COMPARATIVE ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER BY DIFFERENT NANOFLUID

Abhishek Gupta[1], Ranu Rajoria[2]

[1](Research scholar, Astral Institute of Technology and Research, Indore)
[2](Assistant Professor, Astral Institute of Technology and Research, Indore)

Abstract—The heat exchanger are devices that facilitate the exchanger of hear between two fluids that are at different temperature. Generally heat transfer fluid are used is water, but now a days to improve the efficiency of heat exchanger the heat transfer fluid is converted into nanofluid which is having base fluid water. Nano fluid contain nano sized particle (1-100nm). Nano fluid are the fluid which are using for the transfer of heat to improve the performance of heat exchanger. Such type of fluid recently introduces which are superior to convention fluid. In this paper the behavior of cu- water nano fluid and its effect on the performance of single pass counter flow shell and tube type heat exchanger has been observed analytically and also the comparison is made between the cu-water Nano fluid and conventional base fluid that is water. We have done the analytical analysis for the performance of heat exchanger at different percentage of copper nanoparticle and we get the overall heat transfer coefficient is increases with increase in particle of copper in nanofluid. It also increase the performance of heat exchanger and effectiveness.

Keywords— *Nanoparticle, Heat Exchanger, Effectiveness, Cu-Water, Graphite Water*

1. INTRODUCTION

1.1 Heat Exchanger

A heat exchanger is a device used to transfer heat from one to another form, in many applications. In a heat exchanger, heat is transferred from the hot fluid to the cold fluid with the help of wall keeping them from mingling with each other. The simplest type heat exchanger of shell and tube type has wide applications and mostly used in industry process heating and cooling, power production, chemical processing, food industries, petroleum refineries etc. To transfer heat at the maximum rate in a given application is the important role of heat exchanger. The augmentation in heating and cooling rate in process industries promises to energy consumption, reduction in process time, thermal rating and enhances the life of equipment but also affect some processes qualitatively due to enhancement in heat transfer. The main purpose of a heat exchanger is increasing heat transfer between two fluids which reduces the required energy and helps to create a more effective process for both production and economy.
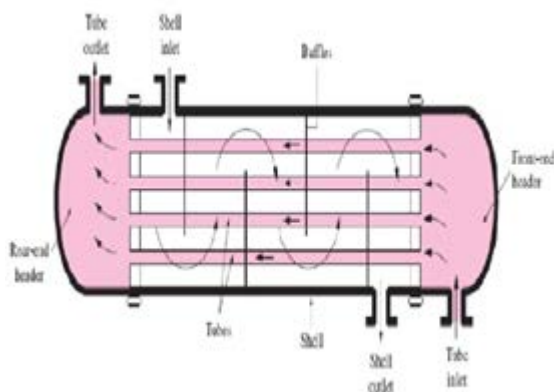

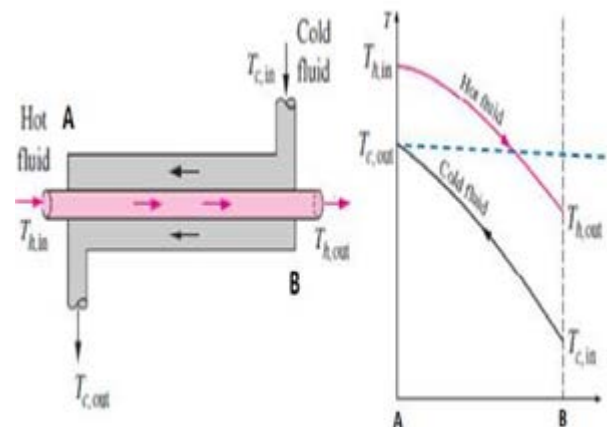Fig -1.1: Shell and Tube heat exchanger

Fig -1.2 Counter flow mechanism

1.2 Nanofluids

A nanofluid is a fluid which contain nanosized particle. A nanofluid is mixture of base fluid and nano particle of different metal. The nanoparticles used in nanofluid s are typically made of metals, oxide carbides etc. The suspension of stable solid nanoparticles, of the size of 10-9 m, into the base fluid or conventional fluid (water) is called 'Nanofluid'. The nanofluid shows the fascinating behaviour, over conventional fluids.

