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A STUDY ON COMPACT HEAT EXCHANGERS AND PERFORMANCE ANALYSIS

V. BHOGESWARA RAO
Research Scholar
Email:pallivayala@gmail.com

Dr. S. CHAKRADHAR GOUD
Principal, Sri Sarada Institute of Science and Technology
Email:cgsakki@yahoo.com

Dr. B. DURGA PRASAD
Professor, JNTUA

ABSTRACT:

Theory behind heat exchanger is simple, just the allowing heat energy to flow in perfectly designed system by means of conduction, convection in case of fluids and when dealt with direct firing radiation will be involved. We discuss about four main types of heat exchangers by comparing their application, capacity and range of duty which are classified based on the flow pattern of fluid in them. Plate fin exchanger is a type of compact heat exchanger where the heat transfer surface area is enhanced by providing the extended metal surface interface between the two fluids and is called as the fins. Out of the various compact heat exchangers, plate-fin heat exchangers are unique due to their construction and performance. They are characterized by high effectiveness, compactness, low weight and moderate cost. As the name suggests, a plate fin heat exchanger (PFHE) is a type of compact exchanger that consists of a stack of alternate flat plates called parting sheets and corrugated fins brazed together as a block. Streams exchange heat by flowing along the passages made by the fins between the parting sheets. Separating plate acts as the primary heat transfer surface and the appendages known as fins act as the secondary heat transfer surfaces intimately connected to the primary surface.

Keywords: *Compact heat exchangers, performance study, internal fins, area of construction.*

INTRODUCTION

Compact heat exchangers are one of the most critical components of many cryogenic components; they are characterized by a high heat transfer surface area per unit volume of the exchanger. The heat exchangers having surface area density (β) greater than 700 m2/m3 in either one or more sides of two-stream or multi stream heat exchanger is called as a compact heat exchanger. Plate fin heat exchanger is a type of compact heat exchanger which is widely used in automobiles, cryogenics, space applications and chemical industries. The plate fin heat exchangers are mostly used for the nitrogen liquefiers, so they need to be highly efficient because no liquid nitrogen is produced, if the effectiveness of heat exchanger is less than 87%. So it becomes necessary to test the effectiveness of these heat exchangers before putting them in to operation.

2. Plate fin heat exchanger:

Plate fin exchanger is a type of compact heat exchanger where the heat transfer surface area is enhanced by providing the extended metal surface interface between the two fluids and is called as the fins. Out of the various compact heat exchangers, plate-fin heat exchangers are unique due to their construction and performance. They are characterized by high effectiveness, compactness, low weight and moderate cost. As the name suggests, a plate fin heat exchanger (PFHE) is a type of compact exchanger that consists of a stack of alternate flat plates called parting sheets and corrugated fins brazed together as a block. Streams exchange heat by flowing along the passages made by the fins between the parting sheets. Separating plate acts as the primary heat transfer surface and the appendages known as fins act as the secondary heat transfer surfaces intimately connected to the primary surface. Fins not only form the extended heat transfer surfaces, but also work as strength supporting member against the internal pressure. The side bars prevent the fluid to spill over and mix with the second fluid. The fins and side bars are brazed with the parting sheet to ensure good thermal link and to provide the mechanical stability. Figure. 1.2 shows the exploded view of two layers of a plate fin heat exchanger. Such layers are arranged together in a monolithic block to form a heat exchanger.

3. Advantages

Plate fin heat exchangers offer several advantages over the other heat exchangers:

1. Compactness: Large heat transfer surface area per unit volume (Typically 1000 m2 /m3), is usually provided by the plate fin heat exchanger. This in turn produces a high overall heat transfer coefficient due to the heat transfer associated with the narrow passages and corrugated surfaces.
2. Effectiveness: very high thermal effectiveness more than 95% can be obtained.
3. Temperature control: The plate heat exchanger can operate with relatively small temperature differences. A close temperature approach (Temperature approach as low as 3K between single phase fluid streams and 1K between boiling and condensing fluids is fairly common.),This is an advantage when high temperatures must be avoided. Local overheating and possibility of stagnant zones can also be reduced by the form of the flow passage.
4. Flexibility: Changes can be made to heat exchanger performance by utilizing a wide range of fluids and conditions that can be modified to adapt to the various design specifications. Multi steam operation is possible up to 10 streams.
5. True counter-flow operation (Unlike the shell and tube heat exchanger, where the shell side flow is usually a mixture of cross and counter flow.

Objectives of the study

The main objective of the present work is to evaluate the performance parameters of a counter flow plate fin heat exchanger through hot testing, which includes-

1. Design and fabrication of the test rig for plate fin heat exchanger.
2. To determine the thermal performance parameters like overall heat transfer coefficient, effectiveness and pressure drop of plate fin heat exchanger through hot testing under balanced flow condition.

LITARATURE SURVEY

Patankar and Prakash [1] presented a two dimensional analysis for the flow and heat transfer in an interrupted plate passage which is an idealization of the OSFs heat exchanger. The main aim of the study is investigating the effect of plate thickness in a non-dimensional form t/H on heat transfer and pressure drop in OSF channels because the impingement region resulting from thick plate on the leading edge and re-circulating region behind the trailing edge are absent if the plate thickness is neglected.

