# Enhancement of Heat Transfer Rate in Heat Exchanger Using Nanofluids

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## Abstract:

*Nanotechnology is concerned with the materials and systems whose structures and components exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes due to their Nano scale size. Workforce development is essential to reap the benefits of nanotechnology development along with technology transfer. The emphasis should be on hands-on educational experiences by developing Nano-tech laboratory demonstration experiments that could be adaptable and incorporated into existing courses in engineering and technology. This is an effort to demonstrate heat transfer using Nano fluids in a mini heat exchanger utilizing commercially available equipment. Theoretical heat transfer rates were calculated using existing relationships in the literature for conventional fluids and Nano fluids. Experiments are conducted to determine the actual heat transfer rates under operational conditions using Nano fluids and the heat transfer enhancement determined compared to fluids without nanoparticles.*

## Keywords:

Nano fluid,de-ionized water,Heatexchanger, Heat transfer rate, nanoparticles.

## Introduction

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigeration, air-conditioning, power plants, chemical plants, petrochemicalplants, petroleum refineries, natural gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a

circulating fluid known as engine coolant flows through radiator coils and airflows past the coils, which cools the coolant and heats the incoming air.

Heat Transfer is transmission of energy from one region to another region as a result of temperature difference between them. There are several laws, which governs the Heat Transfer between mediums, out of which second law of thermodynamics plays an important role which states that "The energy cannot be upgraded (i.e.) Heat cannot flow from a body at lower temperature to a body at higher temperature"Heat exchangers were designed to remove the heat from the hot body by the use of cold fluid. Even though several experiments were already conducted in Heat Exchangers to improve its Heat transfer rates, only a few have succeeded. Hence this paper is also one such attempt to increase the heat transfer rate in Heat Exchangers by the use of new types of coolants called Nano Fluid. These

Nano Fluid are a result of the recent developments in the field of Nanotechnology. Any Fluid containing particles of size smaller than 100µm to form a suspension are called Nano Fluid. These Nano Fluid have a bulk solid Thermal conductivity higher than that of their base liquids.

## Experimental Setup

It is setup with two flow loops, one as heating loop and the other as coolingNano Fluid loop. Each loop has a separate reservoir as well as separate inlet and outlet in the reservoir. A separate water heater unit is used to heat the water flowing through the hot loop with following specifications: Make: Elac, Capacity – 1ltr, Power –3KW. The shell and tube type Heat Exchanger has been designed in such a way that, both parallel and counter flow characteristics of the coolant Nano Fluid could be analyzed. The inner tube of the Heat Exchanger is made of copper and the outer shell is made of galvanized iron (GI) with Inner Diameters 12mm and 40mm respectively. The tube is 1800mm long and has a wall thickness of 3mm. Four J – type thermocouples were inserted at the four openings in the Heat Exchanger to measure the Thin, Thout, Tcin and Tcout. This serves as the temperature measurement system were all the reading were recorded by a thermocouple scanner. The flow of the liquids is governed by a pump with 11 l/min displacement.

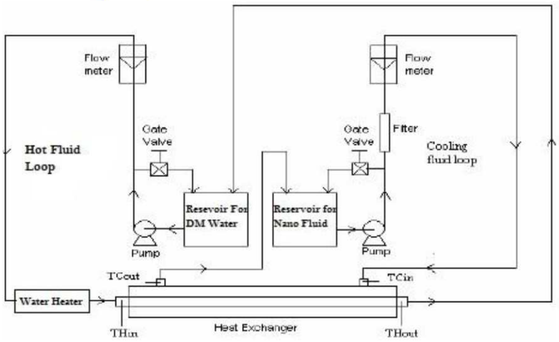


Figure 1: Mini heat exchanger.

## Nano Fluid Preparation

Nano Fluid was found to be stable at less than 4% concentration of Nano particles and the stability lasted over a week, hence with copper – Nano particles dispersed in DM water with 2% of concentration was prepared as Nano Fluid.