1.3 Cu-Water Nanofluid

A new technique and emerging heat transfer cooling fluid called 'nanofluids'. A Cu-Water nanofluid contain particle of copper nanosized (10-9 m) in to the water or base fluid.
A Cu-Water nanofluid, which contains the copper nanosized particles which has higher thermal conductivity, higher thermal conductivity, enhance effectiveness of heat exchanger.

2. PROPOSED METHODOLOGY

The numbers of step we have follow to calculate the performance of heat exchanger:

- Thermo-physical properties of Cu-Water nanofluid
- Flow properties of Cu-Water nanofluid
- Calculation of convective heat transfer coefficient
- Calculation of overall heat transfer coefficient
- Calculation of Number of Transfer units (NTUs)
- Calculation of effectiveness and rate of heat transfer
- Calculation of outlet temperature of both fluids and LMTD
- Calculation of pressure drop and pumping power for Cu-Water nanofluid.

The calculation of all parameter based on the following formulas-

Thermo-physical properties of Cu-Water nanofluid: The thermo-physical properties of Cu-Water nanofluid differ from either of the parent material and these properties. According to change in temperature the physical property also change.

I. Thermal conductivity:
The thermal conductivity of Cu-Water nanofluid can be calculated as

$$K_{nf} = k_f [k_p + (SH-1)k_f - (SH-1)c(k_f - k_p)] / [k_p + (SH-1) k_f + c (k_f - k_p)]$$

Where, SH = solid particle shape factor and it is given by:
$$SH = 3 / \Psi$$
Where, Ψ is the sphericity and its value is unity for spherical particles.

II. Density of Nanofluid
In this paper, the density of Cu-Water nanofluid is been calculated by:
$$\rho_{nf} = c \rho_p + (1-c) \rho_f$$

III. Specific Heat of Nanofluid
The specific heat is the amount of heat which is necessary to rise the unit temperature of unit mass of nanofluid and it is calculated as
$$C_{pnf} = cC_{pp} + (1-c)C_{pf}$$

IV. Viscosity of Nanofluid
In this study, the viscosity of nanofluid is calculated as:
$$\mu_{nf} = \mu_f (1+2.5c)$$

Flow properties of Cu-Water nanofluid:
The following parameters which are discussed below give the flow properties of Cu-Water nanofluid.

I. Mass flow rate of nanofluid:
The mass flow rate of nanofluid is calculated by using the following relation as:
$$M_{nf} = \rho_{nf} * \upsilon_{nf}$$

II. Thermal heat capacity of nanofluid
The thermal heat capacity of nanofluid is calculated as:
$$C_{nf} = m_{nf} * c_{pnf}$$

V. Prandtl number for nanofluid
The Prandtl number for Cu-Water nanofluid is calculated as:
$$Pr = \mu_{nf} * c_{pnf} / k_{nf}$$

VI. Reynolds number for nanofluid
The Reynolds number for nanofluid is calculated as
$$Re = [\rho v x / \mu]_{nf}$$

VII. Nusselt number for nanofluid
The Nusselt number for nanofluid is been calculated as:
$$N_{unf} = [h*d/k]_{nf}$$
The Nusselt number can also be written as the function of Reynolds number and Prandtl number as suggested by:
$N_{unf} = 0.023 Re^{0.8} Pr^n$
Where, n = 0.4, for heating   n = 0.3, for cooling

Performance parameters for heat exchanger:
The parameters which are used for the computation of performance of the heat exchanger are discussed below as:

I. Overall heat transfer coefficient
The overall heat transfer coefficient is been calculated as:
$$U_o = [1/\{r_i/r_o*h_{nf}\} + \{ln(r_0/r_i)r_o\} + \{1/h_o\}]$$

II. Number of Transfer Units (NTUs)
The NTUs for the heat exchanger is calculated as:
$$NTU = UA/C_{min}$$

III. Effectiveness of heat exchanger:
The effectiveness of heat exchanger is calculated using the following relations as:
$$E = Q_{actual}/Q_{maximum}$$
Where,
$$Q_{max} = C_{min} (T_{hi} - T_{ci})$$
For counter flow heat exchanger the effectiveness is also given by:
$$E_{cf} = [1-ex\{-NTU(1-cr)\}] / [1-cr \exp\{-NTU(1-cr)\}]$$
Where, heat capacity ratio
$$Cr = C_{min} / C_{max}$$
Outlet temperature of both fluids: The outlet temperature of both hot and cold fluids is calculated by using energy equation as:
$$Q = m_c * c_{pc} [T_{co} - T_{ci}]$$
$$Q = m_h * c_{ph} [T_{hi} - T_{ho}]$$

