CHAPTER - 1

Introduction

1.1 Plate Heat Exchangers

Chemical industry is one of the major users of energy. In the past, efficient utilization of energy has not received much attention, mainly due to the high profit margins enjoyed by the chemical manufacturers. The steep escalation of energy costs in recent years has forced chemical industry to reverse these trends and minimize the wastage of energy. Recovery of heat from process fluids through heat exchangers is receiving increasing attention by the designers of modern chemical plants. Several types of heat exchangers are now available for wide variety of applications involving high heat transfer performance. Plate Heat Exchangers (PHE) belong to this category, and these are capable of recovering heat efficiently at low temperature differentials, mainly because of high turbulence in such units even at low velocities.

The terminology of a conventional plate heat exchanger is shown in Figure 1.1. It consists of a series of parallel plates, that are corrugated both to increase turbulence and give mechanical rigidity. The corrugated plates, arranged to form a package, resulted in a compact form of heat exchanger having less weight, less space and providing high heat transfer coefficients. The concept of the plate heat exchanger was evolved during the later half of the nineteenth century itself. The first commercially feasible plate heat exchanger was introduced in 1923 by Dr. Richard Seligman. The initial designs were similar to plate and frame type, which employed cast gun metal.
plates. The thin gauge stainless steel plates were introduced in 1930s primarily for heating applications in dairy, food processing and brewing industries. The initial designs were limited to operating temperatures up to 100°C and pressure of about 3 bar. During the last 40 years, it has been recognized that, plate heat exchangers possess many unique characteristics of greater significance to the chemical and allied industries. Applications in these industries demand larger size units and wide range of plate materials for handling wide variety of process fluids. The realization of wide potential of plate heat exchangers has boosted the design which extends the application of the plate heat exchanger up to 250°C temperature and 25 bar pressure. The nature of fluid flow through the plate heat exchanger is shown in the Figure 1.2.
Plate heat exchangers provide a number of advantages over shell and tube heat exchangers. The unique characteristics of compactness, high effectiveness, cost competitiveness, accessibility for cleaning, flexibility in design and ability for efficient heat transfer make the plate heat exchanger ideal for wide variety of heat transfer duties. The construction of the heat exchanger is such that, upon disassembly, all heat transfer areas are available for inspection and cleaning. Disassembly consists only of loosening a small number of tie bolts. The nature of the plate heat exchanger construction permits expansion of the unit after installation. In addition, two or more heat exchangers can be housed in a single frame, thus reducing space requirements and capital costs. The superior thermal performance of the plate heat exchanger and the space efficient design
of the plate arrangement results in a very compact piece of equipment. Though primarily used for hygienic duties involving heat sensitive liquids, in recent years its application is broadened to cover chemical industries, power plants, food treatment, marine installations and the like. In aerospace, it is suited for aviation and engine cooling. PHE is also designed to cool the high heat generating electronic components such as those found in CPUs and transformers. It is specifically suited for oil heating and cooling applications in heavy industrial equipment, and rated for compressed air in pneumatic system. Plate heat exchanger is also suitable for use with refrigerants in cooling system. Recently, the plate heat exchangers (PHEs) also find applications in two-phase heat transfer, particularly in the refrigeration industry as evaporators, condensers, and in chillers and heat pumps.

1.2 Refrigerants in Plate Heat Exchangers

It is well known that the quick destruction of ozone layer in the earth’s atmosphere noted recently has been primarily related to the wide use of chlorofluorocarbon (CFC) refrigerants, which have been employed as the working fluids in many refrigeration, air conditioning and heat pump systems. Under the mandate of the Montreal Protocol, the use of CFC has been phased out in a short period of time. R134a is one of the main alternative HFC refrigerants suggested for replacing the CFC refrigerants. Experimental heat transfer evaluations of HFC 134a and other alternative refrigerants have become increasingly important as reductions in CFCs take effect. As the thermodynamic properties of the two refrigerants are similar, HFC 134a is considered
a potential replacement for CFC12. HFC134a is also more environmentally acceptable with a zero ozone depletion factor. The refrigerants R507A, R134a, R404A, R410A, R407C, and R600 are used as the process fluid in plate heat exchangers and also it is well recognized that these have a nominal pressure loss.

1.3 Bubble Finned Plate Heat Exchanger

There have been several studies on the thermo-hydraulic performance of plate heat exchangers [Wang(2003), Muley(1999), Focke(1985), Yaser Islamoglu(2003) ]. The performance of corrugated plates in the plate heat exchangers was analyzed with different chevron angles. The performance of plate heat exchangers using alternate refrigerant as the heat transfer fluid was also carried out with chevron/herringbone type plates. Encouraging results were obtained in most of the cases.

In the present work, a novel type of plate heat exchanger namely a bubble finned plate heat exchanger as shown in Figure 1.3. was taken up and the study was carried out. The bubble finned plate of a plate heat exchanger has a low pressure drop, compared to that of corrugated plate.
The heat transfer enhancement of the bubble finned plate heat exchanger over the plain plate was also analyzed. From the detailed experimental study, the liquid side heat transfer co-efficient for the single phase flow in the bubble finned plate heat exchanger was proposed in the form of

$$\text{Nu} = C \text{Re}^a \text{Pr}^b \left( \frac{\mu}{\mu_w} \right)^c$$  \hspace{1cm} (1.1)

and the pressure drop between inlet and outlet is correlated as

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\[ \Delta P = C(Re)^n \] (1.2)

The performance of bubble finned plate heat exchanger for two phase evaporation heat transfer with single phase water on one side, and evaporating HFC134a on the other side was also studied. The results are

\[ \text{Nu}_e = C_1 \text{Pr}^{a} \text{Bo}_{eq}^{b} \text{Re}^{c} \left[ (1-x_m) + x_m \left( \frac{\rho_l}{\rho_g} \right)^{0.5} \right] \] (1.3)

and the friction factor

\[ f_p \text{Re}^a = C \text{Re}_{eq}^a \] (1.4)

The heat transfer coefficient for the single phase liquid heat transfer in the bubble finned plate heat exchanger is much higher. The heat transfer rate is enhanced up to 1.5 times in the bubble finned plate heat exchanger over the plate heat exchanger without fins arrangement, for the single phase convective heat transfer. It is also found that the increase in pressure drop due to bubbling of plates is nominal. The evaporation heat transfer co-efficient for R134a flow is quite higher, particularly in the regime of high vapor quality. The heat transfer correlations suggested in the present study can help in the prediction of global heat transfer which is much useful for design engineers.