Performance Evaluation of Nano fluid Based Heat Exchanger

Sanjeev Kumar[1], Raja Pradhan[2], Minesh Vohra[3], Aashish Sharma[4]

[1,3,4]Assistant Professor, School of Mechanical Engineering, Lovely Professional University, Phagwara144402, India

[2] Research Scholar, School of Mechanical Engineering, Lovely Professional University, Phagwara144402, India

ABSTRACT

The heat exchanger is designed to provide the amount of thermal energy needed to either heat or cool a fluid stream during the operation. The heat transfer rate is significant for choosing a particular types of heat exchanger. In this experimental study, the performance of the double pipe heat exchanger in which inner pipe is corrugated pipe with pitch of 3mm and corrugation of 3mm is evaluated. Two working fluids are used in this double pipe heat exchanger in which outer fluid is distilled water and inner fluid is distilled water with 0.025%, 0.05% and 0.075% concentrations of coper oxide nanoparticles. The results show that with increase the concentration of nanoparticles, the heat transfer rate is also increased but with it solely depends upon the mass flow rate. As mass flow rate increase, the heat transfer capacity of the fluid decrease. It is found that with mass flow rate of 0.04 kg/s, the Nusselt number is 93 at Reynold number of 3000. By comparing the Nusselt number of base fluids with Nusselt number with nanoparticles with base fluid, it is found that Nusselt number is increased 1.66 at Reynold number of 1715 for nanoparticles concentration of 0.075%. The value of the Nusselt number goes on decreasing as mass flow rate increases to 0.07kg/s. The result shows that, system is not effective for high mass flow rates. The effectiveness of the heat exchanger at Reynold number of 1715 is 0.26 and 0.24 at 0.075% and 0.05% concentration of nanofluids respectively.

Keywords: Corrugated pipe, nanoparticles, mass flow rates, Nusselt Number, Heater, Thermostat.

1. INTRODUCTION

The current topic focuses on the enhancement of heat transfer in a heat exchanger. The use of heat exchanger is more than decades old and it is always a matter of concern to increase the heat exchange between the two media in concern. It is basically used to transfer the heat from a fluid at a higher temperature to a fluid at lower. It has been seen that by the implementation of various different systems in a heat exchanger, the heat exchange rate can be increased. The increase in heat exchange increases the system efficiency. So, it is for the greater good if a better heat exchanger is built from the previously available heat exchanger. Many researchers have gone through different ways to increase the heat exchange process and find out various different techniques to increase the heat transfer coefficient of the system as a whole. The research done in this field shows that various techniques are successfully used to increase the coefficient of heat transfer, but a higher efficiency is still being explored. The different ways found out which were really effective from the implementation point of view are turbulators inserted in the fluid medium, increase of roughness and nanofluid. So, these are three different techniques which are effective enough to increase the heat transfer capacity and are generally used for increasing the overall heat transfer. The use of such technique individually or as a combination of two has been reported in various research scholars' papers. The most important fact still remains that the number of combinations that can be achieved by using these three techniques has not been explored as there are many factors that can be changed in a single technique itself. As we discussed above that the different techniques are very effective in increasing the heat transfer capacity of the system and the scope becomes very vast when we think of using the three different techniques in a single system.

