International Journal of Research in Engineering, Science and Management
Volume-3, Issue-4, April-2020
www.ijresm.com | ISSN (Online): 2581-5792

Design and Analysis of Heat Exchanger and Condenser in PA Plant

K. Dhilip[1], N. Dhanushraj[2], T. Jagadeesan[3], S. Ramya[4]
[1,2,3]Student, Department of Chemical Engineering, Adhiparasakthi Engineering College, Melmaruvathur, India
[4]Assistant Professor, Dept. of Chemical Engineering, Adhiparasakthi Engg. College, Melmaruvathur, India

***Abstract*: The world is facing a historical increase in energy demand consumption. As consequence the convection fossil fuels are depleting faster with an inherent pollution causing severe damage to our environment. The purpose of our project is to increase the heat transfer by using alternative metal equipment. Our project provides indirect benefits which reduces the thermal pollution. The methodology of our project, to increase the heat transfer and to reduce the heat loss by increasing the efficiency of the double pipe heat exchanger. Heat exchanger is one of the important devices in cooling and heating process in Factories, buildings, transports and others. The heat exchanger is found in large Construction to support cooling process such as fossil fuel power plant. In the present study, heat transfer from hot water to cold water by double pipe heat exchanger consists concentric tube is experimentally investigated. The horizontal double pipe heat exchanger is made from Galvanised iron tube with inner tube and outer tube. The inner tube is consists of 26mm internal and 34 mm outer diameter. The outer tube is consisting of 68 mm internal and 76 mm outer diameter. A set of the experiments were carried out to investigate for counter flow and parallel flow to increase the heat transfer coefficient in a double pipe heat exchanger and to increase the overall heat transfer coefficient and rate of the reaction by increasing the value of Reynolds's number of the fluid in a condenser.**

***Keywords*: Coefficient of heat transfer, Counter flow, Double pipe, Heat Exchanger parallel flow.**

1. Introduction

These are the simplest heat exchangers and condensers used in industries. These heat exchangers are cheap for both design and maintenance, making them a good choice for small industries. In this kind of heat exchanger, two tubes or pipes having different diameters are placed concentrically, the smaller one inside the larger one. The two fluids in between which heat transfer is required, flows in the two different tubes. The utilization, conversion, and recovery of energy in commercial, industrial, and domestic applications usually involve a heat transfer process such as refrigerator, air conditioner etc. Improved quality of heat exchanger above the usual practice can significantly improve the thermal efficiency as well as the economics of their design and production. Usually parallel flow and counter flow of hot and cold fluid can be conducted in double pipe heat exchanger but counter flow transfer more heat than parallel flow, so double pipe heat exchanger counter flow operation is widely used in chemical and other industries. While comparing these type of heat exchanger and condenser with another exchangers and condensers it having more advantages such as, simple in construction, compact, occur less space, etc.

2. Design analysis of heat exchanger

To achieve a particular engineering objective, it is very important to apply certain principles so that the product development is done economically.

This economic is important for the design and selection of good heat transfer equipment. The heat exchangers are manufactured in different types, however the simplest form of the heat exchanger consist of two concentric pipes of different diameters known as double pipe heat exchanger.

In this type of heat exchanger, one fluid flows through the small pipe and another fluid flows through the space between both the pipes.

The flows of these two different fluids, one is at higher temperature called hot fluid and another is at lower temperature called cold fluid, can be in same or in opposite directions.

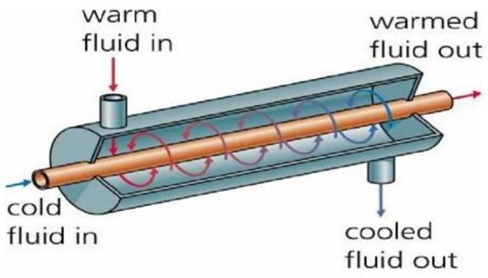

Fig. 1. Alternative model

3. Calculation

The important parts of experimental set-up are blower, the test section containing horizontal concentric copper pipes, hot air tank and cold water tank, rotameter, monoblack pump, whose selection is already discussed in previous section.

All these instruments are selected as per the requirements depending upon their measuring range, accuracy and availability in the market. The test section is made up of copper tubes as it has higher thermal conductivity. Specification:

1. Inner Tube Material: Copper

Table 1
Parallel Flow

S. No.	Hot water Flow rate Q_h (lt/m)	Cold water Flow rate Q_c (lt/m)	Hot water Inlet temp. Thi (T_1)	Hot water Outlet temp. Th_o (T_2)	Cold water inlet Tci (T_3)	Cold water outlet Tco (T_4)
1.	1.1	4	51	49	29	30
2.	1.4	1	53	48	36	33
3.	1.5	0.9	55	47	38	31

Table 2
Counter Flow

S. No.	Hot water Flow rate Q_h (lt/m)	Cold water Flow rate Q_c (lt/m)	Hot water Inlet temp. Thi (T_1)	Hot water Outlet temp. Th_o (T_2)	cold water inlet Tci(T_3)	Cold water outlet Tco (T_4)
1.	1.1	4	51	48	29	30
2.	1.4	0.9	53	49	38	33

