Heat Transfer Analysis of Corrugated Plate Heat Exchanger over Coil Type Heat Exchanger: A Review

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Abstract—**Compared to coil type heat exchanger, corrugated plate heat exchangers (PHE) have larger heat transfer surface. Due to the presence of corrugations on plates of PHE, turbulence level is increased and so the heat transfer. In this study, experiment of heat transfer phenomenon was carried out at bottle washer of beverage making industry. This typical bottle washer which has coil type heat exchanger consumes more amounts of energy. Study shows that employing PHE instead of coil type heat exchanger saves considerable amount of energy.**

Keywords— Coil Heat transfer System, Furnace oil yield, Bottle washer, Plate Heat Exchanger (PHE) .

I. INTRODUCTION

Experiment was performed at bottle washer which is used for rinsing and cleaning of bottles. For this purpose heated caustic solution is used. Heating of caustic solution inside bottle washer is done by coil type heat exchanger. Focus is made to reduce the quantity of steam utilized in bottle washing process. Phenomenon of heating the solution depends on the area expose to heat transfer as well as heat transfer rate of coil type heat exchanger. Study of PHE shows that its effectiveness is much higher than convectional coil system .Configuration of corrugated plates of PHE leads to increase in area expose to heat transfer which causes increased heat transfer rate .When PHE is incorporated instead of coil system, steam consumption is reduced and there is a significant increase in efficiency of the process.

A. Bottle Washer Unit

The bottle washer unit consists of five compartments namely pre-rinse, soak1, soak2, again pre-rinse and final rinse out of which Soak1 and Soak2 have capacity of 28000 L and 8000 L of storage. This soak tanks contains caustic solution which is used for cleaning of bottles. Bottles from market are first passed through pre-rinsed section for hydrowash by the rotary jets. Steam from boiler passes through coils inside the soak tanks. The steam enters the soak through the coils which are nothing but the hollow pipe of metallic material. As this steam passes through the coil type heat exchanger, energy and heat of steam is rejected to the surrounding. The surrounding is a mixture of water and caustic soda solution. The caustic solution at ambient temperature of 28^0C is made to heat up upto 65^0C which is the required temperature. The steam from other end of coil comes out as condensate which is further utilized and fed into feed water tank.

B. Coil Heat Transfer system

The system is placed inside bottle washer. Its purpose is to heat the caustic solution from ambient temperature to to around 65^0C. In this steam generated from boiler is passed through separate coils which are surrounded by caustic solution. Heat rejected by steam is gained by caustic solution. The principle of heating caustic solution is based on the fact that water becomes lighter and comes to the top when it is heated up. The caustic solution which is in contact with coils (carrying steam inside) gets heated up first and comes to the top. This process continues till remaining solution acquires heat. The area exposed to heat transfer is the surface area of the pipe.

C. Plate Heat Exchanger (PHE)

The plate heat exchanger (PHE) is a specialized design well suited to transfer heat between medium and low-pressure fluids. Stainless steel is a commonly used metal for the plates because of its ability to withstand high temperatures, its strength, and its corrosion resistance. The plates are often spaced by rubber sealing gaskets which are cemented into a section around the edge of the plates [9].The plates are pressed to form troughs at right angles to the direction of flow of the liquid which runs through the channels in the heat exchanger. These troughs are arranged so that they interlink with the other plates which forms the channel with gaps of 1.3–1.5 mm between the plates. Arrangement of PHE & Flow through

PHE and construction of plate is shown in figure [2].

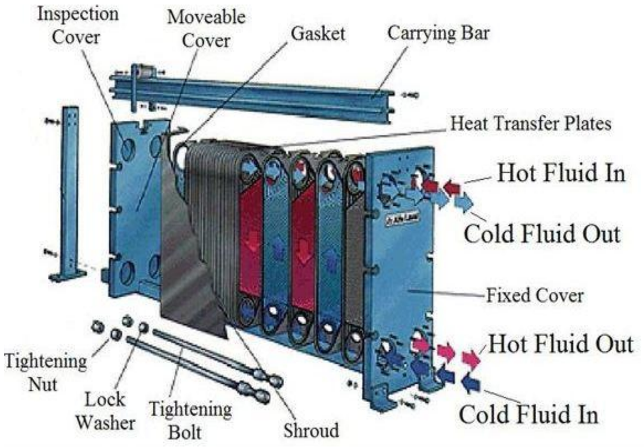

Fig.1. Various Part of Plate Heat Exchanger

The plates produce an extremely large surface area, which allows for the fastest possible transfer. Making each chamber thin ensures that the majority of the volume of the liquid contacts the plate, again aiding exchange. The troughs also create and maintain a turbulent flow in the liquid to maximize heat transfer in the exchanger. A high degree of turbulence can be obtained at low flow rates and high heat transfer coefficient can then be achieved. A plate heat exchanger consists of a series of thin, corrugated plates which are mentioned above. These plates are gasketed, welded or brazed together depending on the application of the heat exchanger. The plates are compressed together in a rigid frame to form an arrangement of parallel flow channels with alternating hot and cold fluids.

