Numerical Study of Corrugation on Performance of Double Pipe Heat Exchanger

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ABSTRACT:- *The conversion, utilization and recovery of energy in every industrial, commercial and domestic application involve a heat exchange process. Some common examples are steam generation and condensation in power and co-generation plants, sensible heating and cooling of viscous media in thermal processing of chemical, pharmaceutical, and agricultural products, refrigerant evaporation and condensation in air conditioning and refrigeration, gas flow heating in manufacturing and waste heat recovery, air and liquid cooling of engine and turbo- machinery systems, and cooling of electrical machines and electronics devices. Improved heat exchange, over and above that in the usual or standard practice, can significantly improve the thermal efficiency in such applications as well as the economics of their design and operation.*

Double pipe heat exchanger (DPHE) or concentric tube heat exchanger is one of the most simple and applicable heat exchanger. This kind of heat exchanger is widely used in chemical, food, oil and gas industries. DPHE having a relatively small diameter and it is easy to fabricate as compared to helical tube, corrugated tube and many more compact types of heat exchanger. Common methods used by the researchers to enhance the heat flow rate are: Active method, Passive method and Compound method. And present work is based on passive method. In the present work numerical study is carried out on DPHE in which hot water is flowing through inner tube where as cold water is flowing through the annulus and hot water to cold water heat exchange is taken into consideration for three different arrangements of DPHE.

i. Plain double pipe heat exchanger

ii. Externally corrugation on inner pipe of heat exchanger

iii. Internally corrugation on inner pipe of heat exchanger

During the study cold water flow rate is kept constant at 50LPH where as hot water flow rate varies from 100LPH to300LPH and comparative study between all the cases has been carried out to know the effect of corrugation on outer and inner surface of inner tube.

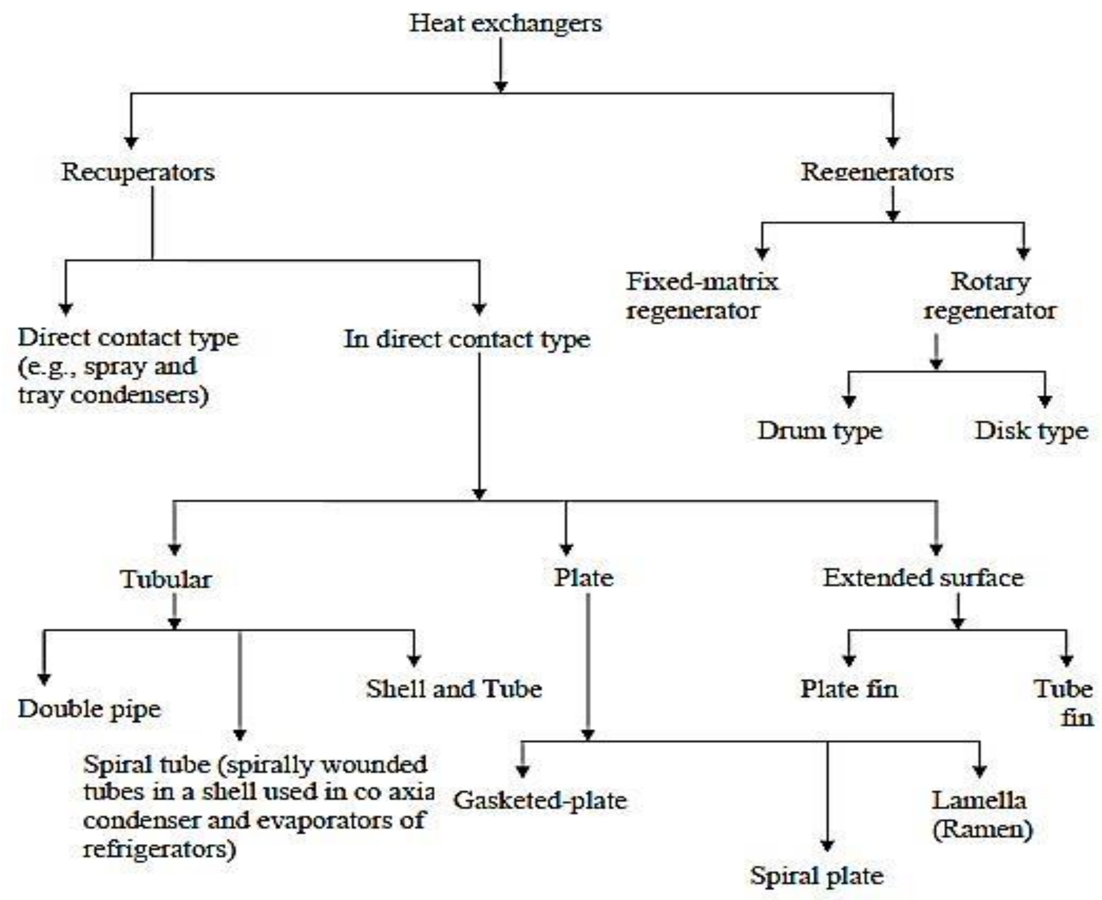
Keywords: Corrugation, Effectiveness, Capacity Ratio, Number of transfer units, Heat transfer coefficient, Heat transfer rate.

INTRODUCTION

1. INTRODUCTION:-The conversion, utilization and recovery of energy in every industrial, commercial and domestic application involve a heat exchange process. Some common examples are steam generation and condensation in power and co-generation plants; sensible heating and cooling of viscous media in thermal processing of chemical, pharmaceutical, and agricultural products, Refrigerant evaporation and condensation in air conditioning and refrigeration, gas flow heating in manufacturing and waste heat recovery, air and liquid cooling of engine and turbo- machinery systems, and cooling of electrical machines and electronics devices. Improved heat exchange, over and above that in the usual or standard practice, can significantly improve the thermal efficiency in such applications as well as the economics of their design and operation.

