CFD ANALYSIS OF DOUBLE TUBE HEAT EXCHANGER USING DIFFERENT NANOFLUID

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***ABSTRACT*: Heat exchanger is a device to transfer heat from one medium to another medium. In order to increase the heat transfer rate many researcher optimized different process parameters of heat exchanger. Due to the reduction of size of heat exchanger there is a pressure on designer to increase heat transfer per unit area of heat exchanger. Now day metal oxide particles of nano size were used to make nano fluid which increases the heat transfer rate inside the heat exchanger. Here in this work we have calculated the effect of different nano fluid on heat transfer, for calculating the effect of different nano particle here we have considered three different nano particles that is Aluminium oxide (Al_2O_3), Ferric oxide (Fe_2O_3) and Copper oxide (CuO). Here we have also calculated the effect of different percentage of nano particles in nano fluid, for calculating the effect of different percentage of nano fluid here we have considered two different volume percentage of nano particle that is 0.25 and 0.5 %. Through analysis it is found that copper-oxide nano fluid shows maximum heat transfer as compared to other nano fluids. CuO nano fluid shows 8% more heat transfer than the Al_2O_3, whereas CuO shows 39.90% more heat transfer as compared to Fe_2O_3.**

***Keywords*: Heat exchanger, nanofluid, heat transfer rate, practical concentration**

1. Introduction

Heat exchanger is a device to transfer heat from one medium to other medium. Tubes in tube heat exchanger were used to transfer heat from one medium to another without coming in connect with each other. To increase the performance of heat exchanger different working fluid were used. Now a days many researcher uses the nano fluid to increase the heat transfer rate, for making the nano fluid different metal oxide where used innano particles foam. For making nano fluid metallic powder in nano size form at a particular volume fraction were mixed with base solution and then ultrasonic were done to properly mixed the nanoparticles in the base solvent. Here in this work we have analyzed the effect of different nano fluid on heat transfer. To analyze the effect of different nano fluid here it considered three different nanofluid that is aluminium oxide (Al_2O_3), Ferric oxide (Fe_2O_3) and copper oxide (CuO). To analyze the effect of volume concentration of nano fluid on heat transfer rate enhancement heat it has considered two volume fractions of nano particles that is 0.25 % and 0.5 % by volume percentage. Here it also analyzed the effect of change in Reynolds number, for analyzing the effect of change in Reynolds number here it considered five different Reynolds numbers that is 20000, 30000, 40000, 50000, 60000 and calculate the value of heat transfer.To perform the numerical analysis, tube in tube heat exchanger geometric parameters as mention in Han et.al [22] were used in this analysis. On the basis of geometric parameters given in Han et.al solid model of double tube heat exchanger were developed.

2. Development of solid model

Here in this work tube in tube heat exchanger were used for the numerical analysis. The geometric dimension of the heat exchanger as taken during the experimental analysis performed by Han et.al [22] is shown in the below table.

Table.1Showing the value of geometric parameters

Parameters	Value
Inner tube diameter	38 mm
Outer tube diameter	100 mm
Tube length	2100 mm
Tube thickness	2 mm

Based on the geometric analysis solid model of tube in tube heat exchanger were developed as shown in the below fig.

