ISSN No:-2456-2165

Study of Plate Type Heat Exchanger with Alternate Pipe Arrangement

Upendra Khare, Manoj Sharma

Abstract:- This paper is an attempt to study the concept of laws of thermodynamics and heat exchanging process. The heat exchanger is a device which obeys the thermodynamic laws for exchanging heat and temperature from one substance to another. In last few decades, the technology used in heat exchanger is traditional and less efficient. But advancement in technology has given new designs of heat exchanger. Plate-fin heat exchanger is in use in power plants and other thermal plants nowadays. These heat exchangers are made up of corrugated plates which increase its efficiency and performance as compared to shell and tube heat exchanger. Plate heat exchangers can be easily assembled and split. Because of which inspection, maintenance, and cleaning are easy. Due to presence of shear rates and shear stresses, high turbulence, secondary flow and mixing and plate corrugation pattern in plate type heat exchangers fouling is reduced about 10 to 25% as compared to shell and tube exchangers heat transfer. In this heat exchanger friction factor is less due to rectangular shape plate and it is more efficient.

I. INTRODUCTION

Plate-fin heat exchangers are broadly utilized as a part of vehicle, aviation, cryogenic and synthetic enterprises. They are described by high adequacy, smallness (high surface range thickness), low weight and direct cost. Despite the fact that these exchanges have been widely utilized the world over for quite a few years, the advancements identified with their outline and fabricate stay restricted to a couple organizations in created nations. As of late endeavours are being made in India towards the advancement of little Plate-fin heat exchangers for cryogenic and aviation applications.They are suitable because these can easily have cleaned and give higher efficiency and also need less space (approximately one third) of shell and tube heat exchangers. Plate type heat exchangers are formed by thin plates and these plates can be smooth or corrugated form. They are either wound or flat in exchangers. Commonly, these type exchangers cannot hold very high pressure, temperatures and also pressure and temperature differences. These are suitable because have better advantages such as ease of production, compactness, sensitivity and easy care after installation. For achieving improvements in plate type heat exchangers amount of heat transfer and pressure drop should be considered. Rate of heat transfer should be more and pressure drop should be less. Corrugated plate can produce resistance in the flow with high friction loss so before designing both factors should be considered. There are also some other plate type heat exchangers in different shape (spiral plate, lamella, and plate-coil).

