# Enhancement of Heat Transfer Rate by Nanofluid in a Heat Exchanger

[1]Atif Aziz and [2]Sujata Pouranik
[1]MTech Department of Mechanical Engineering All Saints College of Technology Bhopal (MP) India
[2]Assistant. Prof. Department of Mechanical Engineering All Saints College of Technology Bhopal (MP) India

## Abstract

A nanofluid is the suspension of nanoparticles in a base fluid. Nanofluids are promising fluids for heat transfer enhancement due to their anomalously high thermal conductivity. Experimental studies are discussed in terms of the effects of some parameters such as particle volume fraction, particle size, and temperature on the thermal conductivity of nanofluids. Research about the forced convection of nanofluids is important for the practical application of nanofluids in heat transfer devices. This paper is an experimental study on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of $Al_2O_3$ nanofluid (1.6–2.4) % flowing in a horizontal shell and tube heat exchanger counterflow laminar flow conditions. The results show that the convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid at same mass flow rate and at same inlet temperature. It is found that heat transfer characteristics improves for 1.6% to 2.0% volume fraction and then decreases at 2.4%.

Keywords: - Nanofluid, shell and tube heat exchanger, heat transfer

## Introduction

In most of the heat transfer systems, the working fluid is circulated by a pump and improvements in heat transfer efficiency can minimize the associated power consumption. The fluids used are water, ethylene glycol and oil to carry away the heat in these devices. The development of nanofluid generally shows a better heat transfer characteristic than the water. 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 microchannels. Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid. The feasibility of the usage of such suspensions of solid particles with sizes on the order of millimetres or micrometres was previously investigated by several researchers and significant drawbacks were observed.[1] The addition of solid particles into heat transfer media has long been known as one of the useful techniques for enhancing heat transfer, although a major consideration when using suspended millimetre- or micrometre-sized particles is that they have the potential to cause some severe problems, such as abrasion, clogging, high pressure drop, and sedimentation of particles.[2] Compared to heat transfer enhancement through the use of suspended large particles, the use of nanoparticles in the fluids exhibited. These properties prevent the sedimentation in the flow that may clog the channel.
From these points of view, there have been some previous studies conducted on the heat transfer of nanoparticles in suspension. Since Choi wrote the first review article on nanofluids [3], Nguyen et al. [4] investigated the heat transfer coefficient and fluid flow characteristic of $Al_2O_3$ nanoparticles dispersed in water flowing through a liquid cooling system of microprocessors under turbulent flow condition. The results revealed that the nanofluid gave a higher heat transfer coefficient than the base liquid and the nanofluid with a 36 nm particle diameter gave higher heat transfer coefficient compared to the nanofluid with a 47 nm particle diameter. A nanofluid is the suspension of nanoparticles in a base fluid. Nanofluids are promising fluids for heat transfer enhancement due to their anomalously high thermal conductivity. At present, there is significant discrepancy in nanofluid thermal conductivity data in the literature.

## Literature Review

Nanofluids consists of particles of nanometre-size (normally less than100 nm) are used instead of micrometre-size for dispersing in base liquids, and they are called nanofluids.

With the recent improvements in nanotechnology, the production of particles with sizes on the order of nanometres (nanoparticles) can be achieved with relative ease.[6] As a consequence, the idea of suspending these nanoparticles in a base liquid for improving thermal conductivity has been proposed recently[3,4]. Such suspension of nanoparticles in a base fluid is called a nanofluid.

**Dhafer A. Hamzah et.al. (2018) [7]** Thermal and hydrodynamics performance of 1 shell and 2-tubes heat exchanger with different concentrations of ethylene glycol, copper and alumina as nanofluid have been investigated, theoretically and numerically. The water-alumina nanofluid has the lowest friction factor compared with the other flow of water-copper nanofluid and water-ethylene glycol. The ideal concentration of copper concentration and alumina is 1-2% for the present work. Single model used in the study satisfied the theoretical results, with maximum error 4%.