A review of the literature suggests that significant research have been made in the field of heat exchanger and on techniques for increasing the rate of heat transfer. In the past various researchers has done the work on heat exchanger. The work on nanofluid was done a century before but the breakthrough was achieved by Choi, S. [1] find out that addition of nanofluid can actually increase the heat transfer rate of the base fluid. This breakthrough became the base for many more researches in the field of enhancement of heat exchange capacity of the heat exchanger. Khairul M.A. et. al [2] examination of CuO/water nanofluid and only water was separately done to check the exergy destruction, pressure drop, heat transfer coefficient and heat transfer rate in the corrugated plate heat exchanger. It was noted that for CuO/water nanofluid, heat transfer coefficient was enhanced from 18.50% to 27.20% when the concentration was increased from 0.50 to 1.50% in comparison with water. This increase in concentration also noted an increase in heat transfer rate along with a reduction of 24% exergy loss. Bhuiya M.M.K. et. al [3] conducted experiment by installing two twisted tape in a pipe with counter direction. The experiment was conducted for different twist ratio (y= 1.95, 7.75, 3.85 and 5.92) with Reynolds number variation of 6950 to 50,050. The experiment demonstrated that with decreasing twist ratio there was an increase in Nusselt number, thermal efficiency and friction factor. It was revealed that a n increase in pressure drop was noted with increase in heat transfer rate. Sadighi Dizaji et. al [4], experimental investigation was conducted for pressure drop, heat transfer rate and effectiveness for a double pipe. The main focus is on the geometry of the corrugated tube where they have made inner and outer tube corrugated with a special machine. Maximum effectiveness of heat exchanger was obtained for concave outer corrugated tube and convex inner corrugated tube. Zhang Cancan et. al [5], twisted tape was referred as an important technique to increase the heat transfer rate. The study focuses over the different data collected from different works both experimental as well as numerical for stationary as well as self-rotating twisted tapes. It was noted that self-rotating tapes gives lower pressure drop. It was concluded that twisted tape with other technique could result in better heat transfer rate. Kareem Zaid S. et al [6], effect of various kind of corrugated pipe in the heat exchange capacity was done. It was understood that with increase in turbulence there is an increase in pressure drop and corrugation increases the heat transfer rate due to the fact that it increases the perimeter. Swirl is induced in the secondary flow by the corrugated tube which is the main reason for heat transfer rate enhancement. Azmi W.H. et al [7] evaluated a system consisting of twisted tape and TiO_2/water nanofluid in a circular pipe arrangement. The nanofluid of up to 3% volume concentration was taken with 30°C average temperature. Reynolds number was varied from 8000-30,000. The result showed that at a concentration level 1% and twist ratio of 5, friction factor and heat transfer coefficient were 1.5 times and 81.1% greater than flow of water in a tube at Re= 23,558. Bhuiya M.M.K. et al [8] conducted experiment installing perforated twisted tape in a circular pipe. The experiment was conducted for different porosities of Rp= 4.5, 1.6, 14.7 and 8.9% with Reynolds number variation of 7200 to 49,800. In the experiment working medium is air. The experiment demonstrated an increase in Nusselt number, thermal efficiency and friction factor by 110-340, 28-59% and 110-360 higher than plan tube. Tiwari Arun Kumar et al [9] convective heat transfer coefficient, heat transfer rate, effectiveness, performance index and overall heat transfer coefficient are optimized. In the result, authors found out different optimized value for different nanofluid with different concentration of 0-3%. The nanofluids are SiO_2/water, Al_2O_3/water, TiO_2/water and CeO_2/water which at a flow of 3 lpm had the optimized values is 1.25%, 1%, 0.75% and 0.75%. With the above configuration heat transfer enhancement was 19.9%, 26.3%, 24.1% and 35.9% respectively. Bhuiya M.M.K. et al [11] conducted experiment installing twisted wire insert in a pipe. The experiment was conducted for different wire densities of 100, 150, 200 and 250 per centimetre which was a winding of 1 mm diameter of copper wire over a 5 mm diameter of two twisted iron core-rods. Reynolds number variation of 7200 to 50,200 was taken. The experiment demonstrates an increase in heat transfer rate, thermal efficiency and friction factor. It was revealed that an increase in pressure drop was noted with increase in heat transfer rate. Friction factor and Nusselt number increased by 2.0 and 2.15 times higher than plan tube. For a constant blower power, a maximum of 1.85 heat transfer was achieved. Morteza and Mehdi a work on variation of twist length in a single strip is done to check for increase in OER. The study was carried for heat transfer, overall performance and pressure drop of Cu-water at different concentration of 0, 0.1 and 0.3 wt. % for Reynolds number ranging from 7500 – 15,000. Different combinations in the twisted tape were used such as High–Low, Low–High, High–Low–High and Low–High–Low. Taking base line for the experiment to be set by flowing base fluid through the system shows that the technique improves the OER by 45%. With the specification of 0.3 wt. % and Low–High twisted tape arrangement, the OER was improved to 87%. Khwanchit and Smith [12], in the study have taken into consideration a helical corrugated pipe with twisted tape of various ratios (y/w=5.3, 2.7 and 3.6), they also varied concentration of CuO/water (0.7, 0.5, 0.3%). The Reynold number was in the range of 6200-24000. The result was correlated with using twisted tape alone and nanofluid alone. It was found that a maximum of 1.57 of thermal performance was found with concentration of 0.7%, Reynolds number configured for 6200 and twist ratio of (y/w) of 2.7.

The most of the researchers have done their work in heat exchanger for increase the heat transfer rate with nanofluids and the use of turbulator and corrugated pipe with variation of different parameters to find an optimized value. The works discussed above shows that many different concentrations for nanofluid have been dealt with which gives a clear picture of which should be used for present work, along with it different turbulator and corrugated pipe geometry have also been tried but corrugated pipe along with low concentration of CuO in water with have not been performed. In this experimental study, the experiments work concentrates over the heat exchange capacity of the system. The work comprises of setting up the test section and after that taking steps to collect appropriate data from the test section. While doing so we will try to make a system in which a double pipe arrangement is used and, in this arrangement, different physical parameters can be changed due to which we may get an increase in heat exchange capacity.

2. EXPERIMENTAL SETUPS

The research work did by different scholars have shown a gap in which the present work is based on. As we have seen that there are number of different types of corrugation in which the heat transfer effectiveness can be checked. The experiment revolves around the effectiveness of the system for the used corrugation with varying nanofluid concentration. The effect on heat transfer is to be checked for the different concentration of nanofluid that is being taken. The use nanofluid increase the pump work s but in this experiment flow rate is low due to which the pressure drop is very less and also the pump work in negligible.

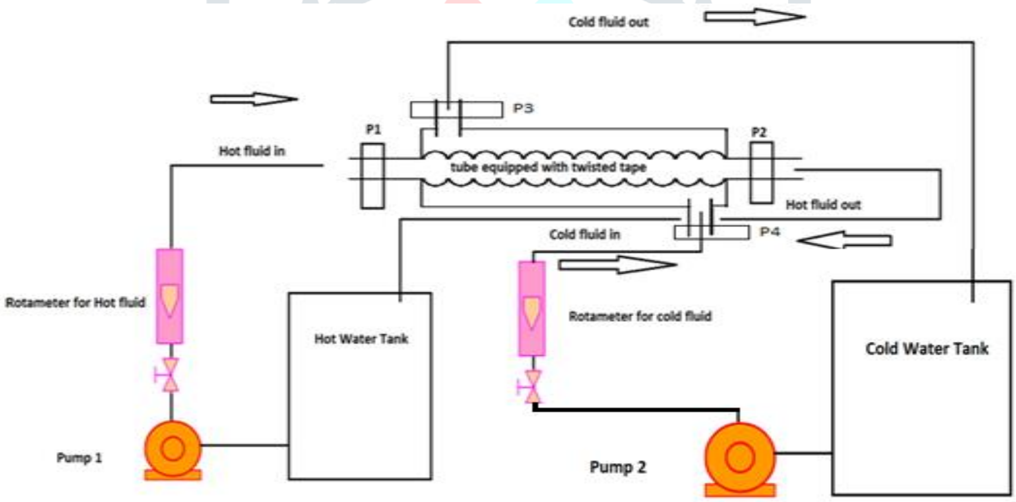

Figure 1: *Experimental setup for Double pipe corrugated heat exchanger*

2.1 Components of Experimental Setups

The experimental setup consists of corrugate tube, heater, thermostat, pump, valve, heater, plane pipe and insulating materials. Some of these components are discussed below.

