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Design and Cost Optimization of Plate Heat Exchanger

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Abstract :- *A plate heat exchanger is a type of heat exchanger that uses metal plates to transfer heat between two fluids. This has a major advantage over a conventional heat exchanger in that the fluids are exposed to a much larger surface area because the fluids spread out over the plates. This facilitates the transfer of heat, and greatly increases the speed of the temperature change. The plate heat exchanger (PHE) is a specialized design well suited to transferring heat between medium- and low-pressure fluids. Welded, semi-welded and brazed heat exchangers are used for heat exchange between high-pressure fluids or where a more compact product is required. The hot fluid flows in one direction in alternating chambers while the cold fluid flows in true counter-current flow in the other alternating chambers. The heat transfer surface consists of a number of thin corrugated plates pressed out of a high grade metal. The pressed pattern on each plate surface induces turbulence and minimizes stagnant areas and fouling. Unlike shell and tube heat exchangers, which can be custom-built to meet almost any capacity and operating conditions, the plates for plate and frame heat exchangers are mass-produced using expensive dies and presses. In this paper we designed the PHE for the required operating conditions. In the design we calculated the overall heat transfer coefficient of PHE. The heat transfer rate and the number of plates required for the PHE were also calculated. Cost optimization of the designed PHE was carried out and it has been found that there is a considerable drop in the cost of the heat exchanger.*
Keywords: - *Plate Heat Exchanger (PHE), Overall heat transfer coefficient, Cost Optimization*

I. INTRODUCTION

The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place. The plate pack is assembled between a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket which seals the interpolate channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. The plate corrugations promote fluid turbulence and support the plates against differential pressure. The plate and the pressure plate are suspended from an upper carrying bar and located by a lower guiding bar, both of which are fixed to a support column. Connections are located in the frame plate or, if either or both fluids make more than a single pass within the unit, in the frame and pressure plates.

The survey of the literature regarding the plate heat exchanger and using of various compressor oils in the household refrigerator and air-conditioners are listed.

ZhenHua Jin et. al. **[1]** designed and estimated the pressure drop of PHE. His investigation verified that the pressure drop in PHE is comparatively lesser than the shell and tube heat exchanger.

Aydın Durmus et. al. **[2]** he investigated the heat transfer in plate heat exchanger and he found that the heat transfer rate in plate heat exchanger is much more than that of conventional heat exchangers.

I.1. Working Principle

Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. Figure1 shows a plate heat exchanger. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.

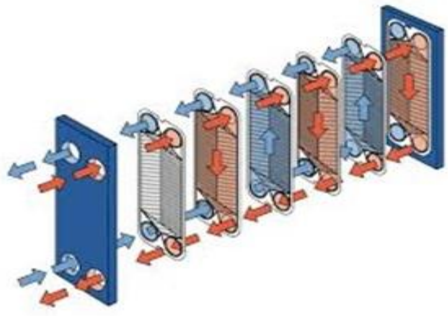

Figure 1: Plate heat exchanger

II. DESIGN OF PHE

II.1. Design Of Big Capacity Heat Exchanger

Mass flow rate = 231000 kg/hr

Hot side : Slurry

T_{si} = 86.6°C

T_{so} = 66°C

Cold side: Cooling water from cooling tower

T_{ci} = 34°C.

Q = mCp (T_{si} – T_{so}) = 231000 x 0.238 (86.6 – 66) = 11.325 x 105 Kcal/hr

T_{co} = T_{ci} + [Q/ m Cp] = 34 + [11.325x 105/ (231000x 0.238) = 54.599°C

To find LMTD

LMTD = [(T_{si}-T_{co}) – (T_{so}-T_{ci})]/ln [(T_{si}-T_{co})/(T_{so}-T_{ci})]

= [(86.66-54.599)-(66-34)]/ln [(86.6 - 54.599)/(66-34)] = 32.00105

U_{avg} = 1/[(1/H)+(x/k)+(1/Hc)+dFc]

Eliminate [1/Hc], dFc

H= Film coefficient

Re_{avg} = 32682.179

H= 0 .742 x Cp x G x (Re_{avg}) - 0.62 x (Pr_{avg}) - 0.667

= 0.742x 0.238 x (231000/1.02) x (32682.17) -0.62 x 1.465- 0.667

Where

Pr = µCp/k

k = 0.573 x 1.02 kcal/hr m² ºC = 0.58446

Pr = 1.465

Then H = 492.817 Kcal/ hr m² º C

U = 327.17 Kcal / hr m² º C

Number of Plates, N = A_t/ A_p

Assume Area of Plate, A_p =1.02 m²

A_t = (Q / UxLMTDxF)

Where Q = 11.325 x 10 5 Kcal/ hr

LMTD = 32.005

U = 327.17 Kcal/hr m² º C

F = 0.98

A_t = (11.3258 x10 5)/(327.17 x 32.0005x 0.98) = 110.377 m^2

Number of plates N = A_t/A_p = 110.377/1.02 = 108.2 = 108

II.2. New Design Parameter

Number of plates, N = 108

Area of heat exchanger A_t = 110.377 m^2

Overall heat transfer coefficient U = 327.17 kcal/hrm^2 °C

LMTD = 32.005

Slurry Inlet, T_{si} = 86.6 º C

Slurry Outlet, T_{so} = 66 º C

Cooling Water Inlet, T_{ci} = 34 º C

Cooling Water Outlet, T_{co} = 54.599 º C

III. COST OPTIMISATION

Number of plates used = 108

So the total cost of newly designed Alpha laval Heat exchanger = 108 x 3750 = Rs 405000