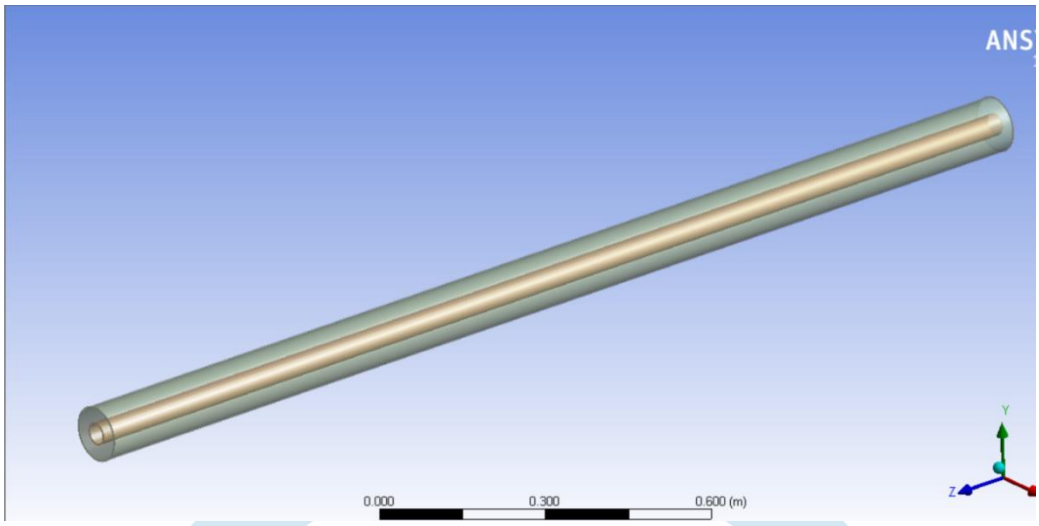

Fig.1 solid model of tube in tube heat exchanger

3. Mesh

In order to perform the numerical analysis of tube in tube nanofluid heat exchanger, discretization of heat exchanger is performed. To perform numerical analysis of heat exchanger, complete body of heat exchanger were discretized in to number of nodes and element. To calculate the effect of number of node and element on result, here solid model of heat exchanger were analyzed as different number of nodes and elements.

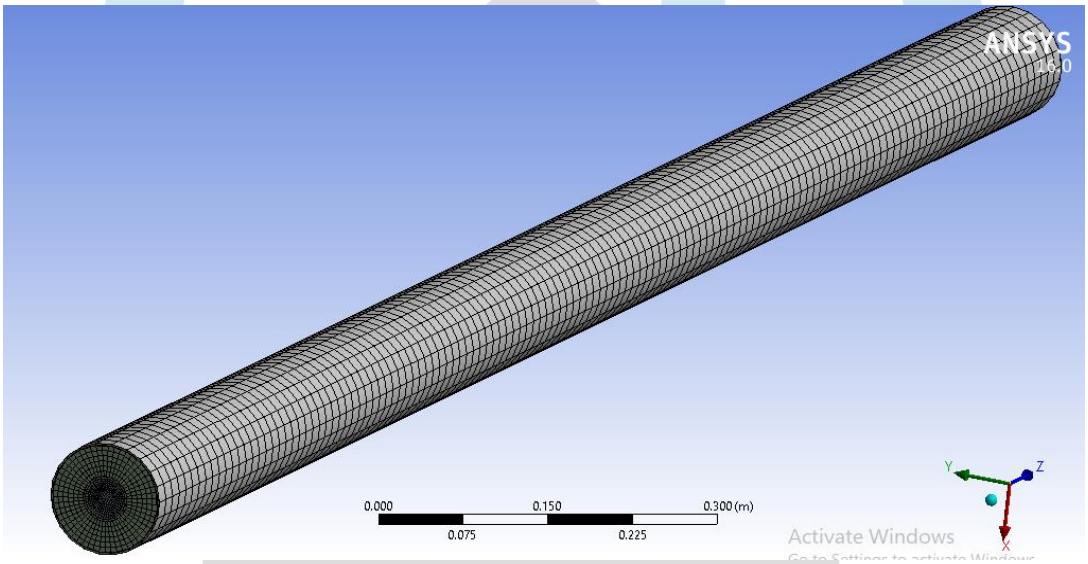

Fig.2 mesh of the tube in tube heat exchanger

4. Material used

Here in this work water with different nanoparticles used as a cold fluid, which is used to extract heat from hot fluid, water steam is used as a hot fluid. Here in this analysis inner tube is made of aluminium, and also the outer tube is made of aluminium. The thermal properties of different materials are shown in following tables.

Table.2 Properties of Al_2O_3 Nano particles [24]

Properties	Value
Thermal conductivity($Wm^{-1}K^{-1}$)	40
Density (Kg/m^3)	3970
Specific heat (J/kg K)	765

Table.3 Properties of CuO Nano particles [24]

Properties	Value
Thermal conductivity($Wm^{-1}K^{-1}$)	76.50
Density (Kg/m^3)	6350
Specific heat (J/kg K)	535.60

Table.4 Properties of Iron oxide nano particles [27]

Properties	Value
Thermal conductivity($Wm^{-1}K^{-1}$)	20
Density (Kg/m^3)	5250
Specific heat (J/kg K)	650

4.1 Water

Water with different nanoparticles used as nanofluid to increases the heat transfer rate inside the heat exchanger. The properties of water is shown in the below table.

Table.5 Properties of water at 40^0C [23]

Properties	Value
Thermal conductivity($Wm^{-1}K^{-1}$)	0.6
Density (Kg/m^3)	998
Specific heat (J/kg K)	4182

4.2 Aluminium

It is used to manufacture inner and outer tube of heat exchanger, the properties of aluminium material is shown in the below table.