2.1.1 Corrugated Tube

Corrugated tube is a tube which is corrugation projected in the inner and outer surface of the tube. The overall heat transfer coefficient has been increased remarkably as there is the presence of corrugation which increases the turbulence in the flow system. Many types of configuration are used in the system where twisted tape, spring inserts are subject to be put inside the corrugated tube so as to increase the turbulence in the tube further which will result in better heat transfer coefficient. The specifications of corrugated Tube are: -

- Length = 650 mm
- Thickness = 0.5mm
- Corrugation depth =3mm
- Pitch = 3 mm
- Internal envelope diameter = 25mm
- Material = stainless steel type AISI 304

2.1.2 Heater

As we further go through the details of the experimental setup, we will come across the situation where we need to create the environment for hot fluid as the nanofluid which has to be tested needs to be heated up to check the heat transfer rate of the same. To heat up the fluid constantly a heater is used. Heater is a heating element which is made up of electrical resistance inside a tube, which can be placed directly inside water to be heated up. The heater is basically an electric resistor and works on the principle of Joule heating. When the heater is placed in water and switched on, the electric resistance works and due to which heat is generated and first by conduction inside the heater and then convection in the fluid the heat is transferred.

2.1.3 Thermostat

It is a temperature controller device which activates or deactivates the system according to the use of the system. This is a device that heats or cools according to the desired set point temperature which includes central heating, HVAC system, oven, building heating along with medical and scientific incubators.

2.1.4 Nanofluids

Nanofluid is a fluid which is an amalgamation of nanoparticle along with base fluid. The size variation can be found in the range of 1- 100nm. The selection and the concentration of nanoparticle is a combination of the enhancement of a specific type of property in the resulting fluid. The present work is carried on nanofluid which is to meet the behaviour of definite characteristics. The nanofluid preparation does not stop with the selection of the nanoparticle there is a great deal of importance to the base fluid also so as to check for which system we will be using it. There are many base fluids and all the base fluid is not suitable for all the operating condition. Therefore, it becomes very important so as to know the operating condition along with the environmental and the material selection, because many a time the material can even react with the base fluid. There is also a chance that the material reacts with the nanoparticle or the nanofluid as a whole.

The present work is based on the fact that addition of nanofluid can increase the of heat transfer. It can be understood by the fact that the particles which are below the size of 100nm have a higher surface area and due to which the particles can absorb and release more heat whenever a temperature difference is conditioned. It shows superiority from the conventional material on the sections of thermal, mechanical, optical, magnetic, and electrical properties.

2.2 Measuring Devices and Instruments

The system in which the experiment was conducted was a double pipe heat exchanger and along with-it corrugated pipe and nanofluid was used to study the behaviour of heat transfer in the newly modified system. As discussed before the system consists of a hot fluid and cold fluid where hot fluid losses its heat to the cold fluid due to temperature difference and in the process effectiveness of the system can be checked and compared with the system when such modification was not introduced. The experiment uses the following measuring devices which helps us to record the various changes that are taking place in the system. The devices are

1. Temperature sensor is used to measure the temperature at various points in the system
2. Manometer used to find the pressure
3. Rotameter is used to measure the flow rate of the working fluid.

3. ANALYSIS OF EXPERIMENTAL PROCEDURE

The work that has been carried out is based on certain theories and equations which help to make an understandable conclusion from the acquired data. It becomes of at most importance to check the values that we gathered from the experiment through these equations so as to check the trend it is following and understand the behaviour of the fluid as it flows through the system. There are different equations formulated by different scholars and scientists through many different experiments conducted on different factors of a flow system. The work that has to be taken will only concern the present work which will be written below along with explanation.

The most basic work is to know the density of different nanofluid as the nanoparticle was varied for different readings along with specific heat of nanofluid. These values can be found only when we have a few particular data's such as concentration (ø), density of water (ρ_w) and specific heat of water (c_p). The equations used below are experimentally calculated by Pak and Cho[1] along with Xuan and Roetzel[15].

$$\rho_{nf} = (1-\phi)\rho_w + \phi\rho_{np} \quad \text{...1}$$

$$c_{p,nf} = \frac{\phi\rho_{np}c_{p,np} + (1-\phi)\rho_w c_{p,w}}{\rho_{nf}} \quad \text{..............................2}$$

As we are using naoparticle which is a metal too so we know that there will be a rise in thermal conductivity because the thermal conductivity of metals is always higher than that of water at the same temperature and pressure. So, we also need to know the thermal conductivity of the nanofluid that we are preparing for the experiment. The equation is summarised from Maxwell model [16] which is allowed for low volume concentration and homogeneous liquid-solid suspensions with random dispersed, uniformly sized and non-interacting spherical particles.

