CFD ANALYSIS OF HEAT TRANSFER ENHANCEMENT IN HEAT EXCHANGERS USING NANOFLUIDS

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Abstract - *Now days to achieve high heat transfer rate, different techniques have been used. One of the advanced techniques among them is suspension of nanoparticle in the base fluids as water, ethylene glycol, oil. In last few years so many research has been done for enhancing the heat transfer rate like inserting baffles, twisted tapes, brushes, etc. This leads to increase in weight of heat exchangers and also cost of manufacturing. The worldwide researchers are making hard efforts to find out suitable alternatives for heat exchangers with different geometry and varying parameters which effects on performance of heat exchanger. Now days Nano fluid has become blessings for researchers. Nano fluid increases the heat transfer rate when suspended in base fluids water, ethylene glycol. With the fast track development of nanotechnology, particles of nanometer size are used for enhancing heat transfer rate are called Nano fluids. This work is focused on study of heat transfer rate enhancement at low concentration.*

Key Words: Nano fluid, overall heat transfer coefficient, mass flow rate, LMTD, CFD.

1.INTRODUCTION

Heating and cooling of fluid is one of the basic processes used in industries such as chemical, electrical, heat recovery, cryogenic, production, transportation, manufacturing, refrigeration and air-conditioning etc. The improvement in the heat transfer with high efficiency is the key requirement for all the industries. method of enhancing heat transfer co-efficient is enhancement in thermo-physical characteristics of the fluid such as thermal conductivity, viscosity etc. Fluids in use i.e., oil, ethylene glycol (EG), water, propylene glycol etc. do not have adequate ability of heat transfer. This is due to low thermal conductivity of these fluids. Suspending metal or metal oxides into the conventional fluid can improve thermo-physical properties of the fluid. It is possible because metal & metal oxide has better thermal conductivity than commonly used fluids. This work is focused on study of heat transfer enhancement at low concentration (1%)

1.1 Objective of the work

The main objective of this work is,

- To study different heat transfer mechanisms associated with nanofluids.
- To study heat-transfer and thermo-physical properties associated with nanofluids.
- To study the convection heat transfer capacity of the water based Al2O3 nanofluids.
- To investigate heat transfer enhancement in heat exchangers with and without using nanofluid by CFD Analyis in Anays Fluent software.

2. CALCULATION OF THERMO-PHYSICAL PROPERTIES OF NANOFLUID

Nanopatilces of Al_2O_3 , CuO, ZnO are commonly used for preparation of nanfluids. Base fluid commonly used are water, oil, ethylene glycol. In this work water based Al_2O_3 nanofluid is used whose thermos-physical properties as given in following table were entered in Ansys Fluent software.

The thermos-physical properties of Al_2O_3 was calculated using following formule,

2.1 Measurement of Density

The density/volumetric mass density, of a substance are its mass per unit volume. The density of nanofluid can be numerically calculated by using the mass balance as,

$$\rho_{nf} = (1 - \emptyset_s)\rho_f + \emptyset_s \rho_p$$

Where, ρ_f = Density of Base Fluid,
$\emptyset_s$ = Concentration of Nanoparticles, ρ_p = Density of Nanoparticles.

The density measured using above equation at different concentration is given in following table.

Table -1: Density measured at different concentration levels

Concentration (%)	Density (kg/m³)
1	1014.22
5	1082.74
10	1168.39
15	1254.03
20	1339.68

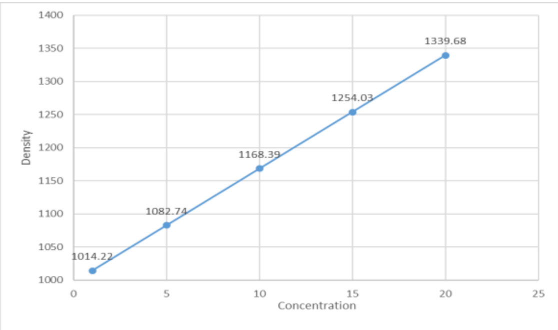


Chart -1: Relationship Between Density and Concentration

2.2 Measurement of Specific Heat

The specific heat/heat capacity/ thermal capacity is a measurable physical quantity equal to the ratio of heat added to/removed from an object to the resulting temperature change. The specific heat of nanofluids can be calculated by using mass balance equation as:

$$C_{nf} = \frac{(1-\emptyset_s)\rho_f C_f - \emptyset_s \rho_p C_p}{\rho_{nf}}$$

Where, Ø = Nanoparticle Percentage,

ρ_f = Density of Base Fluid.