In this work the Al2O3 Nano particle is used to prepare nanofluid and the base fluid used as demineralized water. The main advantage of using PHE in this work is that it has high heat transfer area. The main focus of using nanofluid is that it has high thermal conductivity than base fluid like water, ethylene glycol, etc. The concentration of nanofluid is 0.3 % of its volume concentration.

## Research Methodology

This part deals with the brief description of experimental set-up details about the instruments used. It also describes the methodology used for the measurement of various parameters and their analyses.

Two main preparation methods (two-step and one-step) were used to fabricate/synthesis of the NFs used in this study. For all the NFs systems studied in this work two-step method was used except for DEG based Copper NFs, which was synthesized via one-step method. To design a project that could be used to transfer heat from hot water in a heat exchanger to nanofluid stored in a separate tank and make temperature calibrations for the same by employing two thermocouples. Also, flow meters will be installed in the pipes carrying nanofluid to check its flowing rate.
The nanofluid presented equation are calculated by using of the Pak and Cho correlations, which are defined as follows:

$$\rho_{nf} = (1-\emptyset)\ \rho_f + \emptyset \rho_p$$

where ρnf is the density of the nanofluid, ∅ is the particles volume concentration, $\rho_f$ is the density of the base fluid and $\rho_p$ is the density of the nanoparticles.

The specific heat is calculated from Xuan and Roetzel [5] as following:

$$(\rho Cp)_{nf} = (1-\emptyset)\ (\rho Cp)_f + \emptyset(\rho C_p)_p$$

where Cpnf is the heat capacity of the nanofluid, Cpf is the heat capacity of the base fluid and Cpp is the heat capacity of the nanoparticles

Heat transfer rate can be defined as

Q =_mCpΔT

where Q is the heat transfer rate, m_ is the mass flow rate and ΔT is the temperature

difference of the cooling liquid.

**Result and Discussion**

To evaluate the accuracy of measurements, experimental system has been tested with distilled water before measuring the heat transfer characteristics of different volume concentration of Al2O3/water. From the experimental system, the values that have been measured are, the temperatures of the inlet and outlet of the hot water as well as the inlet of the distilled water and the different concentrations of nanofluids at different mass flow rates. a mass flow rate of 0.0125 L/s.

The Reynolds no. used were in laminar flow range of 800, 1100 and 1500. The volume concentration of nanofluid was increased from 1.6 %, 2.0 % and 2.4%.

The overall heat transfer coefficient, Nusselt number and log mean temperature difference were calculated and show in the form graph.