IV. LMTD for heat exchanger
The LMTD of heat exchanger is calculated as:
$$Q = U*A*\theta_m$$

V. Head loss due to friction:
The loss of head due to friction between the particles and tube wall is calculated by using the relation as:
$$H_f = 4fLV^2/2gd$$
Where $f = .0791/ Re^{(1/4)}$
For turbulent flow

VI. Pressure drop and pumping power for nanofluid

The pressure drop and pumping power for Cu-Water nanofluid is calculated by using the relations:
Pressure drop,

$$\triangle P/\rho g = hf = 4fLV^2/2gd$$

Pumping power,

$$\triangle Pp = \rho*g*Q*hf$$

3. SIMULATION AND RESULTS

The following results which are obtained by using water and Cu-Water nanofluid as a coolant, are discussed below.
From the chart-1, it is seen that the thermal conductivity of Cu-Water nanofluid is higher than pure water. The conductivity of Cu-Water nanofluid increases with increase in concentration of copper nanoparticles into the base fluid i.e. water. This is so because of the conductivity of copper nanoparticles is higher than pure water.
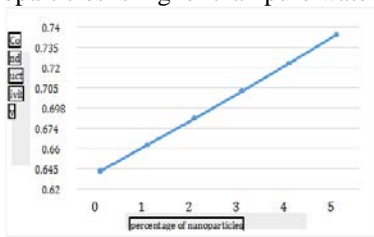

Chart -1: Conductivity of Cu-Water nanofluid at the different percent of nanoparticle

The chart-2 shows the variation in Reynolds number with the different percentage of copper nanoparticles. From this, we can understand that the Reynolds number for Cu-Water nanofluid is higher than pure water and it increases with the volume fraction of nanoparticles into the base fluid.
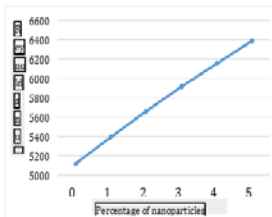

Chart -2: Reynolds number for Cu-Water nanofluid at the different percentage of nanoparticles

For Cu-Water nanofluid, the percentage increase in density is higher than the percentage increase in viscosity, at a particular concentration of the nanoparticles, which leads the higher Reynolds number of Cu-Water nanofluid. Here, the Reynolds number is higher than 2000 which indicates that the flow is turbulent.

The convective heat transfer coefficient between the Cu-Water nanofluid and tube wall is shown in chart-3. From this chart, it can be concluded that the convective heat transfer coefficient increases with the suspension of copper nanoparticles into the base fluid. This convective heat transfer coefficient further increases with the increase in the concentration of the copper nanoparticles into water. The increase in convective heat transfer coefficient, at 5% volume fraction of copper nanoparticles, is approximately 33% as compared to pure water. The convective heat transfer coefficient plays an important role for the enhancement in heat transfer rate.
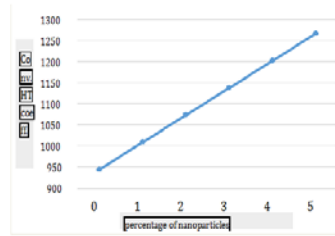

Chart-3: Convective heat transfer coefficient between Cu-Water nanofluid and tube wall, at the different percent of nanoparticles

The below chart-4 shows that the overall heat transfer coefficient of heat exchanger increases with the volume fraction or concentration of copper nanoparticles. The increase in overall heat transfer coefficient, at 5% volume fraction of copper nanoparticles, is approximately 2.5% as compared to pure water alone. This increase in overall heat transfer coefficient is because of the increase in thermal conductivity and convective heat transfer coefficient of nanofluid.
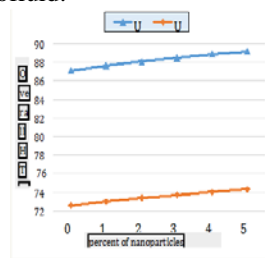

Chart-4: Overall heat transfer coefficient of heat exchanger with Cu-Water nanofluid, at the different concentration of nanoparticles

From chart-5, it is clear that the effectiveness of heat exchanger increases by suspending the copper nanoparticles into pure water. This effectiveness of heat exchanger further increases with the increase in volume fraction or concentration of copper nanoparticles into the base fluid.

