

Numerical Study of Tube to Increase The Heat Transfer Performance by Geometric Modification Using CFD Method

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Abstract— This project comprises a survey of the heat transfer performance of the tube with different geometrical modification following inserted dents over the surface and insert helical baffles in the tube. In this research water and Ethylene glycol used as a flowing fluid and find out the heat transfer rate in all tubes. Results are reveals that the rate of heat transfer increased in tubes which has dents over surface and helical baffles. The rate of heat transfer in tubes which has dents increased as 5% as compared to simple tube while it increased 10% in case of helical baffles. The heat transfer coefficient increased as increasing the inlet temperature and velocity of flowing fluid.

Keywords- Nanofluid, angular bend tube, Rate of Heat Transfer, Pressure drop, Heat transfer coefficient.

Nomenclature:

ρ - Density

ν - Kinematic Viscosity

C_p - Specific Heat Capacity

k - Thermal Conductivity

h - Heat Transfer Co-efficient

V - Velocity

D_h - Hydraulic Diameter

D_i - Diameter of inner tube

D_o - Diameter of outer tube

A_h - Cross-sectional area of inner tube passing hot fluid

A_c - Cross-sectional area of inner tube passing cold fluid

Δp - Pressure Drop

U - Overall Heat Transfer Co-efficient

Q - Heat Transfer Rate

$^{\circ}C$ - Degree Celsius

ΔT - Temperature gradient

K - Kelvin

INTRODUCTION

Heat exchange processes are very crucial and widely used in modern thermal engineering applications. On this account, various studies on heat exchangers have been performed to increase the thermal or heat transfer performance between the fluids during the past several decades [1]. Most of the studies have focused on the development of high-performance compact heat exchangers. The alternate goal of the researchers is to increase the system thermodynamic energy and develop a less expensive heat exchanger. Bergles et al. [2,3] and Webb et al. [4,5] have attempted to simplify this problem by suggesting Performance Evaluation Criteria (PEC). PEC defines the performance benefits of the exchanger which are having enhanced surface area. Bergles et al. [2,3] introduced a method to find out the comparative performance of existing surfaces. Webb et al. [4,5] by using PEC to select the preferred enhancement type to calculate the 'optimum' geometrical parameters for the preferred enhancement type. Various types of heat exchangers are developed to exchange the thermal energy between the fluids for a specific application. There are methods to enhance the heat transfer of the heat exchanger like geometry modification or fluid modification. In case geometry modification, some changes are done in the geometry of the heat exchanger for example adding the baffles in shell and tube exchanger, by adding baffles the turbulence flow developed inside the heat exchanger and baffle make effect on the pressure drop of the heat exchanger. Parnita et al. [6] study the effect of the baffles inside the shell and tube heat exchanger. In their investigation single, double segmental and helical baffles are investigated and evaluate the pressure drop with each baffle of the heat exchanger. Increasing the number of baffles beyond certain number gives serious effect on the pressure drop. They investigate in case of single segmental baffles more pressure drop is noticed while it is reduced by adding helical baffles. Parnita et al. [6] also noticed that single segmental shows the dead zone where the heat transfer not take place effectively and this problem solved by double segmental baffles and these baffles are reduced the vibrational damages. But the use of helical baffles over other two lowers the pressure drop which in turn increases the overall system efficiency. So, it is proved that helical baffles are more advantageous than other two types of baffles.

By fluid modification there are modern fluids are introduced which have higher thermal conductivity, because of higher thermal conductivity the heat transfer performance also increases. These fluids are nanofluid. Choi et al [7] introduced the concept of nanofluid. Nanofluid in the modern fluid. In the base fluid nanoparticles are added, because of the addition of nanoparticles thermal conductivity of the fluid increases. So, the rate of the heat transfer or heat transfer performance increased. There are several experiment research done on the nanofluids and investigate the heat transfer performance and also illustrate the effect of the different nanoparticles on the thermal conductivity and in all experimental data, volume fraction of the nanoparticles is considered as a major parameter. Volume fraction also make serious effect on the thermal conductivity of the nanofluid. Farajollahi et al. [8] evaluate the result of the heat transfer of double pipe heat exchanger by using $c\text{-Al}_2\text{O}_3/\text{water}$ and $\text{TiO}_2/\text{water}$ nanofluids on different volume concentration (0.3%, 0.5%, 0.75 %, 1%) and found out heat transfer increased by 19-56% and 18-58% $\text{Al}_2\text{O}_3/\text{water}$ and $\text{TiO}_2/\text{water}$ nanofluids as compared to distilled water, respectively.

