Performance Enhancement and Analysis of Shell and Tube Type Heat Exchanger

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Abstract: Nano-fluids are playing a very important role in thermal stream due to its physical and thermal properties. Now a day it was observed that there are lots of papers which have explained the deep study on nanofluids. There are so many areas in which nanofluids are used to increase the thermal efficiency and coefficient of heat transfer. In this review comprehension, many research works which are related to nanofluids used as a working fluid in shell and tube heat exchanger will be summarized in efficient way. And theoretical as well as experimental study is to be performed for shell and tube heat exchanger to determine what the effects on various parameters of graphene nanofluid, silver nanofluid, Al2O3 nanofluid and copper nanofluid. Graphite is the cheapest form of producing flanks of graphene and these samples of produced graphene were optimized with help of different type of methods. To increase the performance of heat transfer of shell & tube heat exchanger, the graphene nanofluid is used as a working fluid rather than any different type of ordinary fluid. The thermal efficiency and the coefficient of heat transfer depend upon the inlet temperature, flow rate, concentration of working fluid. The general outcomes show that by increasing in concentration of nanoparticle and flow rate of working fluids, there will be the increment in heat transfer rate, thermal conductivity and efficiency of heat exchanger.

Keywords – Nano-particles, Hybrid nano-fluid, Heat transfer, Volume concentration.

1. INTRODUCTION

In this portion, the overview and the history of different type of nanofluids are presented classically. The nanofluids are explained and its uses in shell and tube heat exchanger. In this century, there is a necessity of cooling which is having high performance in all over industry. The mainly working fluids (purify water, simple oil, ethylene glycol etc.) are being used for conducting heat in shell and tube heat exchanger. But due to poor result comes in to the picture many researchers are focusing on nanofluids because of high accuracy and better outcomes. The nano-particle whose any one dimension is in the range of 1 to 100nm, is perfectly dipped into simple fluid which is having low thermal conductivity, then we get a nanofluid having high convective heat transfer coefficient and thermal conductivity[1].

1.1. HEAT EXCHANGER
Heat exchanger is the device used in various industries (food industries, manufacturing industries and oil refineries) for transferring the heat from one fluid to another fluid which are having the different temperature; it means that heat exchangers are used for the purpose of cooling as well as heating. The main purpose of heat exchanger is to proper recovery of the heat from waste fluid used in industry and utilize it in efficient way. So that consuming cost and performance of industry could be increased[2].

Before 20th century, industry used to pay effort on only transferring the heat from one fluid to another, but after that efficiency have become the major issue with heat exchange. The maximum credit goes to nanofluid to enhance the performance of heat exchanger because of its valuable characteristics. So in this review, the data of characteristics of heat transfer is to be observed in the summarized way [3] [4].

1.2. SHELL AND TUBE HEAT EXCHANGER

Shell and tube heat exchanger is one of the common type heat exchanger which is used in oil refineries and various types of chemical industries [5].

It consists of shell (cylindrical vessel) and hollow tubes. And one fluid is passed through hollow tube (inlet to outlet) another is passed through shell (inlet to outlet) [6][7].

NOMENCLATURE:

| Symbol | Description |
|--------|-------------|
| h      | Coefficient of heat transfer, w/m²k |
| k      | Thermal conductivity, w/m k |
| U      | Overall heat transfer coefficient, w/m²k |
| ε      | Effectiveness |
| LMTD   | Logarithmic mean temperature difference |
| P      | Pressure drop, N/mm² |
| Re     | Reynolds number |
| ηₜ     | Efficiency of hot fluid |
| ηₖ     | Efficiency of cold fluid |
| ηₚ     | Mean efficiency |
| μ      | Viscosity, kg/m s |
| t      | Inlet temperature tube side °C |
2. EXPERIMENTS

There are five types of nanofluids which are analysed in this paper. In first experiment, silver/water nanofluid is used as a working fluid in tube. After that in second experiment, graphene/water nanofluid is used as a working fluid in shell and tube heat exchangers. At the last Cu/water, Al2O3/water and Cu-Al2O3/water are used as a working fluid in shell and tube heat exchangers and analysed on the same parameters[8][9].