The percentage increase in effectiveness, at 5% concentration of copper nanoparticles, is approximately 7.5% as compared the effectiveness with pure water alone. The increase in effectiveness is always desirable for a heat exchanger and Cu-Water nanofluid shows the attractive characteristics.
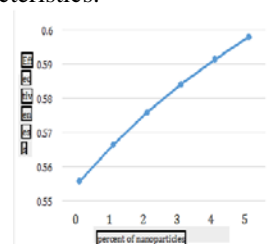

Chart-5: Effectiveness of heat exchanger at different concentration of copper nanoparticles

4. CONCLUSION AND FUTURE SCOPE

From this proposed work, we can conclude that the thermo-physical properties of the nanofluids differ from the parent materials. The conductivity of the nanofluids, nanoparticles of higher thermal conductivity, is higher as

compared with the conventional fluids when used as a coolant. The convective heat transfer coefficient is also improved at nanofluid side. This increase in thermal conductivity and convective heat transfer coefficient would give the higher overall heat transfer coefficient and which in turn increases the rate of heat transfer and effectiveness of the heat exchanger. At the same time, the nanofluids, having the higher density as compared to the conventional fluids, required higher pumping power. The pumping power of nanofluids increases with the volume fraction or concentration of nanoparticles which limits the large concentration of nanoparticles into the conventional fluid.

The more research is required for better understanding the behavior of nanofluids and its effect on operating parameters. An important area for future research is that the thermal conductivity of nanoparticles or nanofluids can be a function of geometrical parameters such as particle shape, particles size, particle agglomeration etc. Therefore, future researches should be focused on finding out the critical parameters which affect the thermal conductivity of nanofluids. Another challenging issue is to obtain the desirable nanoparticle product according to requirement. The recent development in the technology of production of nanosized particles will be helpful for the nanofluids research.

We have to also concern about public safety both in use and in production. Nanofluids engineers are required to introduce green designs by choosing the eco-friendly nanoparticles production techniques with nontoxic and biodegradable nanoparticles. Another and most challenging direction for future applied research is to produce the large volume of stable nanoparticles at low cost.

REFERENCES

[1] Frank Kreith and Mark S. Bohn, Principle of Heat Transfer, sixth edition, Learning India Pvt. Ltd.,2009, pp 485-538.

[2] Ramiar A, Ranjbar A, Hosseinizadeh S., Effect of Axial Conduction and Variable Properties on Two Dimensional Conjugate Heat Transfer of Al2O3-EG/Water Mixture Nanofluid in Micro channel, Journal of Applied Fluid Mechanics, 2012, pp 79-87.

[3] Tarrad Ali Hussain, Mohammad Ali Ghazi, A Mathematical Model for Thermo-Hydraulic Design of Shell and Tube Heat Exchanger Using Step By Step Technique, Journal of Engineering and Development, Volume 10, No.4,December 2006, pp11-35

[4] J. Lee and I. Mudawar, Assessment of the Effectiveness of Nanofluids for Single-Phase and Two-Phase Heat Transfer in Micro-Channels, International Journal of Heat and Mass Transfer, Vol. 50, No. 3-4, 2007, pp. 452-463.

[5] Heydari Ali, Shateri Mostafa, Performance Investigation of Baffled Shell and Tube Heat Exchanger Using Different Nanofluids, 16th conference on fluid dynamics, Razi University, Kermanshah, Iran, November, 2015, 1719

[6] Selvam C., Balaji T., Mohan Lal D., Harish Sivasankaran, Convective Heat Transfer Coefficient and Pressure Drop of Water-Ethylene Glycol Mixture with Graphene Nano platelets, Article in Experimental Thermal and Fluid Science, August 2016.

[7] Y. Xuan, W. Roetzel, Conceptions for Heat Transfer Correlation of Nano fluids, International Journal of Heat and Mass Transfer, 2000, pp 3701-3707.