Along with this we also need to find the viscosity of the new nanofluid whose equation is taken from Einstein's formula [17].

$$\frac{k_{nf}}{k_w} = \frac{k_{np} + 2k_w + 2\phi(k_{np} - k_w)}{k_{np} + 2k_w - \phi(k_{np} - k_w)} \quad \ldots\ldots 3$$

$$\mu_{nf} = \mu_w (1 + \eta\phi) \quad \ldots\ldots 4$$

As we know that the system in which we are working is a heat transfer system and a boundary difference of hot and cold fluid is created so we will have a cold junction as well as hot junction. Due to this cold and hot junction we will have two different heat transfer rate which will be denoted by cold heat transfer (Q_c) and hot heat transfer rate (Q_h). These two heat transfer rate is required to find out the average heat transfer rate (Q_{avg}) which will be used further for the calculation of overall heat transfer coefficient.

$$Q_c = \dot{m}_c c_{pc} (T_{c,out} - T_{c,in}) \quad \ldots\ldots 5$$

$$Q_h = \dot{m} c_{ph} (T_{h,in} - T_{h,out}) \quad \ldots\ldots 6$$

$$Q_{avg} = \frac{(Q_c + Q_h)}{2} \quad \ldots\ldots 7$$

The result from the above equation helps us to know about the heat transfer capacity of the fluid (hot or cold) and an average heat that has been transferred between hot and cold fluid due to their temperature difference along with mass flow rate.

Next we have to check for the convective heat transfer coefficient of the newly prepared nanofluid as due to this heat transfer coefficient, the heat transfer among the molecules will increase and resultant heat transfer rate can be known. Even if we calculate the heat transfer rate but we should have knowledge of the capacity increase of a base fluid due to the addition of nanofluid in it.

$$Q_{avg} = UA_i \Delta T_{LMTD} \quad \ldots\ldots 8$$

$$\Delta T_{LMTD} = \frac{(T_{h,in} - T_{c,out}) - (T_{h,out} - T_{c,in})}{\ln\left(\frac{T_{h,in} - T_{c,out}}{T_{h,out} - T_{c,in}}\right)} \quad \ldots\ldots 9$$

$$A_i = \pi d_i L \quad \ldots\ldots 10$$

Now with the help of the above calculation we know the overall heat transfer unit and this will provide us the required help in taking one step closer to find heat transfer coefficient of nanofluid. It is very important as with the help of heat transfer coefficient we will be able to know the experimental Nusselt number (Nu).

As the heat transfer coefficient cannot be found through the general equation, we need to find it through the equation where overall heat transfer coefficient is involved. The reason behind this is that the overall heat transfer coefficient is a experimentally calculated data and to find the heat transfer coefficient of nanofluid we need to check the effect of experimental value all of it.

$$\frac{1}{U}=\frac{1}{h_i}+\frac{A_i\ln(\frac{d_o}{d_i})}{2\pi kL}+\frac{A_i}{A_o h_o} \quad \text{.........................11}$$

$$\frac{1}{U}=\frac{1}{h_i}+B \quad \text{...12}$$

As we now know the heat transfer coefficient of the nanofluid we can calculate the Nu of the system at different mass flow rate or precisely at different Reynolds number.

$$Nu=\frac{h_i d_i}{k} \quad \text{..13}$$

$$\mathrm{Re}=\frac{\rho V d_i}{\mu} \quad \text{..14}$$

This concludes the result required for the experiment which will show the explanation we are looking for in the direction of increase in heat transfer effect of the system. The use of the data from the above equations will tell us a relation about Nusselt number as well as Reynolds number which will be beneficial to understand the heat transfer behaviour of the fluid that was allowed to flow through the controlled environment that was created.

4. EXPERIMENTAL RESULTS AND DISCUSSION

In this section we discuss the results obtained from the experiment conducted on corrugated double pipe heat exchanger with nanofluid. The experiment was conducted in a double pipe heat exchanger where three different concentrations of nanoparticles were mixed with base fluid to make nanofluid. Apart from the nano fluid it was also checked for the water whose effectiveness is compared with different nanofluid of different concentrations. It was worked for fixed Reynolds number where other parameter was changed accordingly.

The experiments are carried under different cases to evaluate the performance of the heat exchanger with corrugate pipe and different concentration of nanofluids. The total six cases have been studied.

Case 1: Variation of heat transfer rate for hot and cold fluid at equal time interval for base fluid

Case 2: Variation of heat transfer rate for hot and cold fluid at equal time interval for 0.025 % CuO/Water Nanofluid

Case 3: Variation of heat transfer rate for hot and cold fluid at equal time interval for 0.05 % CuO/Water Nanofluid

Case 4: Variation of heat transfer rate for hot and cold fluid at equal time interval for 0.075 % CuO/Water Nanofluid

Case 5: Variation of Nusselt number Vs Reynold Number

Case 6: Comparison of ratio of Nu of Nanofluid and water vs Reynolds number

4.1 Case 1: Variation of heat transfer rate for hot and cold fluid at equal time interval for base fluid

Figure 2 show the variation of heat transfer rate of hot and cold fluid with time for distilled water. The figure shows that almost a controlled behaviour which can be justified with the fact that there are no suspended particles due to which it shows almost a steady heat flow rate. From the graph it can be seen that the increase as well as decrease of the heat transfer rate of the hot and cold fluid on behalf of the mass flow rate with equal time interval. It can be noted that as the time increases the heat transfer capacity of the hot fluid decreases whereas heat transfer capacity of the cold fluid increases. It can be said that due to mass flow rate of the later was varied, so the heat transfer capacity of the fluid is harmed whereas the heat transfer capacity of the cold fluid increases.

