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ANALYSIS AND PRACTICAL STUDY ON PLATE TYPE HEAT TRANSFER SYSTEM (HEAT EXCHANGER)

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ABSTRACT

Inside the thermal discipline, high viability heat exchangers of the order of 0.96 or higher are widely used for conserving the refrigeration effect produced. So, there will be no liquid yield if the effectiveness drops below that of the design value. Due to high effectiveness, low weight & compactness, the small heat exchangers have their vast applications in the air-conditioning system, oil industries, food industries & in the process industries. The plate type heat transfer system is a sort of compact heat exchanger which is produced by brazing a heap of alternate plates (parting sheets) & fluted fins together. The transfer of heat occurs through the streams by the fins. Usually, aluminum metal is utilized for manufacturing due to their high thermal conductivity & low cost. In the plate fin heat exchanger, the stress drop is also marked along with the effectiveness. The increment in pressure gradient can be surpassed by reducing the passage length so that an adequate pressure drop can be accomplished. There are extensive research is going on to make out the heat transfer phenomena & also to determine the dimensionless heat change coefficients that is the Colburn factor (j) and the friction factor (f). This dissertation on the offset strip plate fin heat exchanger equals the effectiveness, overall thermal conductance & the pressure decrease received from the experimental data with some similarities on plate fin heat exchanger i.e., Joshi-Webb correspondence, Maiti-Sarangi correspondence, Manglik-Bergles correspondence and also with the numerically obtained data obtained by using CFD.

Key words: Offset or serrated fin, Computational fluid dynamics, Colburn factor, Friction factor

INTRODUCTION

A heat exchanger is a device via which thermal energy or enthalpy is transferred among two or more fluids having distinctive temperatures and which are further in thermal contact with each other. The enthalpy can flow within two or more fluids, between fluid and solid particulates and within liquid and a solid surface which are in thermal contact with each other. Usually, in heat exchangers, there is no work interaction. The heat exchangers are additionally adiabatically isolated, so none of the heat transfer takes place. The cooling and heating of any fluid, condensation of an individual or multi-compound fluid, evaporation of a single or multi-compound fluid are the main utilization of the heat exchanger. Generally, high effectiveness heat exchangers are used in cryogenic applications. The effectiveness about heat exchangers utilized in liquefiers of the order of .96 and higher. There will be no liquid yield if the efficiency of the heat exchangers falls below the design value. But in case of the application of heat exchangers in aircraft, high effectiveness and performance is not so required instead the aim is to keep the weight and volume of the heat exchanger minimum. These requirements of low volume and weight of the heat exchanger lead to the generation of compact heat exchangers. In general, Small heat exchangers possess great surface area density i.e. large surface area to volume ratio which is of the order 700 m2/m3or greater than this value for gas and it should be 300 m2/m3for two-phase streams and liquids.

Plate blade heat exchangers are the sort of warmth exchangers having triangular or rectangular folded balances, with the separating sheets or plates (spacers) sandwiched between the parallel plates. The plates and blades separate the two liquid streams from each stream sections. At least two liquid sides can be shaped in the warmth exchangers by the association of the elective liquid section utilizing appropriate headers. That implies it is a pile of separating sheets put on the other hand and the ridged plate blades brazed all things considered in a solitary square. Since the progression of the entry is through the separating sheets which is constrained by the blades causes the warmth move between the liquid streams. These blades are framed by the way toward rolling or by utilizing a kick the bucket. The metal joining procedures, for example, welding, brazing, fastening, expulsion and so on are utilized to append the blades to the plates.

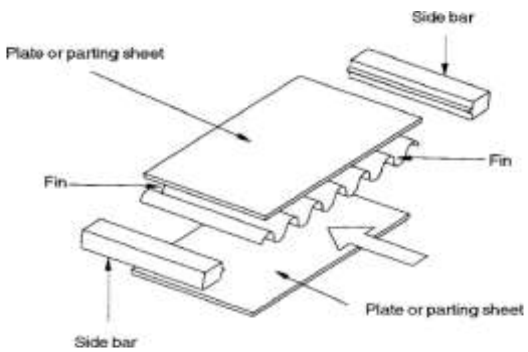

Figure 1. A stack of fins placed between the parting sheets (Shah and Sekulic [39])

These balances might be utilized on the two sides if there should arise an occurrence of the gas-to-gas temperature exchangers, however balances are normally utilized at the gas side just in the event of the gas-to-fluid warmth exchangers. The blades those are utilized on the fluid side are utilized for stream blending procedure and furthermore give auxiliary quality. The plate balance heat exchangers are otherwise called Matrix heat exchangers in Europe. The plate balance heat exchangers have the benefit of high adequacy, low weight, conservativeness and moderate expense.

