Performance Analysis of Compact Heat Exchanger-A Review

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Abstract - 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.

Keywords – Compact Heat Exchanger, Effectiveness, and Heat transfer coefficient.

I. INTRODUCTION

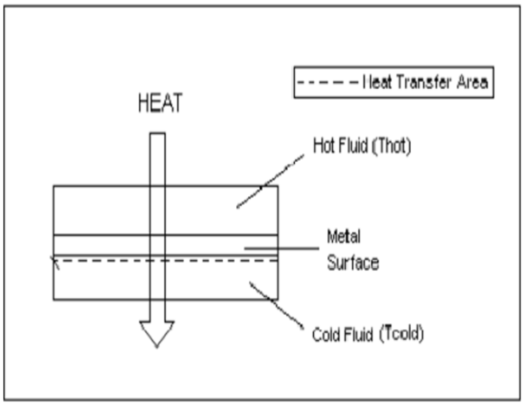
A heat exchanger is a device to transfer heat from a hot fluid to cold fluid across an impermeable wall. Fundamental of heat exchanger principle is to facilitate an efficient heat flow from hot fluid to cold fluid. This heat flow is a direct function of the temperature difference between the two fluids, the area where heat is transferred, and the conductive/convective properties of the fluid and the flow state. This relation was formulated by Newton and called Newton's law of cooling, which is given in Equation

$$Q = h*A*\Delta T$$

Where h is the heat transfer coefficient [W/m^2K], where fluid's conductive/convective properties and the flow state comes in the picture, A is the heat transfer area [m^2], and T is the temperature difference [K].

Above figure shows the basic heat transfer mechanism. Heat exchangers are one of the vital components in diverse engineering plants and systems. So the design and construction of heat exchangers is often vital for the proper functioning of such systems.

It has been shown in [Barron, 1985] that the low temperature plants based on Linde – Hampson cycle cease to produce liquid if the effectiveness of the heat exchanger is below 86.9%. On the other hand in aircrafts and automobiles, for a given heat duty, the volume and weight of the heat exchangers should be as minimum as possible. So the main requirement for any heat exchanger is that it should be able to transfer the required amount of heat with a very high effectiveness. In order to increase the heat transfer in a basic heat exchanger mechanism shown below in Figure 1.1, 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 life span of those materials. As a result of these facts, increasing the heat transfer surface area generally is the best engineering approach.



The above requirements have been the motivation for the development of a separate class of heat exchangers known as Compact heat exchangers. These heat exchangers have a very high heat transfer surface area with respect to their volume and are associated with high heat transfer coefficients. Typically, the heat exchanger is called compact if the surface area density (β) i.e. heat transfer surface area per unit volume is greater than 700 m^2/m^3 in either one or more sides of two-stream or multi stream heat exchanger [R.K Shah, Heat Exchangers, Thermal Hydraulic 1980]. The compact heat exchangers are lightweight and also have much smaller footprint, so they are highly desirable in many applications.

II. LITERATURE SURVEY

Heat exchangers constitute the most important components of many industrial processes and equipment's covering a wide range of engineering applications. Increasing awareness for the effective utilization of energy resources, minimizing operating cost and maintenance free operation have led to the development of efficient heat exchangers like compact heat exchangers.

R.K Shah [15] in his elaborate discussion over the classification of heat exchangers has defined the "compact heat exchangers" as one having a surface area density of more than 700 m2/m3. Such compactness is achieved by providing the extended surfaces i.e. fin on the flow passages which work as the secondary heat transfer area.

The main purpose of a recuperative heat exchanger is to facilitate the effective exchange of thermal energy between the two fluids flowing on the either side of a solid portioning wall, during which both the streams experience some viscous resistance and led to pressure drop. So in any heat exchanger the information regarding the quantity oh heat transfer and pressure drop are of utmost importance. Heat transfer and pressure drop characteristics of heat exchanger are mainly expressed in terms of j and f factor respectively.

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 recalculating region behind the trailing edge are absent if the plate thickness is neglected. Their calculation method was based on the periodically fully developed flow through one periodic module since the flow in OSF channels attains a periodic fully developed behavior after a short entrance region, which may extend to about 5 (at the most 10) ranks of plates (Sparrow, et al. 1977). Steady and laminar flow was assumed by them between Reynolds numbers 100 to 2000. They found the flow to be mainly laminar in this range.

