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Evaluation of performance characteristics of Plate Fin Heat Exchanger

Suhas B Shinde

Abstract— Heat exchangers are main equipmants in the process industries . Heat exchangers having high heat transfer surface area per unit volume(725m^2/m^3) are called compact heat exchangers. Plate fin heat exchanger is one of the type of compact heat exchanger which is widely used in automobiles, cryogenics, liquifires and chemical industries need to be highly efficient becausein gas liquification,effectiveness is the main parameter which denotes the performance of the heat exchangers in terms of heat transfer rate between the lowing fluids.The effectiveness of thesecompact heat exchangers before putting them in to operation should be checked and it should not be below 90 percent in case of gas lequification. The trial is conducted under steady condition i.e the mass flow rate for both sides of fluid stream is same ,and the experiment is carried out at different mass flow rates. Various correlations are available in the literature for estimation of heat transfer and flow friction characteristics of the plate fin heat exchanger, so the various performance characteristics like effectiveness, heat transfer coefficient and pressure drop obtained through experiments are compared with the values obtained from different correlations .

Key words— Cryogenic, compact heat exchanges,effectiveness, flow friction, heat transfer,pressure drop, steady state condition,.

1 Introduction

A heat exchanger is a device to transfer heat from a hot fluid to cold fluid across an impermeable wall. Fundamental of heat exchanger principle is to facilitate an efficient heat flow from hot fluid to cold fluid. This heat flow is a direct function of the temperature difference between the two fluids, the area where heat is transferred, and the conductive/convective properties of the fluid and the flow state. In order to increase the heat transfer in, assuming that the heat transfer coefficient cannot be changed, the area or the temperature differences have to be increased. Usually, the best solution is that the heat transfer surface area is extended although increasing the temperature difference is logical, too. In reality, it may not be much meaningful to increase the temperature difference because either a hotter fluid should be supplied to the heat exchanger or the heat should be transferred to a colder fluid where neither of them are usually available. For both cases either to supply the hot fluid at high temperature or cold fluid at lower temperature extra work has to be done. Furthermore increasing the temperature difference more than enough will cause unwanted thermal stresses on the metal surfaces between two fluids. This usually results in the deformation and also decreases the lifespan of those materials. As a result of these facts, increasing the heat transfer surface area generally is the best engineering approach.

A large amount of study has been conducted to analyze the heat transfer and pressure drop characteristics of compact heat exchangers in the past few decades. But this study mainly focuses on the Offset strip fins type of plate fin heat exchanger. And therefore the emphasis has been given on the literatures related to the prediction of j and f factors and the thermal performance testing of heat exchangers.

The monograph Compact Heat Exchangers by Kays and London remains one of the earliest and the most authoritative sources of experimental j and f data on plate fin surfaces Patankar and Prakash[1] presented a two dimensional analysis for the flow and heat transfer in an interrupted plate passage which is an idealizationn of such heat exchanger arrangements main aim of study is investigating the effect of plate thickness in a non-dimensional form thickness to height ratio on heat transfer and pressure drop in channels because the impingement region resulting from thick plate on the leading edge and recalculating 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.they studied four different regimes of flowand afterwords laminar flow correlation of Joshi and Webb started to under predict the j and f factors at the second regime. So they assumed the Reynolds number at that point as the critical Reynolds number to identify the transition from laminar to turbulent. 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 fm 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<800.Manglik and Bergles[5] carried an experimental research on Offset strip fins. They investigated the effects of fin geometries as non dimensional forms on heat transfer and pressure drop, for their study they used 18 different Offset strip fins. After their analysis they arrived upon two correlations, one for heat transfer and another one for pressure drop Dejong et al [4] carried out an experimental and numerical study for understanding the flow and heat transfer in Offset strip fins. In the study the pressure drop, local

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Nusselt number, average heat transfer and skin friction coefficient on fin surface, instantaneous flow structures and local time averaged velocity profiles in Offset strip fins channel were investigatedFrom the studies of few researchers like Patankar and Prakash [1], it is easy to get information regarding the effects of Offset strip fins on heat transfer and pressure drop. But most of the researchers have not taken into account the effect of manufacturing irregularities such as burred edges, bonding imperfections, separating plate roughness which also affect the heat transfer flow friction characteristics oh the heat exchanger. The plate fin heat exchangers find a variety of applications in the field of cryogenics, where high heat transfer performance and high effectiveness are the foremost requirement. The main objective of the present work is to evaluate the performance parameters of a counter flow plate fm heat exchanger through hot testing To determine the thermal performance parameters like overall heat transfer coefficient, effectiveness and pressure drop of plate fin heat exchanger through hot testing under steady flow condition.

