Improving the Heat Exchanger's Overall Heat Transfer Co-efficient with Nanofluids

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Abstract - *An assortment of mechanical procedures involve the exchange of warmth vitality. The upgrade of warming or cooling in a modern procedure may make a sparing in vitality, decrease process time, raise warm evaluating and stretch the life of hardware. There are a few techniques to improve the warmth move productivity. Warmth exchangers are gadgets that encourage heat move between two liquids while shielding them from blending. Warmth move in a warmth exchanger normally includes convection in every liquid and conduction through the divider isolating the two liquids. While examining heat move rate, it is advantageous to work with by and large warmth move coefficient 'U' that represents the commitment of every one of these consequences for heat move. One of the techniques which show evident outcomes is utilization of Nano-liquids instead of the ordinary warmth move liquids (HTFs).*

Key Words: **Assortment, Vitality, Convection, Conduction, Evident, Utilization**

1. INTRODUCTION

To improve the warmth transport properties of liquids, gigantic exercises are being completed. It is notable that numerous strong metallic and non-metallic materials have a lot higher warm conductivities than typical HTFs. Along these lines, it is a creative thought, attempting to upgrade the warm conductivity by including strong particles into HTFs. In any case, huge strong particles cause irksome issues, for example, scraped spot of the surface, obstructing the miniaturized scale channels, dissolving the pipeline. The circumstance became productive when fabricating nano scale particles was raised and executed effectively.

Here are 5 proven industry practices to boost heat exchanger performance and maintain process efficiency:

1. Online and Offline Cleaning

2. Maintaining Heat Exchanger

3. Periodic Cleaning

4. Cleaning the PHE Manually

5. Minimizing the Fouling Factor

6. Analyzing and Addressing Issues in Heat Exchanger Efficiency [1].

1.1 Working concept of heat exchangers

- Heat exchangers are devices that facilitate heat transfer between two fluids while keeping them from mixing.
- Heat transfer in a heat exchanger usually involves convection in each fluid and conduction through the wall separating the two fluids.
- While analyzing heat transfer rate, it is convenient to work with overall heat transfer coefficient U that accounts for the contribution of all these effects on heat transfer [3].

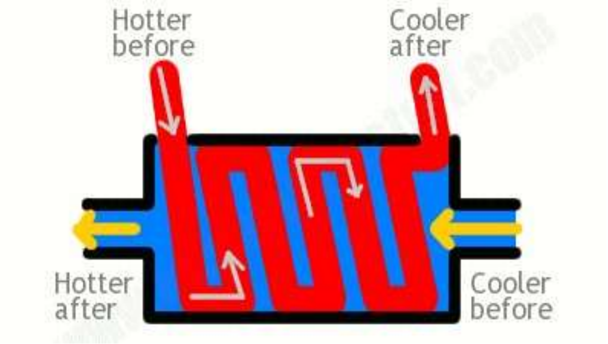

Fig -1: Working of a heat exchanger

1.2 Double Pipe Heat Exchanger

- It is the simplest type of heat exchanger consisting of two concentric pipes of different diameters.
- One fluid in a double-pipe heat exchanger flows through the smaller pipe while the other fluid flows through the annular space between the two pipes.
- Two types of flow arrangement are possible in a double-pipe heat exchanger:

    1. Parallel flow
    2. Counter flow

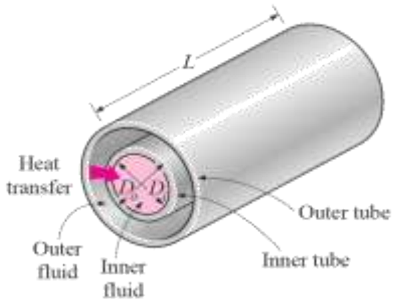

Fig -2: Double pipe heat exchanger

1.3 Flow Arrangements

- In parallel flow, both the hot and cold fluids enter the heat exchanger at the same end and move in the same direction.

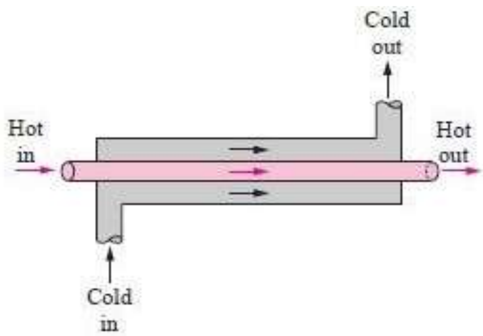

Fig -3: Parallel flow

- In counter flow, on the other hand, the hot and cold fluids enter the heat exchanger at opposite ends and flow in opposite directions.