Table.6 Properties of Aluminium [23]

Properties	Value
Thermal conductivity($Wm^{-1}K^{-1}$)	202.4
Density (Kg/m^3)	2719
Specific heat (J/kg K)	871

5. Data Reduction

Mathematical relation used for the calculation of Nusselt number and heat transfer coefficient of Al_2O_3 at 0.25% volume concentration with water as base fluid.

In order to calculate the different properties of nano fluid after mixing nano particles in to water following relations were used. Relations used for the calculation of nano fluid properties is mention Elsevier [26]

- For calculating the density of nano fluid following relation is used

$$D_{nf} = v\,D_{np} + (1\text{-}v)\,D_{water}$$

- For calculating the dynamic viscosity of nano fluid

$$\mu_{nf} = \mu_{water}(1+2.5v)$$

- For calculating the specific heat of nano fluid

$$C_{pnf} = [v(D_{np}.C_{np}) + (1\text{-}v)(D_{water}.C_{water})\,]/D_{nf}$$

- For Calculating the thermal Conductivity of nano fluid

$$K_{nf} = K_{water}(1+3v)$$

- For calculating heat transfer coefficient with the help of nusselt number

$$Nu = \frac{hD}{k}$$

Where, D_{nf} is density of nanofluid. μ_{nf} is coefficient of viscosity of nanofluid. v is volume concentration of nanoparticles in water. D_{np} is density of nanoparticles. D_{water} is density of water. C_{pnf} is heat capacity of nanofluid. C_{np} is heat capacity of nanoparticles. C_{water} is heat capacity of water. K_{nf} is thermal conductivity of nanofluid . K_{water} is thermal conductivity of water. Nu is nusselt number. h is heat transfer coefficient. D is characteristics length. k is thermal conductivity of fluid.

6. Boundary condition

Here in this work hot water steam is flowing in the upper tube where as cold nanofluid is flowing in inner tube. During the analysis the hot fluidsteam is flowing at velocity 2.5 m/s as mention in base paper Han et.al [22]. Whereas cold nanofluid flowing in inner tube at different Reynolds number (Re) that is 20000, 30000, 40000, 50000, and 60000. The change in Renault number of nanofluid is used to measure the effect of change in mass flow rate of cold fluid on heat transfer. For the initial case of analysis that is flow of fluid at Reynolds number 60000, the velocity of cold fluid inlet is 0.9868 m/s. water steam is flowing in the outer tube as hot fluid. The temperature of hot fluid that is seam is near about 427 K. whereas the cold fluid that is nanofluid at different content of nanoparticles is flowing in inner tube.

7. Validation of the Numerical Model

In order to validate the numerical model of nano fluid heat exchanger, here we have develop the numerical model of tube in tube nano fluid heat exchanger on the basis of boundary condition considered during the experimental analysis performed by Han et.al [22]. For the initial analysis, here it considered Aluminium oxide (Al_2O_3) as a nanoparticle with two different volume fractions that is 0.25% and 0.5 % at different Reynolds number. And measure the value of Nusselt number for different Reynolds number.

7.1 For Al_2O_3

Here in this section Al_2O_3 is used as a nanofluid at two different volume fractions that is 0.25% and 0.5 %.

Table.7 Value of Nusselt number for different Re numbers

Reynolds Number	Nusselt Number at 0.25% of Al_2O_3	Nusselt number at 0.25% of Al_2O_3 from base paper	Percentage error (%)
20000	122.4655	130.50	6.15
30000	182.7567	190.00	3.81
40000	216.1447	230.65	6.28
50000	241.7068	256.50	5.76
60000	269.1495	285.65	5.79