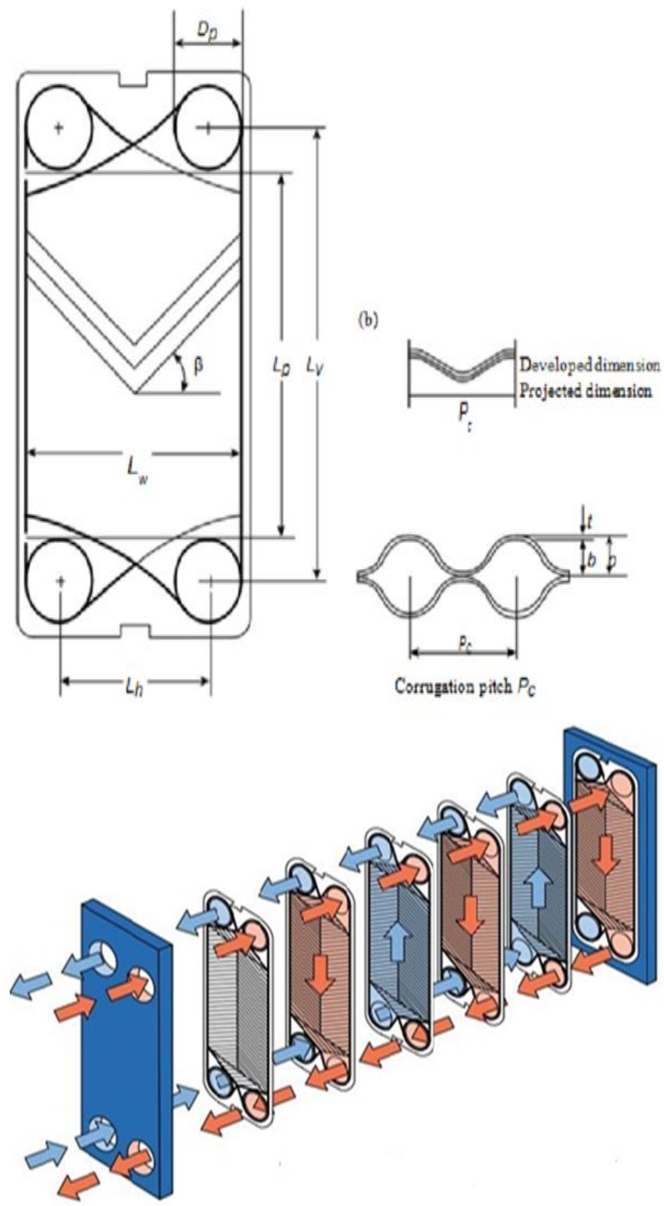

Fig 1:- Flow principle of plate heat exchanger

ISSN No:-2456-2165

II. ADVANTAGES AND LIMITATIONS OF PLATE HEAT EXCHANGERS

There are some following advantages of plate heat exchangers; these can be easily participated into their individual components for cleaning, inspection and maintenance. In this heat exchangers, very high heat transfer coefficients are gained and this was succeeded by breakup and reattachment of boundary layers, swirl or vortex flow generation, and small hydraulic diameter flow passages. For the plate heat exchangers surface area which is required is one half to one third to shell and tube exchangers. Plate type heat exchangers need less space as compared to other type exchangers. Gross weight of plate heat exchanger is almost one-sixth of shell and tube exchangers. Leakage does not take place until holes would not be developed.

Plates and gaskets are cause of some inherent limitations in the plate heat exchangers. Maximum pressure handling capacity of plate heat exchanger is almost 3MPa gauge or 435 psi but practically it works on 1.0MPa or 150 psi. Materials of gasket limit the use of plate heat exchangers in highly corrosive applications. Maximum operating temperature is almost 2608C or 5008F but in practically it works below 1508C or 3008F for avoiding the use of expensive gasket materials. Tracking the pinhole leaks are very difficult work in the plate heat exchangers. Fluids containing fibrous materials are not perfect for plate heat exchangers. Viscous fluids can be managed, but Due to the extremely viscous fluids maldistribution problem is occurred in cooling. For toxic fluids Plate exchangers are suitable in use. Total surface area of largest unit has almost 2500m^2 or 27000 ft^2per frame.

III. MAJOR APPLICATIONS

For milk pasteurization in 1923 firstly plate heat exchanger was discovered. In present time it is used for liquid-liquid heat transfer duties (viscosities up to 10 Pa s). Commonly these are used in dairy, juice, beverage, alcoholic drink, general food processing, and pharmaceutical industries. Plate type heat exchangers are also used in various fields' mostly in industries and also for closed circuit cooling systems of large petrochemical and power plants. For lower density gas to gas operations plate heat exchangers are not suitable.

IV. OTHER TYPES OF PLATE-TYPE HEAT EXCHANGERS

These are spiral plate, lamella, and plate coil exchangers, and plate fin heat exchangers. Classification according to the construction features

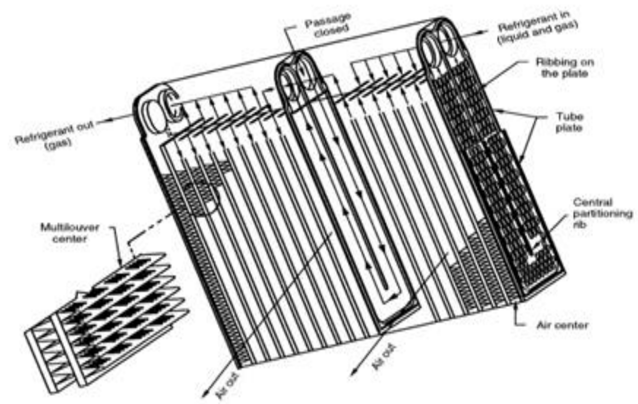

Fig 2:- U- channel ribbed plates and multi louver fin automotive evaporator.

Corrugation depth vs corrugation wavelength plot is given in figure 3. This plot also emphasizes the effect of angles at which fins are assembled.