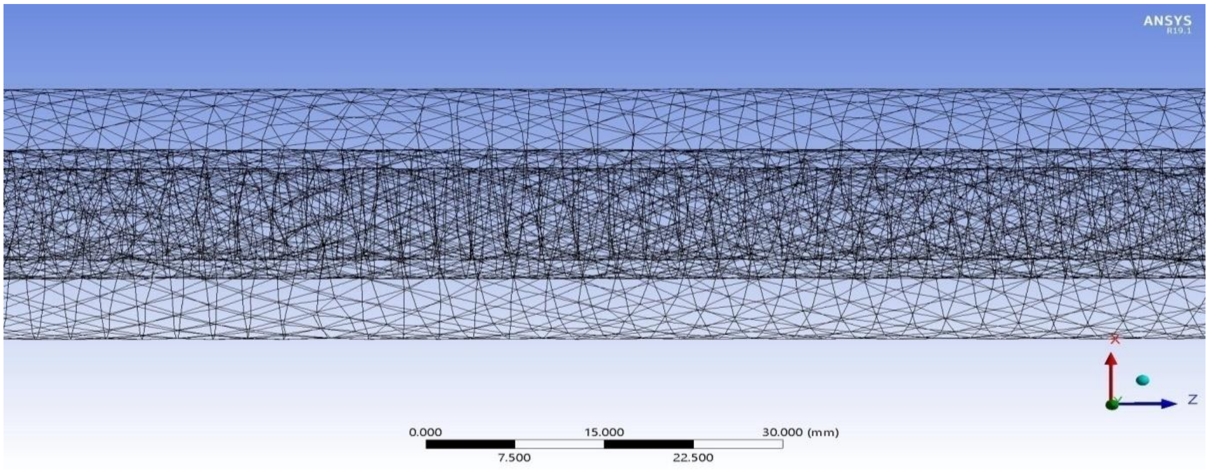
1.1 Heat Exchanger: Heat exchanger is a device that facilitates the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with each other. Heat exchangers differ from mixing chambers in that they do not allow the two fluids involved to mix. Common examples of heat exchangers are shell-and tube exchangers, automobile radiators, condensers, evaporators, air pre-heaters, and cooling towers.