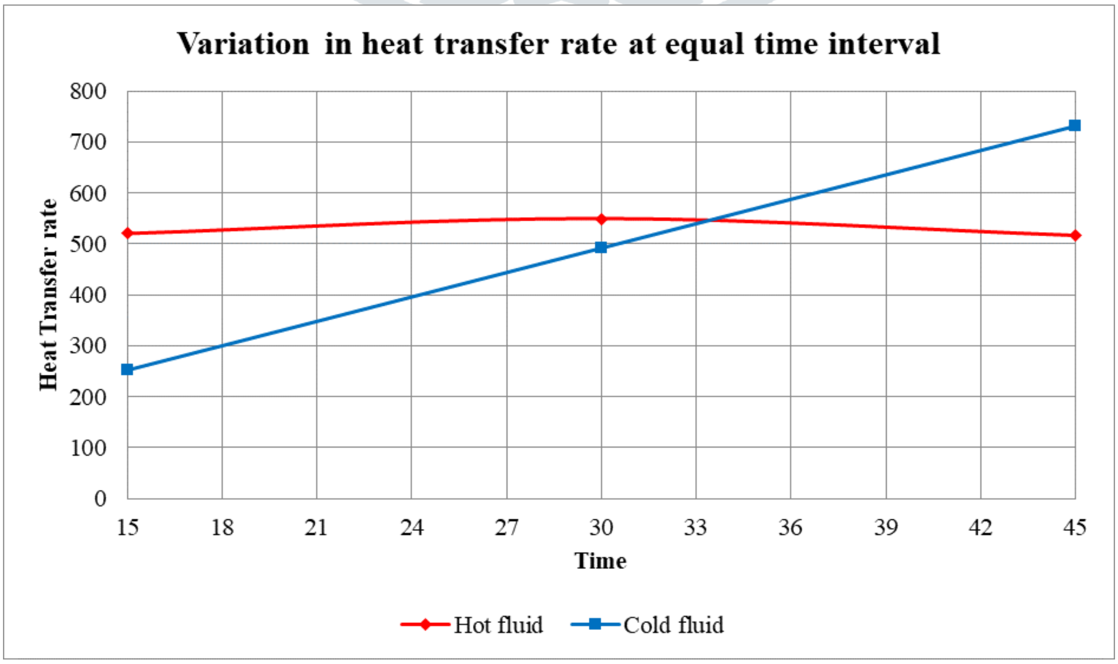

Figure 2: *Variation in heat transfer rate at equal time interval for base fluid*

Since it was distilled water so a flat line can be expected as there is not much thermal conductivity as compared to the nanoparticle which shows a high thermal conductivity and is useful in the heat exchange process.

4.2 Case 2: Variation of heat transfer rate for hot and cold fluid at equal time interval for 0.025 % CuO/Water Nanofluid

Compared to the above graph quite a little change is noted in this graph. It is a graph of nanofluid with concentration of .025% which shows that due to the addition of nanoparticle in the base fluid there is an increase in the heat transfer to the cold fluid also along with it we can see from the graph that though the same Reynolds number is maintained for the system but still, the heat rejected from the hot fluid increases which shows that it is definitely better than distilled water

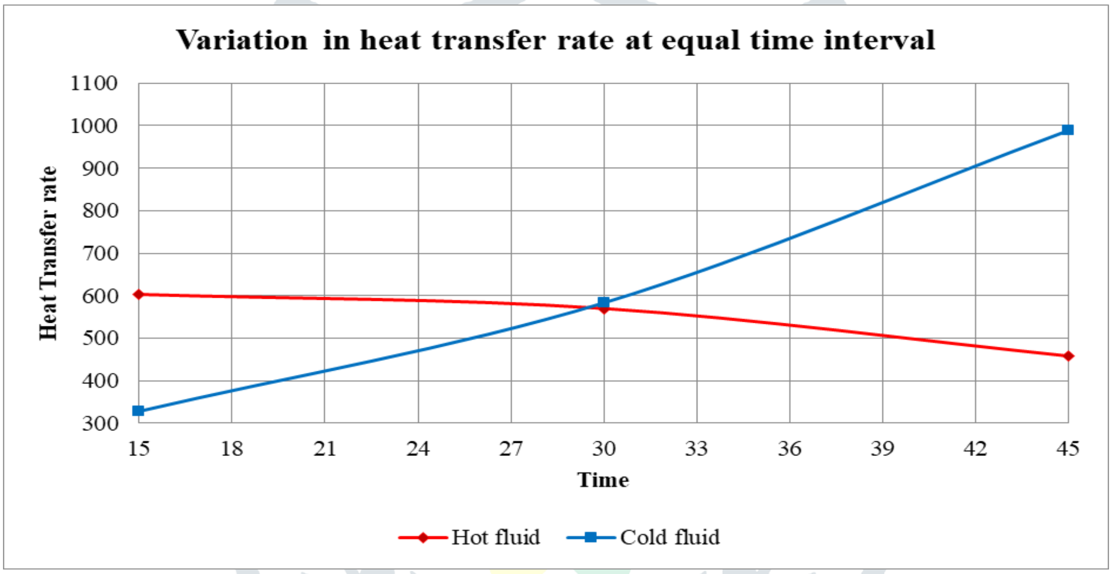

Figure 1: *Variation in heat transfer rate at equal time interval for 0.025 % CuO/Water Nanofluid*

4.3 Case 3: Variation of heat transfer rate for hot and cold fluid at equal time interval for 0.05 % CuO/Water Nanofluid

The graph clearly shows that the concentration of nanoparticle surely affects the heat transfer rate which is depicted in the graph. As we discussed earlier that the thermal conductivity of nanoparticle is more than the distilled water. so, a notable change has to be recorded, this is visible from the following data.

