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Computer Aided Design Analysis of Plate Type Heat Exchanger

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***Abstract* -For many industrial applications plate heat exchangers are demonstrating a large superiority over the shell and tube and other types of heat exchangers. In this paper we design a copper plate heat exchanger for milk pasteurization in a food industry using high temperature in a short time. The efficiency of this device depends on numerous factor likes space requirement, material required for construction, pressure drop.Energy requirement for circulation of milk and water by pump.**

In this paper we present a theoretical analysis of counter flow copper plate type heat exchanger and result and CFD analysis of pressure drop for milk and water over plate heat exchange .The result of CFD validate results predicted theoretically.

Knowing the hot and cold fluid stream inlet and outlet temperatures and mass flow rates of hot and cold fluid and respective heat capacities, and values of heat transfer coefficient. Mathematical model based on steady flow energy balancing for specific heat exchanger geometry and operational parameters the problem is numerically solved by LMTD method. This paper, present modeling done by PROE, CATIA V5R19, and the software analysis prediction of pressure drop and thermal analysis of plate heat exchanger done by CFD tools. CFD prediction are also validate with theoretical analysis of plate heat exchanger.

Key words - Plate heat exchanger, thermal performance, CFD, PROE, PHE, and LMTD.

I. INTRODUCTION

A heat exchanger is specialized devices that assist the heat transfer of one fluid to other, in some cases a solid wall may separates the t fluid and prevent them from mixing. In other design the fluid may direct contact with each other. Plates or baffle fines are sometimes used with wall in order to increase surface area turbulence introduce. A common appliance containing heat exchanger includes air conditioner, refrigerator and space heater. A plate heat exchanger also used in food industry, processing industry, petroleum refineries, sewage treatments cargo ships, space heating chemical processing and power production, perhaps most commonly known heat exchanger is car radiator which cools the hot radiator fluid by taking advantage of air flow over a surface of radiator, there are three primarily flow arrangements with heat exchanger counter flow, parallel flow and cross flow. The counter flow heat exchanger is more effective and efficient design because the fluid flows in opposite sides.

In order to select appropriate heat exchanger, Although the cost is often first consideration criteria evaluated and other several important selection criteria which includes pressure drop across heat exchanger , product mix , fluid flow, material required for construction ,thermal performance, high/low pressure limit, clean ability , maintenance and repair etc.

The rates of heat flow at any points depends upon heat transfer coefficient, temperature difference between hot fluid and cold fluid, material, No. of plates, total heat transfer area of plates.

The main objectives of this present paper theoretically analysis of copper plate heat exchanger, which more preferable over existing heat exchanger having stainless steel and economical analytically we compare volume required , material reduction, energy saving, and also pressure drops for milk and water . The result prediction pressure drop and temperature compare with CFD result.

II.DESIGN METHODOLOGY

The goal of heat exchanger design is to relate the inlet and outlet temperatures, the overall heat transfer coefficient, and the geometry of the heat exchanger, to the rate of heat transfer between the two fluids. The two most common heat exchanger design problems are those of rating and sizing. We will limit ourselves to the design of recuperates only. That is, the design of a two fluid heat exchanger used for the purposes of food pasteurization .Two approaches to heat exchanger design that will be discussed are the LMTD method and NTU method. Each of these methods has particular advantages depending upon the nature of the problem specification. We discuss LMTD method for design PHE

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Steps:

1 For constant specific heats with no change of phase, we may also write with a heat balance, the unknown process variable (flow rate or temperature) of one of the streams can be found.

$$Q_c = (m\,Cp)_c\,(T_{c2} - T_{c1})$$

And

$$Q_h = (m\,Cp)_h\,(T_{h1} - T_{h2})$$

Now from energy conservation we know that $Qc = Q_h = Q$.

2. Considering the type of fluids to be handled, a first guess of the overall the overall heat transfer coefficient Uo,

3. Then calculate LMTD to the some mean temperature difference by means of this relation:-

$$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)}$$

4. With the assumed *Uo*, an value of the heat total heat transfer area of plate required can be calculated as **A**t is given by relation.

$$Q = UoAt\Delta T_{LM}\,F\mathbf{t}$$

Where,

Uo = overall heat transfer coefficient in (W/(m²·c))

Ft= log. Mean correction factor.

