EPH - International Journal Of Science And Engineering
ISSN (Online): 2454 2016
Volume 03 Issue 03 September 2017

DOI: https://doi.org/10.53555/eijse.v3i3.95

SIMULATION STUDY OF FINNED DOUBLE PIPE HEAT EXCHANGER

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Abstract:-
Double pipe heat exchangers are extensively used in process industries. Increasing the surface area of heat exchanger results in enhanced heat transfer. In the current study double pipe heat exchanger was simulated using ANSYS Fluent simulator program. The fins were added to the outer surface of the inner pipe and the geometries studied were, rectangular, triangular and leaf shaped. Water outlet temperature of the heat exchanger was studied with mass flow rates of 0.20 kg/s, 0.24 kg/s and 0.28 kg/s. It was determined that with increase in mass flow rate the outlet temperature of cold water decreased. Higher outlet temperature of cold water was obtained with leaf fins as compared to rectangular, triangular and without-fin cases at mass flow rates of 0.20 kg/s and 0.24 kg/s. The percentage differences in temperature gradient seem to vary with change in mass flow rate. It is shown from the study that the length of heat exchanger with fins could be reduced to half to achieve about 90% of the temperature gradient.

Keywords:- *ANSYS; heat exchanger; fin; double pipe heat exchanger; temperature gradient*

INTRODUCTION

Heat exchanger is a device that helps to transfer heat from one fluid to another. Heat exchangers with different designs are used in different industries. Common type of heat exchangers available in the market are shell and tube, double pipe and plate heat exchanger.

There are many places where heat exchange concept is used such as cars, machines in factories, petroleum refineries and air conditioners. In cars, engine is cooled by coolants which take the heat to be transferred outside using radiator. Refineries uses heat exchanger to exchange heat between a product that has the heat of the process and feed that has just entered the process. The working principle of air conditioner is to transfer heat from inside the room to outside. This is achieved through the finned pipe that is used in air conditioners.

Double pipe heat exchanger is widely used in industries and simulation has been used to study the flow patterns [1]. Heat exchangers with fins are commonly being employed for increasing the rate of heat transfer. Various researches have performed simulation study with different designs of fins for efficient heat transfer. In a study by Patel & Makadia [2] rectangular fins were used to increase the heat transfer rate. Pressure drop was found to increase which caused high pumping cost. Mass flow rate also played a significant role in increasing the heat transfer rate in the studied case. It was noticed that there was an increase in heat transfer rate with the double pipe heat exchanger (DPHE) that had fins as compared with the case without fins. Analysis was carried out on industrial DPHE reading which was validated with the ANSYS simulation results. The outlet temperature of the hot water without fins was 97 °C as compared to 94 °C the case with fins at 0.25 kg/h mass flow rate. Heat transfer rate at that mass flow rate was 12.5 kW without fins and 14.5 kW with fins. The study concluded that heat exchanger with and without fins has proportional relationship between mass flow rate and heat transfer. It was determined that when mass flow rate increased, fluid velocity, Reynolds number, Nusselt number and heat transfer coefficient increased, while friction factor decreased.

Another studby by Kumar et al. [3] has highlighted the use of different fins geometries and different flow rates in both cold and hot water. The study compared the results of the designed and simulated DPHE to validate the model. Different height of fins was simulated for selecting the suitable fin height. Different fin geometries were simulated with fixed height. The analysis showed that rectangular fin is the best in terms of heat transfer rate.

Concave parabolic fin was shown to be the best in terms of pressure drop. Varying hot mass flow rate gave better performance than changing cold water mass flow rate. At 0.02 kg/s of cold mass flow rate and varying hot flow rate, rectangular fin showed improvement of 6.1% than triangular and parabolic designs. The pressure drop that occurred in parabolic fin was less than others, 38% and 65% for triangular and rectangular fins respectively.

Ameen et al. [4] studied different fin angles using ANSYS to find the stress and strain that occurs at 7 bar pressure. The study showed that stress of 55.24 MN/m^2 is developed on a fin that has 60^0 angle. On comparing with other fins, 60^0 fins gave the lowest value of stress against other angles, 90^0, 75^0, 45^0 and 30^0 angles. The heat flux also increased to 1365 W/m^2.

The aim of the current study was to simulate different fin geometries for double pipe heat exchanger and study its effect on the temperature gradient.