The use of plate fin heat exchanger is very wide because it works over a very large range of pressure and temperature for gas-to-gas, gas-to-liquid and in multiphase applications. There is a wide variety of applications. In the cryogenic field, for the liquefaction of air, for the separation of air the plate fin heat exchangers are widely used. In the petrochemical industries and in very large refrigerating systems for the processing of natural gas, and their liquefaction, it is also widely used. The plate fin heat exchanger being used in cryogenic application, are very large and complex units with large dimensions. In the aerospace industries, aluminium brazed PFHEs are widely used because of its compactness and low weight-to-volume ratio. These plate fin heat exchangers are mainly used in control system of the aircraft, cooling system of the aircraft, hydraulic cooling of oil and fuel heating. Because of the space consciousness of the automobile companies and the aircraft designers, there is more demand for the designing of the compact heat exchangers. For the application of preheating/precooling of air coming to the conditioned space, a treated hygroscopic paper with the operating limit temperature of 50℃ plate fin heat exchangers are used.

EXPERIMENTAL SET-UP

In the experimental set-up, a counter-flow plate fin heat exchanger having offset strip fin surface is the major component. In the set-up, the compressor draws the cold air from the surrounding and forces this air to flow through a channel whereas hot air coming from that of a heating unit is made to flow across the second channel in a counter direction of flow. The experimental set-up includes a layout of the experimental set-up, different components of the set-up, principles of measurement and the procedure for the calibration of the instruments.The test apparatus comprise of the warmth exchanger center, air supply framework, warming unit and the estimation/instrumentation framework as appeared in the figure 13. In the test, the liquids are streaming in the counter stream bearings. The working liquid for this examination is air. A screw blower is utilized for the constant supply of dry air to the plate blade heat exchanger. For the guideline of the stream rate, a control valve is utilized. The bay of the virus air is at the base of the warmth exchanger. At the point when the virus air goes through the warmth exchanger it gets warmed by the exchange of warmth from the tourist to the virus air. At that point, the air leaves the warmth exchanger and again gets warmed when going through the warming unit. Here the delta of the tourist which turns out from the warmer is provided to the warmth exchanger from the top end. At the gulf of the tourist i.e., at the channel to the sight-seeing, a valve is utilized for controlling the mass stream pace of the sight-seeing. At the point when both the liquids have equivalent mass stream rates, the detour valve is shut.

The bay and outlet weight of both hot and cold liquids are estimated by the weight checks. For estimating the weight drop over the warmth exchanger, at both the upstream and downstream of the warmth exchanger weight taps are utilized. The U-tube manometer that associated with the weight tap gives the weight drop. RTDs (Resistance temperature locators) are utilized to quantify the bay and outlet liquid temperatures.

At the outlet of the heat exchanger, a rotameter is installed to measure the flow rate for the balanced flow. Hole meters are utilized to quantify the stream pace of both hot and cold liquids, for the unequal stream. The rotameter is also used for the calibration of the orifice meter when desired.

For resisting the heat loss from the system to the surrounding, the test section is thoroughly insulated by using polystyrene foam or thermocouple sheets and glass wool. On the outer surface of the insulation, a resistance temperature detector is placed to indicate the temperature difference. From this temperature difference, heat loss to the surrounding can be calculated.