INTRODUCTION TO TUBES:

The tube is the prominent part of the heat exchanger and the tube plays a vital role in the heat exchanger or other heat removal devices. It is specially designed to transfer the heat or cooling the fluid with low-medium viscosity. The tube is used to increase the heat transfer performance to place it inside the shell of the heat exchanger which provides a more heat transfer between the fluid flowing inside the tubes and fluid flowing inside the shell of the heat exchanger, this information is experimentally investigated by Labbadlia et al [9]. Main purpose of the tubes inside the shell is to enhance the heat transfer rate. There are so many methods to increase the heat transfer of heat exchanger for example geometry modification and fluid modification. Geometry modification is focused on modifying the geometry of the tube the rate of heat transfer will increase. The geometry modification of heat exchanger is one of the efficient ways to reduce the fouling factor, it is said by Anthony Chambon et al [10]. Nowadays the geometry modification of shell and tube in heat exchanger receive some attention because to enhance the heat transfer rate in heat exchanger in heat exchanger the fouling factor is one of common factor which reduce the heat transfer rate in heat exchanger So Yang et al. [11] and S. Eiamsa-ard et al [12] studied on fouling factor and enhance the heat transfer by adding the twisted tape in the tube to increase the turbulence flow in the tube so that the fouling will reduce and the heat transfer rate will increase and the further thermal characteristics of the round tube in which the twisted tape was fitted were studied by S. Eiamsa-ard, P. Promvong [13]

On the other hand, tube material also affects heat transfer performance, mainly these tubes are made up of copper or steel alloys which May be welded but their many numerous alloys can also be used as per their desire like titanium, aluminum, and nickel. The material of the tube depends upon their requirements. M. A. Deleaver et al [14] studied the effects of micro structural metal foam properties, such as porosity, pore and fiber diameters, pore density, and relative density, on the heat exchanger performance.

They found that by using porous material the high specific area increased because of it the heat will extract more through the

area. Because of the high thermal conductivity of aluminum, it will transfer more heat. Selecting a suitable material for a tube in cases that play an effective role in cost determination. In the study, tubes made of copper alloy, type 304 and 316 stainless steel, 6 percent molybdenum alloy, Super Ferritic and titanium. Nowadays every industry desire to enhance the efficiency of heat exchangers. An easy way to increase the heat transfer rate in any heat exchanger is by increasing the efficiency of the tube and shell in heat exchangers. This research was done by He, Z., Fang, et al [15].

Beside geometry modification, fluid also makes an impact on the rate of heat transfer. To increase the heat transfer of heat exchangers, researchers are investigating the influence of heat transfer by using different fluids. After investigation, Choi et al [16] was introduced to nanofluids. Nanofluid is a liquid which contains nanometer size particles. These nanoparticles can be metals, oxides or allotropes of carbon with thermal conductivity. Metal nanoparticles should be chemically stable for example copper, gold and silver. Metal oxide for example aluminum, silica, titania, bismuth oxide, titania and zirconia are used as nanoparticles. Choi, experimentally studied that by adding and suspending the nanoparticles in base fluid the thermal conductivity increases so heat transfer will also increase. Yang et al. [17] studied the convective heat transfer performance, to increase it they used graphite nanoparticles in aq laminar flow through circular pipe. By adding the nanoparticles, the thermal conductivity increased and Yang et al. basically found that to increasing the volume fraction of nanoparticle and Reynolds number the heat transfer increased. There are some other factors are existed which are influence to the rate of heat transfer namely shape of tube, size of tube or, surface roughness of tube. Some important factors mentioned below which are responsible for increasing the heat transfer.