D. Physical Parameters Affecting Plate Heat Exchanger

The six most important parameters are as follows:
• The amount of heat to be transferred (heat load).
• The inlet and outlet temperatures on the primary and secondary sides.
• The maximum allowable pressure drop on the primary and secondary sides.
• The maximum operating temperature.
• The maximum operating pressure.
• The flow rate on the primary and secondary sides.

Temperature Program:
This means the inlet and outlet temperatures of both media in the heat exchanger.

Heat Load:
Disregarding heat losses to the atmosphere, which are negligible, the heat lost (heat load) by one side of a plate heat exchanger is equal to the heat gained by the other. The heat load (P) is expressed in kW or kcal/h.

Logarithmic Mean Temperature Difference:
Logarithmic mean temperature difference (LMTD) is the effective driving force in the heat exchanger.

Density:
Density (ρ) is the mass per unit volume and is expressed in kg/m^3 or kg/dm^3.

Flow Rate:
This can be expressed in two different terms, either by weight or by volume. The units of flow by weight are in kg/s or kg/h, the units of flow by volume in m^3/h or l/min. To convert units of volume into units of weight, it is necessary to multiply the volume flow by the density.

Pressure Drop:
Pressure drop (Δp) is in direct relationship to the size of the plate heat exchanger. If it is possible to increase the allowable pressure drop, and incidentally accept higher pumping costs, then the heat exchanger will be smaller and less expensive. As a guide, allowable pressure drops between 20 and 100 kPa are accepted as normal for water/water duties.

Specific Heat:
Specific heat (c_p) is the amount of energy required to raise 1 kg of a substance by one degree centigrade. The specific heat of water at 20°C is 4.182 kJ/kg °C or 1.0 kcal/kg °C.

Viscosity:
Viscosity is a measure of the ease of flow of a liquid. The lower the viscosity, the more easily it flows. Viscosity is expressed in centipoises (cP) or centistokes (cSt).

Overall Heat Transfer Coefficient:
Overall heat transfer coefficient (U) is a measure of the resistance to heat flow, made up of the resistances caused by the plate material, amount of fouling, nature of the fluids and type of exchanger used. Overall heat transfer coefficient is expressed as W/m^2 °C or kcal/h, m^2 °C.

Operating Principle of Plate Heat Exchanger

- Channels are formed between the plates & corner ports are arranged so that the two media flow through alternate channels.
- The heat is transferred through the thin plate between the channels, and complete counter current flow is created for highest possible efficiency. No intermixing of the media or leakage to the surroundings will take place as gaskets around the edges of the plates seal the unit. Operating Principle of Plate Heat Exchanger.

Fluid Flow in Plate Heat Exchanger
Figure 2, illustrates the nature of fluid flow through the plate heat exchanger. The primary and secondary fluids flow in opposite directions on either side of the plates. Water flow and circuiting are controlled by the placement of the plate gaskets. By varying the position of the gasket, water can be channelled over a plate or past it. Gaskets are installed in such a way that a gasket failure cannot result in a mixing of the fluids. In addition, the outer circumference of all gaskets is exposed to

the atmosphere. As a result, should a leak occur, a visual indication is provided.

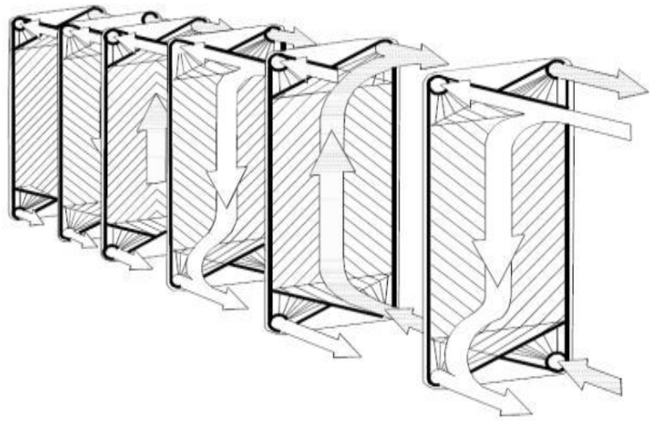

Fig.3. Fluid flow in plate heat exchanger

Heat transfer in Plate Heat Exchanger

- Conduction

  Energy is transferred between solids or stationary fluids by the movement of atoms or molecules.