1.2 Classification of Heat Exchangers:-

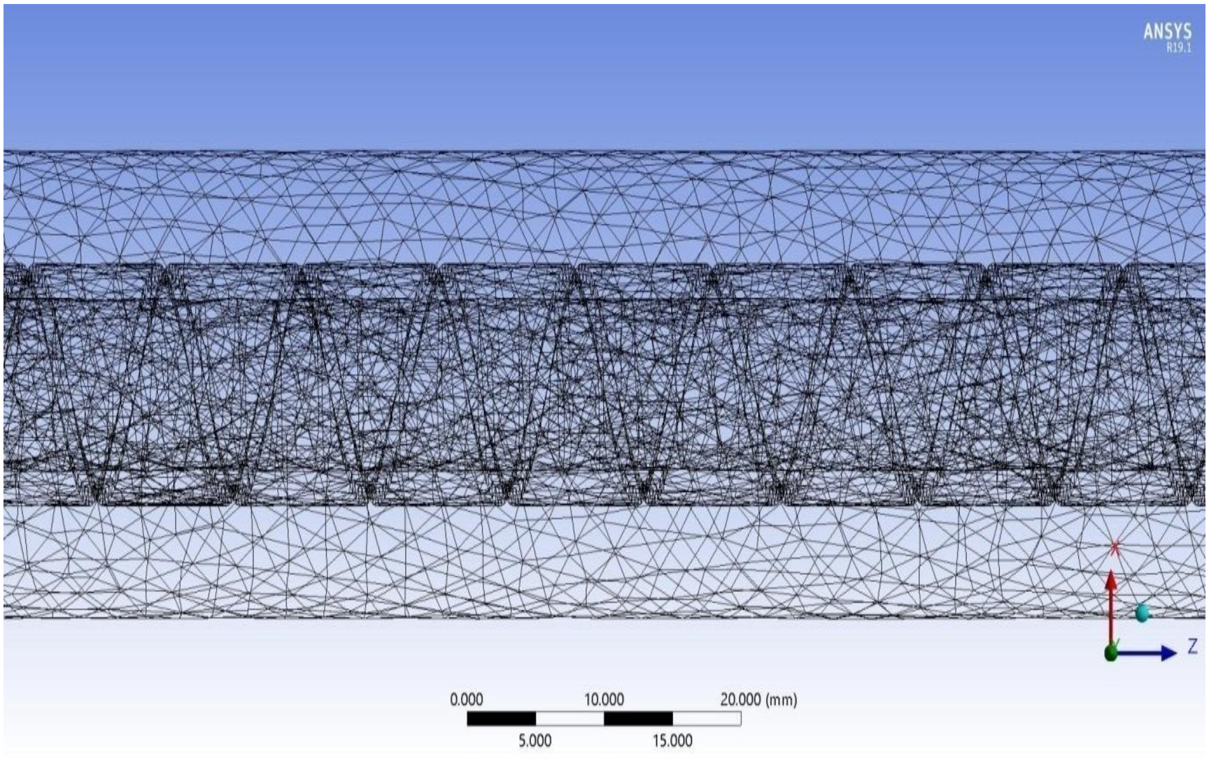


SIMULATION RESULT

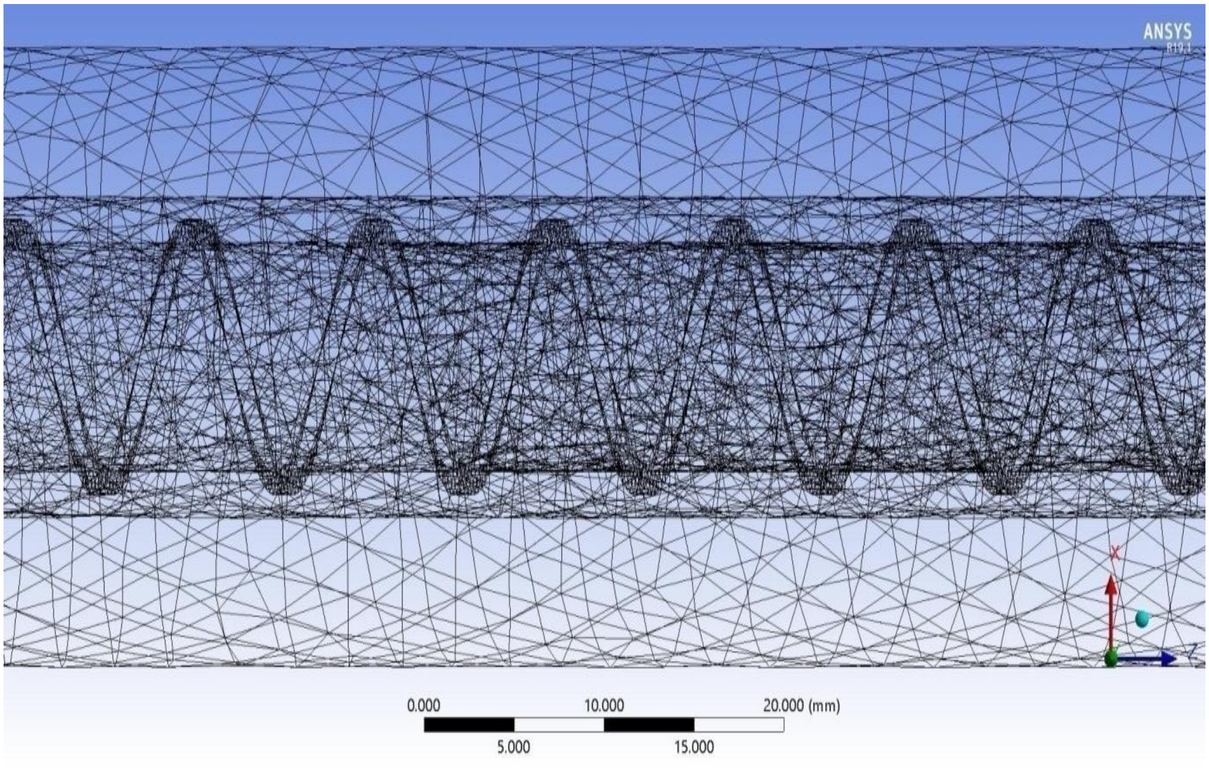
Meshing



Mesh Domain of Plain Tube

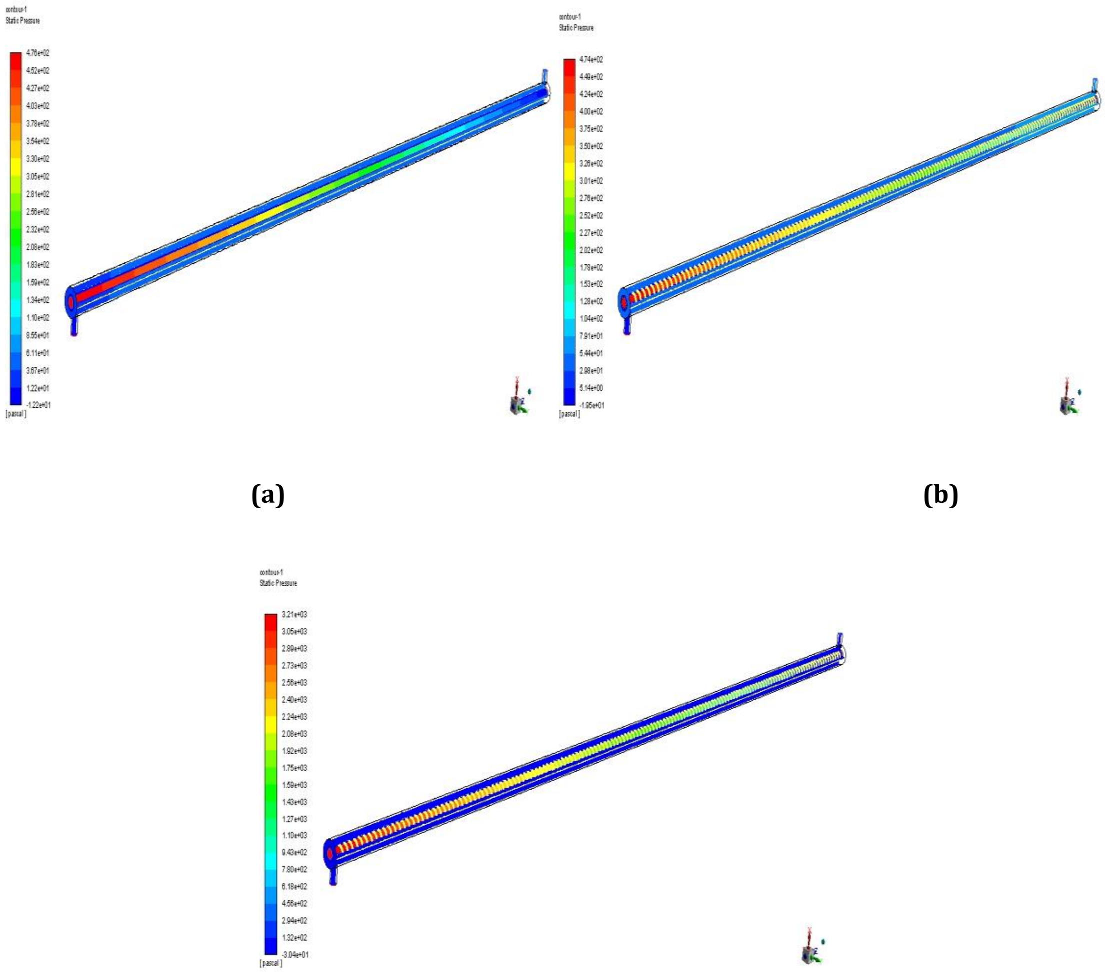


Mesh Domain of Outer corrugated Tube



Mesh Domain of Inner corrugated Tube

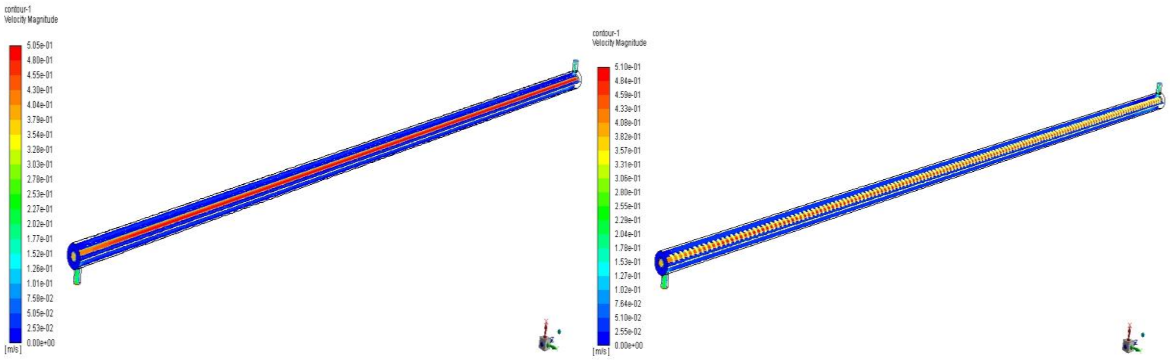
Numerical Result



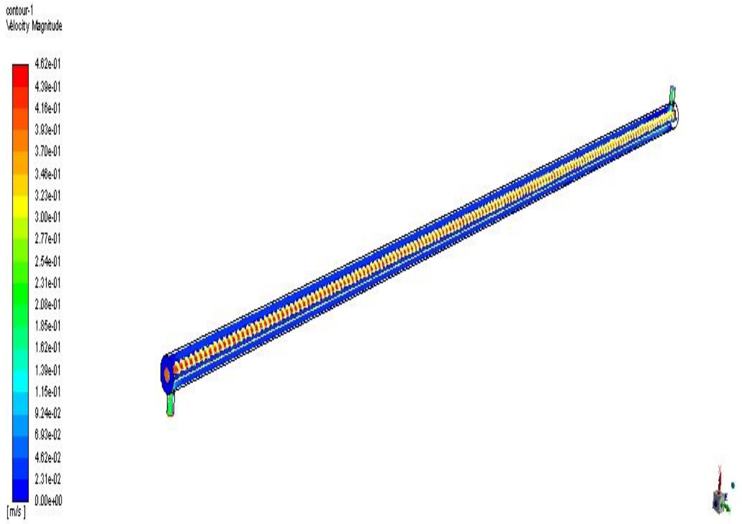
(a) **(b)**

Figure 4.5 Comparison of pressure at 4000 Reynold's Number for all the three cases.

