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Simulating Flow of Nanofluids for Heat Transfer

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Abstract—*A new class of fluids which is obtained by the dispersion of nanoparticles in base fluids, has been in focus due to its increased heat transfer characteristics. The usual dimension ranges from 10nm-50nm. The advantages of using nano particles over microparticles, in these suspensions are two fold. The particles being smaller, flow of nanofluids through pipes and channels cause lesser damage to the walls and the suspensions are more stable as the problem of sedimentation is drastically reduced. Designing light and compact heat exchangers is the ultimate aim in all the processes which involve generation and efficient removal of heat. In particular, in the electronics industry, miniaturization has resulted in the increase in the number of components per unit area. As a result there is an enormous generation of heat. Similarly in the automobile industry there is a requirement of efficient heat removal in the manufacturing processes and nanofluids therefore, can replace the conventional coolants both in the vehicles and in the industries like the tyre manufacturing sector where there is a continuous need for efficient heat removal. In this paper, we explore the characteristics of heat transfer for nanofluids enclosed within a cavity and study the phenomenon of natural convection for titanium dioxide nanoparticles dispersed in water. In particular we explore the effect of the volume fraction of the nanoparticles on the heat transfer rate of conduction and convection.*

1. INTRODUCTION

Nanofluids, in the present decade has become a topic of extensive research due to the diverse applications. Engineering nanoparticles for efficient removal of heat has drawn a lot of attention ever since Choi[1] coined the term nanofluid which is a homogenous suspension of nanoparticles in a base fluid. In the present paper, we assume that the particles are distributed uniformly and there exists a thermodynamic equilibrium between the nanoparticles and the base fluid. We therefore assume the nanofluid as a single phase fluid with altered thermophysical properties. We investigate the heat transfer characteristics of TiO_2 nanoparticles dispersed in water[2]. The special application of this nanofluid is in solar collectors where this nanofluid enhances the heat transfer. This nanofluid is also used in the cosmetic and the paint industry and therefore exploring the transport properties like thermal conductivity and viscosity for this nanofluid is very significant. Earlier studies have been carried on CuO -water nanofluids in a differentially heated enclosure and the natural convection heat transfer has been explored[3].

2. DESCRIPTION OF THE PROBLEM

In the present paper we will study the natural convection in the TiO_2 nanofluid. Our system is similar to the conventional Rayleigh Benard system. It consists of two horizontal plates with the lower one at the higher temperature and the upper one at the lower temperature. These horizontal walls are maintained at constant temperatures. The side vertical walls are insulated and all the four walls of the cavity are impermable and rigid. The cavity is filled with the TiO_2 nanofluid. We will focus on the buoyancy driven heat transfer using this nanofluid[4].

3. THERMOPHYSICAL PROPERTIES

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_s$$

$$\beta_{nf} = ((1-\varphi)\rho_f\beta_f + \varphi\rho_s\beta_s)/\rho_{nf}$$

$$c_{nf} = ((1-\varphi)\rho_f c_f + \varphi\rho_s c_s)/\rho_{nf}$$

$$k_{nf} = k_f(k_s + 2k_f - 2\varphi(k_f - k_s)/(k_s + 2k_f + \varphi(k_f - k_s))$$

$$\mu_{nf} = \mu_f(1 + 2.5\varphi)$$

where the symbols have the following meaning.

ρ_{nf} represents the density of the nanofluid.

φ is the volume fraction of the nanoparticles suspended in base fluid

ρ_f is the density of the base fluid

ρ_s is the density of the nanoparticle.

μ_{nf} is the viscosity of the nanofluid

μ_f is the viscosity of the base fluid.

β_{nf} is the coefficient of volume expansion of the nanofluid

β_f is the coefficient of volume expansion of the base fluid

β_s is the coefficient of volume expansion of the nanoparticle

c_{nf} is the specific heat capacity of nanofluid at constant pressure

c_f is the specific heat capacity of base fluid at constant pressure

c_s is the specific heat capacity of nanoparticle at constant pressure

k_{nf} is the thermal conductivity of the nanofluid

$k_f$is the thermal conductivity of the base fluid

k_s is the thermal conductivity of the nanoparticle

[5] ,[6],[7],[8],[9].