Materials and Methods

ANSYS workbench program (win 64) program [5] was installed in the computer in 64 bit architecture to make use of all the memory RAM. ANSYS workbench package was used. The Design modeller was used for designing the physical domain (the geometry of the heat exchanger). ANSYS Meshing was used for generating mesh in the physical domain. ANSYS Fluent program was selected to perform heat transfer simulation. Table 1 gives the material properties used in the simulation and Figure 1 shows the fin geometry designs used in the study.

Table 1. Material properties used in the ANSYS simulation.

Parameter	Water	Aluminum
Density (Kg/m^3)	998.2	2719
Specific Heat (J/kg.K)	4182	871
Thermal conductivity (W/m.K)	0.60	202.4
Viscosity (Kg/m.s)	0.001003	-

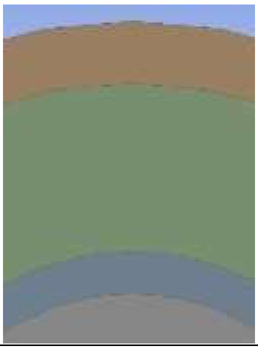
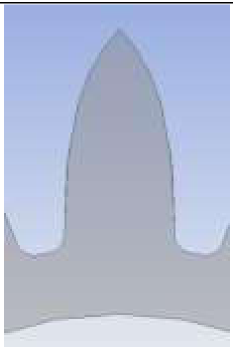
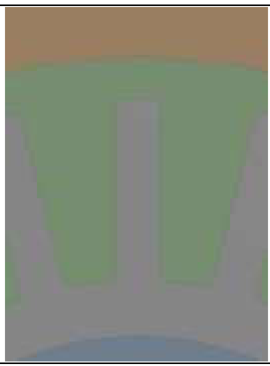
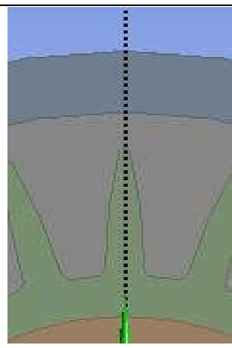
	
DPHE without fins	DPHE with leaf fins
	
DPHE with rectangular fins	DPHE triangular fins

Figure 1. Fin geometry used in the study.

Standard dimensions of double pipe heat exchanger were selected for designing the model. The standard used was schedule 40 for both inner and outer pipes. Table 2 shows the dimensions of the tubes with the fins attached with the number of fins designed.

Table 2. Dimensions of double pipe heat exchanger and number of fins used in the simulation.

Tube	Side		Dimension (m)
Inner	Inside diameter		0.0409
	Outside diameter		0.0483
Outer	Inside diameter		0.0779
	Outside diameter		0.0889
Fins	height		0.0723
	Number	Max cap.	18
		Rectangular	24
		Triangular	24
		Leaf	18

The heat exchanger was assumed to be counter flow. Inlet temperature of water in the outer tube was 300 K (27 ^{0}C) and hot water temperature in the inner tube was 340 K (67 ^{0}C). The mass flow rate in the inner tube was fixed at 0.30 kg/s and for the outer tube three flow rates 0.20 kg/s, 0.24 kg/s and 0.28 kg/s were used in the study. The length of the heat exchanger was taken as 3 meters.

Boundary conditions

Outer pipe and inner fluid was designed using circle tool from sketching tab. Half fin was designed using structure point and spline. The half fin was duplicated to create the fins. The outer fluid space was made by reserving the area between the fins and the outer pipe with a circle. The 2D sketch is converted to 3D using extrude tool. In this stage, the depth of the body (length of heat exchanger) was specified and the body state was selected (fluid or solid). From the main bar symmetry tool was selected to cut the heat exchanger from the axial axis to form one quarter. This reduced the number of cells and the time taken by the CPU to calculate the solution. Symmetry was taken at axial axis, XY-plane and ZX-plane.

Meshing the model

Faces of the geometry were named. The inlets, outlets, symmetry sides and the insulation side were selected by using "Meshing" from ANSYS workbench. Cells and nodes are created and distributed. Program controlled automatic inflation was used to have enough and well distributed cells (element). Fluent program was used for solving the model.