At 4000 Reynold's number Figure (a) shows pressure profile for plain tube whereas Figure (b) shows pressure profile for outer corrugated copper tube and, Figure (c) shows pressure for inner corrugated copper tube.



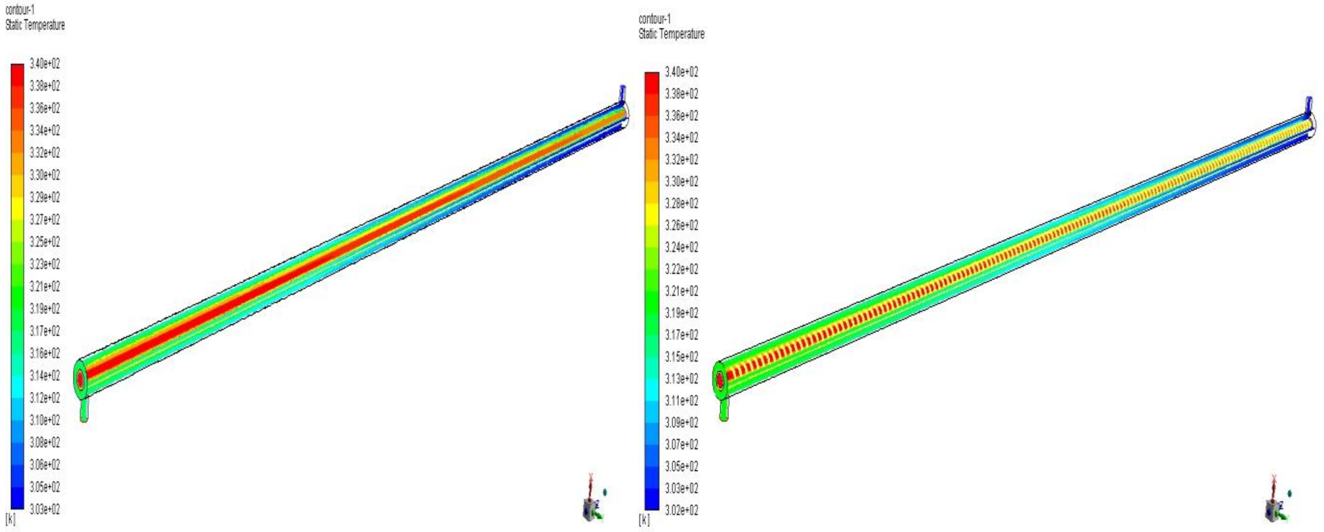
(a) **(b)**



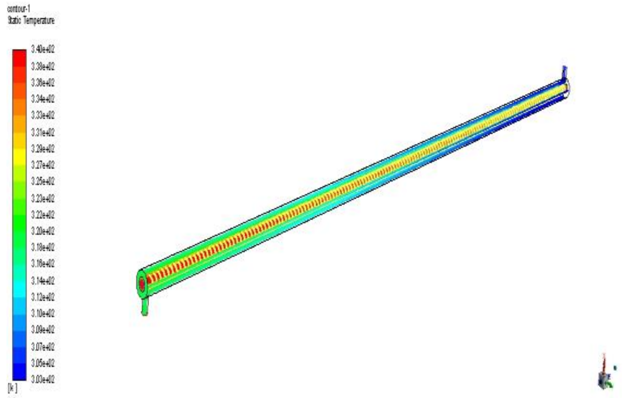
(c)

Figure shows comparison of velocity at 4000 Reynold's Number for all the three cases.

At 4000 Reynold's number Figure (a) shows velocity profile for plain tube whereas Figure (b) shows velocity profile for outer corrugated copper tube and, Figure (c) shows velocity for inner corrugated copper tube.



(a) **(b)**



(c)

Figure showing comparison of temperature at 4000 Reynold's Number for all the three cases.

At 4000 Reynold's number Figure (a) shows temperature profile for plain tube whereas Figure (b) shows temperature profile for outer corrugated copper tube and, Figure (c) shows temperature profile for inner corrugated copper tube.

RESULTS AND DISCUSSION

In this part results obtained from the numerical study for effectiveness, Logarithmic mean temperature difference, overall heat transfer coefficient and heat flow rate is discussed. When cold fluid flow rate is kept constant at 50LPH and hot fluid flow rate varies from 100LPH to 300LPH.

Type of tube material used and dimensions are as shown in Table-1 below:-

Table 1 Details of numerical model:-

Tube	Material	Inner diameter(mm)	Outer diameter(mm)	Length(mm)
Inner tube	Copper	10	14	1500
Outer tube	Steel	27	-----	1500

Table 2 Details of Meshing:-

S. No.	**Plain Tube**		**Inner Corrugated**		**Outer Corrugated**	
	Node	**Element**	**Node**	**Element**	**Node**	**Element**
1	52349	196726	191042	665425	150762	546763
3	52349	196726	191042	665425	150762	546763
4	52349	196726	191042	665425	150762	546763
5	52349	196726	191042	665425	150762	546763
2	52349	196726	191042	665425	150762	546763

Table: 3. Plain Copper Tube Heat Exchanger When Cold Water is Fixed at 50 LPH

In counter flow:- Observation table

S.No.	Vol. flow Rate of Hot Water (LPH)	T_{hot}(inlet) (° K)	T_{hot} (Outlet) (° K)	T_{cold}(inlet) (°K)	T_{cold} (Outlet) (°K)	Average Surface temp of inner tube (°K)
1.	100	339.65	332.5648	303.15	317.1223	327.731
2.	150	339.65	335.5116	303.15	319.4741	332.1461
3.	200	339.65	336.7136	303.15	320.5182	334.0574
4.	250	339.65	337.3703	303.15	321.1163	335.1706
5.	300	339.65	337.7903	303.15	321.485	335.9108

Table: 4. Outer Corrugated Copper Tube Heat Exchanger When Cold Water is Fixed at 50 LPH