2 EXPERIMENTAL PROCEDURE

Air is used as the as working fluid in this experiment supplied by screw compressor through a control valve which is used to regulate the flow rate of testing heat exchanger. This is the cold side fluid which is made to enter the heat exchanger from the bottom side and when it comes out it is made to pass through the heater, where it gets heated up and which is then again fed into the heat exchanger from top end and which finally results in hot and cold fluid streams. The heat supplied to the heater. The pressure taps are located across the heat exchanger and connected with tubing and which is connected to a U-tube manometer to give an average reading of the pressure drop. The air inlet and outlet temperatures at both ends of heat exchanger core were measured using four RTD's. The air flow rate was measured using the rotameter . The orifice meter is used only when the mass flow rates on both sides is different. The system was then allowed to run until the steady state is achieved. The system was considered to be at steady state when all the temperature readings steadily decrease and steadily increase for at least one minute. Once the steady state was achieved for a particular mass flow rate and readings were recorded for estimating the properties.

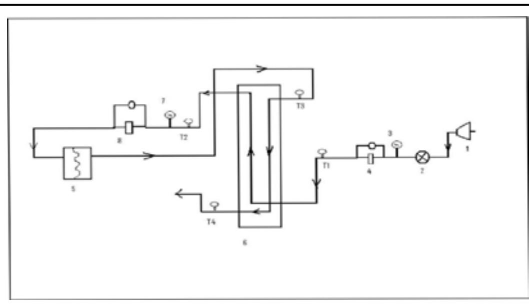

Fig. 1 Test Rig

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3 RESULT AND DISCUSSIONS

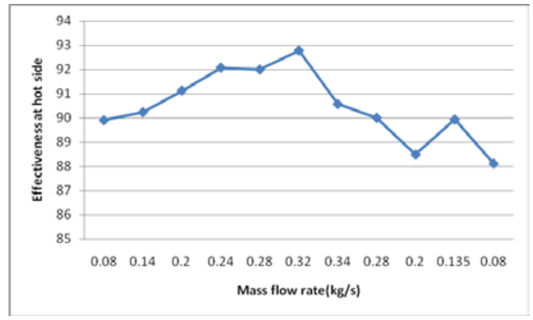

Fig. 2 Plot of Effectiness at Hot side Vs Mass Flow Rate (kg/s)

It is been observed that with increase in mass flow rate of air there is uniform ncrese in effectiveness it shows some abrupt nature at high mass flow rate and with decreasing mass flow rate effectiveness also decreases .

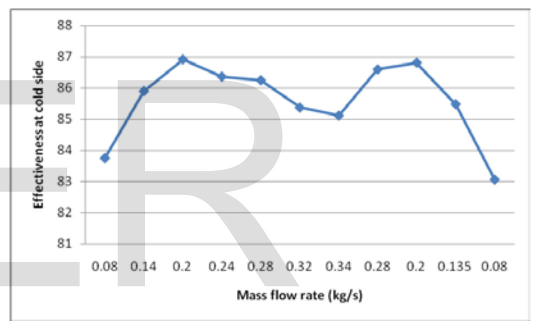

Fig.3 Plot of Effectiness at Cold side Vs Mass Flow Rate (kg/s)

At the beginning effectiveness shows sudden rise in effectives it is due to counter flow arrangement but as flow rate goes on further increasing, effectiveness falls.

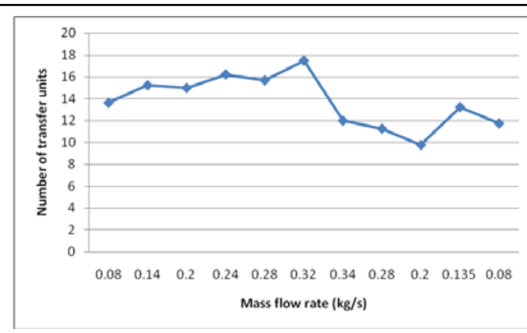

Fig. 4 Plot of Number of Transfer Units Vs Mass Flow Rate (kg/s)

In a plot of NTU Vs mass flow rate it is observed that with increase in mass flow rate NTU curve shows hasty nature it is not maintaining its shape.

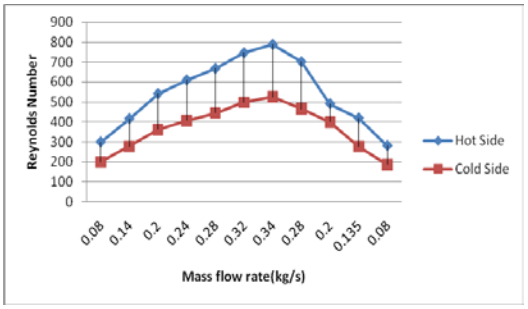

Fig. 5 Plot of Reynolds Number Vs Mass Flow Rate (kg/s)

While studying nature of Reynolds number variation it is observed that it is fully in laminar region (Re<2000). It may be due to straight passage through the plates flow is smooth.

