

“AN OVERVIEW ON THERMO-PHYSICAL PROPERTIES OF NANOFLUIDS AND ITS EFFECT ON HEAT TRANSFER”

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ABSTRACT: The literature in enhanced heat transfer is growing faster. The enhancement of heating or cooling in an industrial process may create a saving in energy, reduce process time, raise thermal rating and lengthen the working life of equipment. Some processes are even affected qualitatively by the action of enhanced heat transfer. A number of investigations have been performed to gain an understanding of the heat transfer performance for their practical application to heat transfer enhancement. There are several methods to improve the heat transfer efficiency. Some methods are utilization of extended surfaces, application of vibration to the heat transfer surfaces, and usage of micro channels. Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid. In recent years, the nanofluid has emerged as an alternative heat transfer fluid for heat transfer applications showing a significant potential for heat transfer improvement. Nanofluids are this new class of heat transfer fluids and are engineered by suspending nanometer-sized particles in conventional heat transfer fluids. Nanofluids appear to be a very interesting alternative heat transfer fluids for many advanced thermal applications as in Electronics, Power generation, transmission and Renewable energy. The purpose of this review paper is to go through the thermo-physical properties of the nanofluids. This review paper also focused on the nanofluids performance in tube and covered the enhancement in heat transfer by the use of nanofluids in all applications and the effect of concentration, Reynolds number, type of nanofluid, and diameter of nanoparticles and other parameters.

1. INTRODUCTION

The convective heat transfer can be enhanced passively by changing the flow geometry, boundary conditions, or by enhancing the thermal conductivity of the fluid. Researchers tried to increase the heat transfer rate by increasing the thermal conductivity of the fluid. As a new research and technology frontier, nanofluids are used to enhance heat transfer. Nanofluids are engineered colloids which are made of a base fluid and nanoparticles (1-100) nm. The advantages of nanofluids are: (1) higher thermal conductivity, (2) excellent stability, and (3) little penalty due to an enhancement in pressure drop and pipe wall erosion experienced by suspensions of micrometer or millimeter particles. Such advantages of nanofluid offer important benefits for numerous applications in many fields such as petrochemical, refining, electronic, transportation, medicine, heating, and air-conditioning.

2. THERMO PHYSICAL PROPERTIES OF NANOFLUIDS

Thermo physical properties of the nanofluids are quite essential to predict their heat transfer behavior. It is extremely important in the control for the industrial and energy saving perspectives. There is great industrial interest in nanofluids. Nanoparticles have great potential to improve the thermal

transport properties compared to conventional particles fluids suspension, millimetre and micrometer sized particles. In the last decade, nanofluids have gained significant attention due to its enhanced thermal properties.

Experimental studies show that thermal conductivity of nanofluids depends on many factors such as particle volume fraction, particle material, particle size, particle shape, base fluid material, and temperature. Amount and types of additives and the acidity of the nanofluid were also shown to be effective in the thermal conductivity enhancement.

3. THERMAL CONDUCTIVITY

A wide range of experimental and theoretical studies were conducted in the literature to model thermal conductivity of nanofluids. The existing results were generally based on the definition of the effective thermal conductivity of a two-component mixture. The Maxwell (1881) [1] model was one the first models proposed for solid-liquid mixture with relatively large particles. It was based on the solution of heat conduction equation through a stationary random suspension of spheres. The effective thermal conductivity is given by

$$k_{eff} = \frac{k_p + 2k_{bf} + 2\phi(k_p - k_{bf})}{k_p + 2k_{bf} - \phi(k_p - k_{bf})} k_{bf}$$

Where k_p is the thermal conductivity of the particles, k_{eff} is the effective thermal conductivity of nanofluid, k_{bf} is the base fluid thermal conductivity, and ϕ is the volume fraction of the suspended particles.

4. VISCOSITY

Einstein (1956) [2] determined the effective viscosity of a suspension of spherical solids as a function of volume fraction (volume concentration lower than 5%) using the phenomenological hydrodynamic equations. This equation was expressed by

$$\mu_{eff} = (1 + 2.5\phi) \mu_{bf}$$

Where μ_{eff} is the effective viscosity of nanofluid, μ_{bf} is the base fluid viscosity, and ϕ is the volume fraction of the suspended particles.

5. SPECIFIC HEAT AND DENSITY

Using classical formulas derived for a two-phase mixture, the specific heat capacity (Pak and Cho, 1998) [3] and density (Xuan and Roetzel, 2000) [4] of the nanofluid as a function of the particle volume concentration and individual properties can be computed using following equations respectively:

$$\rho_{eff} = (1 - \phi) \rho_{bf} + \phi \rho_p$$

$$(\rho C_p)_{eff} = (1 - \phi) (\rho C_p)_{bf} + \phi (\rho C_p)_p$$

6. EFFECT OF NANOFLUIDS IN HEAT TRANSFER

The increases in effective thermal conductivity are important in improving the heat transfer behavior of fluids. A number of other variables also play key roles. For example, the heat transfer coefficient for forced convection in tubes depends on many physical quantities related to the fluid or the geometry of the system through which the fluid is flowing. These quantities include intrinsic properties of the fluid such as its thermal conductivity, specific heat, density, and viscosity, along with extrinsic system parameters such as tube diameter and length and average fluid velocity. Therefore, it is essential to measure the heat transfer performance of nanofluids directly under flow conditions. Researchers have shown that nanofluids have not only better heat conductivity but also greater convective heat transfer capability than that of base fluids.