DESIGN MODIFY WITH DIFFERENT TUBE GEOMETRY:

The rate of heat transfer in shell and tube heat exchanger is experimentally increased by N. Jamshidi's work. They use the Wilson plot method to calculate the heat transmitted coefficient. Mass flow rate of fluid, pitch diameter of fluid are most favorable parameters which are determined by the Taguchi method. Nusselt number, larger coil diameter and coil pitch are used to give a good result of rate of heat transfer [18]. The shell and tube heat exchanger used in food corporations, with the help of Newtonian and non-Newtonian fluids experiment of the helical tube is modified, the friction loss and convective heat is considered in this process. And the result given as an increase in the Reynolds number is that the heating process will be high as compared to the cooling process. This information is given by S. Rozzi et al [19]. R. Haseini et al [20] experimentally work on shell and tube heat exchanger by using the three tubes i.e. smooth tube, corrugated tube and micro fins tube. And Nusselt, Euler Reynolds and Prandtl number are used to declare the result by varying the shell and tube heat exchanger performance over these three tubes. The micro fin tube gives the better result than others at the higher production rate of Reynolds number and Prandtl number. Vidhya et al [21] determine the effect of insulation on the shell and tube heat exchanger. With the different loads thermal analysis is conducted on it. This investigation declared the result that requirement in the increment on heat transfer rate at below the critical thickness,

Following figures are showing the geometry of tubes with different geometrical parameters. There are three type of tubes the first one is simple tube showing in figure, second one has dents over the surface and last one has helical baffles which showing in figure 1 and figure 2 respectively :

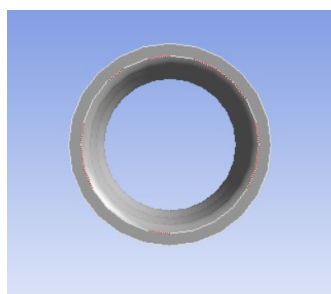
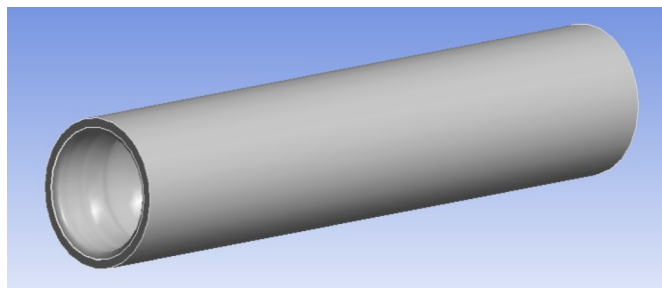


Fig. 1. 3d Modeling of Simple Tube

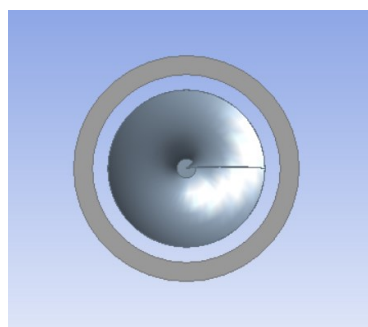
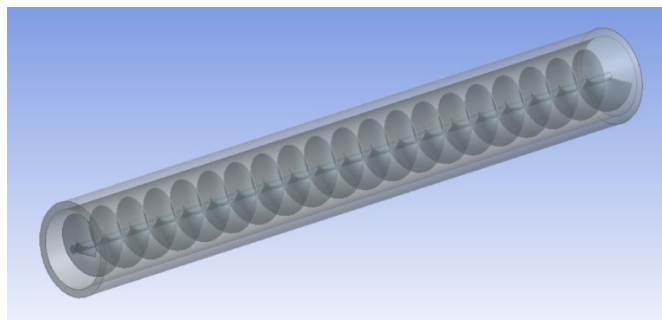


Fig 2. Helical Baffles Inserted Tube

MESHING:

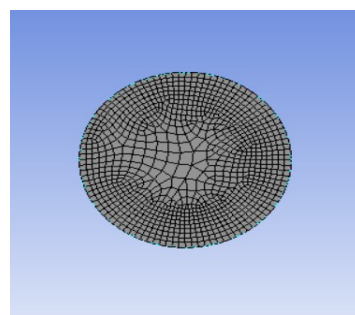
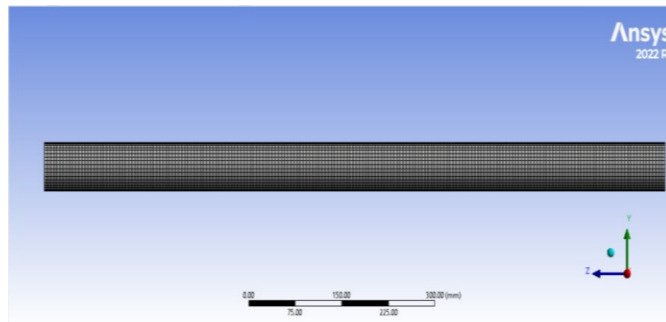


Fig 3. Meshing of Simple Tube

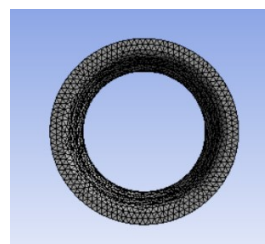
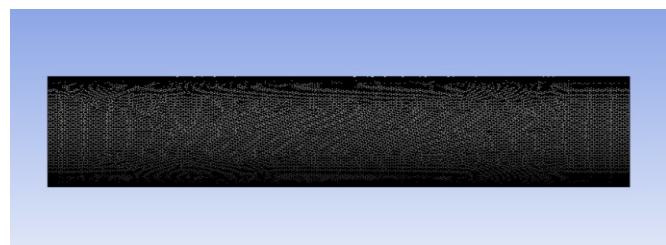


Fig. 4, Meshing Of Tubes Which Has Dents Over Surface

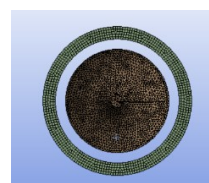
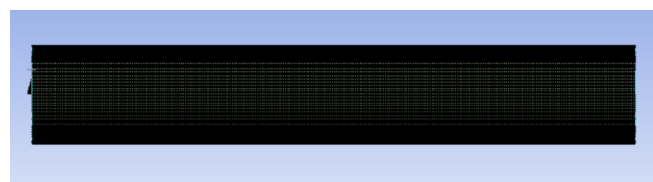


Fig 5. Meshing Of Tube Which Has Helical Baffles

OPERATING PARAMETERS:

The operating parameters of Aluminum oxide (Al₂O₃) are given in table below:

Table 3. properties of Water

Properties of Water			
Density	Specific heat	Viscosity	Thermal Conductivity
998.2	4182	0.001003	0.600

Table 4. Ethylene Glycol Property

Properties of Ethylene glycol			
Density	Specific heat	Viscosity	Thermal Conductivity
1111.4	2415	0.0157	0.252

BOUNDARY CONDITIONS:

Three sets of boundary conditions have been taken into consideration for the investigation of flat tube Heat Exchanger. The boundary conditions are shown in table 5.

Table 5. Boundary condition

Set No.	Fluid	Velocity	Inlet Temperature (°C)	Mass flow Rate Kg/s
1.	Water	2m/s-3 m/s	100-140	15.17596
2.	Ethylene Glycol	2m/s-3m/s	100-140	15.17596

SIMULATION PROCEDURE:

- To select Ansys fluent tool.
- Select geometry option and draw tube in design modular.
- Next to select meshing part and by using sizing meshing tool, meshing done on tube.
- Define inlet, outlet and wall parameter of the tube.
- Start setup of the ANSYS fluent.
- Now allow the energy equation to on and select model name.
- By using boundary conditions, table based on different temperatures, volume concentration and no fluid applied boundary conditions.
- Initialize the process using hybrid initialization.
- Calculate the simulation result by using simulation option.
- After completing the simulation, in report menu, select surface integral menu and compute outlet temperature of the tube.
- Same in report menu, select flux menu to calculate mass flow rate.
- Transfer the data in excel sheet and calculate results of heat transfer.