In order to compare our experimental results with the values that are obtained from theoretical correlations, some graphs are plotted for which the experiment is conducted at different mass flow rates and at two different hot inlet temperatures of 66 and 96°C. Some of the graphs are shown below.

VARIATION OF OVERALL THERMAL CONDUCTANCE WITH MASS FLOW RATE

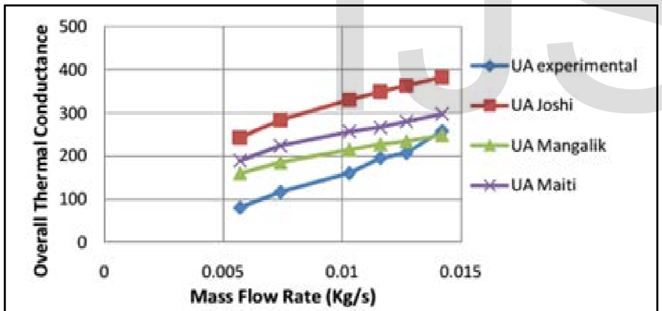

Fig.6. Variation of overall conductance with mass flow rate (hot inlet Temp =96°C)

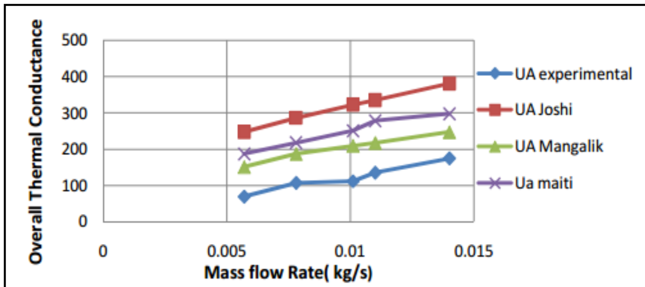

Fig.7. Variation of overall conductance with mass flow rate (hot inlet Temp =66°C)

Figure 6 and 7 shows the variation of overall thermal conductance with mass flow rate for hot inlet temperature of 96°C and 66°C respectively. It can be seen that the theoretical as well as experimental overall heat transfer coefficient increases with increasing mass flow rate. It is due to the fact that with increasing mass flow rate the Reynolds number increases and as a result Colburn factor (j) also increases which is directly proportional to heat transfer coefficient, so overall thermal conductance increases

VARIATION OF HOT AND COLD EFFECTIVENESS WITH MASS FLOW RATE

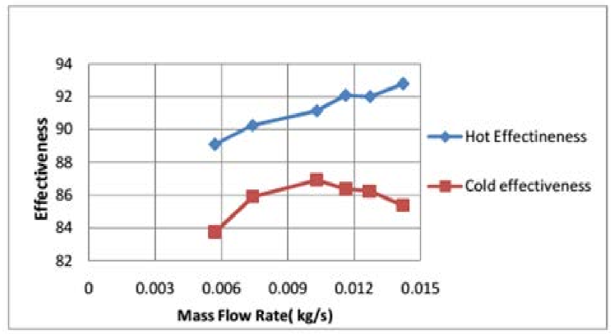

Fig.7. Variation of effectiveness with mass flow rate (hot inlet Temp =96°C)

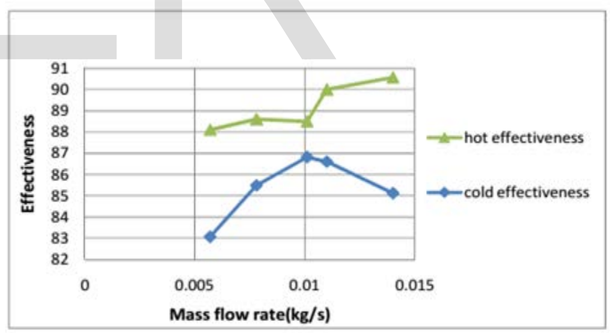

Fig.8. Variation of overall conductance with mass flow rate (hot inlet Temp =66°C)

Figure7 and 8 show how the experimental hot and cold effectiveness varies with the mass flow rate for hot inlet temperature of 96 and 66°C respectively. It is seen that both hot and cold effectiveness increases with increasing mass flow rate and try to approach other and there is an optimum mass flow rate for each hot inlet temperature at which the gap between the two effectiveness is minimum and then again increases. Also after the optimum point the cold effectiveness again decreases, this is because a heat exchanger is designed for a particular mass flow rate and inlet temperatures at which it gives maximum effectiveness, after which its performance deteriorates. Also the imbalance increases because of heat loss to the environment as we are not able to provide the complete insulation. It can also be seen from the graphs that at lower hot inlet temperature the imbalance i.e. difference between the two effectiveness is less as compared to the imbalance at high temperatures.