In counter flow:- Observation table

S.No.	Vol. flow Rate of Hot Water (LPH)	T_{hot}(inlet) (° K)	T_{hot} (Outlet) (° K)	T_{cold}(inlet) (°K)	T_{cold} (Outlet) (°K)	Average Surface temp of inner tube (°K)
1.	100	339.65	331.5328	303.15	319.5849	325.8458
2.	150	339.65	334.8031	303.15	322.7515	330.7454
3.	200	339.65	336.183	303.15	324.1655	332.9949
4.	250	339.65	336.9497	303.15	324.9713	334.2977
5.	300	339.65	337.4375	303.15	325.4969	335.1532

Table: 5. Inner Corrugated Copper Tube Heat Exchanger When Cold Water is Fixed at 50 LPH

In counter flow:- Observation table

S.No.	Vol. flow Rate of Hot Water (LPH)	T_{hot}(inlet) (° K)	T_{hot} (Outlet) (° K)	T_{cold}(inlet) (°K)	T_{cold} (Outlet) (°K)	Average Surface temp of inner tube (°K)
1.	100	339.65	331.6426	303.15	318.9587	327.9557
2.	150	339.65	335.1445	303.15	321.0253	331.5448
3.	200	339.65	336.4609	303.15	322.1425	333.486
4.	250	339.65	337.1753	303.15	322.8088	334.6659
5.	300	339.65	337.6267	303.15	323.245	335.4483

Table 6: Results of Plain copper Tube

S.No	Vol. flow Rate of Hot Water (LPH)	Reynolds Number	Nusselt Number	Friction Factor	Effectiveness (ϵ)	Overall heat Transfer Coefficient (U)	Heat gain by cold fluid (Qc)	Heat lost by hot fluid (Qh)
1.	100	4000	38.67006	0.009928	0.385516	788.359144	902.589	915.3862
2.	150	8000	69.6253	0.008161	0.450379	906.124797	1054.51	1069.338
3.	200	12000	97.6463	0.007219	0.479268	960.168548	1121.95	1138.122
4.	250	16000	124.8331	0.006699	0.495943	992.022691	1160.59	1178.121
5.	300	20000	151.3168	0.006352	0.505917	1010.59219	1184.41	1201.338

Table 7: Results of Outer Corrugated copper Tube

S. No	Vol. flow Rate of Hot Water (LPH)	Reynolds Number	Nusselt Number	Friction Factor	Effectiveness (ϵ)	Overall heat Transfer Coefficient (U)	Heat gain by cold fluid (Qc)	Heat lost by hot fluid (Qh)
1.	100	4000	38.07832	0.00987	0.447524	1019.0163	1061.6	1048.71
2.	150	8000	68.37891	0.00807	0.534097	1211.8502	1266.2	1252.41
3.	200	12000	96.61596	0.00725	0.572842	1301.27035	1357.5	1343.77
4.	250	16000	123.384	0.00677	0.594845	1353.05462	1409.6	1395.48
5.	300	20000	149.1637	0.00641	0.609204	1387.50799	1443.5	1429.24

Table 8: Results of Inner Corrugated copper Tube

S. No	Vol. flow Rate of Hot Water (LPH)	Reynolds Number	Nusselt Number	Friction Factor	Effectiveness (ϵ)	Overall heat Transfer Coefficient (U)	Heat gain by cold fluid (Qc)	Heat lost by hot fluid (Qh)
1.	100	4000	47.60049	0.01910	0.435938	968.534147	1034.5	1021.21
2.	150	8000	70.39073	0.01657	0.491743	1044.66991	1164.1	1154.71
3.	200	12000	95.72064	0.01636	0.522289	1103.0112	1236.0	1226.88
4.	250	16000	120.7836	0.01604	0.540498	1139.84838	1278.8	1269.92
5.	300	20000	144.9816	0.01594	0.552438	1164.50641	1307.0	1298.10