Nanoparticles, Nano fibres, nanotubes, or other nanomaterial used in this method are first produced as dry powders by chemical or physical methods. Then, the Nano sized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling.

## Sedimentation and Centrifugation Methods for Stability Evaluation Methods of Nano Fluid

The sediment weight or the sedimentvolume of nanoparticles in a Nano Fluid under an external force field is an indication

of the stability of the characterized Nano Fluid. The variation of concentration or particle size of supernatant particle with sediment time can be obtained by special apparatus. The Nano Fluid is considered to be stable when the concentration or particle size of supernatant particles keeps constant. Sedimentation photograph of Nano Fluid in test tubes taken by a camera is also a usual method for observing the stability of Nano Fluid.The tray of sedimentation balance immerged in

the fresh graphite suspension. The weight of sediment nanoparticles during a certain period was measured. The suspension fraction of graphite nanoparticles at a certaintime could be calculated. For the sedimentation method, long period for observation is the defect. Therefore, centrifugation method is developed to evaluate the stability of Nano Fluid.

stability ofsilver Nano Fluid prepared by the microwave synthesis in ethanol by reduction of Ag $NO_3$ with PVP as stabilizing agent. It has been found that the obtained Nano Fluid is stable for more than 1 month in the stationary state and more than 10 h under centrifugation at 3,000 rpm without sedimentation. Excellent stability of the obtained Nano Fluid is due to the protective role of PVP, as it retards the growth and agglomeration of nanoparticles by steric effect. Li prepared the aqueous polyanilinecolloids and used the centrifugation method to evaluate the stability of the colloids. Electrostatic repulsive forces between nanofibers enabled the long-term stability of the colloids.

## Zeta Potential Analysisfor Stability Evaluation Methods of Nano Fluid

Zeta potential is electric potential in the interfacial double layer at the location of the slipping plane versus a point in the bulk fluid away from the interface, and it shows the potential difference between the dispersion medium and the stationary layer of fluid attached to the dispersed particle. The significance of zeta potential is that its value can be related to the stability of colloidal dispersions. So, colloids with high zeta potential (negative or positive) are electrically stabilized, while colloids with low zeta potentials tend to coagulate or flocculate. In general, a value of 25 mV (positive or negative) can be taken as the arbitrary value that separates low-charged surfaces from highly charged surfaces. The colloids with zeta potential from 40 to 60 mV are believed to be good stable, and those with more than 60 mV have excellent stability.zeta potential analysis was an important technique to evaluate the stability. Zhu et al. measured the zeta potential of $Al_2O_3$ -$H_2O$ Nano Fluid under different pH values and different SDBS concentration.

## Results and Discussion

### Experimental Results

The prepared Nano fluids are new and hence the standard properties such as the specific heat, Viscosity are to be calculated. The mass flow rate was calculated by collecting the sample in the measuring flask over a period of time. The transport properties of Nano fluids are more important, as the flow of fluid is dependent on a pump action.

Preliminary experiments with water were performed to gain experience in operating the set-up. The experiments were performed varying the Nano fluid flow rate at a given concentration.

### Base line experiment using water/water

Using de-ionized water as the heating fluid in the tube side, and water as the cooling medium on the shell side, temperature measurements were taken at fluid inlet and exit positions after steady state has been reached. Steady state was determined when the temperatures remained constant with time for a 10 min. period. The mass flow rate (kg/s) of the fluid flowing inside the tube, and heat transfer rate (W) were plotted and the result shown in Fig.2.