ρ_p = Density of Nanoparticle

Specific heat measured using above equation at different concentration is given in following table,

Concentration (%)	Specific Heat (J/kg K)
1	4146.2
5	4015.05
10	3851.12
15	3687.15
20	3523.21

Table-2: Specific Heat Measured at Different concentration

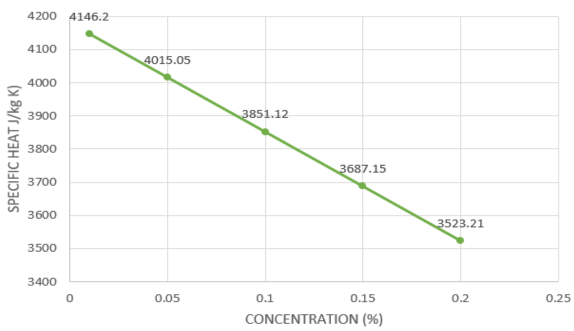


Chart-2: Relationship between Specific Heat and Concentration

2.3 Measurement of Thermal Conductivity

Thermal conductivity can be defined as amount of heat transferred through unit thickness of material in a direction normal to a surface of unit area. Thermal conductivity refers to the amount/speed of heat transmitted through a material. Heat transfer occurs at a higher rate across materials of high thermal conductivity than those of low thermal conductivity.

Thermal conductivity of nanofluid is determined by following equation,

$$k_{nf} = \frac{k_p + (2 * k_{water}) + \left(2 * (k_p - k_{water})\right) * \emptyset}{k_p + (2 * k_{water}) - \left((k_p - k_{water})\right) * \emptyset}$$

Where, k_p = Thermal conductivity of nanoparticle

K_{water}= Thermal conductivity of water.

Specific heat measured using above equation at different concentration is given in following table,

Concentration (%)	Thermal conductivity (W/mK)
1	1.03
5	1.165
10	1.33
15	1.524
20	1.742

Table-3: Thermal conductivity at different concentration

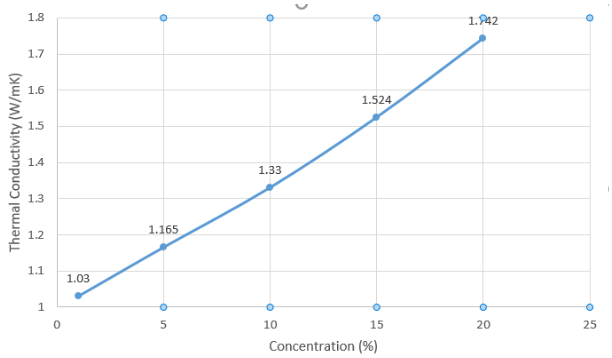


Chart-3 Relationship between Thermal conductivity and Concentration

3. CFD ANALYISIS PROCEDURE

3.1 Modelling of Heat Exchanger

Heat exchanger is modelled in Design Modeler of Ansys software.