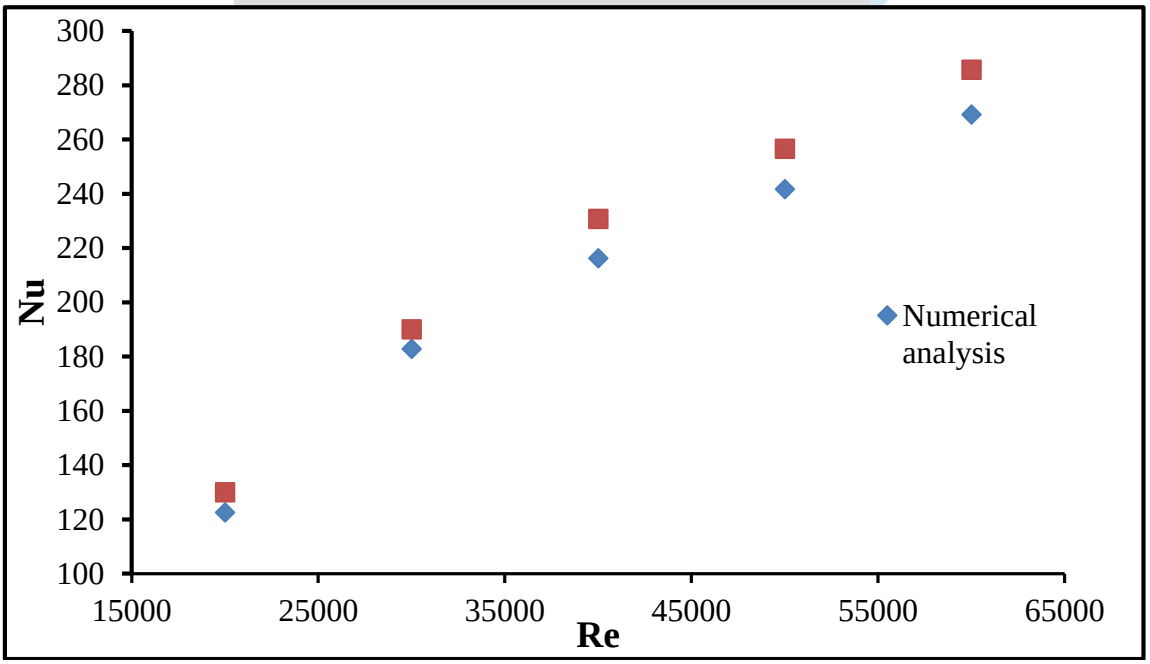

Fig.3 comparison of Value of Nusselt number for different Reynolds number

From the above graph it is found that the value of Nu number calculated from numerical analysis is closer to value of Nu Number obtained from the base paper which means that numerical model of nanofluid heat exchanger is correct. There is much lesser

difference in numerical values. At 0.5% volume fraction and remaining is water is used as a cold fluid in tube in tube heat exchanger. To calculate the effect of change in Reynolds number, here nano fluid is flowing with five different Reynolds number.

Comparison of value of Nusselt number calculated from the numerical analysis with the value give in base paper for 0.5% volume fraction of nanofluid. The comparison of nusselt number is shown below

Table.8 Shows comparison of nusselt number at 0.5%

Reynolds Number	Nusselt Number calculated of Al_2O_3	Nusselt Number of Al_2O_3 from Base paper	Percentage error (%)
20000	126.44	137.35	7.94
30000	207.94	220.60	5.73
40000	237.14	250.85	5.46
50000	275.14	288.50	4.63
60000	307.23	320.00	3.99