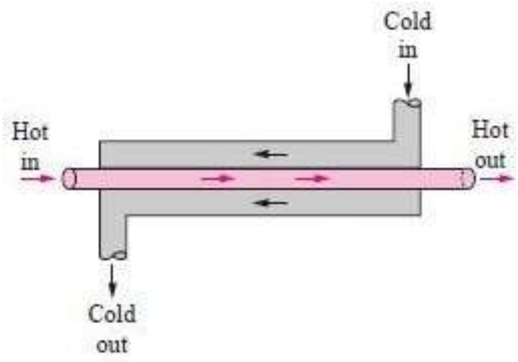

Fig -4: Counter flow

1.4 Overall Heat Transfer Coefficient

- A heat exchanger typically involves two flowing fluids separated by a solid wall. Therefore, there are two convection and one conduction resistances.

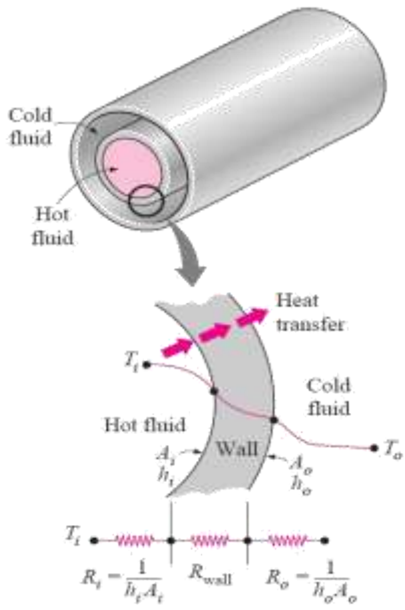

Fig -5: Double pipe heat exchanger

$$R_{Total} = R_i + R_{wall} + R_o = \frac{1}{h_i A_i} + \frac{\ln (D_o/D_i)}{2\pi k L} + \frac{1}{h_o A_o}$$

The overall heat transfer coefficient is obtained from

$$\frac{1}{UA_s} = R = \frac{1}{h_i A_i} + R_{wall} + \frac{1}{h_o A_o}$$

2. NANOFLUIDS

- Nanofluid is a fluid containing nanometer-sized particles, called nanoparticles.
- These fluids are engineered colloidal suspensions of nanoparticles in a base fluid.
- The nanoparticles used in nanofluids are typically made of metals, oxides, carbides and carbon nanotubes.
- Common base fluids include water, ethylene glycol and oil.

2.1 Preparation of Nanofluids

- Dispersing the nanoparticles uniformly and suspending them stably in the host liquid is critical in producing high-quality nanofluids.
- The key in producing extremely stable nanofluids is to disperse mono sized nanoparticles before they agglomerate.
- Out of the various processes of making nano-fluids, the significant ones are:

1. One step method
2. Two step method
3. Continuous flow method

2.2 Preparation of Nanofluids using Two step method

- In two-step method, nanoparticles are first produced as a dry powder.
- This step is followed by powder dispersion in the liquid.
- However, these nanofluids aren't stable, although stability can be enhanced by controlling pH and adding surfactant.

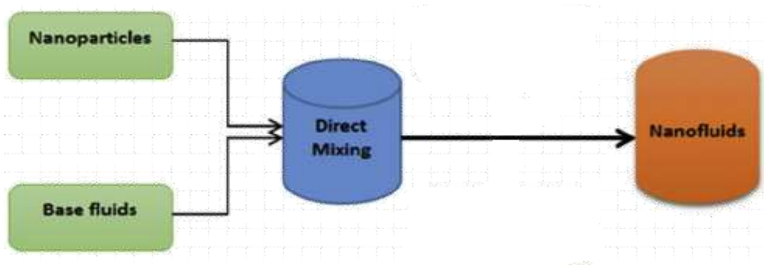

Fig -6: Preparation of Nanofluids

2.3 Advantages of Nano fluids

Compared to conventional solid-liquid suspensions for heat transfer intensifications, nanofluids having properly dispersed nanoparticles possess the following advantages:

- High specific surface area and therefore more heat transfer surface between particles and fluids.
- High dispersion stability with predominant Brownian motion of particles.
- Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification [2].

3. Experimental Setup

The experimental arrangement consists of the following components:

- Heat exchanger test rig • Nanofluid tank
- Radiator • Pump

Fig -7: Experimental setup

3.1 Preparation of CuO Water Using Nanofluids

- The nanofluid is prepared using the two-step method and the step by step process is as follows:
- Take the 2ltrs of water in a container and add 5%vol glycerin to it.
- Add the required quantity of CuO nanoparticles based on the volume percentage of the particles in the fluid to be made.
- Stir the solution vigorously for 20-30 minutes.
- If the volumetric concentration of the particles in the fluid is to be increased, additional quantity of the nanoparticles must be calculated and added in the existing mixture.
- For this particular experiment, the volumetric concentration of the CuO particles in the fluid are in the stages of 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%.
- The quantity of CuO to be added in 2ltrs of water as per the percentages is mentioned in the table below.