RESULT AND DISCUSSION

In this investigation, the counter flow configuration of tubes has been taken into consideration and different materials and fluids selected.

HEAT TRANSFER RATE:

The rate of heat transfer determines the heat transfer performance in the Simple tube, tube with dents and tube with helical baffles. It has been evaluated by using following equation:

$$Q = m \cdot c_p \cdot (T_{in} - T_{out})$$

HEAT TRANSFER IN SIMPLE TUBE WITH FLOWING WATER INSIDE THE TUBE:

The rate of heat transfer is measured by using ansys fluent tool. Following tables shows the heat transfer on 100 deg. Celcius temperature. But the velocity of the flowing fluid is varied from 2-3 m/s. The specific heat at 100 deg. Temperature is found out that is given in the tables.

Table 6. Rate of heat transfer of water in simple tube at 100 deg. Temperature

V	Ti	To	M	cp	Q
2	100	97.63205	15.66937	4.2157	156.4205
2.5	100	97.82517	19.58672	4.2157	179.5795
3	100	97.98056	23.50406	4.2157	200.0984

Table 7. Rate of heat transfer of water in simple tube at 120 deg. Temperature

Ti	To	M	cp	Q
120	117.0401	15.66937	4.2435	196.8125
120	117.2815	19.58665	4.2435	225.9507
120	117.4757	23.50406	4.2435	251.7724

Table 8. Rate of heat transfer of water in simple tube at 140 deg. Temperature

V	Ti	To	M	cp	Q
2	140	136.4481	15.66937	4.2826	238.3525
2.5	140	136.7378	19.58672	4.2826	273.6401
3	140	136.9708	23.50406	4.2826	304.9147

HEAT TRANSFER IN TUBE WHICH HAS DENTS OVER THE SURFACE:

Similar, the rate of heat transfer is found out on different temprature and velocity. But in this case the dents are placed over the surafce of the tube. Due to dents the roughness of the tube surface is increased , cause of it the rate of heat trasnfer is increased which are showing in following tables.

Table 9. Rate of Heat transfer of water in tube at 100 deg. Temperature

V	Ti	To	m	cp	Q
2	100	97.50105	15.66937	4.2157	165.074
2.5	100	97.72517	19.58672	4.2157	187.8367
3	100	97.88056	23.50406	4.2157	210.007

Table 10. Rate of Heat transfer of water in tube at 120 deg. Temperature

V	Ti	To	m	cp	Q
2	120	116.8921	15.66937	4.2435	206.653
2.5	120	117.1456	19.58665	4.2435	237.248
3	120	117.3495	23.50406	4.2435	264.36

Table 11. Rate of Heat transfer of water in tube at 140 deg. Temperature

V	Ti	To	m	cp	Q
2	140	136.2705	15.66937	4.2826	250.2702
2.5	140	136.5747	19.58672	4.2826	287.3222
3	140	136.8193	23.50406	4.2826	320.1604

HEAT TRANSFER IN TUBE WHICH HAS HELICAL BAFFLES:
Helical baffles are also affected to the heat transfer of the tube. It can be easily identified by analyzing the given data in following tables. By adding helical baffles, the rate of heat transfer increased by 10 % as compared to the simple tube.