Results and Discussion

Figure 2 shows the outlet cold water temperature along the heat exchanger length for the three different fin designs with cold water flow rate of 0.20 kg/s. It can be seen that the leaf fin design has resulted in higher cold water outlet temperature. The temperature gradient of leaf fin was 5.1% higher than rectangular fin, 11.1% higher than triangular fin and 25.9% higher than the case with no fin. This was primarily attributed to higher heat transfer area as compared to the other fin designs. With increase in the cold water flow rate to 0.24 kg/s as shown in Figure 3, the temperature gradient of leaf fin was found to be 13% higher than rectangular fin, 20% higher than triangular fin and 34% higher than no fin. It was observed that the differences between leaf fin and other fin designs increased with increase in flow rate. With further increase in flow rate to 0.28 kg/s (Figure 4), the temperature gradient of leaf fin was found to be 10% higher than rectangular fin, 15% higher than triangular fin and 45% higher than no fin.

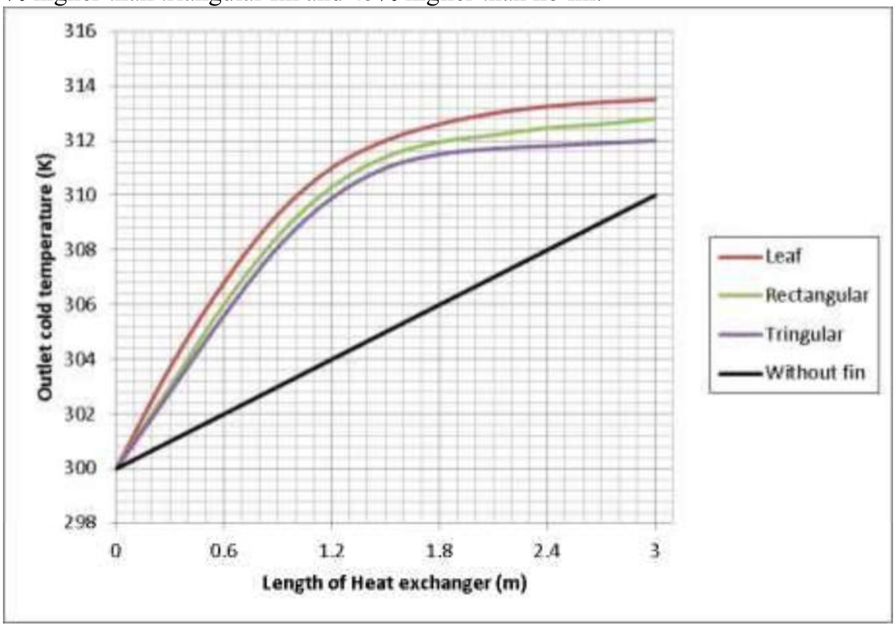


Figure 2. Temperature gradients of cold water against length of heat exchanger at mass flow rate of 0.20 kg/s.

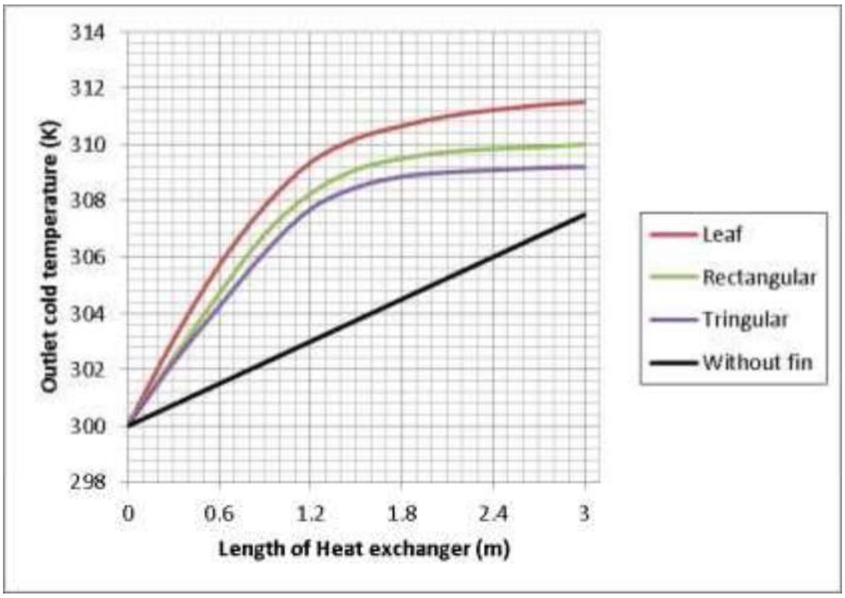


Figure 3. Temperature gradients of cold water against length of heat exchanger at mass flow rate of 0.24 kg/s.