Ravikanth and Kulkarni [5] investigated experimentally the convective heat transfer and pressure loss characteristics of three nanofluids (Aluminum Oxide, Copper Oxide and Silicon dioxide dispersed in 60 % ethylene glycol and 40 % water by mass) flowing in a circular tube in the turbulent regime. The

thermo physical properties such as viscosity, density, specific heat and thermal conductivity were measured at different temperatures for varying particle volume concentrations. Heat transfer coefficient of nanofluids showed an increase with the particle volumetric concentration. For example, at a Reynolds number of 7240, the percentage increase in the heat transfer coefficient over the base fluid for a 10 % Al_2O_3 nanofluid is 81.74 %. The pressure loss of nanofluids also increases with an increase in particle volume concentration. The increase of pressure loss for a 10 % Al_2O_3 nanofluid at a Reynolds number of 6700 is about 4.7 times than that of the base fluid. This is due to the increase in the viscosity of the nanofluid with concentration. The pressure loss was also measured and a new correlation was developed to represent friction factor for nanofluid.

Nasiri et al. [6] investigated experimentally the heat transfer performance of Al_2O_3/H_2O and TiO_2/H_2O nanofluids through an annular channel with constant wall temperature boundary condition under turbulent flow regime. The constant temperature is applied on the outer wall of the channel. Experimental investigation was done for nanoparticle concentrations 0.1, 0.5, 1.0 and 1.5 % and Reynolds number range (4000-13000). Based on the experimental results, for specific Peclet number, Nusselt number of nanofluids is higher than that of the base fluid. The enhancement increases with increase of nanoparticle concentration for both employed nanofluids. Based on the results of this investigation there is no significant difference on the heat transfer enhancement associated with two employed nanofluids.

Sajadi [7] investigated experimentally turbulent heat transfer behavior of TiO_2 /water nanofluid in a circular pipe with volume fraction of nanoparticles in the base fluid was in the range (0.05-0.25 %) and Reynolds number range (5000-30000). The results indicated that addition of small amounts of nanoparticles to the base fluid augmented heat transfer remarkably. The measurements also showed that the pressure drop of nanofluid was slightly higher than that of the base fluid and increased with increasing the volume concentration. Experimental results have been compared with the existing correlations for nanofluid convective heat transfer coefficient in turbulent regime.

Khodadadi et al. [8] analyzed numerically the turbulent flow of nanofluids with different volume concentrations of nanoparticles flowing through a two-dimensional duct under constant heat flux condition. The nanofluids considered are mixtures of copper oxide (CuO), alumina (Al_2O_3) and oxide titanium (TiO_2) nanoparticles and water as the base fluid. All the thermo-physical properties of nanofluids are temperature dependent. The viscosity of nanofluids is obtained on basis of experimental data. The predicted Nusselt numbers exhibit good agreement with Gnielinski's correlation. The results show that by increasing the volume concentration, the wall shear stress and heat transfer rates increase. For a constant volume concentration and Reynolds number, the effect of CuO nanoparticles to enhance the Nusselt number is better than Al_2O_3 and TiO_2 nanoparticles.

7. CONCLUSIONS

This review presents the recent studies of single phase and two-phase nanofluid flows in tubes and channels and also helps to determine the thermo-physical properties of nanofluids chronologically. Nanofluid is considered as an innovative heat transfer fluid with superior potential for enhancing the heat transfer performance of conventional fluids. Nanofluid has been classified as a new class of heat transfer fluids engineered by dispersing metallic or non-metallic nanoparticles with a typical size of less than 100 nm in the conventional heat transfer fluids. According to the researches, we can summarize the conclusions as follows:

1. Heat transfer performance of the base fluid can significantly be increased by the suspended nanoparticles since heat transfer coefficient of the nanofluid was found to be larger than that of its base fluid for the same Reynolds number.
2. The higher the nanoparticles weight fraction, the more the rate of heat transfer enhancement.
3. The volume fraction of nanoparticles increases the heat transfer feature of a nanofluid. Pressure drop and friction factors of nanofluids are also larger than its base fluids.
4. The heat transfer rate is directly proportional to Nusselt and Peclet number of the fluid.
5. The fine grade of nanoparticles increases the surface area which results in increase in the heat transfer rate.
6. There has been considerable pressure drop by the use of nanofluid, but can overcome to some extent if extremely fine powder is used (less than 20 nm).

8. REFERENCES

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