Although in some cases just before the Reynolds no. 2000 there was a transition from laminar to turbulence. Especially for the higher values of t/H. They used the constant heat flow boundary condition with each row of fins at fixed temperature. They made their analysis for different fin thickness ratios t/H= 0, 0.1, 0.2, 0.3 for the same fin length L/H = 1, and they fixed the Prandtl number of fluid = 0.7. For proper validation they compared there numerical results with the experimental results of [London and Shah] for offset strip fin heat exchangers. The result indicates reasonable agreement for the f factors, but the predicted j factor is twice as large as the experimental data. They concluded that the thick [plate situation leads to significantly higher pressure drop while the heat transfer does not sufficiently improve despite the increased surface area and increased mean velocity.

III. SYSTEM MODEL

My proposed Experimental Setup………….

IV. PREVIOUS WORK

Till time there is no finding effectiveness of compact heat exchanger, Only finding effectiveness and other parameter like heat transfer coefficient etc..

V. PROPOSED METHODOLOGY

With the help of finding experimental data and some software like mat lab to analyze that data.

REFERENCES

[1] Patankar S. V. and Prakash C. 1981 An Analysis of Plate Thickness on Laminar Flow and Heat transfer in Interrupted Plate passages. International Journal of Heat and Mass Transfer 24: 1801-1810.

[2] Joshi H. M. and Webb R. L. 1987. Heat Transfer and Friction in Offset Strip Fin Heat Exchanger, International Journal of Heat and Mass Transfer. 30(1): 69-80

[3] Suzuki, K., Hiral, E., Miyake, T., Numerical and Experimental studies on a two Dimensional Model of an Offset-Strip-Fin type Compact Heat Exchanger used at low Reynolds Number. International Journal of Heat and Mass Transfer 1985 28(4) 823-836.

[4] Tinaut F. V., Melgar A. and Rehman Ali A. A. 1992 Correlations for Heat Transfer and Flow Friction Characteristics of Compact Plate Type Heat Exchangers. International Journal of Heat and Mass Transfer. 35(7):1659:1665

[5] Manglik and Bergles A. E. 1995 Heat Transfer and Pressure drop Correlations for Rectangular Offset Strip Finn Compact Heat Exchangers. Experimental Fluid Science 10:171- 180.

[6] Hu S and Herold K. E. 1995a Prandtl Number Effect on Offset Strip Fin Heat Exchanger Performance: Predictive

Model for Heat Transfer and Pressure Drop. International Journal of Heat and Mass Transfer 38(6) 1043-1051

[7] Hu S and Herold K. E. 1995b Prandtl number Effect on Offset Strip Fin Heat Exchanger Performance: Experimental Results. International Journal of Heat and Mass Transfer 38(6) 1053-1061.

[8] Zhang L. W., Balachandar S., Tafti D. K. and Najjar F. M. 1997. Heat Transfer Enhancement Mechanisms in Inline and Staggered Parallel Plate Fin Heat Exchanger. International Journal of Heat and Mass Transfer 40(10):2307-2325

[9] Dejong N. C., Zhang L. W., Jacobi A. M., Balchandar S. and Tafti D. K. 1998. A Complementary Experimental and Numerical Study of Flow and Heat Transfer in Offset Strip Fin Heat Exchangers. Journal of Heat Transfer 12:690:702

[10] Bhowmik H., Kwan- Soo Lee 2009. Analysis of Heat Transfer and Pressure Drop Characteristics in an Offset Strip Fin Heat Exchanger. International Journal of Heat and Mass Transfer 259-263

[11] Saidi A. and Sudden B. 2001. A Numerical Investigation of Heat Transfer Enhancement in Offset Strip Fin Heat Exchangers in Self Sustained Oscillatory Flow. International Journal of Numerical Methods for Heat and Fluid Flow. 11(7): 699-716

[12] Dong J., Chen J., Chen Z. and Zhou Y. 2007. Air Side Thermal hydraulic Performance of Offset Strip Fin Heat Exchangers Fin Aluminum Heat Exchangers. Applied Thermal Engineering 27:306-313

[13] Michna J. G., Jacobi A. M. and Burton L. R. 2005. Air Side Thermal- Hydraulic Performance of an Offset Strip Fin Array at Reynolds Number up to 12, 0000. Fifth International Conference on Enhanced Compact and Ultra Compact Heat Exchangers. Science, Engineering and Technology 8-14.

[14] Prabhat Gupta, Atrey M. D. Performance Evaluation Of Counter Flow Heat Exchangers Considering the Heat In Leak and Longitudinal Conduction for Low Temperature applications. Cryogenics Volume 40, issue 7, Pages 469-474.

[15] Barron R. F., Cryogenic Heat Transfer, Taylor and Francis (1999) 311-318.

[16] Shah R. K. and Sekulic D. P. Fundamentals of Heat Exchangers, John Willey & Sons Inc., pp 10-13

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