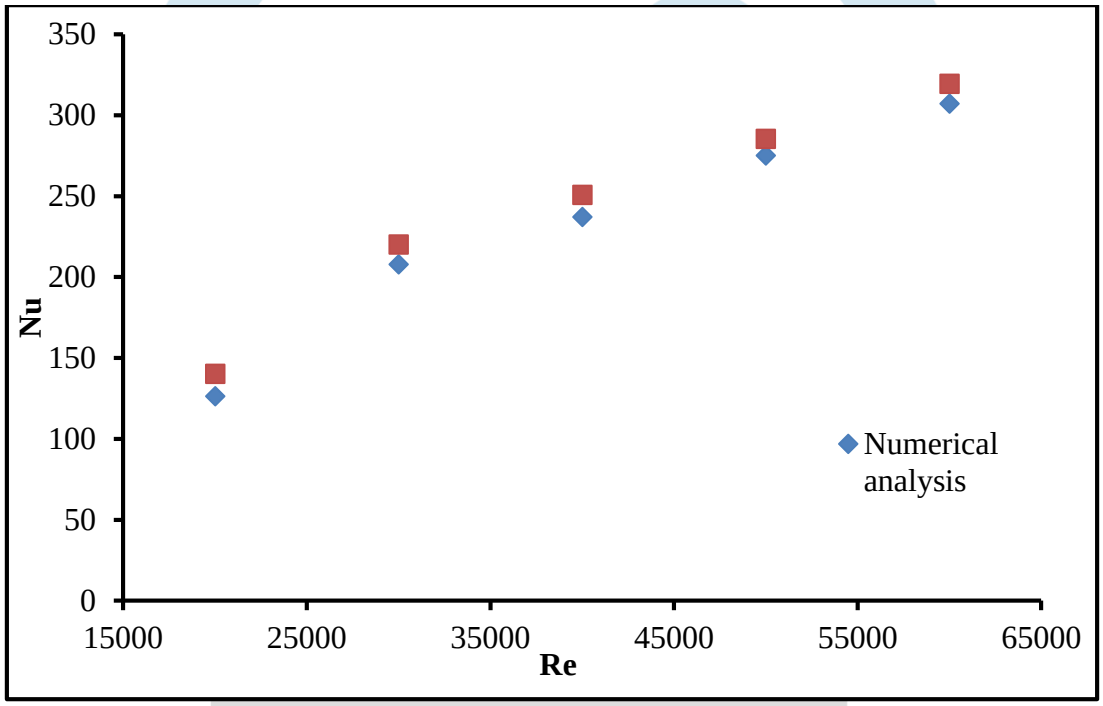

Fig.4 comparison of Nusselt for different Re at 0.5% volume fraction of Al_2O_3

From the above analysis it is found that the value of Nusselt number for 0.5% volume fraction of Al_2O_3 nano fluid is close enough to the value of Nusselt number given in the base paper. It is also conclude that as the Reynolds number increases, heat transfer also increases.

After calculating the value of nusselt number from CFD analysis here it also calculates the value of heat transfer coefficient for different Reynolds number.

Table.9 Value of heat transfer coefficient for different Re number at different volume fraction

Reynolds number	Al_2O_3 heat transfer coefficient at 0.25%	Al_2O_3 heat transfer coefficient at 0.5%
20000	2022.63	2123.7
30000	3238.45	3501.39
40000	3632.87	4059.29
50000	3759.84	4672.911
60000	4573.87	5184.38

7.2 For CuO

Copper oxide is mixed with water to make nanofluid, it is then used as a cold fluid in tube in tube heat exchanger at volume fraction. Here in this section, it calculates the value of Nusselt Number for different Re number at two different volume fraction.

Table.10 shows the value of Nusseltnuber for different Re at 0.5% of CuO

S.No	Reynolds Number	Nusselt number at 0.25%	Nusselt number at 0.25%
1	20000	136.1135	138.3422
2	30000	211.2087	241.6494
3	40000	233.86624	272.4185
4	50000	262.8948	301.007
5	60000	298.938	323.4901

Value of Heat transfer coefficient for different Re number is shown in the below table

Table.11 Shows the value of heat transfer coefficient for different Re number

Reynold number	CuO heat transfer coefficient at 0.25%	CuO heat transfer coefficient at 0.5%
20000	2192.143	2275.361
30000	3401.57	3974.49
40000	3766.473	4480.559
50000	4233.97	4950.773
60000	4814.47	5320.56

7.3 For Fe_2O_3

Here we are using the iron oxide as nanoparticles, to prepared the nano fluid iron oxide is mixed with water at two different proportion that is 0.25 and 0.5% of volume fraction.

Table.12 Shows the value of Nusselt number and Heat transfer coefficient for different Re at 0.25% of Fe_2O_3

Reynold number	Fe_2O_3 Nusselt number at 0.25%	Fe_2O_3 heat transfer coefficient at 0.25%
20000	82.3362	1317.37
30000	131.4349	2102.95
40000	184.8015	2956.82
50000	216.0685	3457.09
60000	254.5391	4072.62

Table.13Shows the value of Nusselt number and Heat transfer coefficient for different Re at 0.5% of Fe_2O_3

Reynold number	Fe_2O_3 Nusselt number at 0.5%	Fe_2O_3 heat transfer coefficient at 0.5%
20000	86.5270	1402.64
30000	159.4803	2585.254
40000	208.3741	3377.852
50000	242.8227	3936.27
60000	294.2475	4769.89

8. Comparison of different nano fluid

After analyzing the different nano fluid at different volume fraction, it is then compare and find out the nano fluid which enhances heat transfer.