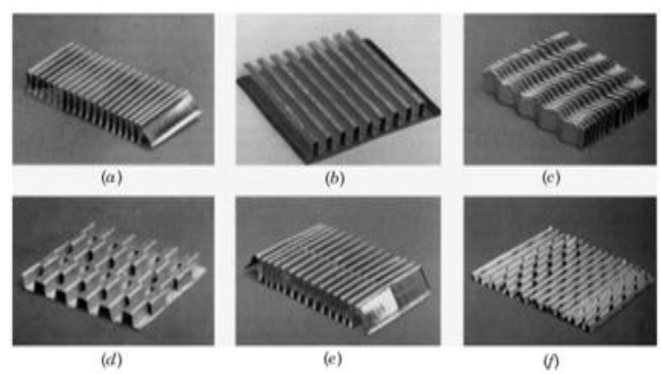

Figure 3:- Corrugated fin geometries for plate-fin heat exchangers; (a) Plain triangular fin; (b) Plain rectangular fin; (c) Wavy fin;) d) Offset fin; (e) Multi louver fin ; (f) Perforated fin.

Plate-fin heat exchangers are commonly triangular and rectangular cross section in shape. These can be sandwiched shape between in parallel plate. Flat tube and webs are used with or without introduce for displacing the parting sheet because liquid or phase change liquid flows on the other sides.

For moderate operating pressures {less than about 700KPa gauge (100psi)} plate-fin exchangers are commonly designed. For operating pressure up to about 8300Kpa gauge (1200psi) plate-fin exchangers are commercially available.

V. CALCULATION TOPIC

➢ *Stepwise Performance Analysis*

The required heat load can be calculated from the heat balance as
Qrh = 0.14 × 0.931 × (35-4) = 4.04 W
Qrc = 0.14 × 4.20501 × (11.34-1.5) = 17.378 W

The effective number of plates is
N e = Nt − 2 = 20 – 2 = 18

The effective flow length between the vertical ports is Leff ≈ Lv = 27.5 cm

The plate pitch can be determined from Equation,
p=Lc/Nt

Where Nt is the total no. of plates
=50/25 = 2.5 cm

Mean channel flow gap is given by,
b = p – t = 25 – 6 = 19 mm = 1.9 cm

The one channel flow area is, Ach = b × Lw = 1.9 × 17.5 = 33.25 cm2
And the single-plate heat transfer area is, A1 =Ae/Ne = 1.44/18 = 0.08 m2

The projected plate area A1p from Equation is,
A1p = LP.LW = 70 x 15 = 600 cm2 = 0.06 m2

The enlargement factor has been specified by the manufacturer, but it can be verified from Equation
Φ = A1/A1p = 0.08/0.06=1.33
The channel hydraulic/equivalent diameter from Equation
Dh = = = 0.02857 m

The number of channels per pass, Ncp, from Equation
= Ncp = = = 10

➢ *Heat Transfer Analysis:*

Mass flow rate per channel is given by mch = 0.014 Kg/S

And the mass velocity, Gch:
Gch = = 4.211 Kg/m2s

The hot fluid Reynolds number can be calculated as
Reh = = = 247.76

And the cold fluid Reynolds number can be calculated as
Rec = = =435.29

The hot fluid heat transfer coefficient, hh, can be obtained by using Equation

From Table , Ch = 0.3 and n = 0.663, so the heat transfer coefficient from above Equation can be found as
Nuh = = 0.3(Re)0.663(Pr)1/3( )0.17
Assuming µb ≈ µw
Nuh = 30.01
hh = = = 113.085 W/m2K

Cold fluid heat transfer coefficient, hc is determined similarly,
Nuh = = 0.3(435.29)0.663(9.419 x 10-3)1/3 = 3.615
hc = = = 15.61 W/m2K
For the overall heat transfer coefficient, the clean overall heat transfer coefficient can be found by the Equation is
=
= 13.71 W/m2K

The fouled (or service) overall heat transfer coefficient is calculated from Equation
= 13.693 W/m2K

The corresponding cleanliness factor is
CF = =

Which is rather low because of the high fouling factor.
The actual heat duties for clean and fouled surfaces are Qc = UcAeΔTm= 13.71 X 1.44 X 9.415 = 185.87 W Qf = UfAeΔTm= 13.693 X 1.44 X 9.415 = 185.644 W

The safety factor is
Cs = = = 0.998 The percent over surface design, from Equation is
OS = 100Uc Rft = 100 x 13.71 x 0.0000907
Where Rft = higher fouling resistance OS = 12.43 %