From the results it can be inferred that the percentage temperature gradient change between the fins is due to the mass flow rate and different degree of turbulence caused by the fin geometry.

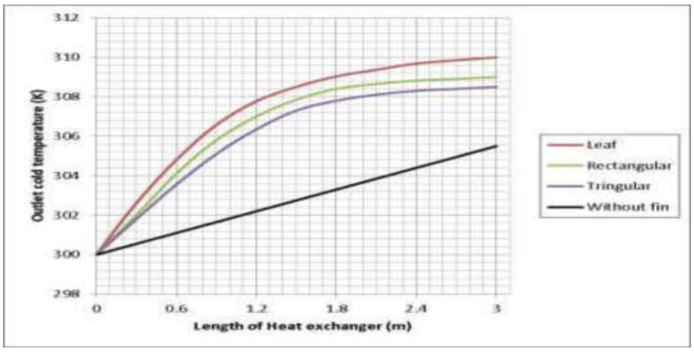


Figure 4. Temperature gradients of cold water against length of heat exchanger at mass flow rate of 0.28 kg/s.

The temperature profile for the studied mass flow rate for individual fin design is presented in Figure 5. It can be seen that as the cold water flow rate increases the outlet temperature decreases. This is because with increase in the flow rate of water the rate of heat transfer is decreased. The temperature gradient decreases in the order of leaf fin, rectangular fin and triangular fin.