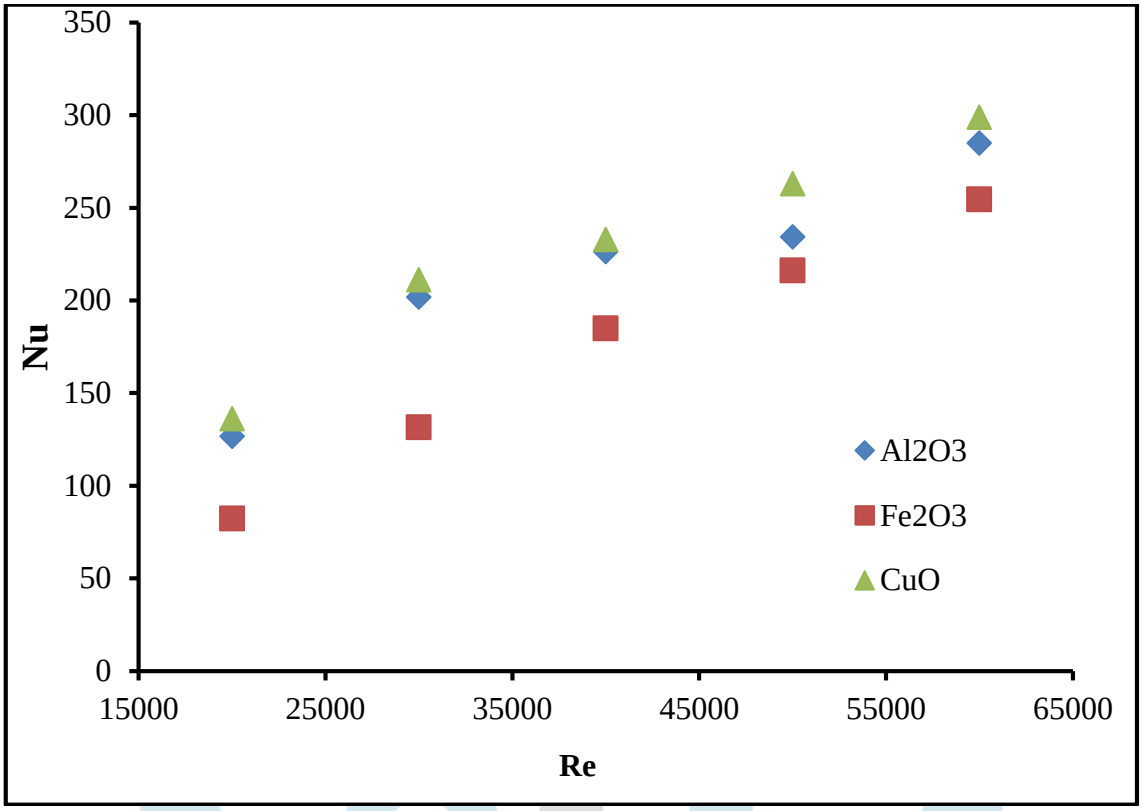

Fig.5 shows the comparison of different nano fluid at 0.25% volume fraction

From the above graph it is found that the value of Nu number increases as the Re number increases. This means that the heat transfer increases with increase in velocity of cold fluid. It is also found that nano fluid in which copper oxide used as a nano particle shows higher heat transfer as compared to the other nano fluid, at all different Reynolds Number. After comparing the value of Nu for 0.25% volume fraction of nano particles, it is then compared the value of Nu for 0.5 % volume fraction of nano fluid.

Here we have compare the value of heat transfer coefficient for differentnano fluid at different Re number