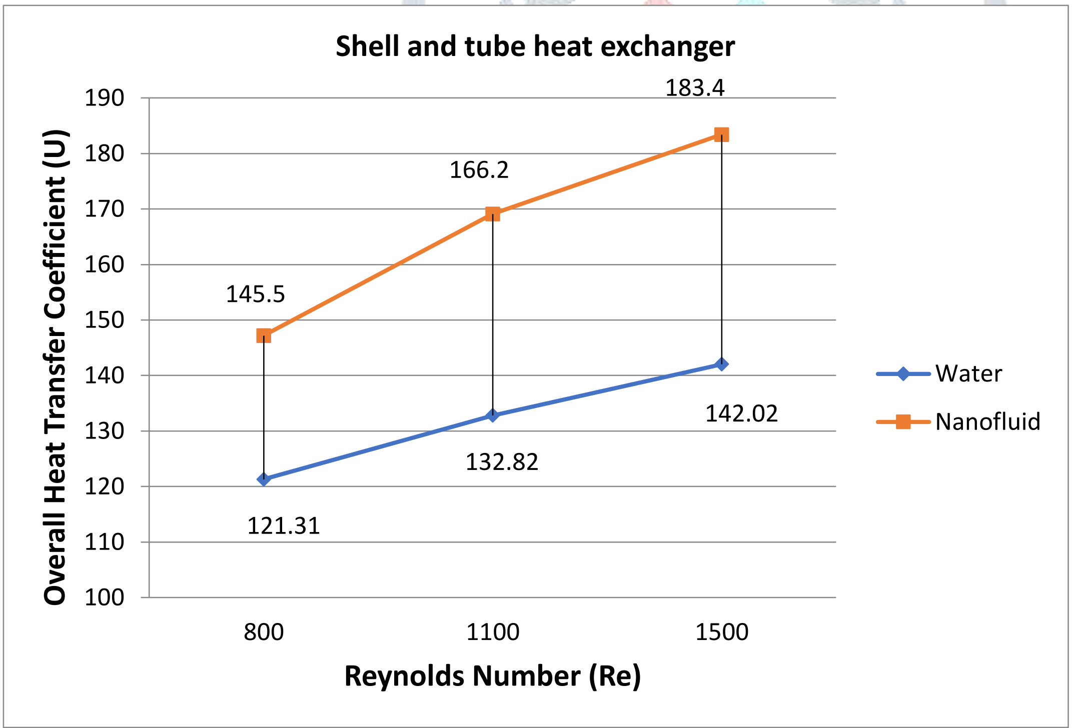


**Fig. 1 (1.6% Nanofluid at 30°C)**

The overall heat transfer coefficient is 183.4 W/m$^2$ K for nanofluid as compared to water which is 142.02 W/m$^2$ K.

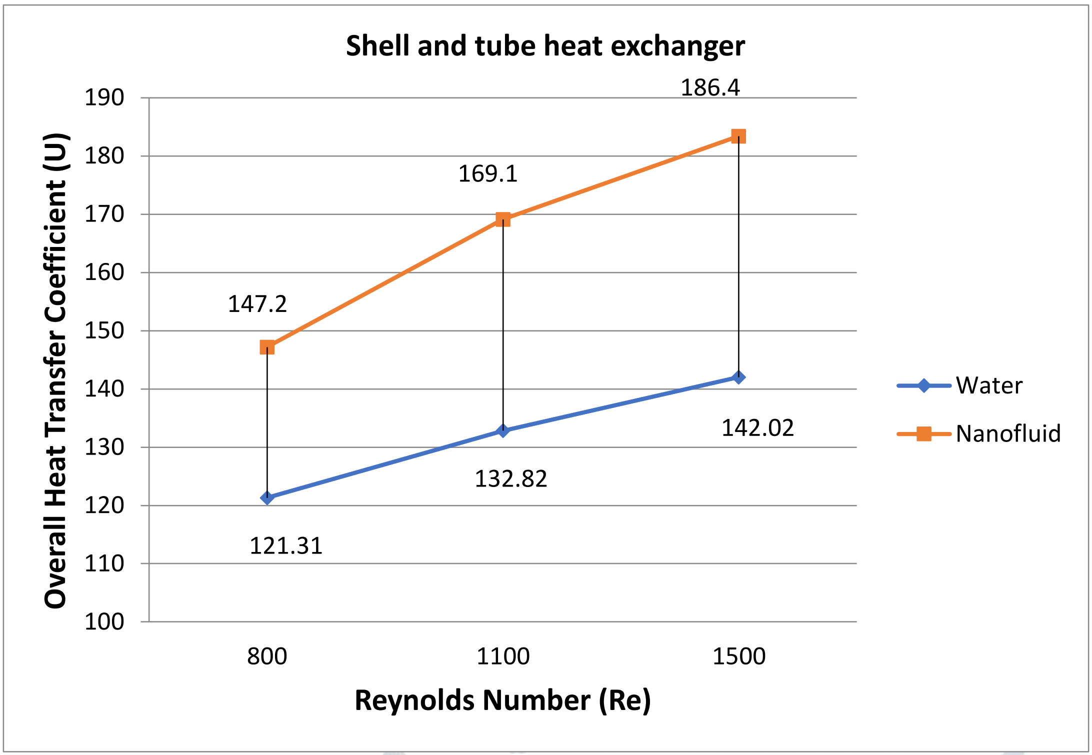


**Fig.2 2.0% Nanofluid at 30°C**

The overall heat transfer coefficient is 183.4 W/m$^2$ K for nanofluid as compared to water which is 142.02 W/m$^2$ K.