4. HEAT TRANSFER CHARACTERISTICS

Our system is a bottom heated cavity filled with nanofluid . The basic objective is to study the effect of adding TiO_2 nanoparticles (to the base fluid) on the heat transfer rates of conduction and convection. Thermophysical properties of the nanofluids are temperature dependent[10]. In the present analysis, however, we consider only the density of the nanofluid to be temperature dependent and all other properties are approximated as constants over the temperature difference range under investigation.

The heat trsnsfer characteristics are examined in terms of the Rayleigh numbers for the base fluid as well as the nanofluid.

We calculate the Rayleigh number for the given nanofluid using the formula from literature [11,12].

$$R_{nf} = \frac{(\rho\beta)_{nf}\, k_f (\rho c)_{nf} \mu_f R_f}{(\rho\beta)_f k_{nf} (\rho c)_f \mu_{nf}}$$

where R_{nf} and R_f represent the Rayleigh number of the nanofluid and the base fluid respectively. All symbols have been described in the previous section. The dependence of the Rayleigh number on the volume fraction is through the thermophysical properties which are all functions of the volume fraction.

5. RESULTS

We calculate the values of the thermal conductivity, viscosity, coefficient of volume expansion, density and the specific heat for the nanofluids for volume fractions ranging from 0.01-0.08 from the given relations. We compute the value of the Rayleigh number for the nanofluid for each volume fraction varying the Rayleigh number of the base fluid .

Table 1: Thermophysical Properties for TiO_2

$\rho_s(kg/m^3)$	$C_s(J/kgK)$	$k_s(W/mK)$	$\beta_s(\frac{1}{K})x10^6$
4250	686.2	8.95	9

Table 2

Vol.Fr	**0**	**.01**	**.02**	**.04**	**.05**	**.06**	**.08**
R_{nf}/R	1	**.941**	.8867	.7884	.7441	.7027	.62

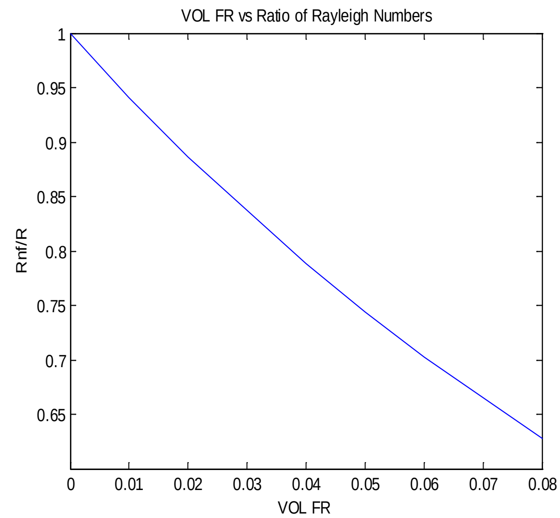

Fig. 1: Rnf/R as a function of vol. fr.