ΔT_{LM} = log. Mean temp. difference.(·c)

hm = convective heat transfer coefficient.

hw =convective heat transfer coefficient for water.

tp = thickness of plate of plate ,

K= Thermal conductivity of material.

5. Overall heat transfer coefficient (Uo),

$$\frac{1}{Uo} = \frac{1}{hm} + \frac{1}{hw} + \frac{tp}{K}$$

6. Choose the Effective Area of the plate, which includes plate length, width & thickness of plate.

7. Select the number pass arrangement. And Select the number of Plates required.

8. Total Material required in kg mass (m) = ρ *V … kg

9. Calculated Pressure Drop by milk and water can be calculated by using relation,

$\Delta P = 64/Re\ De * \rho * V^2 /2De\ x*L$

10. Power required for circulating milk & water P=Pressure drop (ΔP) x mass flow rate (m)/Density(ρ)… Watt.

Table: 1.Operating condition

Content	Milk	Water
Density(kg/m	1050	996.13
Prandelt No.	0.002	0.000832
Temp.Inlet (C)	4	90
Temp.outlet(C)	80	65
Mass flow rate(kg/sec)	22.22	41.66

Specification of Stainless steel plate heat exchanger

Equipment selection duty =2008KW
Material = Stainless steel
Pass arrangement = 1:1
Length L = 1.5m
Width (w) = 0.5m
Spacing = 3mm
No. of channel (Nc) = 20
Thickness of plate (tp) =5mm
No. of plate = 41
Pressure drop for milk = ΔP = 1879.95 N/ m2
Pressure drop for water = ΔP = 1541.97 N/ m2
Total power required circulation of Milk & Water by pump =104.26 Watt

Energy required for circulation = 913 Units

Specification of Copper plate Heat Exchanger:

Equipment selection duty =2008KW
Material = copper
Pass arrangement = 1:1
Length (L) = 0.532m
Width (w) = 0.5 m
Spacing = 3mm
Thickness of plate (tp) = 2.5mm
No. of channel (Nc) = 20
No. of plate = 41
Pressure drop for milk = ΔP = 666.88 N/ m2
Pressure drop for water = ΔP = 545.91 N/ m2
Total power required circulation of Milk& Water by pumps =36.90 Watt
Energy required for circulation =323Units.

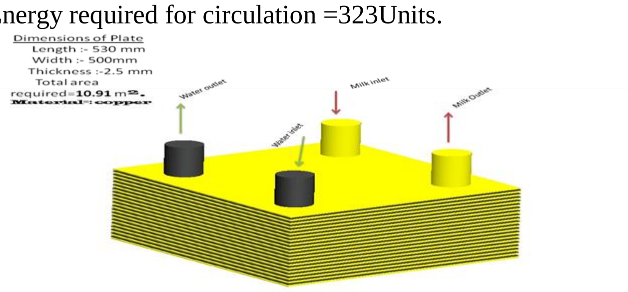

Fig 1:3D Model of Plate heat exchanger with 41 plates.

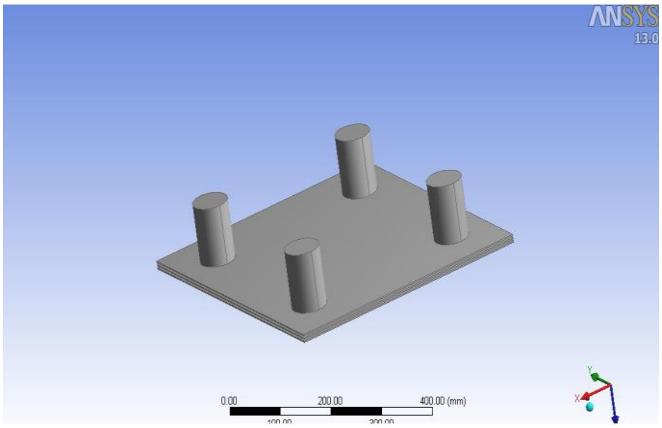

Fig 2: Import geometry

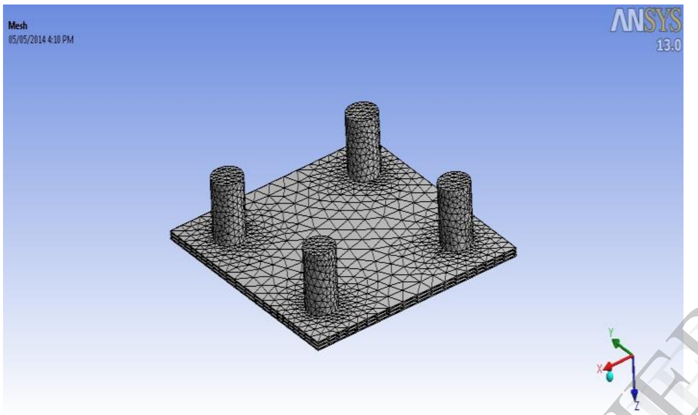

Fig3: Mesh model of Plate heat exchanger

Table 2.: Mesh Report

Mesh Information for CFX

Domain	Nodes	Elements
Milk	2371	8129
Water	3816	12522
All domain	6187	20651

.

Table 3:Boundary condition:

Boundary Physics for CFX	Default Domain Setting:
Boundary – Inlet Milk	Flow Regime = Subsonic
Type – INLET	Mass And Momentum = Normal Speed Normal Speed = 0.74 [m s^-1]
Location – inlet Milk	Heat Transfer = Static Temperature
	Static Temperature = 4 [C]
Boundary – outlet Milk	Flow Regime = Subsonic
Type – OUTLET Pressure & Direction	Mass And Momentum - Opening Relative Pressure = 0 [Pa]
Heat Transfer = Opening Temperature	Opening Temperature = 80 [C]
Boundary – Inlet Water	Flow Regime – Subsonic
Type – INLET	Mass And Momentum - Normal Speed Normal Speed = 1.386 [m s^-1]
Location – inlet Water	Heat Transfer = Static Temperature
Boundary – Outlet Water Type – OUTLET	Flow Regime - Subsonic Mass And Momentum - Opening
Pressure & Direction Location – Outlet Water	Relative Pressure = 0 [Pa Opening Temperature = 65 [C]

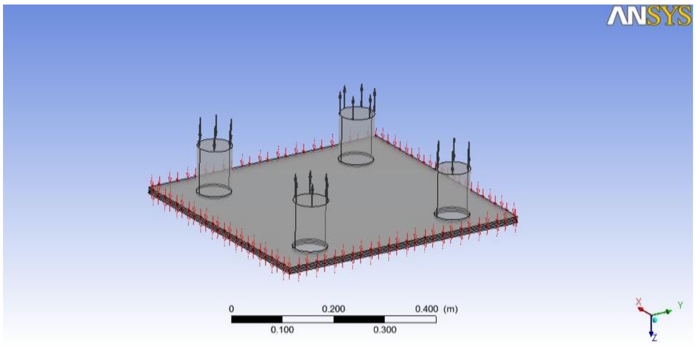

Fig 4: Boundary condition

I. CFD RESULT AND DISCUSSION

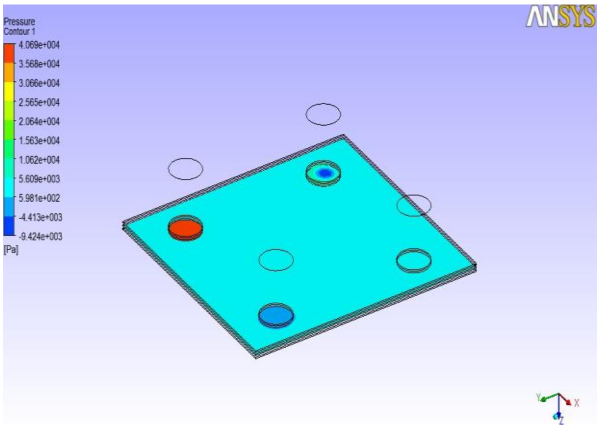

Fig 5: Pressure Drop variation for milk over plate.

Zones	Value in Pa.	Discussion
Blue	1.001e+002	Shows the very low pressure at the water outlet section due to extraction of heat with low flow velocity
SkyBlue	2.278e+002	Shows the pressure create on throughout milk plate.
Red	7.026+002	Shows maximum pressure occurred at the inlet of water because due to high velocity value

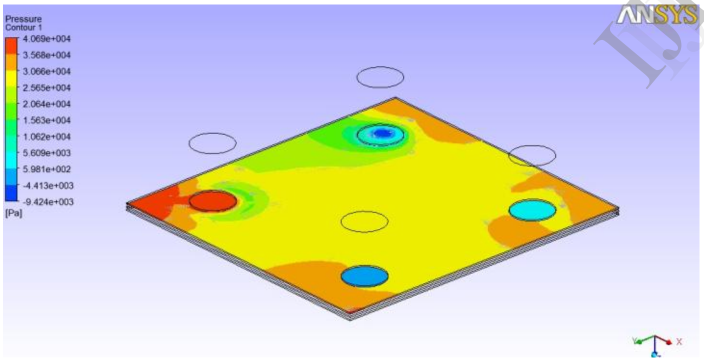

Fig 6: Pressure Drop variation for water over plate

Zones	**Values in Pa.**	Discussion
Blue	9.728e+001	Shows very low pressure is created at the outlet section due to Extraction of heat with low velocity flow
Sky-blue	1.942e+002	Shows the pressure create on thoughts the water plates
Green	3.395e+002	Its shows the little high pressure occurred at the water flow side
Yellow	4.364e+002	Shows the little high pressure occurred at middle section of water plates
Red	5.817e+002	Shows the maximum pressure occurred at the inlet of water because due to high velocity value

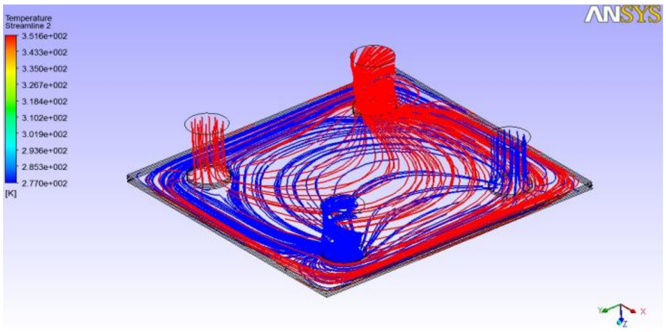

Fig. 7: Temperature distribution over plate.

Pressure drop Analytical result:

Value of pressure drop for milk =666.63 N/ m2
Value of pressure drop for water =545.91 N/ m2

Pressure drop CFD result:

Value of pressure drop for milk = 598.1 N/ m2
Value of pressure drop for water = 533.3 N/ m2

Temperature Analytical result

Maximum temperature Value = 334 ·K
Minimum temperature Value = 283 · K

Temperature CFD results:

Maximum temperature Value = 351·K
Minimum temperature Value = 277 · K

IV. CONCLUSIONS

1. It is concluded that the results obtained the total volume Occupied by the stainless steel material plate heat exchanger is 0.153m³, while the volume of the copper plate heat exchanger is 0.02727m³ using of copper material. Copper plate type heat exchanger results in an 82.17 % reduction in volume relative to the existing plate heat exchanger.

2. Material required for the copper plate heat Exchanger is 242.5 Kg but stainless steel plate heat exchanger is required 1232.45 Kg. Saving material required for construction copper material plate heat exchanger.

3. The pressure drop associated with the use of copper plate heat exchanger are significantly less than for conventional concentric tube configuration & the stainless plate heat exchanger. i.e. low power consumption.

4. For circulating milk and water for stainless steel plate exchanger, the total power required 104.268Watt, the annual units required for circulating is 913.18 units. A copper material of plate heat exchanger required the total power 36.90Watt, the annual units required only 324.29 units.

5. The CFD result of pressure drop is low as compare to the analytical result, & temperature results validate with analytical result we save energy require for circulation of water & milk is very low as compare to the stainless steel due to the above points hence prefer copper model of PHE.

This is an attempt to validate the CFD predictions with that of the analytically result.

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