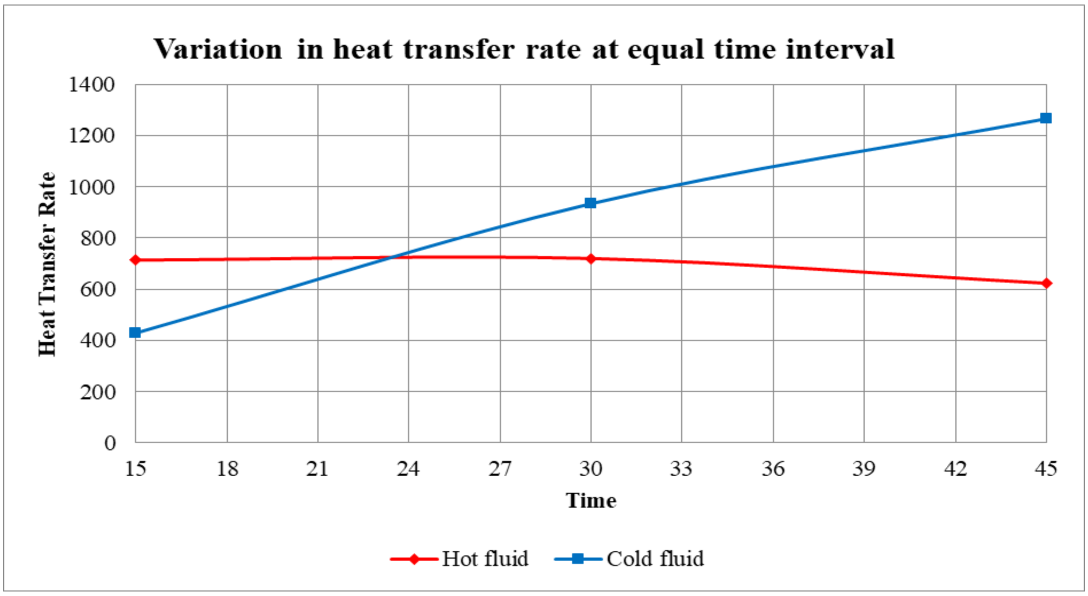

Figure 2: *Variation in heat transfer rate at equal time interval for 0.05 % CuO/Water Nanofluid*

Other than this it can also be said that the arrangement contains a corrugated tube in the inner section due to which turbulence is created and this turbulence increases the heat carrying capacity of the fluid. Though the changes are noted in comparison to the distilled water we still can see the difference between the heat transfer capacity of the nanofluid and distilled water. The decrease in heat transfer rate of hot fluid is due to the fact that the mass flow rate of the hot fluid is increased in definite interval of 15 minutes due to which a steady graph was possible. On the other hand, the cold fluid's mass flow rate was maintained at a single constant value so that we can study the behaviour of the inner pipe fluid.

4.4 Case 4: Variation of heat transfer rate for hot and cold fluid at equal time interval for 0.075 % CuO/Water Nanofluid

The final graph is plotted for nanofluid with concentration of .075 % v/v which also has the highest concentration used in the experiment. Now to and analyse it better we can understand a few theories such as the fact that it is to be expected that a higher concentration of a particular type of nanofluid should yield in a better heat exchange process since it contains nanoparticle which is a suitable option to the heat transfer effect. The trend may not be the same as the behaviour of nanoparticle is unpredictable, the vary movement nanoparticle is added to the base fluid with the help of sonicator it starts getting stable and settles down, so the basic behaviour cannot be predicted on the theories of the given data.

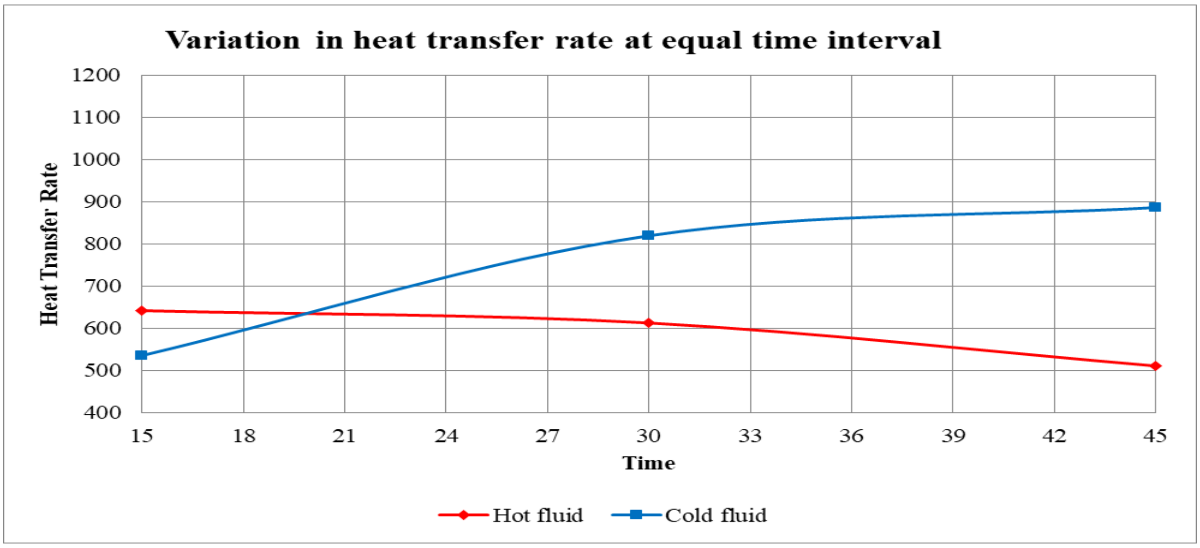

Figure 3: *Variation in heat transfer rate at equal time interval for 0.075 % CuO/Water Nanofluid*

This is the reason to conduct a physical experimentation rather than a computer-based analysis. A computer-based analysis is unable to show the cons of using a nanoparticle with base fluid as it will work on the basis of the data that is supplied to the system. Due to the same reason it becomes impossible to predict the behaviour of nanoparticle in the nanofluid, when we carry on the work by computer analysis.