Variation of Effectiveness with Mass Flow Rate

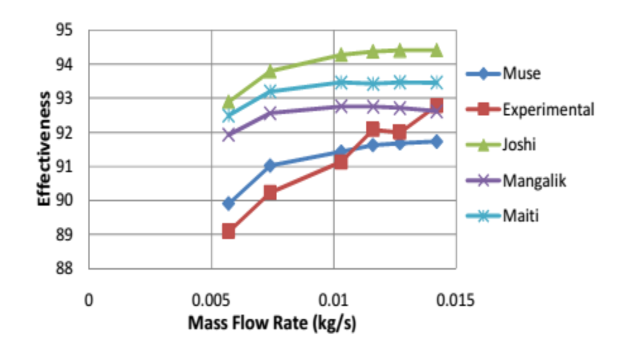

Fig.9. Effectiveness with mass flow rate (hot inlet Temp =96°C)

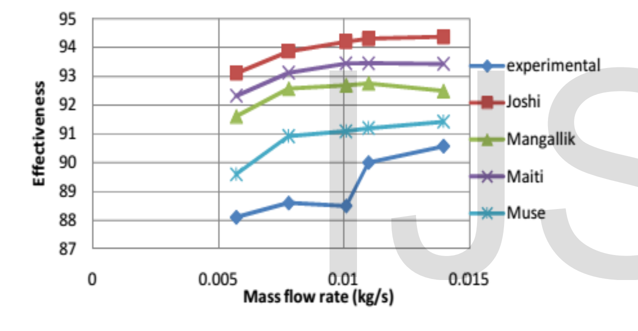

Fig.10. Effectiveness with mass flow rate (hot inlet Temp =66°C)

Figure 9 and 10 shows the variation of effectiveness obtained experimentally as well as with theoretical correlations and that obtained with simulation software Aspen with mass flow rate. It is seen that in both the cases effectiveness increases with mass flow rate. Experimental hot effectiveness first increases, then becomes almost constant for certain mass flow rates and then again increases. However from two figures it can be seen that the value of experimental effectiveness is more when hot inlet temperature is 96°C as compared to effectiveness value when hot inlet temperature is 66°C. So it can be concluded that with increase in hot inlet temperature effectiveness increases.

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Variation of Pressure Drop with Mass Flow Rate

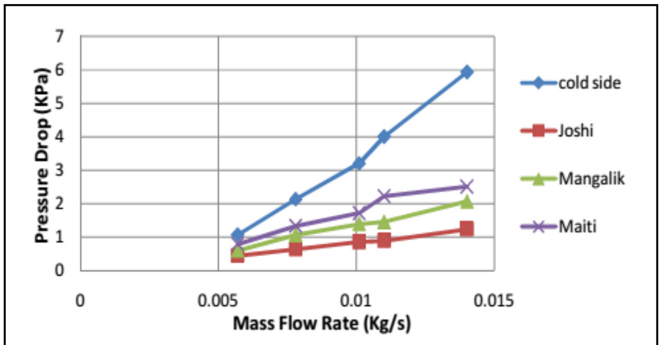

Fig.11 Variation of pressure drop with mass flow rate

Figure 11 shows how the pressure drop in the heat exchanger varies with varying mass flow rate and also the comparison between experimental and theoretical pressure drop. It can be seen that the pressure drop increases with mass flow rate for each case. However the experimental pressure drop is much more as compared to the theoretical pressure drop because in theoretical calculations we have not taken in to account the pressure drop taking place in piping's and also the manufacturing irregularities and header losses.

4 Conclusion

The hot test is conducted to determine the thermal performance parameters of the available plate fm heat exchanger at different mass flow rates and two different hot inlet temperatures of 96 and 66°C. An average effectiveness of 91% is obtained. It is found in both the cases that the effectiveness and overall thermal conductance increases with increasing mass flow rate It is also found that hot fluid effectiveness increases with flow rate of the fluid and agrees within 4% with the effectiveness value calculated by different correlations and that obtained by using the simulation software, Aspen. Also the pressure drop increases with increasing mass flow rate and experimental values are more as compared to theoretical results because the losses in pipes and manufacturing irregularities have not been taken in to account.
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.

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Notations:-

1 Screw.Compressor.
2. Flow Control Valve.
3,7.Pressure Taps.
4,8 Manometers.
5. Heater.
6.Test Section.
T1- Inlet Temprature of Cold fluid.
T2-Outlet Tempratuure of Cold fluid.
T3- Inlet Temprature of Hot fluid.
T4 Inlet Temprature of Hot fluid.