Cost of existing Alpha Laval Heat Exchanger = Rs 560000

Reduction in cost = Rs 560000 – Rs 405000 = Rs 155000

Maintenance cost per hour loss = Rs 75000

Total time = 8hr for cleaning

Labour = 5 people (Rs 200/hr)

Considering the two Heat exchangers there would be 4 maintenance schedules, 2 for each

Down time loss = 8 x 4= 32hrs per hour = Rs 75000

So for 8 hours = 75000 x 32= Rs 240000

Considering the newly designed Heat exchanger there is an average of 3 maintenance schedule

Downtime loss = 8 x 3 = 24 hrs

Per hour assumed to be = Rs 75000

So for designed Heat exchanger = 75000 x 24 = Rs 1800000

Labour Cost for Maintenance for existing Heat Exchanger:

For 1 worker = Rs 200/hr

For 5 worker = 5 x 32 x 200 = Rs 32000

Labour cost for newly designed Heat exchanger

For 1 worker = Rs 200/hr

For 5 worker = 200 x 24 x 5 = Rs 24000

Saving from downtime cost

Rs 2400000- Rs 1800000 = Rs 600000

Savings from Labour cost

Rs 32000 – Rs 24000 = Rs 8000

Cost of the Alfa Laval heat exchanger = Rs 493000

Cost of one plate of alpha Laval heat exchanger = Rs 3750

Cost of Spondex heat exchanger = Rs 453000

Number of plates used in alpha Laval Heat Exchanger = 84

Total cost of Laval Heat Exchanger = 84 x 3750 = Rs 315000

Number of plates in Spondex heat exchanger = 70

Total cost of Spondex heat exchanger = 70 x 3500 = Rs 245000

So total cost of both heat exchanger (Existing) = 315000 + 245000 = Rs 560000

IV. RESULTS

The advantages of using PHE were investigated experimentally. The main results are listed as follows:

[1]. The slurry temperature was reduced from 84°C to 66°C.
[2]. A considerable increase of cooling water temperature from 34°C to 54.5°C was observed.
[3]. The observations on temperature of the newly designed big capacity heat exchanger are shown in Figure 2.

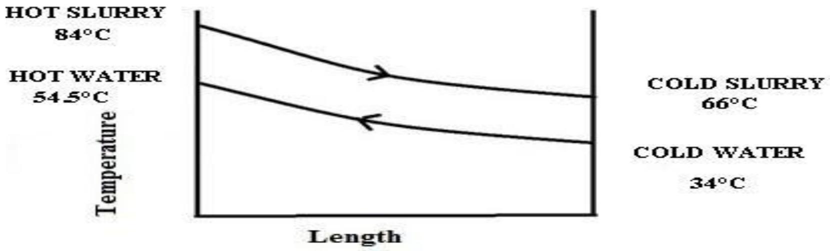

Figure 2: Temperatur vs Length Plot

Figure 3 shows the Layout of the new heat exchanger

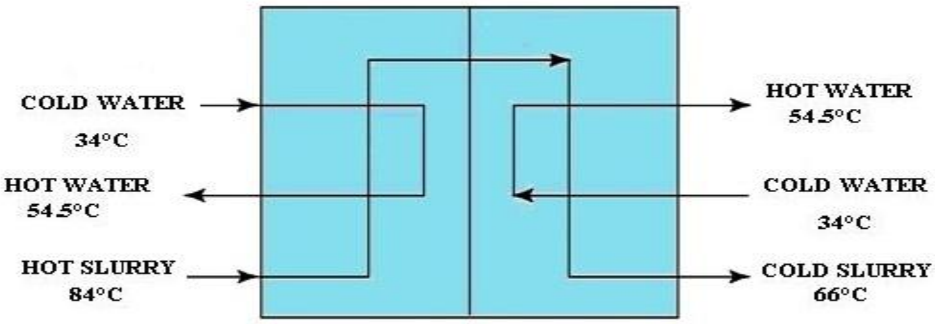

Figure 3: Layout of the new heat exchanger

V. CONCLUSIONS

When the application is within the pressure and temperature limits of both designs, the selection process should focus on initial cost, maintenance requirements, and future operating conditions.

The advantages of using PHE were investigated experimentally. The main conclusions are listed as follows:

[1]. A plate costs approximately Rs 3750. So the newly designed plate heat exchanger will cost approximately Rs 405000 which can replace the present two heat exchangers which together cost Rs 560000.
[2]. This leads to great reduction in space and cost without affecting the heat will transfer efficiency.
[3]. Initial cost is generally a function of approach temperature. Close approach temperatures temperature crosses favour the plate and frame heat exchanger while wide temperature approaches favour the shell and tube design.
[4]. When considering the maintenance costs, the determining factor should be the properties of fluid involve. When the fluid has a greater tendency to foul, the plate and frame design offer easier access to heat transfer surface for cleaning. In addition, because of high turbulence, plate type heat exchangers have less of a tendency to scale or foul when compared to a shell and tube design.
[5]. If your application requires a high probability against leakage, the better choice is shell and tube design. While the gasket is a weakness in the plate and frame design, the ability to expand or reduce the thermal capacity by adding or reducing plate s is a major advantage for the plate and frame heat exchanger. If you think the application may be expanded in the future, a plate heat exchanger is far the easiest and the most economical design.

In summary, properly selected, installed and maintained heat exchanger is probably the most trouble free piece of equipment in the system.

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