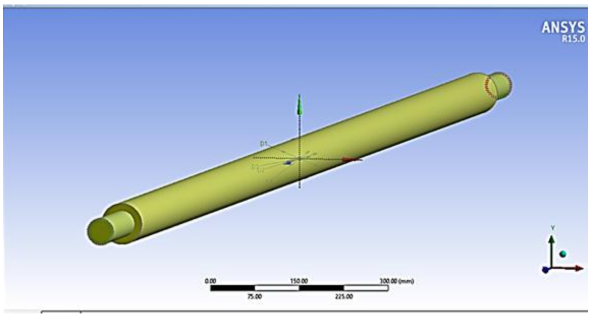


Fig-1: Model of Heat Exchanger

3.2 Mesh Genenration

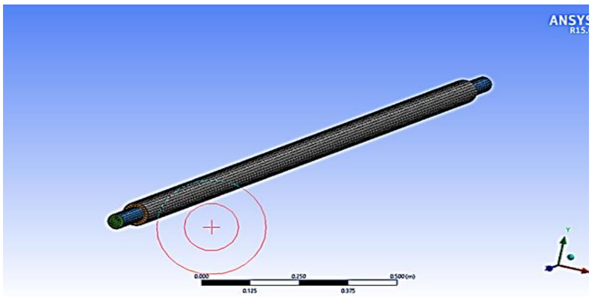


Fig-2: Meshed model of Heat exchanger

3.3 Setting of Boundary Conditions

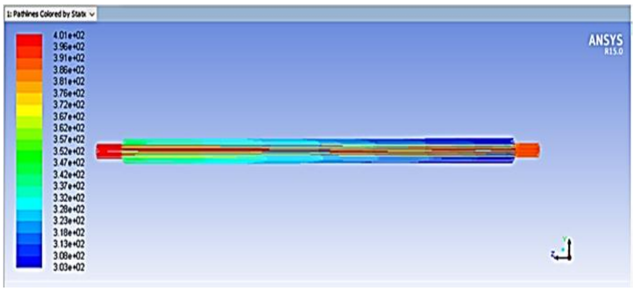
Quantities	Boundary Conditions			
Working Fluid	Water		Nanofluid	
Inner Pipe (Hot Fluid)	Mass flow rate	Temp.		
	0.5 kg/s	130°C		
Outer Pipe (Cold Fluid)	Mass flow rate	Temp.	Mass flow rate	Temp.
	0.8 kg/s	30°C	0.8 kg/s	30°C

Table-4 Boundary Conditions

3.4 Post Processing

In post processing, contours of Temperature are plotted at different concentration levels.

Using Nanofluid



Using water

Temperature readings got from CFD analysis is given in following table,

CONCENTRATION	HOT OUTLET TEMP (k)
1	391.42
5	389.74
10	388.89
15	387.85
20	386.68

Table-5 Value of Outlet temp. at different concentration

4 LMTD ANALYSIS OF HEAT EXCHANGER

LMTD Method of analysis of heat exchanger is most common method for analysis of heat exchanger if inlet and outlet temperature are known.

LMTD is given by,

$$\Delta T_{\text{lm}} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}$$

Where,

$$\Delta T_1 = T_{h,i} - T_{c,o} \text{ and } \Delta T_2 = T_{h,o} - T_{c,i}$$

LMTD Calculated when water is used as a cold fluid,

LMTD = 89.41°c.

Heat transfer rate calculated when water is used as a cold fluid,

Q=16727Watt

Similarly LMTD and Heat Transfer rate in case of Nanofluid at different concentration is given in following table,

CONCENTRATION (%)	LMTD (K)	HEAT TRANSFER RATE (Watt)
1	90	17936.49
5	89.66	20597.2
10	88.75	21392.97
15	71.79	22399.4
20	70.36	23464.57

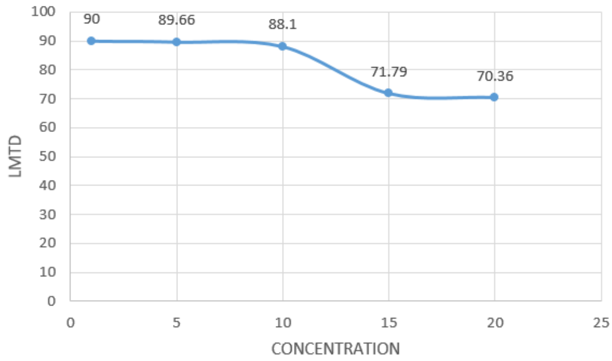


Fig.-3 Graph Showing relationship between LMTD and Partical concentration

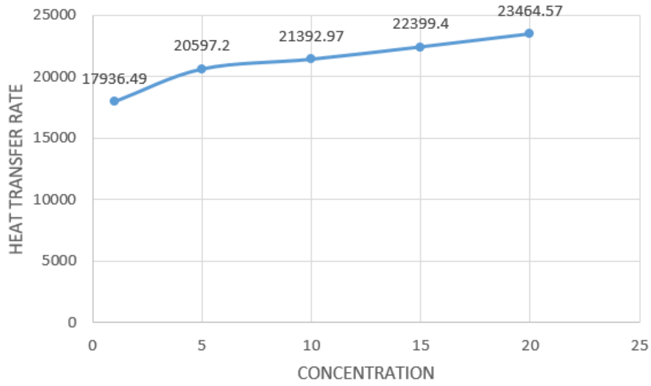


Fig.-4 Graph showing relationship between Heat transfer rate and partical concentration.

From the above graphs it is found that as Particle concentration incerases, LMTD decreases and Heat Transfer Rate increases.

CONCLUSION

From the CFD Analysis it is found that temperature of hot fluid decreases from 400K to 391K when water is used as a cold fluid. Whereas, when nanofluid is used as a cold fluid at different concentration levels, temperature decreases as concentration increases
From the LMTD Analysis, it is found that heat transfer rate when water is used as a cold fluid was 16727 Watt. In case of Nanofluid the heat transfer rate becomes 20194Watt. It is seen that as concentration increases, the heat transfer rate increases.
Thus, it can be concluded that.

- Nano fluids can show great promise for use in heat transfer applications and related technologies.
- With the increase in particle size, the enhancement increases rapidly.
- The nanofluids can be used efficiently in convective heat transfer applications.

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