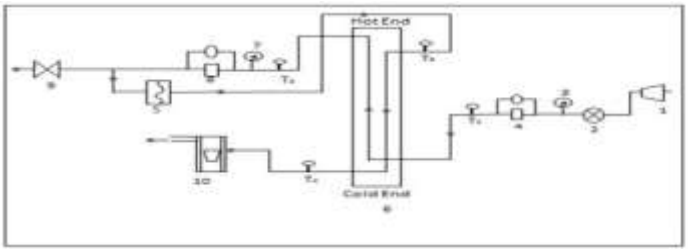

Figure 2. Schematic diagram showing Piping &Instrumentation of the experimental test rig

DESIGN OF THE PLATE FIN HEAT EXCHANGER

The basic design considerations of a plate fin heat exchanger include:

i. Process & design specifications
ii. Hydraulic & thermal design
iii. Mechanical design
iv. Manufacturing considerations
v. Trade-off factors and system based optimization

i. Process & design specifications:

In warmth exchanger structure, the procedure and issue particular is one of the most significant advances. Any detail for procedure and plan technique tallies all the required data for planning and enhancing the exchanger for a specific application. It incorporates:

- Specification of the issue for working conditions
- Type of heat exchanger
- Type of stream course of action
- Materials
- Considerations for configuration/fabricating/activity
- Information on the base information particulars

The choice of configuration conditions is the first and significant thought. At that point, the following is the off-structure and configuration point condition. The particular for working conditions and the working condition ought to be referenced which incorporates:

- Mass stream rates
- Fluid types and their canteen physical properties
- Inlet temperature and weight of both liquid streams
- Maximum passable weight drop on both liquid sides

- Inlet temperature and weight vacillation because of variety all the while or ecological parameters
- Corrosiveness
- Fouling normal for liquids and
- Operating condition

RATING PROBLEM OF HEAT EXCHANGER

Rating problem is the calculation of pressure drop & heat transfer of an already sized heat exchanger or an existing heat exchanger. The rating problem is also known as performance problem or simulation problem. The inputs to the rating problem are:

(a) Heat exchanger construction (b) flow arrangement (c) overall dimensions (d) Both side surface geometries (e) pressure drop and heat transfer characteristics (f) mass flow rate (g) inlet temperature and (h) fouling factor

The parameters to be determined are:

(a) The fluid inlet temperature, (b) the total rate of heat transfer & the pressure drop on each side of the heat exchanger.

The calculation of various surface geometrical properties of the heat exchanger is the first step in the rating procedure. Our project on plate fin heat exchanger with offset strip fin geometry is described by the following parameters:

(i) Spacing between the fins (*s*) (excluding thickness of fin)
(ii) Height of the fin (*h*), (excluding thickness of fin)
(iii) Thickness of the fin(*t*) and
(iv) Strip length of the fin (*l* or *Lf*)

Table 1. Fin dimensions used in the heat exchanger

Fin geometry	**High pressure Side**	**Low pressure Side**
Fin frequency, f	714 fins per metre	588 fins per metre
Length of fin, l	0.003 m	0.005 m
Thickness of the fin, t	0.0002 m	0.0002 m
Height of the fin, h	0.0093 m	0.0093 m
No. of layers	05	04

HEAT TRANSFER AREA CALCULATION

The various heat transfer area in the hot side are calculated as follows:

(i) The high pressure side heat transfer area is calculated as follows:

Total area between the plates, A $_{frh} = b´\ N_h\ ´W$ = 0.00950´5´ 0.0730 = 0.0035 m^2

(ii) Total free flow area, A $_{ffh} = s\ ´\ A_{frh}$ = 0.002425 m^2

(iii) Wall conduction area on the hot side, $a_{wh} = A_{frh} - A_{ffh} = 0.0010430\ m^2$

(iv) Total wall conduction area $a_{wh} + a_{wc} = 0.001043 + 0.00069736 = 0.00174\ m^2$

Similarly, the cold side heat transfer areas and the free flow area can be calculated.

HEAT EXCHANGER INPUT DATA

The hot gas inlet temperature = 368.80 K The cold gas inlet temperature = 311.92 K The inlet pressure of cold gas = 1.20 bar The inlet pressure of hot gas = 1.170 bar The cold gas mass flow rate = 0.0095 kg/s The hot gas mass flow rate = 0.0095 kg/s

PERFORMANCE ANALYSIS

The exhibition parameters of a plate balance heat exchanger for the most part incorporate adequacy, in general warm conductance and weight drop. Various tests have been performed at various mass stream rates and at various hot liquid gulf temperatures under parity conditions by S. Alur. We have contrasted these tentatively acquired outcomes and Joshi-Webb relationship, Maiti-Sarangi, Manglik-Bergles connection and by utilizing CFD examination.