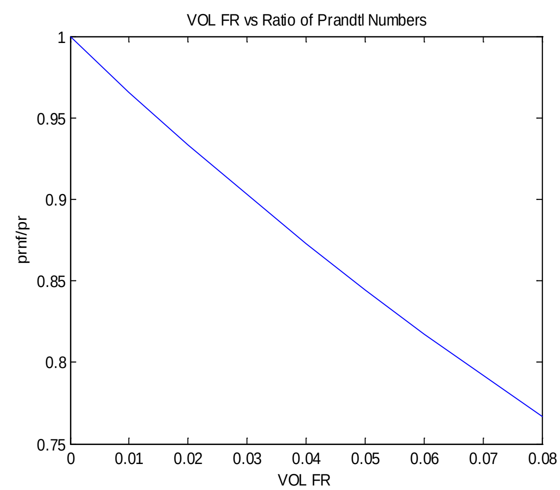

Fig. 2: Prnf/Pr as function of vol.Fr

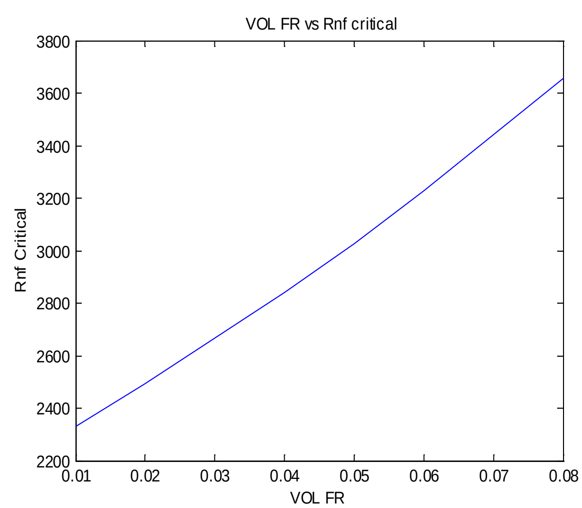

Fig. 3: Rnf critical as afunction of Vol. Fr

6. CONCLUSIONS AND DISCUSSIONS

From the calculations of the ratio of the Rayleigh number of the nanofluid to that of the base fluid, we find that it decreases with an increase in the volume fraction. This is evident from Fig.1. We have further calculated the ratio of the Prandtl number of the nanofluid to the Prandtl number of the base fluid and studied its dependence on volume fraction. The implication therefore is that addition of nanoparticles to the base fluid results in a decrease of the Rayleigh number of the nanofluid. Similarly addition of particles decreases the Prandtl number of the nanofluid. The critical Rayleigh number of the nanofluid at which convection sets in is illustrated in Fig. 3. Thus our conclusion is that the addition of nanoparticle has a stabilizing effect on the nanofluid. The transition to convection happens at higher values of the Rayleigh number in comparison to the base fluid. A further complexity can be introduced in the present problem where all the thermophysical properties will be a function of temperature. These results will be more accurate and free convection over larger temperatures can be investigated which will have industrial applications particularly in heat exchangers.

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REFERENCES

[1] Choi SUS "Enhancing Thermal Conductivity of fluids with nanoparticle",in *Developments and Applications of Non Newtonian flows ASME* ,1995, 99

[2] Rosari Saleh, Nandy Putra et al, in *Experimental Thermal and Fluid Science*, vol 52, January 2014, pp. 19-29.

[3] Abu Nada E.,Chamkha AJ,"Effect of nanofluid variable properties on natural convection in enclosures filled with a CuO-EG-Water nanofluid" in*International J of Thermal Sciences* 2010, 49, 2339.

[4] Rehena Nasrin,M.A.Alim, Ali J Chamkha, "Buoyancy driven heat transfer of water Al_2O_3 nanofluid in a closed chamber" in *Int.J of Heatand Mass Transfer* 2012, 55 ,pp. 7355-7365.

[5] Brinkman H C, "The viscosity of concentrated suspensions and solution" in *Journal of Chemistry and Physics* 1952,20,571

[6] X.Q.Wang and A.S. Majumdar,"Heat transfer characteristics of nanofluids: a review" in *Int. J. of Thermal Sciences*,2007, vol 46,no.1, pp. 1-19.

[7] S. Lee,S.U.S. Choi,J.A.Eastman,"Measuring thermal conductivity of fluids containing oxide nanoparticles" in *J.Heat Transf Trans*, ASME 1999,121, pp. 280-289.

[8] Rashmi et al,"Preparation ,thermophysical properties and heat transfer enhancements of nanofluids" in *Materials ResearchExpress* 2014 ,032001

[9] X. Wang, X.Xu and S.U.S Choi ,"Thermal conductivity of nanoparticle fluid mixture" in*J of Thermophysics and Heat Transfer*, 199, vol125 no.1 pp. 474-480.

[10] Das Supreeti, "Nanofluids for heat transfer: An analysis of thermophysical properties" in *IOSR J of Applied Physics*, Sept-Oct 2015, vol 7,no.5 pp. 34-40.

[11] Primoz Ternik, Rebeka Rudolf, Zoran Zunic ,"Numerical Study of Rayleigh Benard Natural convection heat transfer Characteristics of water based Au nanofluids",*Materials and Technology*, 2013, vol 47, n0.2, pp. 211-215.

[12] Bilal Elhajjar, Glades Bachir, Abdelkader Mojtabi, Chakib Fakih,Marie Catherine, Charrier-Mojtabi, "Modelling of Rayleigh Benard natural convection heat transfer in nanofluids",in *Comtes Rendus Mecanique* ,2010, vol 338,pp. 350-354.

[13] N. Putra, W. Roetzel, S.K.Das, "Natural convection of Nanofluids",in *HeatMass Transfer*,2003, pp. 775-784