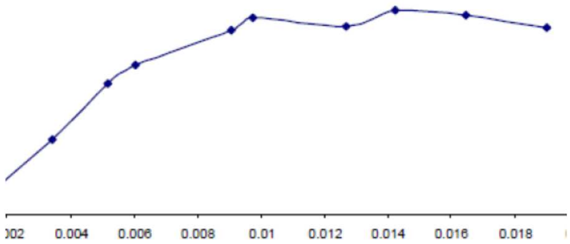


**Figure 2**.Heat Transfer rate-Water/water exchange

### Heat transfer between water/Nano fluids with concentration of10x10- 3%volume

A very low Nano fluid concentration was used as the first Nano heat transfer experiment. An increase in heat transfer rate is observed at any given flow rate. The plot of mass flow rate vs. heat transfer rate is shown in Fig.3. There is an improvement in heat flow rate due to the addition of nanoparticles even at very low concentrations. For example at a mass flow rate of 0.005 kg/s, a 5.5% increase in heat transfer rate is observed.

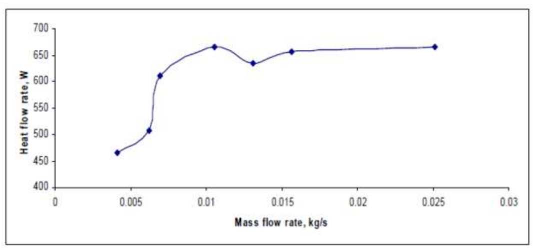


**Figure 3**.Heat Transfer rate-Water/nano concentration, $10x10^{-3}$ % by volume.

### Heat transfer between water/Nano fluids with concentration of 20x10- 3%volume

As the concentration of nanoparticles in the fluid increases, a further increase in the heat transfer rate is observed. The results for the higher concentration of Nano fluid is shown in Fig.4.

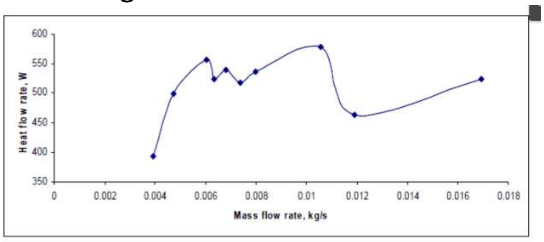


**Figure 4**.Heat Transfer rate-Water/nano concentration, $20x10^{-3}$ % by volume.

### Heat transfer rate and Reynolds number

The relationship between heat transfer rate and Reynolds number forthe water/water exchange and water/Nano fluid concentration of $10x10^{-3}$ are shown in Figure 5.

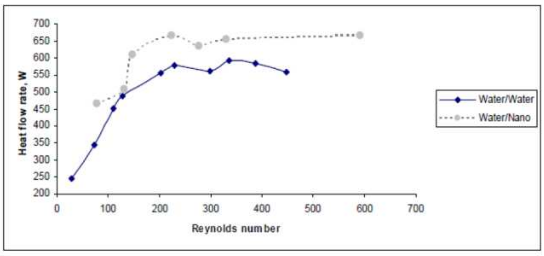


**Figure 5**. Reynolds number versus Heat Transfer rate.

### Model Calculation

Considering,

$Tc_{in} = 25^\circ$ C

$Tc_{out} = 33^\circ$ C

$Th_{in} = 70^\circ$ C

$Th_{out} = 50^\circ$ C

$C_p = 4180$ J/Kg.K

$h_i, h_o = 1590$ W/m2 K

$m_c = 1495$ Kg/h

$m_h = 605$ Kg/h

$$m_c.C_{pc}(T_{co} - T_{ci}) = m_h.C_{ph}(T_{hi} - T_{ho})$$

$$\Delta T_1 = T_{hi} - T_{ci} = 45^\circ C$$

$$\Delta T_2 = T_{ho} - T_{co} = 17^\circ C$$

$$\Delta T_{lm} = 29^\circ C$$

$$Q = m_h.C_{ph}(T_{hi} - T_{ho}) = 14050 \text{ W.}$$

## Conclusion

This project was started with an idea to increase the Heat Transfer rate. Severalfactors increased the effective thermal conductivity of the Nano fluid. The presence of nanoparticles resulted in the desired results, as the use of nanoparticles dispersed in de-ionized water improved the heat transfer rate.

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