Volumetric concentration (%)	Weight of particles (gms)
0.5	78.90
1	157.75
1.5	236.60
2	315.50
2.5	394.35
3	473.25
3.5	552.10

Table -1: Volumetric concentration of CuO

S. no.	Volumetric concentration (%)	Density*Specific heat (kJ/L°C)
1	0	4.180
2	0.5	4.176
3	1	4.172
4	1.5	4.168
5	2	4.164
6	2.5	4.160
7	3	4.155
8	3.5	4.151

Table -2: Volumetric concentration of CuO with density*specific heat.

3.1.1 Experimental Procedure

- Start the flow of water into the hot water line by opening the valve and set the flow to 3 LPM.
- Switch on the heating system.
- Set the cold fluid into flow by switching on the pump and the flow rate must be 1.5 LPM.
- Switch on the radiator and the temperature measurement system (thermocouples).
- Wait for the system to reach steady state and note down the thermocouples' readings.
- The procedure is repeated with varying the volumetric percentage of CuO in the nanofluid.
- The experiment is done for both parallel and counter flows.

3.2 Analysis Of Heat Exchanger

- As the main aim of experiment is to determine the variation in the overall heat exchange coefficient, LMTD method is preferred to analyze the heat exchanger.
- LMTD method:

$$\dot{Q}_h = \dot{m}_h C_{ph} (T_{h,in} - T_{h,out})$$

3.3 Sample Calculation

Volumetric concentration of CuO = 2.5%

Flow type: Parallel

$$A_o = \pi * d * l = \pi * 0.0125 * 1.5 = 0.0589\ m^2$$

$$\text{Flow rate}_{hot} = 1.5\ \text{lpm},\ \left(\rho c_p\right)_h = 4.18 \frac{kJ}{kg}{}^\circ C,\ T_{h,in} = 53^\circ C,\ T_{h,out} = 50^\circ C$$

$$Q_h = \frac{3}{60} * 4.18 * (53 - 50) = 0.627\ kW$$

$$\text{Flow rate}_{cold} = 3\ \text{lpm},\ \left(\rho c_p\right)_c = 4.160 \frac{kJ}{kg}{}^\circ C,\ T_{c,in} = 40^\circ C,\ T_{c,out} = 44^\circ C$$

$$Q_c = \frac{1.5}{60} * 4.16 * (44 - 40) = 0.416\ kW$$

$$\dot{Q} = \frac{Q_h + Q_c}{2} = 0.522\ kW$$

$$\text{LMTD}, \Delta T_{lm} = \frac{6-13}{\ln(6/13)} = 9.508\ ^{\circ}\text{C}$$

$$U_o = \frac{0.522}{0.0589 * 9.508} = 0.932\ \frac{\text{kW}}{\text{m}^2}\ ^{\circ}\text{C}$$

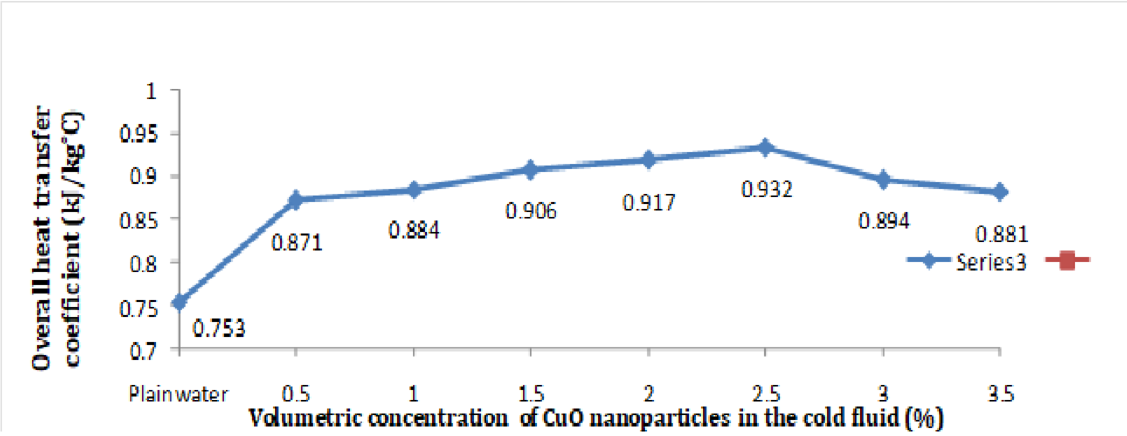

Chart -1: Experimental graph

4. CONCLUSIONS

- From the results of the experiment, it has been shown that by adding a little quantity (0.5%) of CuO nanoparticles in water, the overall heat transfer coefficient increased by 15%.
- But, the heat transfer coefficient doesn't keep on increasing with the increase in CuO concentration. Rather after a certain limit, 2.5% CuO in this case, it starts declining.
- This particular behavior of the overall heat transfer coefficient can be explained by the change in Thermal Transport properties of the nanofluids.
- Therefore, it can be concluded that the CuO-water nanofluid performs at its best when the volumetric concentration of CuO particles is 2.5%.

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