Numerical analysis by CFD

The computational fluid dynamics is used for the prediction of fluid flows & heat transfer using the computation method.

1. Description to the problem & geometry:

In the present thesis, an offset strip fin plate fin heat exchanger is investigated numerically & is compared with the experimentally obtained results.

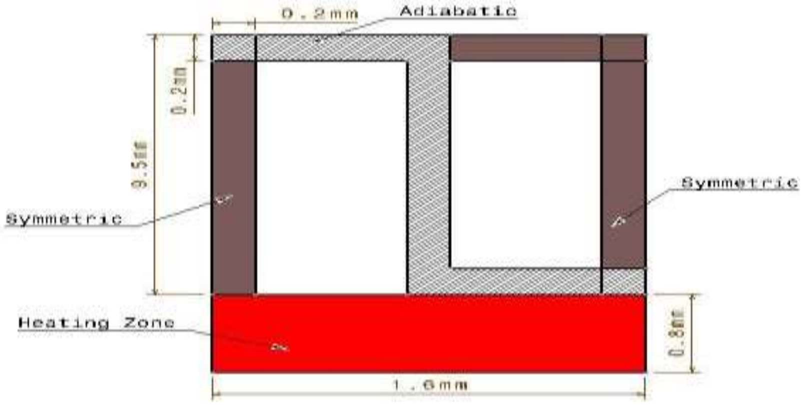

Figure 3. The geometry concerning the offset fin inclusive of the dimensions

Materials properties

The blade material is made of aluminum or aluminum based composites. Aluminum is broadly utilized in counterbalanced strip blade heat exchangers on account of its great canteen physical qualities, little thickness and generally low cost. The following constant thermos-physical properties of aluminum are used for the numerical calculations:

Density of aluminium= r_{Al} =2719 Kg/m^3 Specific heat of aluminium= $C_{p,\,Al}$ =871 J/Kg K

The thermo-physical properties of air that taken for CFD calculation are:

Density of air $= r_{air}$

=1.225 Kg/m^3

Specific heat of air= $C_{p,air}$ =1006.43 J/Kg K

Boundary conditions:

Boundary conditions are given to the physical models in order to solve the numerical problem.

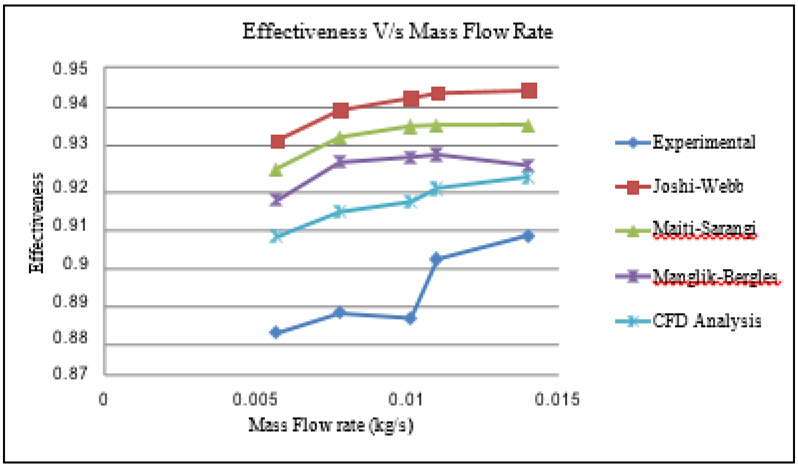

Figure 4 Effectiveness difference among the quantity flow rate (at a close inlet temperature of 66 °C or 339 K)