Table 12. Rate of Heat transfer of water in tube (helical baffles) at 100 deg. Temperature

V	Ti	To	m	cp	Q
2	100	97.39526	15.66937	4.2157	172.0626
2.5	100	97.60769	19.58672	4.2157	197.5374
3	100	97.77862	23.50406	4.2157	220.1082

Table 13. Rate of Heat transfer of water in tube (helical baffles) at 120 deg. Temperature

V	Ti	To	m	cp	Q
2	120	116.5813	15.66937	4.2435	227.3185
2.5	120	116.8601	19.58665	4.2435	260.9731
3	120	117.0844	23.50406	4.2435	290.7971

Table 14. Rate of Heat transfer of water in tube (helical baffles) at 140 deg. Temperature

V	Ti	To	m	cp	Q
2	140	136.0929	15.66937	4.2826	262.1878
2.5	140	136.4116	19.58672	4.2826	301.0042
3	140	136.6679	23.50406	4.2826	335.4062

HEAT TRANSFER IN SIMPLE TUBE WITH FLOWING ETHYLENE GLYCOL INSIDE THE TUBE:

The rate of heat trasnfer calculate of the Ethylene Glycol also to flowing this fluid in all different geometrical modified tubes. On different temprature, different velocity the rate of heat trasnfer calculated.

Table 15. Rate of Heat transfer of Ethylene Glycol in tube at 100 deg. Temperature.

V	Ti	To	m	cp	Q
2	100	98.11756	17.44637	2.433	79.90396
2.5	100	98.20725	21.80793	2.433	95.12097
3	100	98.26703	26.16909	2.433	110.3372

Table 16. Rate of Heat transfer of Ethylene Glycol in tube at 120 deg. Temperature.

V	Ti	To	m	cp	Q
2	120	117.897	17.44617	2.4608	90.28502
2.5	120	118.0091	21.80793	2.4608	106.8416
3	120	118.0838	26.16909	2.4608	123.3973

Table 17. Rate of Heat transfer of Ethylene Glycol in tube at 140 deg. Temperature.

V	Ti	To	m	cp	Q
2	140	137.6765	17.44637	2.4999	101.3375
2.5	140	137.811	21.80793	2.4999	119.3391
3	140	137.9006	26.16909	2.4999	137.343

HEAT TRANSFER IN TUBE WHICH HAS DENTS OVER THE SURFACE:

Similarly, in case of heat transfer of water, the rate of heat transfer also increased as compare to the simple tubes.

Table 18. Rate of Heat transfer of water in tube at 100 deg. Temperature.

V	Ti	To	m	cp	Q
2	100	98.02344	17.44637	2.433	83.89916
2.5	100	98.11761	21.80793	2.433	99.87702
3	100	98.18038	26.16909	2.433	115.854

Table 19. Rate of Heat transfer of water in tube at 120 deg. Temperature.

V	Ti	To	m	cp	Q
2	120	117.7919	17.44617	2.4608	94.79927
2.5	120	117.9096	21.80793	2.4608	112.1836
3	120	117.988	26.16909	2.4608	129.5672

Table 20. Rate of Heat transfer of water in tube at 140 deg. Temperature.

V	Ti	To	m	cp	Q
2	140	137.5603	17.44637	2.4999	106.4044
2.5	140	137.7016	21.80793	2.4999	125.3061
3	140	137.7956	26.16909	2.4999	144.2101

HEAT TRANSFER IN TUBE WHICH HAS HELICAL BAFFLES:

In helical baffles the heat transfer performance of tube is increased as compared to the other geometry of the tubes.

Table 21. Rate of Heat transfer of Ethylene Glycol in tube (helical baffles) at 100 deg. Temperature.

V	Ti	To	m	cp	Q
2	100	97.82578	17.44637	2.433	92.28908
2.5	100	97.92937	21.80793	2.433	109.8647
3	100	97.99842	26.16909	2.433	127.4394

Table 22. Rate of Heat transfer of Ethylene Glycol in tube (helical baffles) at 120 deg. Temperature.

V	Ti	To	m	cp	Q
2	120	117.571	17.44617	2.4608	104.2792
2.5	120	117.7005	21.80793	2.4608	123.402
3	120	117.7868	26.16909	2.4608	142.5239

Table 23. Rate of Heat transfer of Ethylene Glycol in tube (helical baffles) at 140 deg. Temperature.