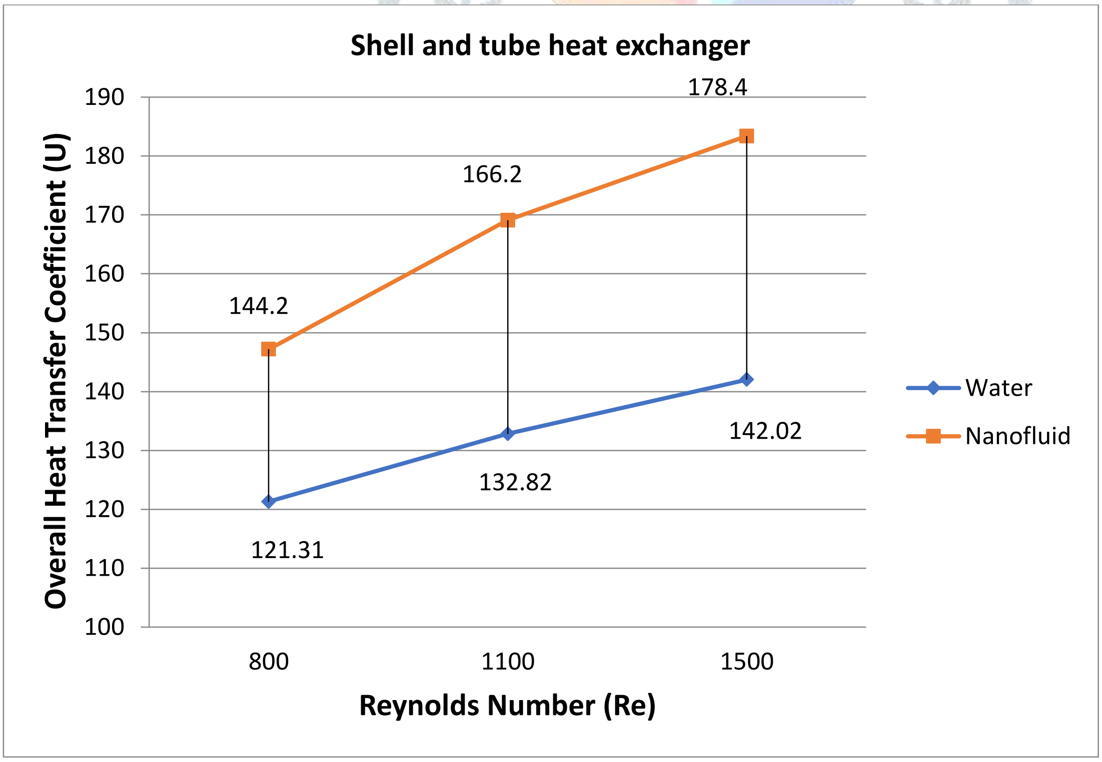


**Fig.3 2.4% Nanofluid at 30°C**

**Conclusion**

The effect of particle concentration and the Reynolds number on the heat transfer performance and flow behaviour of the nanofluid has been determined. Important conclusions have been obtained and are summarized as following:

1. Dispersion of the nanoparticles into the distilled water increases the thermal conductivity and viscosity of the nanofluid, this augmentation increases with the increase in particle concentrations.

2. At a particle volume concentration of 2% the use of $Al_2O_3$/water nanofluid gives significantly higher heat transfer characteristics.

At the particle volume concentration of 2% the overall heat transfer coefficient is 181.2 $W/m^2$ K and for the water it is 142.02 W/m2 K for a mass flow rate of 0.0125 L/s so the enhancement ratio of the overall heat transfer coefficient is 1.275, this means the amount of the overall heat transfer coefficient of the nanofluid is 29% greater than that of distilled water.

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