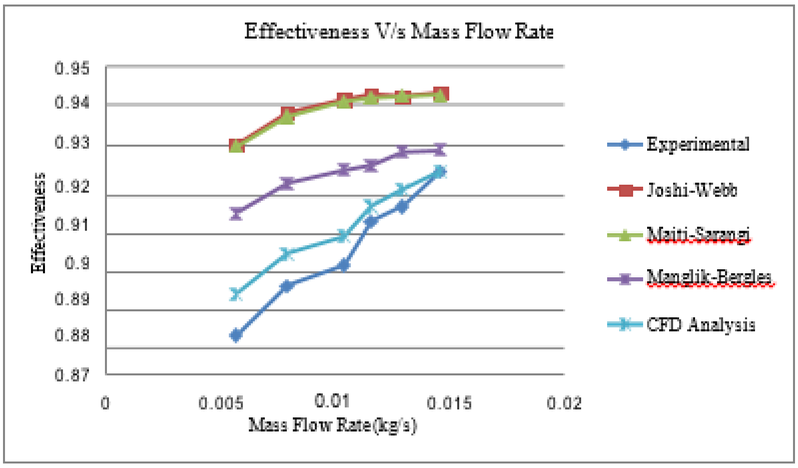

Figure 5.Effectiveness contrast among the mass discharge rate (at a hot inlet temperature of 86 °C or 359 K)

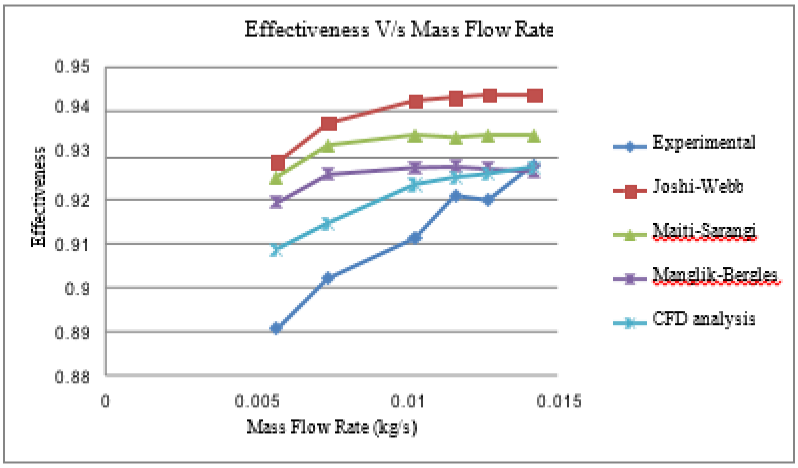

Figure 6. Effectiveness contrast among the volume flow rate (at a hot inlet temperature of 96 °C or 369 K)

CONCLUSIONS

The experimentally obtained results are compared with various correlation results and also with the results obtained from the simulation software of the CFD-fluent. The effectiveness v/s mass flow rate, overall thermal conductance v/s mass flow rate & pressure drop v/s mass flow rate for different hot inlet temperature are evaluated by using the correlations and by using CFD, fluent simulation software. The correlations used for the comparison of the performance parameters with the experimental results are Joshi-Webb correlation, Maiti- Sarangi correlation and Manglik-Bergles correlation. The comparison of the experimental results with the results obtained from the correlations & from the simulation software of Ansys fluent gives the following points:

(i) There is a percentage deviation of the effectiveness of experimentally obtained results from that of the value obtained by the simulation software Ansys fluent.

(ii) There are also deviations between the experimental value & the predicted values of effectiveness calculated by using Maiti-Sarangi, Joshi-Webb and Manglik-Bergles.

(iii) It is observed that the correlation developed by Maiti-Sarangi is better suited to the experimental results compared to the other correlations.

(iv) Up to the Reynolds number 500 the pressure drop of the fluids is below the allowable pressure drop of 0.05 bar. Thereafter, the pressure drop increases rapidly. Between the theoretical pressure drop obtained from various correlations and the pressure drop obtained from the experimental results, there is a large amount of deviation.

FUTURE WORK

A cold fluid test can be carried out using fluids at cryogenic temperatures for checking the validity of the used correlations at cryogenic temperature. Since, in the hot-test the heat loss to the surrounding should n't be neglected, for plate fin heat exchanger having large surface area the heat loss should be considered, when calculating the effectiveness. So, some new correlations can be developed considering the heat loss.

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