V	Ti	To	m	cp	Q
2	140	137.4442	17.44637	2.4999	111.4713
2.5	140	137.5921	21.80793	2.4999	131.273
3	140	137.6907	26.16909	2.4999	151.0773

GRAPH OF HEAT TRANSFER OF WATER IN ALL GEOMETRIES OF TUBE:

By analyzing the data of all tables of the heat transfer of the water and Ethylene Glycol to flowing inside the different modified tubes, the graphs are generated.

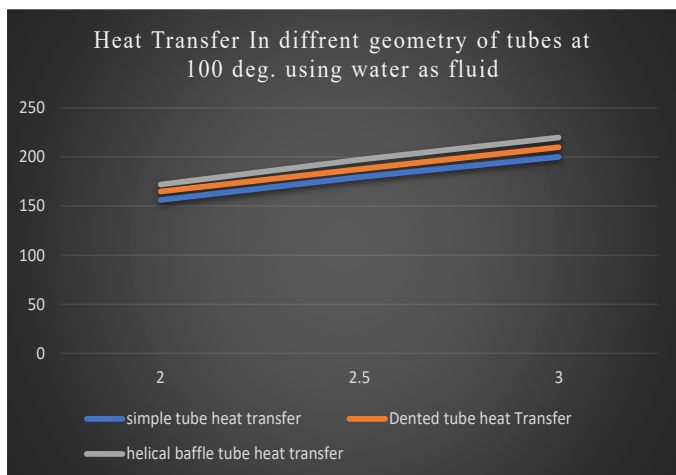


Fig. 6 Graph of Heat transfer in all tubes at 100 deg. Temperature.

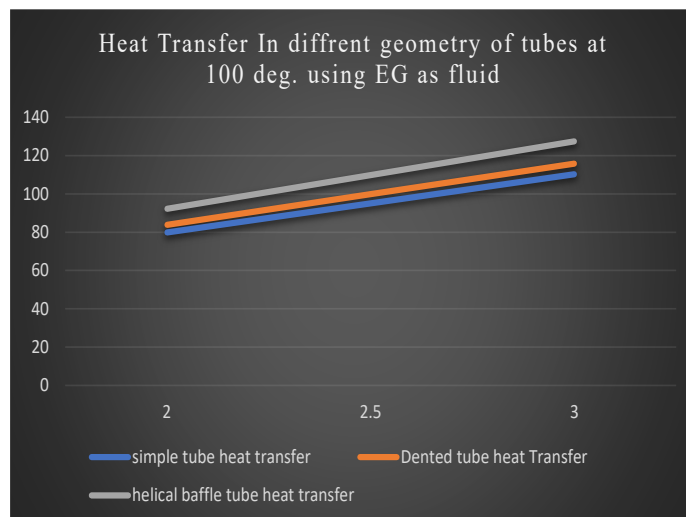


Fig. 9 Graph of Heat transfer in all tubes at 100 deg. Temperature

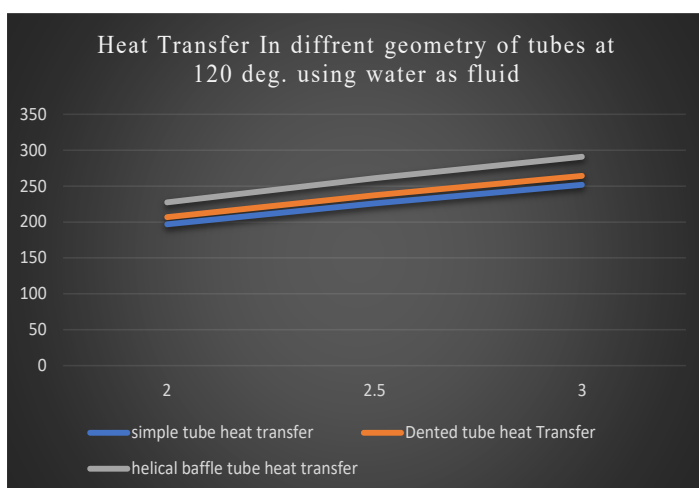


Fig. 7 Graph of Heat transfer in all tubes at 120 deg. Temperature.

