $Re_B$ | Brownian Reynolds number |
| $Re_1$ | permeability Reynolds number |
| $Re_2$ | rotational Reynolds number |

*Greek symbols*

| | |
|---|---|
| $\alpha$ | constant rotational velocity |
| $\phi$ | dimensionless concentration |
| μ | dynamic viscosity |
| $\upsilon$ | kinematic viscosity |
| $\theta$ | dimensionless temperature |
| $\rho$ | fluid density |

*Subscripts*

| | |
|---|---|
| $f$ | base fluid |
| $p$ | nano particle |

$TiO_2$ in water and ethylene glycol as base fluids) using porous media approach and the Galerkin method. They applied Response surface methodology (RSM) to obtain the desirability of the optimum design of the channel geometry. They found that Ag-water nanofluid has the maximum Nusselt number enhancement.

Influence of buoyancy forces is also considered. A model of fluid volume was proposed by Rashidi et al. [11] to investigate the water based aluminum oxide nanoliquid solar still productivity along with entropy generation analysis. It was noted that volume fraction caused enhancement in solar still productivity. The flow behavior with non-Newtonian based power law model was examined by Ijaz et al. [12] through a wavy channel with finite symmetric properties. Zeeshan et al. [13] studied the impact of convective condition, chemical reaction over the flow of MHD radiative Couette–Poiseuille nanofluid in a horizontal channel by taking Buongiorno model. Nanoparticles concentration was found directly proportional with chemical reaction. Pourmehran et al. [14] investigated the application of nanofluid in fin-shaped microchannel to enhance the microchannel heat transfer rate. They also applied CCD and RSM to optimize the microchannel geometry and performance to develop the heat transfer rate for using such a microchannel in micro possessors [15,16]. The thermal performance and heat transfer characteristics of nanofluids in two-phase regimes have also been investigated in the literature [17–20]. Shirvan et al. [21] considered a cosine corrugated square cavity occupied with nanofluid and investigated the impact of wavy surface characteristics on naturally convective heat transferal properties of fluid. Wavy amplitudes caused decline in Nusselt number. [22]. Various research studied accomplished to solve such a problem [23,24].

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, Kármán [25] 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

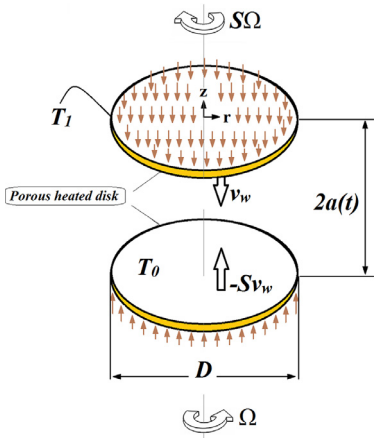


**Fig. 1.** Nanofluid flow between expanding/contracting porous disks.

equations. By 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. [26]. They reported that increasing magnetic parameter or viscosity parameter leads to decreasing Nusselt number, while by increasing the rotation parameter, blowing velocity parameter, and Pr, the Nusselt number increases. Sibanda and Makinde [27] 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 contracting and rotating plates is investigated. New model is used in simulation of nanofluid. The effect of active parameter on hydrothermal behavior is examined.

## 2. Formulation of the problem

We consider the motion of nanofluid between contracting or expanding, rotating disks. The top and bottom boundaries are porous and heated disks. The distance between the disks is $2a(t)$. As shown in Fig. 1, a cylindrical coordinate system may be chosen with the origin at the middle of the disks. The velocity components $u$, $v$, $w$ are taken to be in the $r$, $\zeta$, $z$ directions in this cylindrical coordinate system, respectively. Under these assumptions, the continuity and momentum equations are given by the following relations, respectively.

$$\frac{1}{r}\frac{\partial(ru)}{\partial r}+\frac{1}{r}\frac{\partial v}{\partial \zeta}+\frac{\partial w}{\partial z}=0, \tag{1}$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial r}+\frac{1}{r}v\frac{\partial u}{\partial \zeta}+w\frac{\partial u}{\partial z}-\frac{1}{r}v^2 = -\frac{1}{\rho_{nf}}\frac{\partial p}{\partial r}+\frac{\mu_{nf}}{\rho_{nf}}\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 u}{\partial \zeta^2}+\frac{\partial^2 u}{\partial z^2}-\frac{u}{r^2}-\frac{2}{r^2}\frac{\partial v}{\partial \zeta}\right), \tag{2}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial r}+\frac{1}{r}v\frac{\partial v}{\partial \zeta}+w\frac{\partial v}{\partial z}+\frac{1}{r}vu = -\frac{1}{\rho_{nf}r}\frac{\partial p}{\partial \zeta}+\frac{\mu_{nf}}{\rho_{nf}}\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 v}{\partial \zeta^2}+\frac{\partial^2 v}{\partial z^2}-\frac{v}{r^2}+\frac{2}{r^2}\frac{\partial u}{\partial \zeta}\right), \tag{3}$$

Download English Version:

https://daneshyari.com/en/article/7104553

Download Persian Version:

https://daneshyari.com/article/7104553

Daneshyari.com