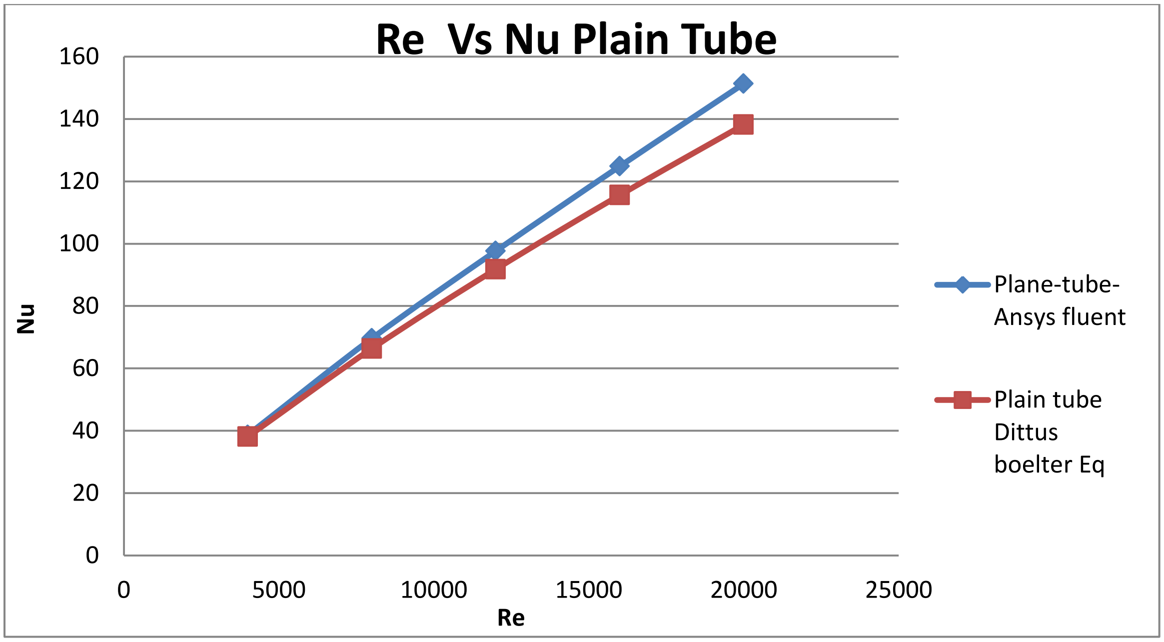


Fig 5.1 : Graph shows model validation of Reynolds Vs Nusselt number

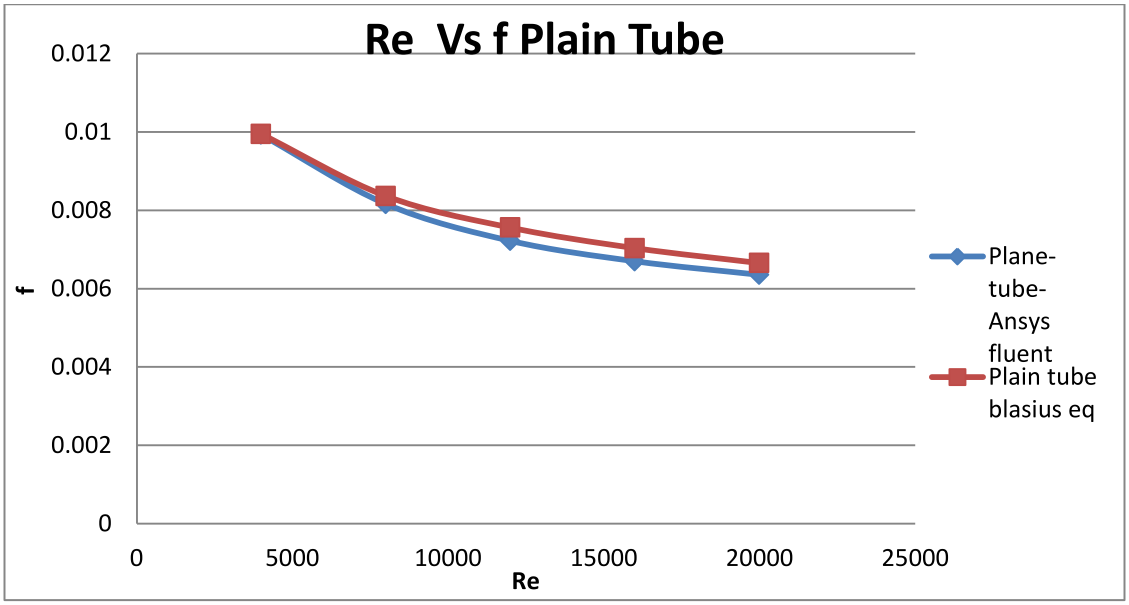


Fig 5.2: Graph shows model validation of Reynolds Vs Friction Factor

To validate the accuracy of the heat transfer system, Nusselt number and friction factor of the plain tube in numerical study are compared with theoretical values as shown in Fig 5.1. The values of Nusselt number and friction factor in the numerical study of plain tube are respectively compared with Dittus-Boelter equation and Blasius equation as shown in Fig.5.2.

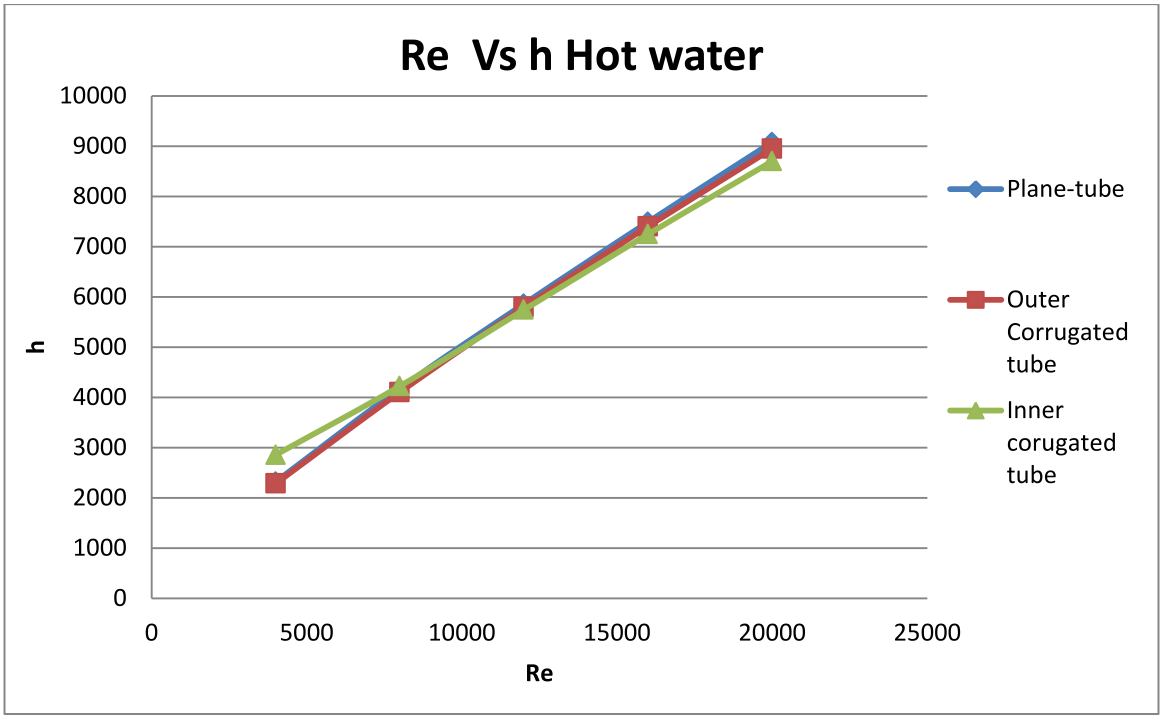


Fig. 5.3: Graph shows Re Vs h for plain, internally corrugated and externally corrugated copper tube.