  Heat transfer by conduction within chevron plates during whole process of heat transfer in chevron plates heat exchanger.

- Convection

  Energy is transferred by mixing part of a medium with another part.

  Heat transfer takes between molecules of water in chevron plate heat exchanger.

II. Calculations and Results

(1) Efficiency of the boiler:-

In determining the boiler efficiency, rate of steam produced per hour is taken as output whereas energy liberated from burning of fuel is taken as input.

$$\eta_B = \frac{m_s C_{ps}(t_{h1} - t_{h2})}{m_f C_v} = 81.98\ \%$$

(2) Efficiency of the bottle washing process considering coil system:-

In calculating bottle washer process efficiency by coil type heat exchanger, the amount of caustic solution being heated up from 28^o C to 65^{o}C is taken as output and the amount of steam utilized is taken as input. Here the heat rejected by steam is gained by caustic solution. The efficiency of process is found out to be 56.05%.

$$\eta_C = \frac{m_w C_{pw}(t_{c2} - t_{c1})}{m_s C_{ps}(h_1 - h_2)} = 56.05\ \%$$

In case of PHE, the area exposed to heat transfer and the heat transfer rate are much more than that of the coil type heat exchanger. Therefore replacing the coil system with PHE leads to raise the bottle washer process efficiency up to 84%.

Now by performing reverse calculations and putting efficiency equal to 84% in eq^n 2, new steam consumption is assumed as 'x' and thus new steam consumption rate was found out to be reduced by 34% Further to calculate amount of fuel saved (i.e. furnace oil) in boiler due to reduction in steam consumption,

Reduction in furnace oil considering boiler efficiency =

$$\frac{\text{saving in steam} \times \text{enthalpy of steam at working pressure} \times \eta_B}{\text{Calorific value of fuel}}$$

Thus furnace oil consumption was found out to be reduced by 23%.

III. Comparison of Consumption of Furnace Oil and Steam in Coil Heat Exchanger vs. PHE

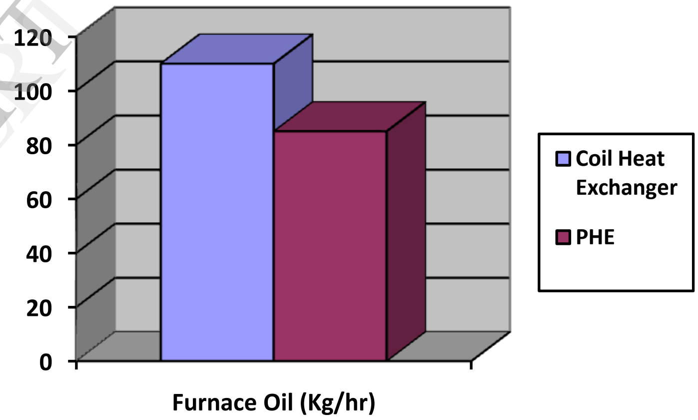

Fig. 5. Consumption of furnace oil

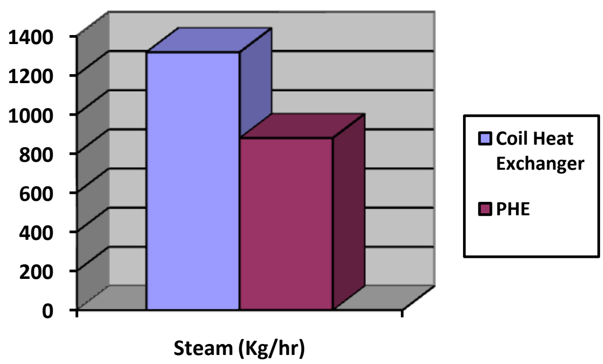

Fig.6. Consumption of steam

Thus the furnace oil yield is increased i.e. liters of beverage produced is more at the expense of reduced furnace oil ,which will further lead to increased the overall efficiency of the plant.

IV. CONCLUSIONS

Heat transfer analysis of PHE shows that as the effectiveness of PHE is more than that of the coil type heat exchanger ,more effective heat transfer takes place with reduced amount of energy inputs(steam and fuel).

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