Case 5: Variation of Nusselt number Vs Reynold Number

The above graph is a plot of the distilled water along with different nanofluid concentration of the 0.025 %, 0.050%, and 0.075%. The graph clearly shows that nanoparticle concentration of 0.075% in base fluid is definitely the best choice as it gave the best result when plotted along with other nanofluid and base fluid for the comparison. We can also see that the graph does not follow a start and text book path for the same reason explain that it is nearly impossible to predict the behaviour of the nanofluid. This brings us to know that when we disperse nanoparticle in the base fluid it can show some uncontrollable characteristics which will harm the heat transfer behaviour of the system.

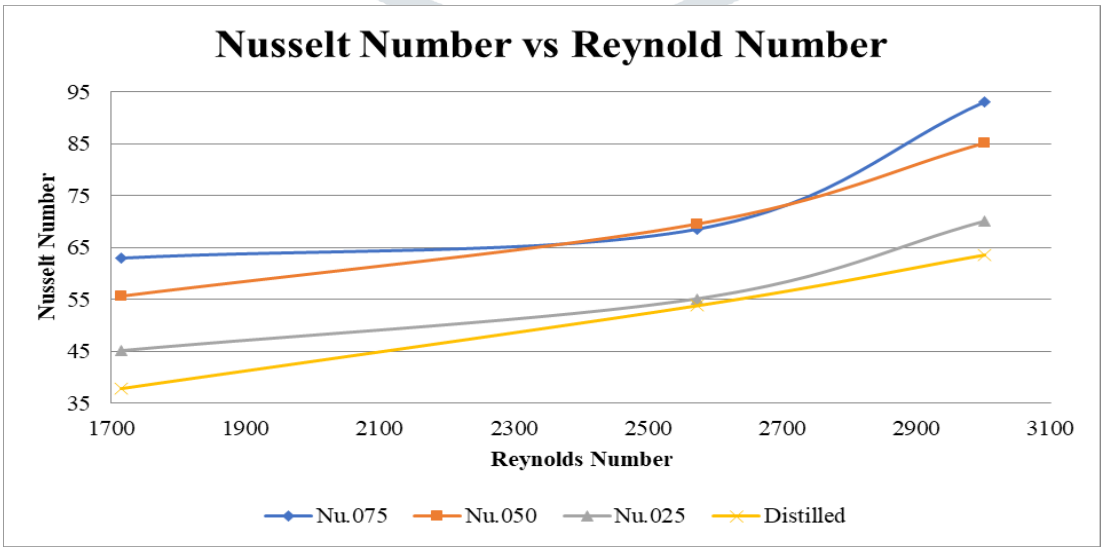

Figure 4: *Nusselt number Vs Reynold Number*

With this note we can write that with the increase in Reynolds number, we see an increase in Nusselt number too. This is true for the fluid used for the experiment such as base fluid along with nanofluid of different concentration.

Case 6: Comparison of ratio of Nu of Nanofluid and water vs Reynolds number

In the previous graph we have seen that all the fluid whether it be a base fluid or nanofluid with different concentration shows an increase in Nusselt number whenever Reynolds number of the system increases. This conclusion is important from the experiment's validation also, as it show the behaviour it is required to be shown for the experiment to carry on. The above data lacks a very important point on which the experiment was started, that the amount of increment to be noted when a nanofluid with different concentration is used.

This bring us to the present graph which lets us see the comparison of the Nusselt number of the base fluid with that of the nanofluid with different concentration and it clearly show us that all the concentration used for the experiment shows an increment in Nusselt number.

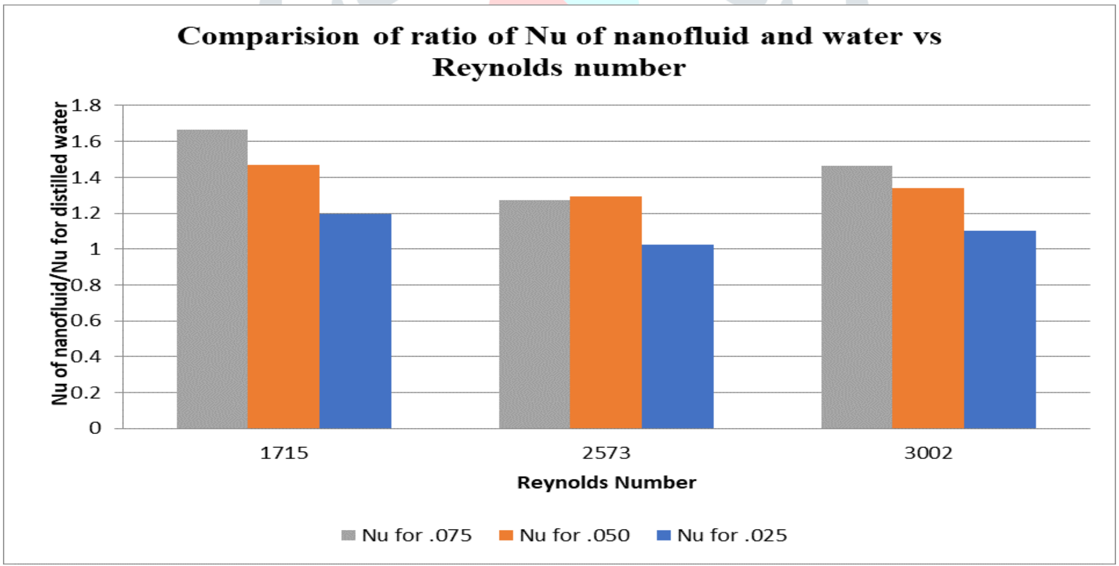

Figure 5: *Comparison of ratio of Nu of Nanofluid and water vs Reynolds number*

Along with this there are some interesting facts that is to be noted while over viewing the graph, is the behaviour of the nanofluid as the Reynolds number is increased we can clearly see that when increase the Reynolds number we can record a decrease in the performance of the nanofluid based on the fact that the nanoparticles are unable to transfer the heat accumulated by them and it travels out of the system with transferring heat to the system.