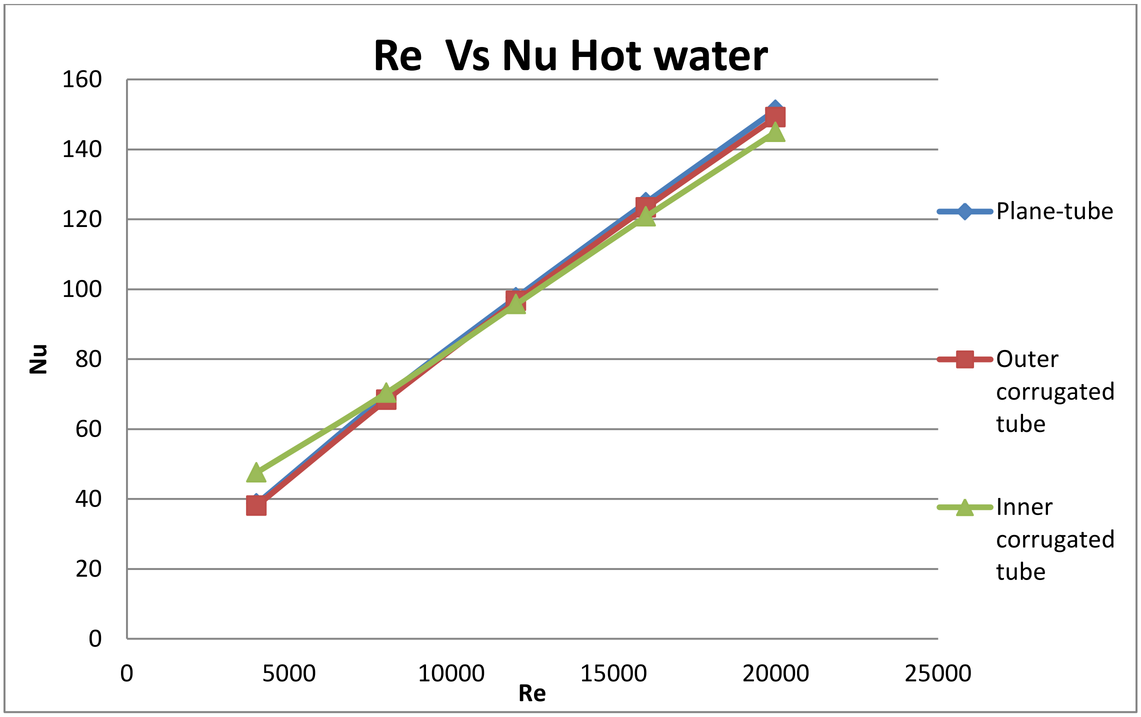


Fig. 5.4: Graph shows Re Vs Nu for plain, internally corrugated and externally corrugated copper tube.

Variations of Nusselt number with Reynolds number are shown in figure 5.4. As seen from the figure, Nusselt number increases as Reynolds number increases. This is primarily attributed to the increase of turbulent intensity as Reynolds number increases, leading to an amplification of convective heat transfer. At low Reynolds number Nusselt number of internally corrugated tube is higher as compared to externally corrugated tube and plain tube but at high Reynolds number it is lesser than the other two tubes.

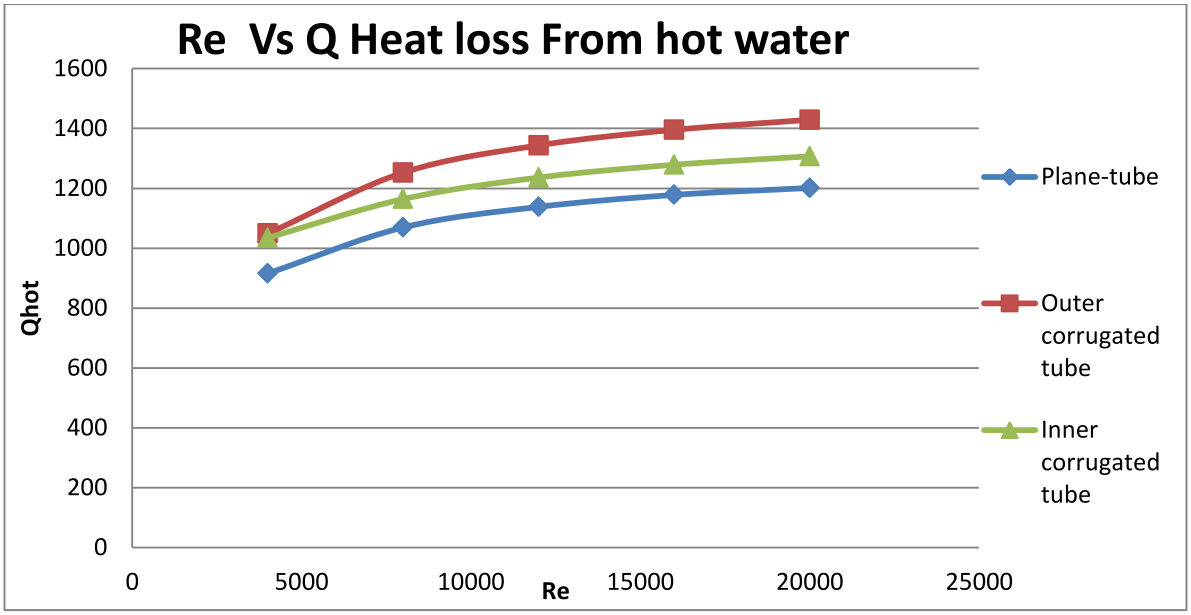


Fig. 5.5: Graph shows Re Vs Q for plain, internally corrugated and externally corrugated copper tube.

Variation of heat transfer rate with Q Reynolds number are shown in figure 5.5 and it is observed that for all the cases heat transfer rate increases as Reynolds number increases and it is maximum in outer corrugated tube for all values of Reynolds number. Variation of h with Reynold number are as shown in Fig 5.3. As seen from the figure h increases as Re increases. At low Reynold.no h of internally corrugated tube is higher as compared to externally corrugated tube and plain tube but at high Reynold number it is lesser than the other two.

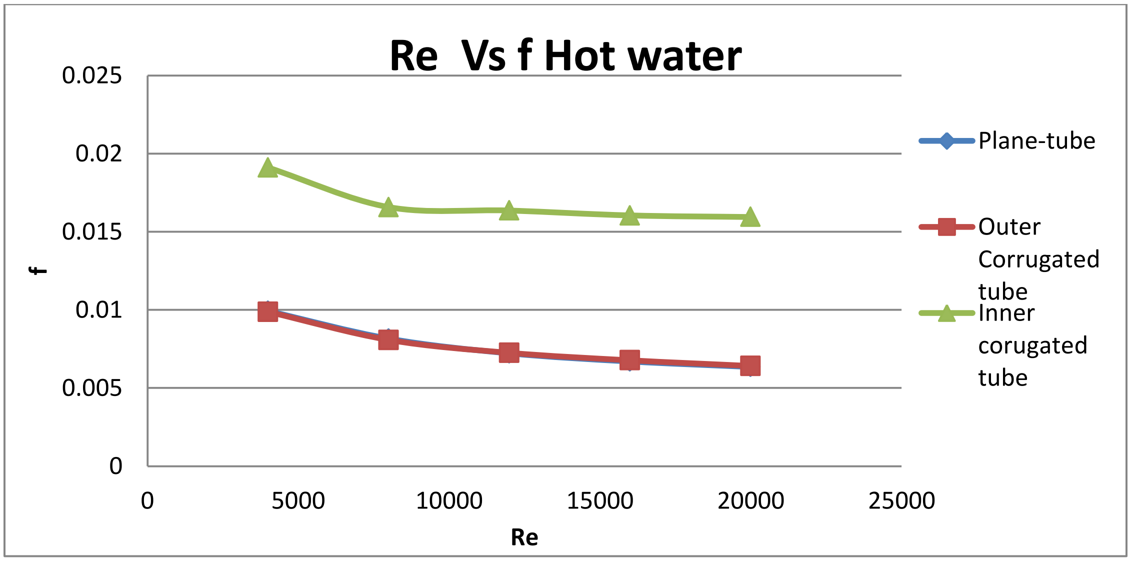


Fig. 5.6: Graph shows Re Vs f for plain, internally corrugated and externally corrugated copper tube.