Joshi and Webb [2] developed an analytical model to predict the heat transfer coefficient and the friction factor of the offset strip fin surface geometry. To study the transition from laminar to turbulent flow they conducted the flow visualization experiments and an equation based on the conditions in wake was developed.

Suzuki et al [3] in order to study the thermal performance of a staggered array of vertical flat plates at low Reynolds number has taken a different numerical approach by solving the elliptic differential equations governing the flow of momentum and energy. The validation of their numerical model has been done by carrying out experiments on a two dimensional system, followed by those on a practical offset strip fin heat exchanger. The experimental result was in good agreement with the performance study for the practical offset-strip-fin type heat exchanger in the range of Reynolds number of Re.

Manglik and Bergles[5] carried an experimental research on OSFs. They investigated the effects of fin geometries as non dimensional forms on heat transfer and pressure drop, for their study they used 18 different OSFs. After their analysis they arrived upon two correlations, one for heat transfer and another one for pressure drop. The correlations were developed for all the three regions. They compared there results from the data obtained by other researchers in the deep laminar and fully turbulent regions. There correlations can be acceptable when comparing the results of the expressions to the experimental data obtained by Kays and London [16].

Hu and Herold [6] presented two papers to show the effect of Prandtl no. on heat transfer and pressure drop in OSF array. Experimental study was carried out in the first paper to study the effect for which they used the seven OSFs having different geometries and three working fluids with different Prandtl number. At the same time the effect of changing the Prandtl number of fluid with temperature was also investigated. The study was carried out in the range of Reynolds number varying from 10 to 2000 in both the papers. The results of the two studies showed that the Prandtl number has a significant effect on heat transfer in OSF channel. Although there is no effect on the pressure drop.

RESULTS OF STUDY

Various experiments are carried out in order to find out the j and f factors of the various heat exchangers and are called as the thermal performance testing. These testing are needed for heat exchangers, which do not have reported j and f data. Therefore, this test is conducted for any new development or modification of the finned surfaces. T. Lestina & K. Bell, Advances in Heat Transfer, told for heat exchangers already existing in the plants this test is done for the following reasons: a) Comparison of the measured performance with specification or manufacturing design rating data. b) Evaluation of the cause of degradation or malfunctioning. c) Assessment of process improvements such as those due to enhancement or heat exchanger

Design of heat exchanger involves two types of problem – (a) Sizing and (b) Rating. Sizing involves the determination or we can say selection of type of heat exchanger, flow arrangement, material of heat exchanger and physical dimensions of the heat exchanger to meet the specified heat transfer and pressure drop requirements. Whereas, Rating of the heat exchanger consists of finding the thermal performance parameters like, effectiveness, heat transfer coefficient and pressure drop of an already designed heat exchanger whose dimensions are known to us. We are working on the rating problem. Since the outlet temperatures are not known for the rating problem, the average fluids mean temperatures have to be projected first. The heat transfer coefficient and the effectiveness of the plate fin heat exchanger are found based on different correlations existing in literature. The outlet temperatures and the average fluid temperatures are calculated from the effectiveness value and then compared with the values assumed earlier. The above procedure is carried out until the calculated values of the mean fluid temperatures matches with the assumed values. Following steps show the detailed rating procedure: 1. The first step in rating procedure is to calculate the various surface geometrical properties of the heat exchanger. We are using a plate fin heat exchanger with offset strip fin geometry, and geometry of the offset strip fin surface is described by the following parameters: i) Fin spacing (s), excluding the fin thickness, ii) Fin height (h), excluding the fin thickness, iii) Fin thickness(t) and, iv) Fin strip length(l or Lf).

Core Data (fin specifications)

There are some secondary geometrical parameters which are derived from the basic fin geometries,

	Hot Fluid	Cold Fluid
No. Of passes (N)	4	5
Fin thickness (t)	0.2mm	0.2mm
Fin frequency (f)	588	714
Fin length (l)	5mm	3mm
Fin height (h)	9.5mm	9.5mm
Plate thickness (a)	0.8mm	0.8mm

PERFORMANCE ANALYSIS

In order to find the performance of present heat exchanger a number of experiments have to be carried out at different mass flow rates and at different hot fluid inlet temperature under balanced flow.

CONCLUSIONS OF THE STUDY

For a particular hot inlet temperature there is an optimum mass flow rate at which the difference between the hot and cold effectiveness of the heat exchanger is minimum and at this point the imbalance is also minimum. We found that the insulation which is provided in the heat exchanger has a significant effect on its performance. It is expected that the imbalance i.e. difference between the hot and cold end temperature can be brought to a minimum level if a perfect insulation like vacuum is provided.

FUTURE RESEARCH APPLICATIONS

Present tests are conducted at room temperatures and in future we can perform the experiment at low temperatures in order to check the performance of the present heat exchanger for Cryogenic applications. In cold testing air at about 100K will be used as the cold fluid. In cold test in place of heater a cold box will be used.

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