CONCLUSIONS

The gathered data provides us much different information regarding the experiment that was conducted. The data's that were concluded from the experimental result were formulated to know about the heat transfer effect that was felt by the cold fluid along with the heat transfer from the hot fluid.

- The experiment reveals that the heat transfer rate of the hot fluid decreases with passage of time and increase in mass flow rate and the heat transfer rate of the cold fluid increases with passage of time.
- The temperature drop of the hot fluid decrease from 5-6°C to 1-2°C which is concluded by the increase in mass flow rate of the system where as cold fluid shows a complete different behavior, initially the temperature range happens to be 2-3°C but with time and variation of mass flow rate of hot fluid increases the temperature range to 5-8° C.
- The most important part of the experiment was to check the Nusselt number of the nanofluids and the base fluid. It showed that highest Nusselt number was found for concentration of 0.075 % CuO–water nanofluid at a Reynolds number of 3000 was 93, which shows that the higher concentration of the nanoparticle in this range is effective to increase the convection to conduction heat transfer through the boundary of the system.

5 The experiment also compared the Nusselt number of base fluid with that of different nanofluid concentration which show that the higher nanofluid concentration is better for heat exchange process but along with that it also showed that as the Reynolds number increases the ratio of Nusselt number between base fluid and nanofluid decreases, which marks that with increase in Reynolds number the system is not effective or is better suited for low flow rate.

References

[1] Choi, S. U. S. (1995). Enhancing thermal conductivity of fluids with nanoparticles. Proceedings of the 1995 ASME International Mechanical Engineering Congress and Exposition, 66, 99–105.

[2] Khairul, M. A., Alim, M. A., Mahbubul, I. M., Saidur, R., Hepbasli, A., & Hossain, A. (2014). Heat transfer performance and exergy analyses of a corrugated plate heat exchanger using metal oxide nanofluids. International Communications in Heat and Mass Transfer, 50, 8–14.

[3] Bhuiya, M. M. K., Sayem, a. S. M., Islam, M., Chowdhury, M. S. U., & Shahabuddin, M. (2014). Performance assessment in a heat exchanger tube fitted with double counter twisted tape inserts. International Communications in Heat and Mass Transfer, 50, 25–33.

[4] Sadighi Dizaji, H., Jafarmadar, S., & Mobadersani, F. (2015). Experimental studies on heat transfer and pressure drop characteristics for new arrangements of corrugated tubes in a double pipe heat exchanger. International Journal of Thermal Sciences, 96, 211–220.

[5] Zhang, C., Wang, D., Ren, K., Han, Y., Zhu, Y., & Peng, X. (2016). A comparative review of self-rotating and stationary twisted tape inserts in heat exchanger. Renewable and Sustainable Energy Reviews, 53, 433–449.

[6] Kareem, Z. S., Mohd Jaafar, M. N., Lazim, T. M., Abdullah, S., & Abdulwahid, A. F. (2015). Passive heat transfer enhancement review in corrugation. Experimental Thermal and Fluid Science, 68, 22–38.

[7] Azmi, W. H., Sharma, K. V., Sarma, P. K., Mamat, R., & Anuar, S. (2014). Comparison of convective heat transfer coefficient and friction factor of TiO2 nanofluid flow in a tube with twisted tape inserts. International Journal of Thermal Sciences, 81(1), 84–93.

[8] Bhuiya, M. M. K., Chowdhury, M. S. U., Saha, M., & Islam, M. T. (2013). Heat transfer and friction factor characteristics in turbulent flow through a tube fitted with perforated twisted tape inserts. International Communications in Heat and Mass Transfer, 46, 49–57.

[9] Tiwari, A. K., Ghosh, P., & Sarkar, J. (2015). Particle concentration levels of various nanofluids in plate heat exchanger for best performance. International Journal of Heat and Mass Transfer, 89, 1110–1118.

[10] Tiwari, A. K., Ghosh, P., & Sarkar, J. (2013). Performance comparison of the plate heat exchanger using different nanofluids. Experimental Thermal and Fluid Science, 49, 141–151.

[11] Bhuiya, M. M. K., Chowdhury, M. S. U., Islam, M., Ahamed, J. U., Khan, M. J. H., Sarker, M. R. I., & Saha, M. (2012). Heat transfer performance evaluation for turbulent flow through a tube with twisted wire brush inserts. International Communications in Heat and Mass Transfer, 39(10), 1505–1512.

[12] Khoshvaght-aliabadi, M., & Eskandari, M. (2015). Influence of twist length variations on thermal – hydraulic specifications of twisted-tape inserts in presence of Cu – water nanofluid. Experimental Thermal and Fluid Science, 61, 230–240.

[13] Wongcharee, K., & Eiamsa-ard, S. (2012). Heat transfer enhancement by using CuO/water nanofluid in corrugated tube equipped with twisted tape. International Communications in Heat and Mass Transfer, 39(2), 251–257.