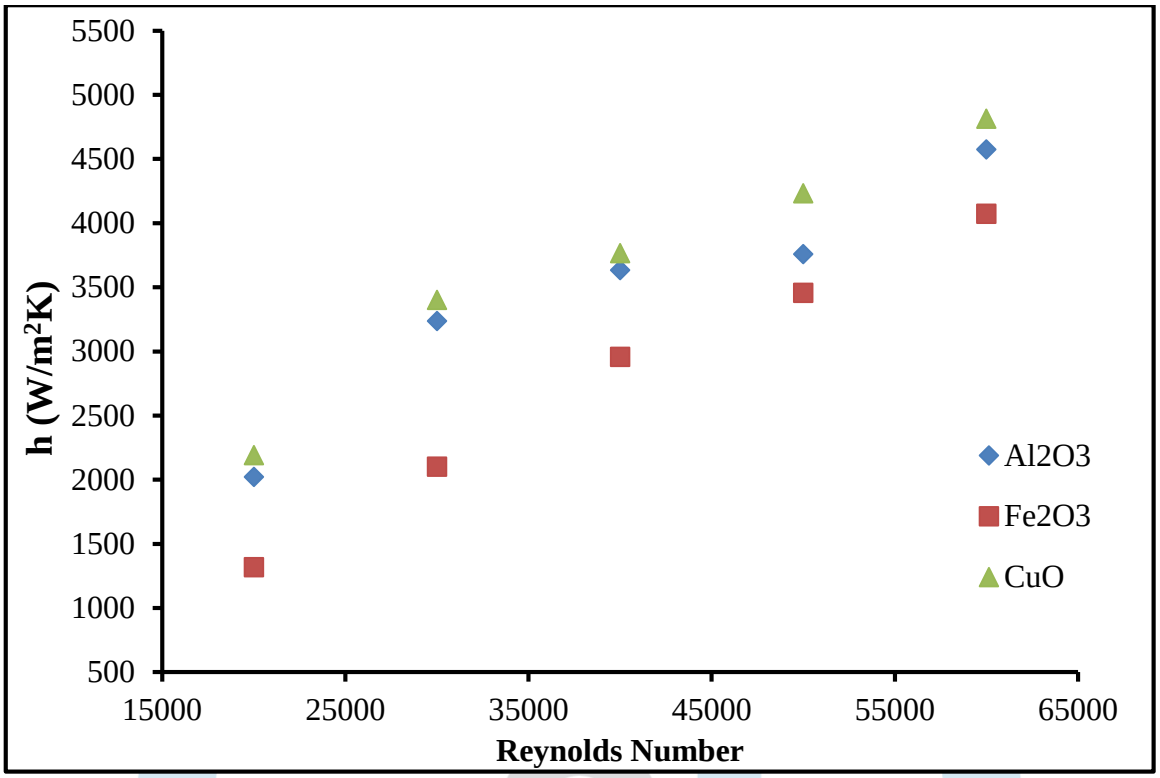

Fig.6 comparision of heat transfer coefficient for different nano fluid at 0.25%

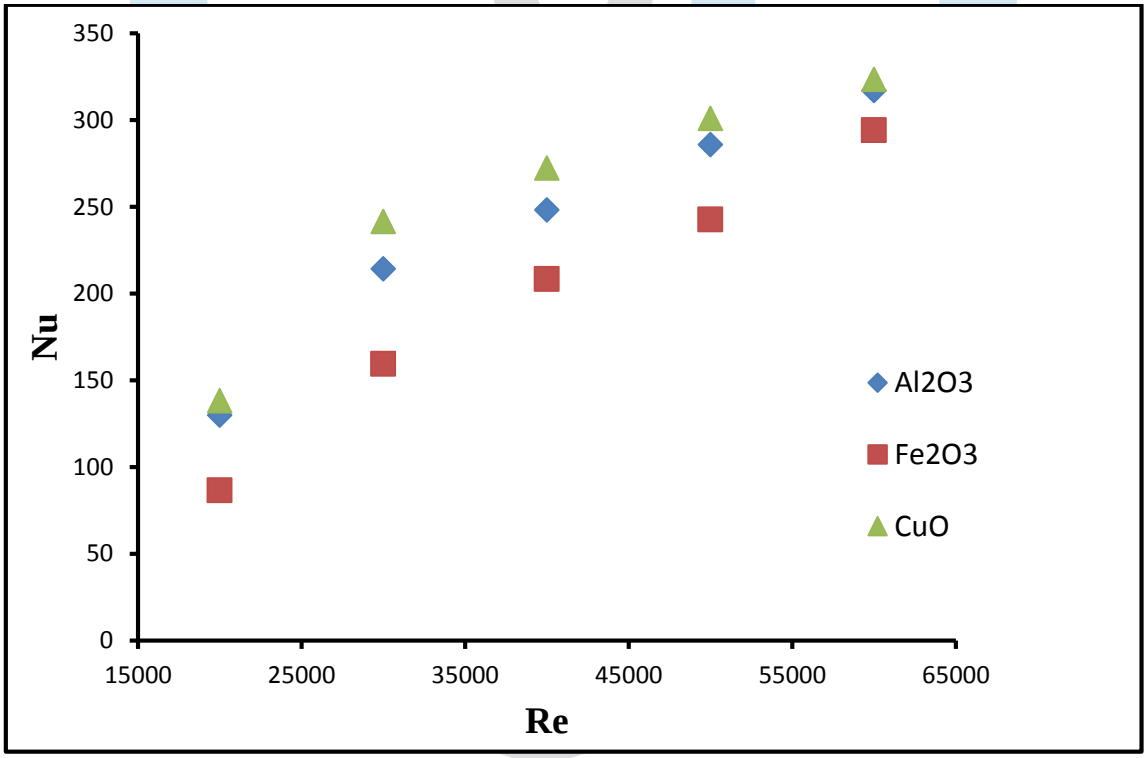

Fig.7 Shows the comparison of Nu number of different nano fluid at 0.5% volume fraction