2.1. SILVER/WATER NANOFLUID

In this study, silver/water nanofluid is used as working fluid in shell and tube heat exchanger to calculation the overall heat transfer coefficient, effectiveness, LMTD and pressure drop with respect to the Reynolds number which is varied from 5000 to 15000, particle volume concentration of 0.01%, 0.03% and 0.04%.[10] [26].

The average nanoparticle of silver having 54nm of any one dimension mixed with polyvinyl pyrolidine (PVP), diluted with distilled water. [11]

After performing the experiment successfully, the variations of heat transfer coefficient, effectiveness, pressure drop and logarithmic mean temperature difference are observed with change the flow of working fluid. As the particle volume concentration is increased, the heat transfer coefficient, effectiveness and pressure drop will be increased in parallel, we know that heat transfer coefficient is inversely proportional to LMTD that’s why the logarithmic mean temperature difference (LMTD) decreases too. [12] [25].

**TABLE.1:** Variation of heat transfer coefficient, effectiveness, pressure drop and LMTD with respect to particle volume concentration and Reynolds number.

| % of vol. con | Re-5000 | Re-10000 | Re-15000 |
|---------------|---------|----------|----------|
|               | h | ε  | p  | LMTD | h | ε  | p  | LMTD | h | ε  | p  | LMTD |
| 0.01          | 640 | 0.65 | 4.4 | 7.2  | 980 | 0.69 | 14 | 6.8  | 1650 | 0.71 | 21 | 6   |
| 0.03          | 660 | 0.67 | 4.7 | 7    | 1100| 0.70 | 15 | 6.4  | 1800 | 0.73 | 22 | 5.6 |
| 0.04          | 700 | 0.69 | 5   | 6.4  | 1200| 0.72 | 16 | 5.9  | 1950 | 0.74 | 23 | 5   |
| water         | 600 | 0.65 | 4.2 | 7.6  | 900 | 0.68 | 13 | 7.1  | 1500 | 0.70 | 20 | 6.6 |

2.2. GRAPHENE/WATER NANOFLUID

In this study, graphene/water nanofluid is used as a working fluid in shell and tube heat exchanger and investigates the characteristics of nanofluid to better understanding of its
physical properties. [13] [24]

The graphene is found in the form of graphene flakes which is obtained by graphite foam, and the size of graphene flakes is in the range of 60nm to 130nm. graphene/water nanofluid is made by dispersing the graphene powder into de-ionized water, to eliminated the possibility of unstable of graphene flakes suspension, we have to mix surfactant agent into de-ionized water. As result the graphene/water nanofluid is obtained with particle weight concentration of 0.01%, 0.05%, 0.1% and 0.2% [14] [15].

**TABLE.2:** Variation of overall convective heat transfer coefficient, efficiency of hot and cold fluid with respect to flow rate and particle concentration at inlet temperature of 70°C.

| % of vol. con. | flow rate 1.20(l/min) |  | flow rate 1.44(l/min) |  | flow rate 1.68(l/min) |  |
|----------------|-----------------------|--|-----------------------|---|-----------------------|---|
|                | U    | ηₕ     | ηₖ     | ηₘ      | U    | ηₕ     | ηₖ     | ηₘ      | U    | ηₕ     | ηₖ     | ηₘ      |
| water 0.01     | 1040 | 19.2   | 18.4   | 18.8    | 1180 | 18.4   | 20     | 19.2    | 1280 | 17     | 21.8   | 19.4    |
| water 0.05     | 1130 | 20.8   | 19     | 19.9    | 1270 | 20     | 21.2   | 20.6    | 1420 | 19.2   | 22.4   | 20.8    |
| water 0.1      | 1160 | 21.5   | 19.4   | 20.4    | 1340 | 20.6   | 21.6   | 21.1    | 1450 | 19.6   | 23.2   | 21.4    |
| water 0.2      | 1240 | 22.4   | 19.6   | 21      | 1420 | 21.6   | 22     | 21.8    | 1550 | 20.8   | 23.6   | 22.2    |
| water          | 1280 | 23     | 20     | 21.5    | 1460 | 22.4   | 22.4   | 22.4    | 1620 | 22     | 24     | 23      |