VI. MODEL

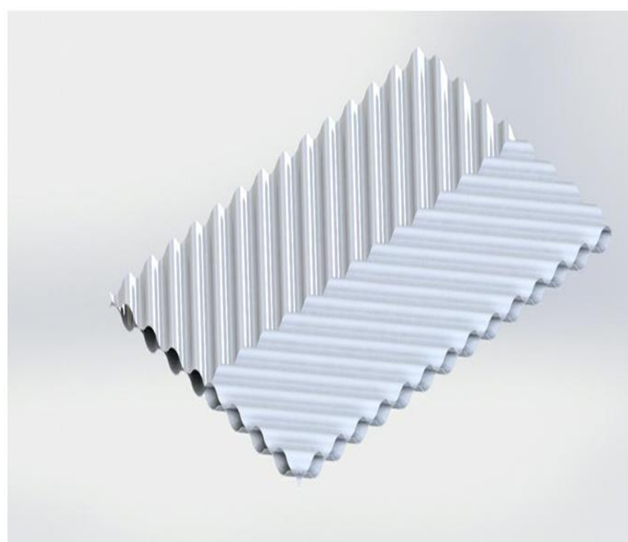

Fig 4:- Model of corrupted plate heat exchanger

Modelling of corrupted plate heat exchanger is done on Solidworks 2014. For simplicity, the geometry is made such that the sharp edges are replaced by curved surfaces. This helps in the thermal analysis because of easy meshing required.

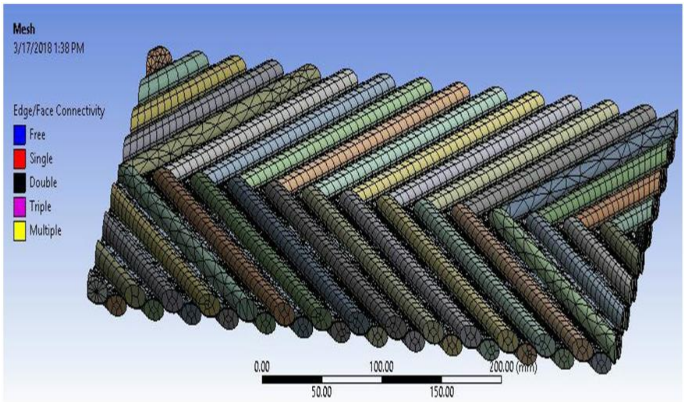

Fig 5:- Edge/face connectivity with meshing.

VII. RESULTS

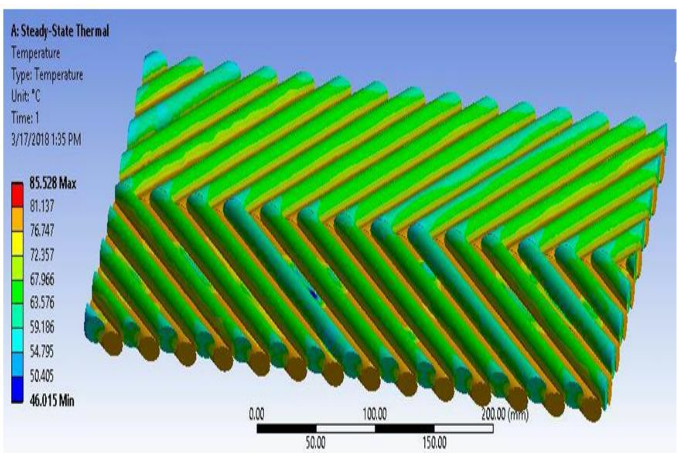

Fig 6:- ANSYS result of temperature variation around heat exchanger.

The above results show the variation of temperature around the corrugated heat exchanger. It is evident that the temperature is more at the bottom plate as compared to upper plate. This results in proper dissipation of heat as the upper surface is losing heat at a higher rate than the bottom plate. The temperature difference is around 40 degree Celsius.

VIII. CONCLUSION

Plate-fin heat exchanger are more efficient than shell-and-tube type heat exchanger because of low-pressure drop and high heat transfer coefficients. Plate-fin heat exchanger have compact size due to which it is used in power plant rather than shell-and-tube type heat exchanger, which have large and bulky structure and can't be easily cleaned and maintained as compared to plate fin heat exchanger. Small size, expandable capacity, and closer approach temperatures are also the traits of plate heat exchangers.

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