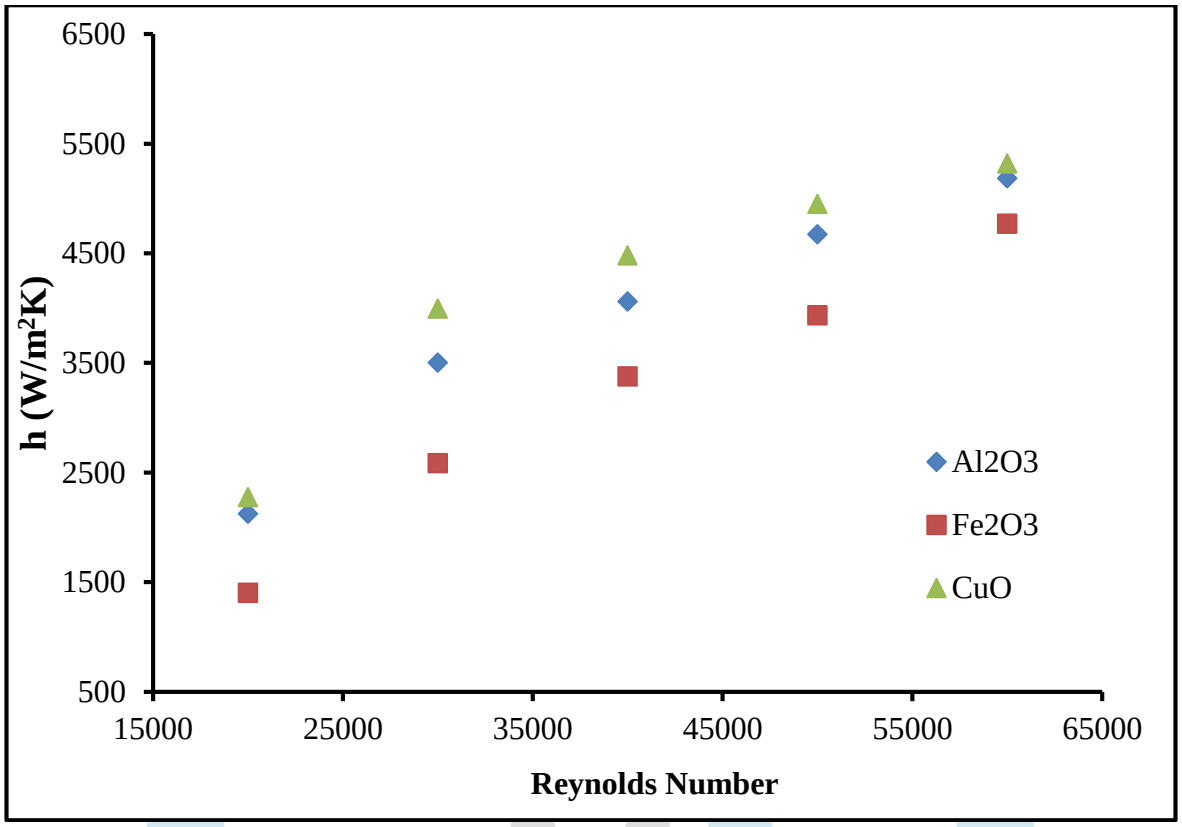

Fig.8 shows the comparison of heat transfer coefficient of different nano fluid at 0.5% volume fraction

From the above graph it is found that the value of Nu for copper oxide nano fluid is higher as compared to other nano fluid at all Reynolds number. From the analysis it is found that as the percentage of nano particles increases in nano fluid heat transfer get also increases because increases in nano particle concentration increases the specific heat of nano fluid whereas it also increases the thermal conductivity of nano fluid.

9. Conclusion

Developed the numerical model of nanofluid heat exchanger on the basis of experimental analysis performed in the base paper and calculate the nusselt number, function of heat transfer rate.

I. It is found that the value of heat transfer increases as the mass flow rate of nanofluid increases inside the heat exchanger.
II. From analysis it is also observed that the heat transfer is higher in case of CuO nanofluid as compared to other nanofluid.
III. It is found that as compared to Al_2O_3nano fluid used in base paper CuO shows 8.68% increase in heat transfer at 20000 Reynolds number and 0.25% concentration.
IV. After analyzing the comparison graph it is also found that with increase in nano particle concentration in nano fluid heat transfer get also increased for all nano fluids as mention.

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