The prepared graphene/water nano-fluid is used as the working fluid in shell and tube heat exchanger, when the nano-fluid is being passed through tubes, then the effect on the overall convective heat transfer coefficient, efficiency of hot and cold fluid by varying the flow rate of working fluid as well as particle weight concentration of 0.01%, 0.05%, 0.1% and 0.2% by keeping the inlet temperature of side tubes at 70°C. [16][23]

As the outcomes show that the flow rate of working fluid increases, the overall convective heat transfer coefficient increases too, either we are taking the reading of overall convective heat transfer at same flow rate or same concentration. While the efficiency of hot fluid decreases with increasing the flow rate at same concentration, on other hand the efficiency of hot fluid increases with increasing the concentration at same flow rate,[17]

The flow rate of working fluid increases, the efficiency of cold fluid increases too, either we are taking the reading of cold fluid efficiency at same flow rate or same concentration. Finally as compare to base fluid, heat transfer coefficient can be enhanced up to 29% by using 0.2wt% graphene/water nanofluid. In addition, the maximum increase in the mean thermal efficiency was 13.7% using nanofluids concentration and flow rate of 0.2 and 2.16 l/min. [18] [22]

2.3. Cu/water, Al2O3/water and Cu-Al2O3/water (HYBRID NANOFLUID)

In this study, Al2O3/water and Cu/water nanofluid are used as a working fluids in shell and tube heat exchanger to investigate the effect on its properties i.e. heat transfer coefficient, thermal conductivity and viscosity of fluid by varying the volume concentration of nanofluid. If we mix both nanofluids then we will get the hybrid fluid (Al2O3-Cu/water) whose parameter is stronger than nanofluids.
The thermal conductivity of Cu/water nanofluid is greater than Al2O3/water, but in case of hybrid-fluid with same concentration its value is too much high.

The heat transfer coefficient of Cu/water nanofluid is also greater than Al2O3/water, but in case of hybrid-fluid with same concentration its value is too much high. In the same way these parameters is also increased with increase in volume concentration, so finally the parameter of hybrid fluid (Al2O3-Cu/water) are stronger than other nano fluids to achieve the higher performance of shell and tube heat exchangers.[19][21]

| % of vol. con | Cu/water | Al2O3/water | Al2O3-Cu/water |
|---------------|----------|-------------|----------------|
|               | k        | h           | μ              | k    | h   | μ    | k    | h   | μ    |
| 1%            | 1.03     | 1150        | 1.01           | 1.02 | 1050| 1.01 | 1.04 | 1300| 1.04 |
| 4%            | 1.12     | 1350        | 1.09           | 1.11 | 1225| 1.09 | 1.13 | 2800| 1.12 |
| 8%            | 1.21     | 2025        | 1.18           | 1.19 | 1300| 1.18 | 1.25 | 2800| 1.21 |
| 10%           | 1.25     | 2300        | 1.23           | 1.24 | 1550| 1.23 | 1.28 | 3500| 1.25 |
| 20%           | 1.52     | 3550        | 1.48           | 1.28 | 1800| 1.48 | 1.63 | 4650| 1.52 |

3. CONCLUSION:

In this review paper, many research works have been summarized for better understanding of different types of nano-fluids and its physical characteristics in shell and tube heat exchanger.

The heat transfer coefficient, thermal efficiency and thermal conductivity are controlled by concentration of nano-particle and flow rate of working fluid.

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