Variations of friction factors with Reynolds number are shown in figure 5.6 above. As seen from the figure, friction factors decreases as Reynolds number increases for all the cases. Friction factors for the internally corrugated tube are higher than the externally corrugated tube and plain tube due to surface roughness.

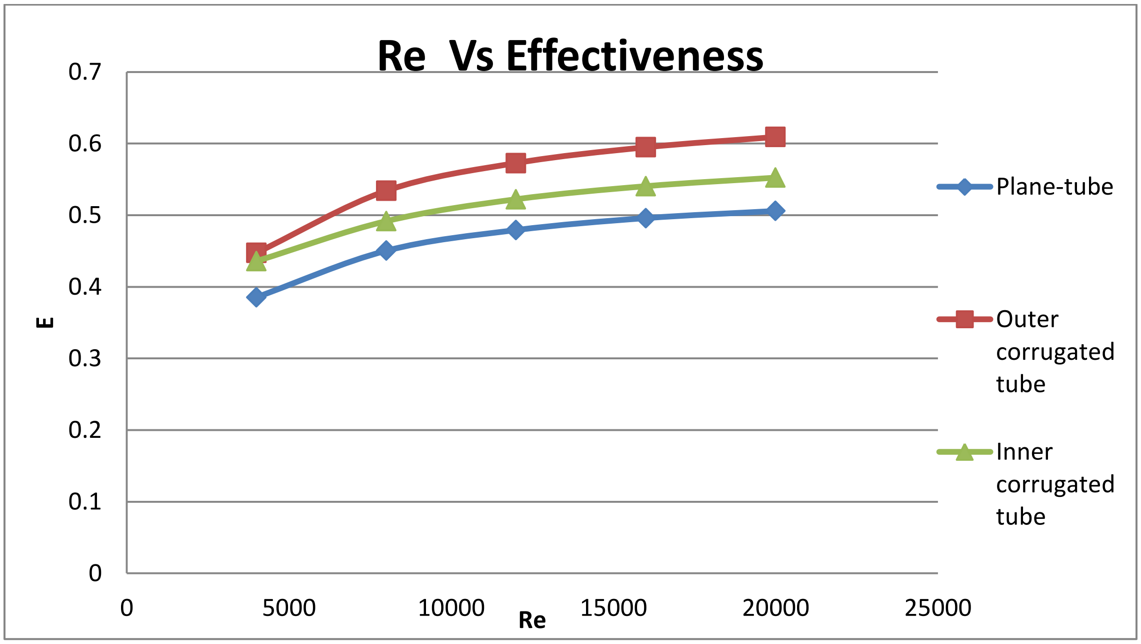


Fig. 5.7: Graph shows Re Vs Effectiveness for plain, internally corrugated and externally corrugated copper tube

Variations of effectiveness with Reynolds number are shown in figure 5.7 above. As seen from the figure, effectiveness increases as Reynolds number increases for all the cases. Effectiveness for the externally corrugated tube is higher than the internally corrugated tube and plain tube.

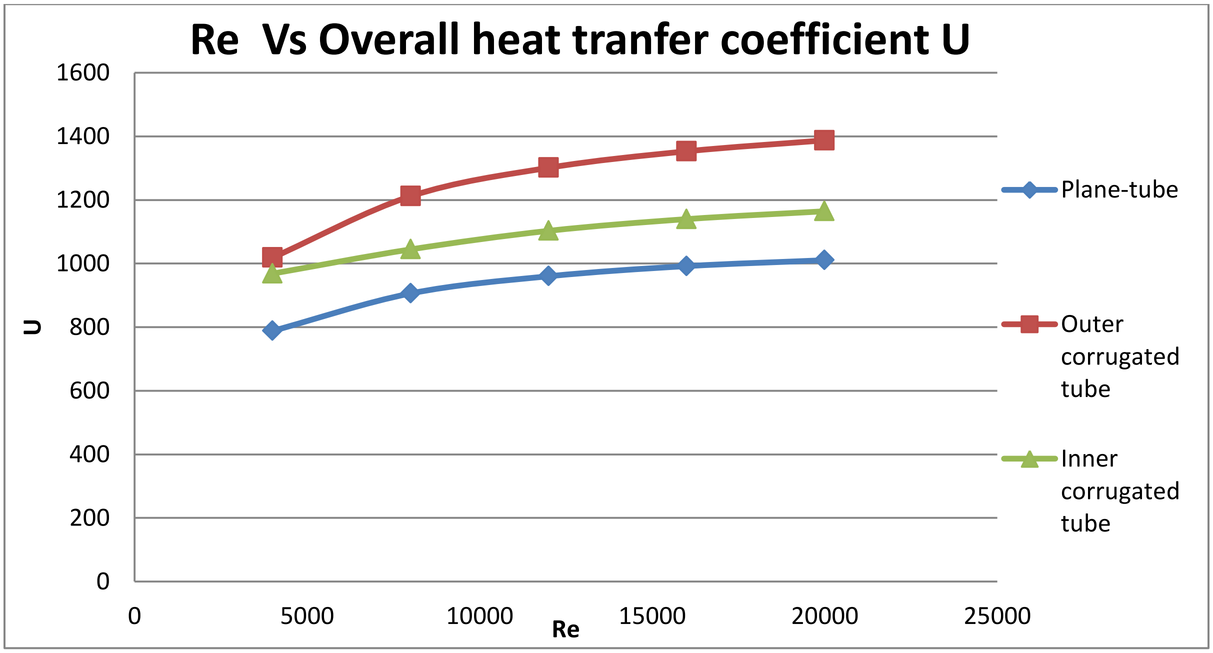


Fig. 5.8: Graph shows Re Vs overall heat transfer coefficient for plain, internally corrugated and externally corrugated copper tube

Variations of overall heat transfer coefficient with Reynolds number are shown in figure 5.8 above. As seen from the figure, overall heat transfer coefficient increases as Reynolds number increases for all the cases. Overall heat transfer coefficient for the externally corrugated tube is higher than the internally corrugated tube and plain tube.

CONCLUSIONS

Numerical study on characteristics of heat transfer and friction in double pipe heat exchanger for single phase forced convective flow with internally and externally corrugation have been carried out and the following conclusion has been drawn based on the above study.

- Internally corrugated tube is more effective as compared to externally corrugated tube and plain tube at low Reynolds number.
- At high Reynolds number externally corrugated tube is more effective than the plain tube and internally corrugated tube.
- Friction factor in case of internally corrugated tube is much larger than the other two tubes for all values of Reynolds number.
- Heat transfer rate, effectiveness and overall heat transfer coefficient of externally corrugated tube is higher than the other two tubes at all values of Reynolds number.

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