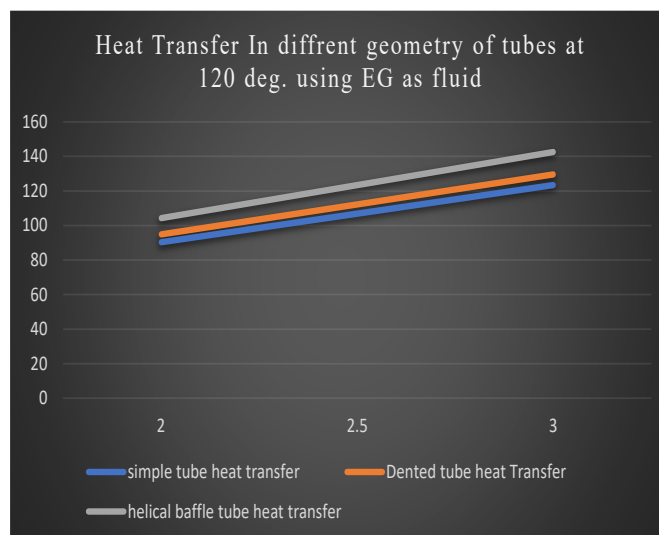


Fig. 10 Graph of Heat transfer in all tubes at 120 deg. Temperature

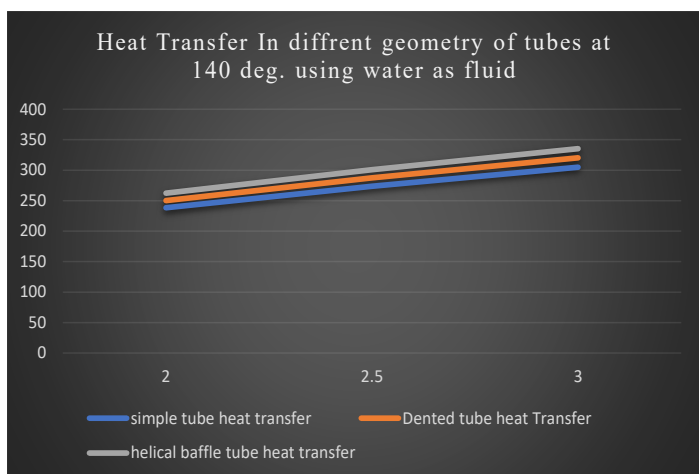


Fig. 8 Graph of Heat transfer in all tubes at 140 deg. Temperature

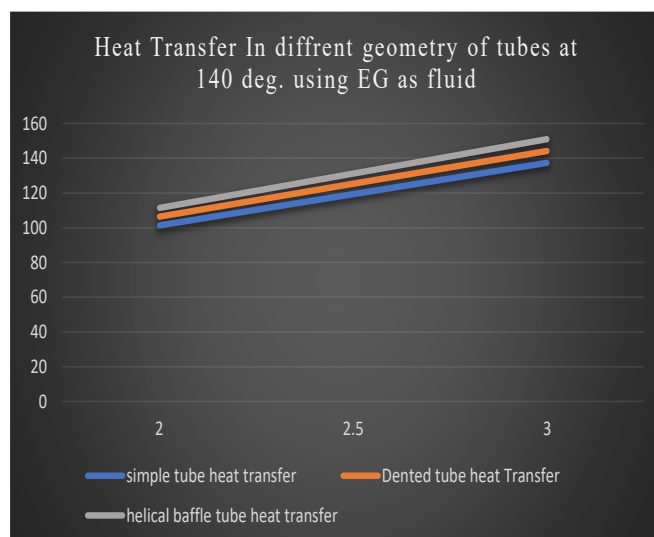


Fig. 11 Graph of Heat transfer in all tubes at 140 deg. Temperature

GRAPH OF HEAT TRANSFER OF EG IN ALL GEOMETRIES OF TUBE:

Similarly, water, the graphs of heat transfer of Ethylene Glycol are also draw, which are following given:

