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DESIGN AND COST OPTMISATION OF PLATE HEAT EXCHANGER

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Abstract² 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. The concept behind a heat exchanger is the use of pipes or other containment vessels to heat or cool one fluid by transferring heat between it and another fluid. The objective of the paper is to design a plate heat exchanger to replace two existing plate heat exchanger and also to optimize the cost for the design and maintenance and also analyze the performance of the plate heat exchanger. The sub objective is to find any ways to reduce the fouling occurring in the plate heat exchanger. The plate heat exchanger to be designed is to take less space and easier to maintain.

Keywords- plate heat exchanger, cost optimization, fouling, design, performance

I. INTRODUCTION

The concept behind a heat exchanger is the use of pipes or other containment vessels to heat or cool one fluid by transferring heat between it and another fluid. A heat exchanger is a device in which two IOXLG VWUHDPV RQH KRW DQG DQRWKHU FROG DUH EURXJKW LQWR µWKHUPDO FRQWDFW¶LQ of heat from the hot fluid stream to the cold.It provides relatively large area of heat transfer for a given volume of the equipment. They are in frequent use in the chemical process industries as well as in the refrigeration, cryogenic, waste-heat recovery, metallurgical and manufacturing applications [1].The driving force for the operation of a heat exchanger is the temperature difference between the fluids. The plates are often spaced by rubber sealing gaskets which are cemented into a section around the edge of the plates. Heat exchanger is a transfer device that is used for transfer thermal energy between two or more fluids available at different temperatures. In most heat exchangers, the fluids are separated by heat exchanger surface and ideally they do not mix. [2]

II. DESIGN CALCULATION

2.1 Design of small plate heat exchanger [3]

Temperature of the fluids flowing through the plates

$T_{si} = 82.36\ ^0 c$ $T_{so} = 61.2\ ^0 c$

$T_{ci} = 34\ ^0 c$ $T_{co} = 61\ ^0 c$

Where,

T_{si}, T_{so} are the inlet and outlet temperatures of the slurry flowing through the heat exchanger respectively

T_{ci}, T_{co} are the inlet and outlet temperatures of the water flowing through the heat exchanger respectively

Heat load, Q

Specific heat capacity of slurry, C_{ps}

C_{ps} = 0.9948 KJ/Kg K

ǻ7 si - T_{so}

Q = m C_{ps} ǻ

Mass flow rate, m = volumetric flow rate x density of slurry

Volumetric flow rate = 70 m^3/hr.
Specific gravity = density of slurry / density of water (specific gravity = 1.1)
Density of slurry = specific gravity x 100
= 1100 kg/m^3
Mass flow rate through the first sub stream = 231000 kg/hr
Assuming one-third of the hot stream flowing through small heat exchanger
= 1/3 x 231000
= 77000 kg/hr. = 21.3889 kg / s
Therefore,
Q = 21.3889 x 0.9948 x 24.1
= 512.79 kW
Hydraulic diameter, De
Width of the plate, w = 0.422m
Length of the plate, L = 0.950 m
Spacing between plates, b = 0.004m
Area of the plates, A_p = L x w = 0.95 x 0.422
= 0.4 m^2
Hydraulic diameter, De = [2 x w b] / [w + b]
= [2 x 0.422 x 0.004] / [0.422 +0.004]
= 7.92 x 10^{-3} m
Reynolds number, Re
Mass flow area, G = mass flow rate (m) / Area of plate (A_p)
= 77000/0.4
= 192500 kg/ hr. m^2
One centipoise, μ = 3.6 kg/m hr.
Reynolds number, Re = De x G/ μ
= 7.92 x 10^{-3} x 192500 / 3.6
= 423.5
As the value of Re < 2000 flow is laminar
Effective heat transfer area, A_t.
Total number of plates, n = 70
Effective heat transfer area A_t = n x A_p
= 70 X 0.4 = 28 m^2
Log mean temperature difference, LMTD

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

= 24.13 ^{0} c
Overall heat transfer coefficient, U
Friction factor, F = 0.98
U = Q / A_t x LMTD x F =512.79 / 28 x 24.13 x 0.98
= 774.46 w / m^2 c

Parameters calculated
Number of plates = 70
Area of the plate = 0.4 m^2
Effective heat transfer area = 28 m^2
Heat load = 512.79 kW
Log mean temperature difference = 24.13 ^{0} c
Overall heat transfer coefficient = 774.46 w / m^2 c

3.2 Design of large plate heat exchanger

Temperature of the fluids flowing through the plates

$T_{si} = 82.36\ ^0$ c $\qquad T_{so} = 69.8\ ^0$ c

$T_{ci} = 34\ ^0$ c $\qquad T_{co} = 50\ ^0$ c

Where,

T_{si}, T_{so} are the inlet and outlet temperatures of the slurry flowing through the heat exchanger respectively

T_{ci}, T_{co} are the inlet and outlet temperatures of the water flowing through the heat exchanger respectively

Heat load, Q

Specific heat capacity of slurry, C_{ps}

C_{ps} = 0.9948 KJ/Kg K

ǻ 7 $_{si}$ - T_{so}

Q = m C_{ps} ǻ

Mass flow rate, m = volumetric flow rate x density of slurry

Volumetric flow rate = 70 m^3/hr.

Specific gravity = density of slurry / density of water (specific gravity = 1.1)

Density of slurry = specific gravity x 100

= 1100 kg/m^3

Mass flow rate through the first sub stream = 231000 kg/hr.

Assuming two-third of the hot stream flowing through small heat exchanger

= 2/3 x 231000

= 154000 kg/hr. = 42.778 kg / s

Therefore, Q = 42.778 x 0.9948 x 24.1

= 531.79 kW

Hydraulic diameter, De

Width of the plate W = 0.62m

Length of the plate, L = 1.16 m

Spacing between plates, b = 0.004m

Area of the plates, A_p = L x w = 0.62 x 1.16

= 0.7192 m^2

Hydraulic diameter, De = [2 x w b] / [w+ b]

= [2 x 0.62 x 0.004] / [0.62 +0.004]

= 7.95 x 10^{-3} m

Reynolds number, Re

Mass flow area, G = mass flow rate (m) / Area of plate (A_p)

= 154000/0.7192

= 214,186.37 kg/ hr. m^2

One centipoise, μ = 3.6 kg/m hr.

Reynolds number, Re = De x G/ μ

= 7.92 x 10^{-3} x 214186.37 / 3.6

= 472.995

As the value of Re < 2000 flow is laminar

Effective heat transfer area A_t

Total number of plates, n = 84

Effective heat transfer area A_t = n x A_p

= 84 X 0.7192 = 60.42 m^2

Log mean temperature difference, LMTD

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

= 29.39 ^{0} c
Overall heat transfer coefficient, U
Friction factor, F = 0.98
U = Q / A_t x LMTD x F =531.94 / 60.4 x 29.39 x 0.98
= 264.16 w / m^2 c
Parameters calculated
Number of plates = 84
Area of the plate =0.7192 m^2
Effective heat transfer area = 60.42 m^2
Heat load = 531.79 kW
Log mean temperature difference = 29.39 ^{0} c
Overall heat transfer coefficient = 264.16 w / m^2 c

3.3 Design of new plate heat exchanger

Temperature of the fluids flowing through the plates
T_{si} = 91.1 ^{0} c T_{so} = 67.3 ^{0} c
T_{ci} = 34 ^{0} c
Where,
T_{si}, T_{so} are the inlet and outlet temperatures of the slurry flowing through the heat exchanger respectively
T_{ci}, is the inlet temperatures of the water flowing through the heat exchanger respectively
Heat load, Q
Specific heat capacity of slurry, C_{ps}
C_{ps} = 0.9948 KJ/Kg K
ǻ7 $_{si}$ - T_{so}
Q = m C_{ps} ǻ
ǻ7 $_{si}$ - T_{so} = 91.1 ± 67.3
= 23.8 ^{0} c
Mass flow rate through the first sub stream = 231000 kg/hr.
Mass flow rate of cold water, m = 41350 kg/ hr. =64.167 kg/s
Therefore,
Q = 64.1667 x 0.9948 x 23.8
= 1519.225 kW
Cold water outlet temperature, $T_{co} = T_{ci}$ + Q / [m x C_{pw}]
= 34+36.93 = 70.93 ^{0} c
Log mean temperature difference, LMTD

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

= 26.188 ^{0} c
Overall heat transfer coefficient, U
Friction factor, F = 0.98
U = $U = 1 / (1 / h_H + x/ k_p + 1/ H_c + 1 / h_C + D_{fh} + D_{fc})$
D_{fh} and D_{fc} are fouling factors and they are neglected. H_c is the higher value so $1/ H_c$ is very less, so $1/ H_c$ is neglected.
$U_{avg} = 1 / (1 / h_H + x/ k_p)$
To find the value of H_h
H_h = Nu x K_{slurry} / De
Prandtl Number
One centipoise, μ = 0.001 kg/ ms
Pr = μ x C_{ps} / K_{slurry} = 1.509

$YHUDJH5H\QROG¶V1XPEHU5H$_{avg}$ = 423.5 +472.88 / 2
= 448.04

To find nusslet number

$Nu = 0.256 \times (Re_{avg})^{0.65} \times (pr)^{0.4}$

$= 0.256 \times (448.04)^{0.65} \times (1.509)^{0.4}$

Nu = 15.69

$H_h = 15.69 \times 0.66 / 7.62 \times 10^{-3}$

$= 1330$ w / m$^{2\,0}$ c

Thermal conductivity of plate, $K_p = 10.2$ w/ m^0 c

Thickness of plate, $x = 0.6 \times 10^{-3}$ m

Overall heat transfer coefficient

$U_{avg} = 1 / (1 / 1330 + 0.6 \times 10^{-3} / 10.2)$

$= 1233.5$ w/ m^{0}c

Effective heat transfer area $A_t = Q / LMTD \times F \times U_{avg}$

$= 1519.225 / 26.188 \times 0.98 \times 1233.5$

$= 47.99$ m^2

To find number of plates, n

Area of plate, $A_p = 0.4$ m^2

$N = A_t / A_p = 47.99 / 0.4$

=119.975 =120

Parameters calculated

Number of plates = 120

Area of the plate =0.4 m^2

Effective heat transfer area = 47.99 m^2

Heat load = 1519.225 kW

Log mean temperature difference = 26.188 ^{0} c

Overall heat transfer coefficient = 1233.5 w / m^2 c

III.COST OPTIMISATION CALCULATION

Cost of Alfa small heat exchanger	= Rs 4, 93,000.
Cost of one plate of small heat exchanger	= Rs 3,200
Cost of Alfa Laval big heat exchanger	= Rs 4, 53,000
Cost of one plate of big heat exchanger	= Rs 3,100
No of plates used in Alfa Laval small heat exchanger	= 70
So, total cost of plates of small heat exchangers	= 70 x 3200
	= 2, 24,000
No of plates used in Alfa Laval big heat exchanger	= 84
So, total cost of plates of big heat exchangers	= 84 x 3100
	= 2, 60,400
So, total cost of both the heat exchanger plates	= 2, 24,000 + 2, 60,400
	= 4, 84,400

For the newly designed Alfa Laval heat exchanger

No of plates used	= 120
Total cost of plates newly designed Alfa Laval heat exchanger	
	= 120 x 3200
	= Rs 3, 84,000
Reduction in cost	= Rs 1, 00,400

Maintenance cost per hour loss	= Rs 50,000
Total time	= 8 hours for cleaning
Labour	= 5 people Rs 150/ hr.
Considering two heat exchangers,	
There would be four maintenance schedule two for each	= 8x4
	= 32
For 8 hours	= Rs 50,000 x 32
	= Rs 16, 00,000
Considering the new heat exchanger there would be an average of 2 maintenance schedule.	
So down time loss is assumed to be 8 x 2	= 16 hrs.
Per hour loss	= Rs 50,000
So for designed heat exchanger	= Rs 50,000 x16
	= Rs 8, 00,000
Labour cost for maintenance of existing heat exchanger for five workers	
	=Rs 150/hr x 32hr x 5
	=Rs 24,000
Labour cost of newly designed heat exchanger for five workers	= Rs 150/hr x 16 hr x 5
	= Rs 12,000
Saving from down time cost	= Rs 16, 00,000 ± 8, 00,000
	= Rs 8, 00,000
Saving from labour cost	=Rs 24,000 ± 12,000
	= Rs 12,000

IV. CONCLUSION

When the application is within the pressure and temperature limits of both designs the selection process should focus on cost, maintenance requirement and future operating conditions. When the fluid has a high tendency to foul the plate and frame design offers easier access to the heat transfer surface for cleaning.in addition because of high turbulence plate type heat exchanger have less tendency to foul when compare with shell and tube design. It leads to greater reduction in space and cost A plate cost approximately Rs 3200/- so the newly designed heat exchanger will cost approximately RS 3,84,000/- which can replace the present two heat exchanger which will together cost Rs 4,84,400/-

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

REFERENCES

[1] Taborek, J., Hewitt, G.F. and Afgan, N. (1983). *Heat Exchangers: Theory and Practice*. Hemisphere Publishing Corporation. ISBN 0-07-062806-8.
[2] Kuppan Thulukkanam, Heat Exchanger Design Handbook, Second Edition, 1-1187, 2013
[3] Sadik Kakac and Hongtan Liu (March 2002). Heat Exchangers: Selection, Rating and Thermal Design (2nd Edition Ed.). CRC Press. ISBN 0-8493-0902-6.

