CHAPTER 7

COMPARISON OF HEAT EXCHANGERS

Heat exchangers may be classified according to their flow arrangement. In parallel flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is most efficient, in that it can transfer the most heat. In a cross flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.

For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence. Each of the three types of heat exchangers has advantages and disadvantages. But of the three, the counter flow heat exchanger design is the most efficient when comparing heat transfer rate per unit surface area. The efficiency of a counter flow heat exchanger is due to the fact that the average ΔT between the two fluids over the length of the heat exchanger is maximized, therefore the log mean temperature for a counter flow heat exchanger is larger than the log mean temperature for a similar parallel or cross flow heat exchanger.

In this research work, experiments were conducted on various types of heat exchangers to compare their efficiencies, effectiveness and over all
heat transfer coefficients. The various heat exchangers used were shell and tube heat exchanger, cross flow plate fin heat exchanger, spiral heat exchanger and plate type heat exchanger. In each type of heat exchangers various miscible systems like kerosene – water system, toluene – water system and immiscible systems like acetic acid – water system, ethylene glycol – water system were used to compare the different parameters for both parallel and counter flow systems. The various parameters used were Reynolds number and Nusselt number applied for both hot fluid side and cold fluid side at different temperatures and mass flow rates, overall heat transfer coefficient which was obtained by calculating the individual coefficients of the hot and cold fluid side, capacity rate ratio, number of transfer units (NTU), effectiveness and the efficiency of the hot and cold fluid side. Graphs were drawn between “Nusselt number of the cold fluid versus Reynolds number of the cold fluid” for various systems at different composition, “Nusselt number of the hot fluid versus Reynolds number of cold fluid”, “Hot side efficiency against Reynolds number of cold fluid”, “Cold side efficiency versus Reynolds number of the cold fluid” and “Effectiveness against Reynolds number of the cold fluid”. Various parameters like the overall heat transfer coefficient, cold and hot fluid side efficiency and effectiveness were compared for parallel and counter flow for all the different heat exchangers.

In the shell and tube heat exchanger with the increase in the Reynolds number the tube side efficiency increased while the shell side efficiency decreased. While in a cross flow heat exchanger it was found that when the Reynolds number decreased there was an increase in the hot side efficiency of the heat exchanger, as the hot side flowrate was kept constant.

In a spiral heat exchanger the efficiency of the cold fluid was compared with respect to the Reynolds number for both miscible and immiscible systems in parallel and counter flow. The cold fluid side
efficiency decreased with increase in Reynolds number for both the systems. But for a counter flow, the cold fluid side efficiency was greater than the hot fluid side efficiency for a particular Reynolds number and the systems showed an inverse proportional change in the efficiency with respect to Nusselt number. On proceeding with the hot fluid side efficiency it was found that it increased with increase in the Reynolds number. For a counter flow it was found to be greater than parallel flow for various compositions for both miscible and immiscible systems.

As far as the plate type heat exchangers were concerned, as the Reynolds number increased the cold fluid side efficiency decreased. But when the parallel and counter flow patterns were compared the cold fluid side efficiency showed 2 to 5% increase in counter flow than in parallel flow. Coming onto its hot fluid side efficiency, it increased with increase in the Reynolds number of cold fluid for miscible and immiscible systems. The hot fluid side efficiency increased up to 17% for a counter flow as compared to a parallel flow for various compositions for both miscible and immiscible systems. It increased up to 17% for counter flow as compared to parallel flow for both miscible and immiscible systems for various compositions.

On comparing the effectiveness of various heat exchangers it was found that in a shell and tube heat exchanger for a counter flow system, the effectiveness was found to be higher than a parallel flow system for miscible and immiscible system at various compositions. But in a cross flow heat exchanger it was found that the overall effectiveness of heat exchanger was found to increase with decrease in the composition of water.

The effectiveness of the spiral heat exchanger calculated for parallel and counter flow for various miscible and immiscible systems, showed that the effectiveness increased with increase in the mole fraction of
systems. It was found that the effectiveness was 2 to 10% higher for counter flow as compared to that of the parallel flow for both miscible and immiscible systems.

Experimental results showed that the effectiveness of the plate heat exchanger increased as the mole fraction of the system increased at constant flow rate. For a counter flow system the effectiveness was found to be higher than a parallel flow system for miscible and immiscible system at various compositions.

When the overall heat transfer coefficients for various heat exchangers were compared it was found that in a shell and tube heat exchanger the overall heat transfer coefficient increased with increase in flow rate of cold fluid. Also the overall heat transfer coefficient increased with increase in the composition of water.

In a cross flow heat exchanger for both miscible and immiscible systems, as the Reynolds number (Cold) increased the overall heat transfer coefficient decreased. But as the Reynolds number (Hot) decreased the overall heat transfer coefficient also decreased.

Experiments were conducted on various miscible and immiscible systems for both parallel and counter flow in a spiral heat exchanger and were found that as the Reynolds number increased the individual heat transfer coefficient also increased. The heat transfer coefficient for both the types of flow showed that, for counter flow the heat transfer coefficient was 2 to 5% greater as compared to that of a parallel flow for miscible and immiscible systems for various compositions.
In a plate type heat exchanger when the individual heat transfers coefficients increased the overall heat transfer coefficient increased. As compared to parallel flow the heat transfer coefficient of counter flow was 10 to 90 % greater for both miscible and immiscible systems for various compositions.

All the types of heat exchangers have their own advantages and disadvantages. But particularly the counter flow heat exchanger design is found to be the most efficient one of all the others when heat transfer rate per unit surface area is taken into consideration.

The results reveal that under the same operating conditions, operating the same heat exchanger in a counter flow manner will result in a greater heat transfer rate than operating in a parallel flow. In actuality, most large heat exchangers are not purely parallel flow, counter flow, or cross flow; they are usually a combination of the two or all three types of heat exchangers. The reason for the combination of the various types is to maximize the efficiency of the heat exchanger within the restrictions placed on the design, i.e, size, cost, weight, and required efficiency, type of fluids, operating pressures, and temperatures.

In a nutshell, it is found that in all the cases the counter flow pattern has better efficiency and effectiveness as compared to parallel flow pattern. Among the various heat exchangers compared, the cross flow heat exchanger has been found to be the most efficient and effective heat exchanger as compared to that of the other heat exchangers like shell and tube heat exchanger, spiral heat exchanger and plate type heat exchanger. Thus we can conclude saying that the cross flow heat exchanger could be the most preferable one for industrial use based on its performance.