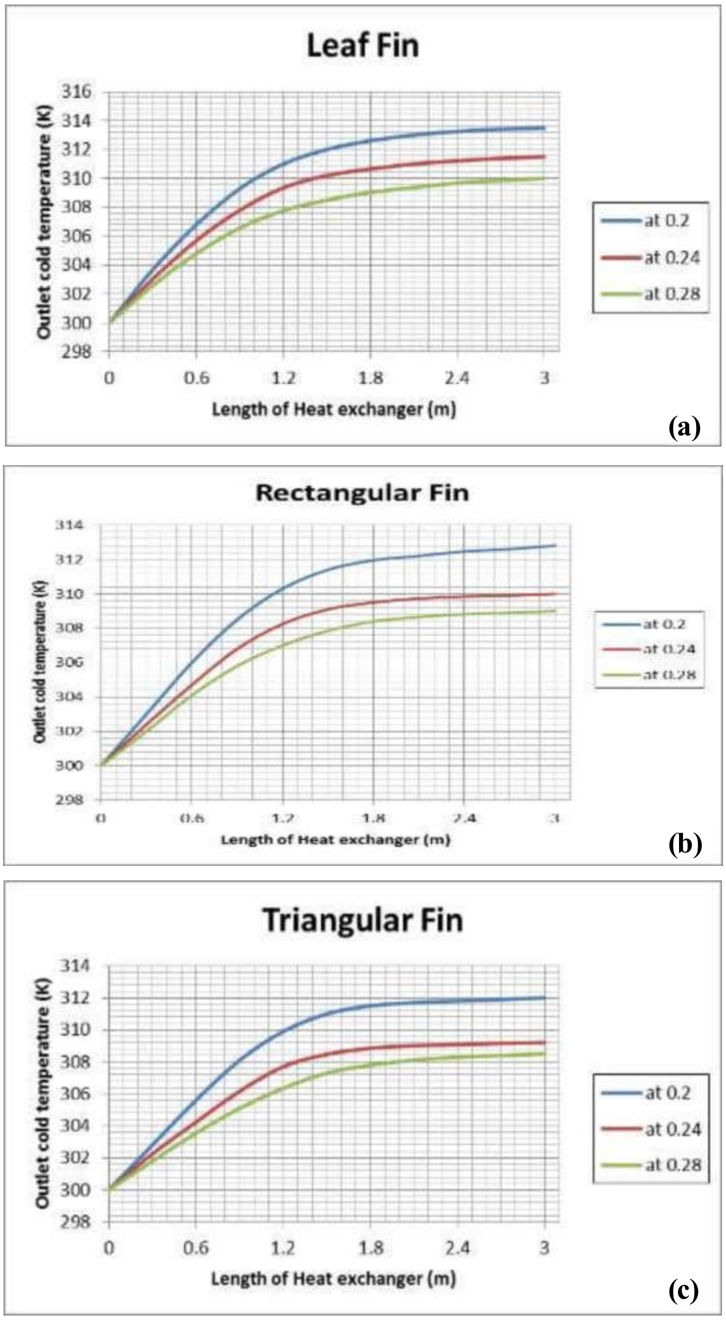


Figure 5. Variation of cold water outlet temperature with respect to fin design along the length of heat exchanger for different mass flow rates, (a) Leaf fin, (b) Rectangular fin, (c) Triangular fin.

Outlet cold water temperature with the use of different fin designs and different mass flow rates are shown in Figure 6.

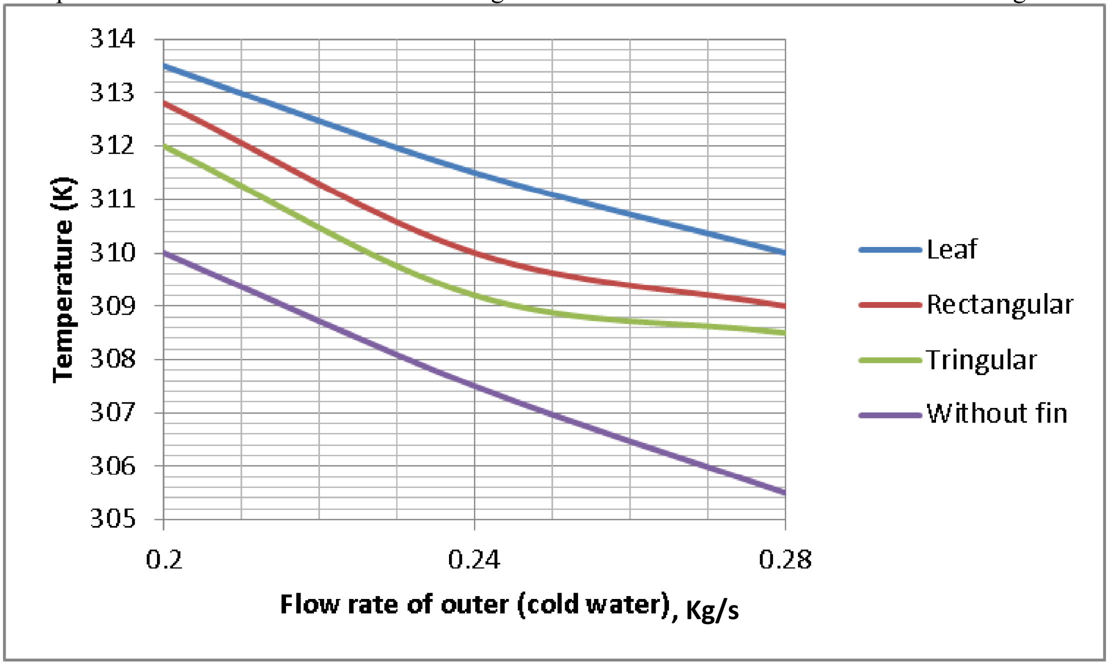


Figure 6. Variation of cold water outlet temperature with respect to cold water flow rate for different fin designs.

It can be seen from Figure 6 that the decrease in temperature of cold water for rectangular and triangular fins are slower after mass flow rate of 0.24 kg/s, whereas for leaf fin the decrease was steep. Higher heat transfer with a particular fin design would eventually result in higher pressure drop leading to higher pumping cost. Greater the fin surface area higher is the heat exchanged. Therefore fin design has to be made to optimise all parameters.

Conclusion

Simulation of double pipe heat exchanger was successfully done using ANSYS workbench and ANSYS Fluent program. Leaf, rectangular and triangular fin shapes were designed and studied. It was determined that with increase in mass flow rate the outlet temperature of cold water decreased. Leaf fins gave a higher outlet temperature of cold water as compared to rectangular, triangular and without-fin cases at mass flow rates of 0.20 kg/s and 0.24 kg/s. The percentage differences in temperature gradient seem to vary with change in mass flow rate. The length of heat exchanger with fins could be reduced to half (1.5 m) to achieve about 90% of the temperature gradient.

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