Internal diameter of inner tube (di) = 26mm
Outer diameter of inner tube (do) = 34 mm
Length of inner tube (Li) = 1.2 m
Thickness of inner Tube (ti) = 4 mm

2. Outer Tube Material: Copper
Internal diameter of inner tube (di) = 68mm
Outer diameter of inner tube (do) = 76 mm
Length of inner tube (Lo) = 1.2 m
Thickness of inner Tube (to) = 4 mm

3. Specific Heat of Water = 4.186 Kw/kg^{0}K

4. Mass of hot water, mh =60 g

5. Mass of cold water, mc =100 g

Solution:
1. Heat transfer from hot water
(q_n): $q_n = m_h.\ cp_h.(Thi- Tho)$
= 60×4.186×(51-49)
=0.2787 Kwatt
2. Heat Transfer rate to cold water
(q_c): q_c = mc Cpc (Tco-Tci)
= 100×4.186×(30-29)
=0.153 Kwatt
3.Average heat transfer rate (Q)
Q = qn – qc / 2
= (0.2787-0.153)/2
= 0.215
4. L.M.T.D :
$\Delta Tm = \Delta Ti - \Delta To / \ln (\Delta Ti / \Delta To)$
= (22-19)/ ln (22/19)
= 3 ^{0}K
5.Oveall Heat transfer based on Internal Area of Tube Ui
q = Ui Ai (ΔTm)
Ai = π di L
= 3.14×26×1.2
= 97.96
q = 71.21×97.96×(3)
= 1637 KWatt
6. Effectiveness
$n = M_h\ Cph\ (Th_i - Th_o) / M_c\ Cpo\ (Tc_o – Tc_i)$
= 60×4.186×(51- 49) / 100× 4.186×(30-29)
n = 54.89%

4. Design of condenser in shell and tube heat exchanger

A condenser is a type of heat exchanger in which vapours are transferred into liquid state by removing the latent heat with the help of a coolant such as water.

Condensers may be classified into two main types:

1. Those in which the coolant and condensing vapour are brought into direct contact.
2. Those in which the coolant and condensate stream are separated by a solid surface, usually a tube wall.

5. Design calculation for condenser

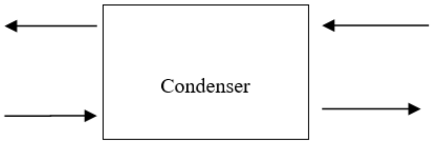

Fig. 2. Design of condenser

Inlet temperature of the process stream ‘T_1’ =45^{0}C
Outlet temperature of the process stream ‘T_2’=45^{0}C
Inlet temperature of the water ‘t_1’ =25^{0}C
Outlet temperature of the water ‘t_2’ =40^{0}C
Mass flow rate of the process stream ‘m’ =8060 Kg/hr
Enthalpy of vapours of process stream removed ‘λ_1’ =1940 KJ/Kg

Heat Load:
$Q=m(\lambda_1)$
Q=4343 KW

Mass flow rate of cooling water:

$$m = \frac{Q}{cp\ \Delta t}$$

C_p =4.2 KJ/Kg.K
m =68.9 Kg/sec

Log mean temperature difference

$$LMTD = \frac{(\Delta t2 - \Delta t1)}{\log(\frac{\Delta t2}{\Delta t1})}$$

LMTD = 14.4^{0}C

Assumed value of overall heat transfer coefficient ‘U_0’ =1000 W/m^{2}C

True Mean Temperature Difference:

Dimensionless temperature Ratios

R

$$R = \frac{(T1-T2)}{(t2-t1)}$$

$$= \frac{(45-45)}{(40-25)}$$

$$= 0$$

S

$$s = \frac{(t2-t1)}{(T1-t1)}$$

$$= \frac{(40-25)}{(45-25)}$$

$$= 0.75$$

From Literature the value of F_t is 1

$$\Delta t_m = F_t \times LMTD$$

$$= 1\times 14.4$$

$$= 14.4^0C$$

Heat Transfer Area:

$$A = \frac{Q}{UD\Delta t}$$

$$= 301\ m^2$$

Surface area of single tube $= \frac{3.14\times19\times4.88}{1000}$

$$=0.292\ m^2$$

No . of tubes $= \frac{301}{0.292}$

$$= 1030$$

Pitch ‘P_t’ $= 1.25\times19.05$

$$= 23.8\ mm$$

Tube Bundle Diameter

$$D_b = d_0(\frac{Nt}{K1})^{\wedge(1/n)}$$

$$= 19(1030/0.158)^{\wedge(1/2.263)}$$

$$= 920\ mm$$

No. of tubes in centre row

$$Nr = Db/Pt$$

$$= 920/23.8$$

$$= 39$$

A. *Shell Side Calculations*

Estimation tube wall temperature T_w

Assume condensing coefficient of 4250 W/m^2c

Mean Temperature

Shell side $= (45+45)/2 = 45^0C$

Tube side $= (25+40)/2 = 32.5\ ^0C$

$$(45-T_w) \times 4250 = (45-25) \times 1000$$

$$T_w = 40.3\ ^0C$$

Physical properties:

Viscosity of the liquid ‘μ_L’ $=0.8\ mNs/m^2$

Density of liquid ‘ρ_L’ $=993\ Kg/m^3$

Thermal conductivity ‘K_L’ $=0.571$ W/m C

Average Mol. wt. of vapors =42.8

Density of vapor

$$= \frac{29 \times 273 \times 1}{(22.4 \times 1 \times (273 + 42))}$$

$$= 1.12 Kg/m^3$$

Condensate loading on a horizontal tube

$$Th = \frac{m}{L\times Nt}$$

$$= \frac{8060}{3600 \times (4.88 \times 1030)}$$

$$= 4.45 \times 10^{-3}\ Kg/ms$$

No of tubes in the vertical row ‘Nr’ $= \frac{2}{3\times39}$

$$= 26\ mm$$

Heat transfer coefficient in condensation

‘h_0’ $= (0.95 \times K_L(\rho_L \times (\rho_L - \rho_v)g)/(\mu_L \times \acute{\Gamma} h)^{1/3} \times Nr^{-1/6}$

As our value is approximately correct so we no need to change the wall temperature.

B. *Tube Side Calculations*

Tube cross sectional area

$$= \frac{3.14 \times 4}{4 \times (19\ \times 10^{-3})^\wedge(2 \times 1030)}$$

$$= 0.073\ m^2$$

Density of water at 30^0C $=993\ Kg/m^3$

Tube velocity $= m/(\rho_{H20}\times A_t)$

$$= \frac{68.9}{(993\times0.073)}$$

$$= 0.95\ m/s$$

Film heat transfer coefficient inside a tube

‘h_i’ $= 4200(1.35+0.02\times t)Vt^{0.8}/ d_i^{0.2}$

$$= 4809.67\ W/m^{20}C$$

From Literature take fouling factor as 6000 $W/m^{2\ 0}C$

Thermal conductivity of the tube wall material

‘K_W’$=50\ W/m\ ^0C$

Overall Heat transfer coefficient:

$1/U_0 = 1/h_o + 1/h_{0d} + (d_o \ln(d_o/d_i))/2k_w + (d_o/d_i) \times (1/h_{id}) + (d_o/d_i) \times (1/h_i) = 0.001$

$$U_0 = 1100.29\ W/m^{2\ 0}C$$

The value is approximately correct

Shell side pressure Drop

For pull through floating head with 45% cut baffles

From literature clearance= 88 mm

Shell internal diameter ‘Ds’= Db+88

$$= 1008\ mm$$

Cross flow area $A_s = m^2 p_t\, d_0\, D_s l_B$

$$A_s = \frac{(pt-d0)DslB}{pt}$$

$$A = 0.205\ m^2$$

Mass Velocity:

$$G_t = m/A_s$$

$$= \frac{8060}{(3600 \times 0.205)}$$

$$= 10.92\ Kg/s\ m^2$$

Equivalent diameter 'de' = $1.27(pt^2-0.785d_0^2) / d_0$
= 19 mm
Viscosity of vapors 'μ' = 0.009 mNs/m^2
Reynold's No:
Re = D V ρ /μ
= $d_e G_t / \mu$
= $(19\times10^{-3}\times10.92)/ (0.009\times10^{-3})$
Re = 23053

From literature
Jf = 0.029
By neglecting the viscosity correction factor
$\Delta P_s = 8jf (D_s/d_e) (L/l_B) (\rho u_s^2/2) (\mu/\mu_w)$ ^$^{-0.14}$
Where
Ds = diameter of shell
L = Length of tubes
l_B = baffle spacing
So,
= 765 N/m^2
= 0.765 Kpa
= 0.109 Psi

Tube side pressure drop:
Viscosity of water 'μ' = 0.9×10^{-3} Ns/m^2
Re = Vt ρ di /μ
= $0.95 \times 993 \times 16.56 \times 10^{-3}/ 0.6 \times 10^{-3}$
= 26036
From literature
Jf = 0.0039
$\Delta P = 8jf (L'/d_i) (\rho u_t^2/2) (\mu/\mu_w)^{-m}$
Where
Np = No. of tube passes
So
ΔP_t = 4119.8 N/m^2
= 4.119 Kpa
= 0.59 Psi
Acceptable
h_{io} = hi × I.D /O.D
h_{io} = 4165.2 W/m^2 ^{0}C
Clean overall Coefficient:
$U_C = (h_{io}h_{io})/ (h_{io}+ h_{io})$
= 2138.7 W/m^2 ^{0}C
Design Overall Coefficient Calculated:

$$Rd = \frac{\text{Uc}-\text{UD}}{\text{Uc UD}}$$

Direct factor Rd = 0.0005

6. Specification of condenser

Identification: condenser
Function: condense vapor by removing the latent heat of vaporization
Operation: Continuous
Type: Horizontal condenser with shell side condensation
Heat Duty = 4343 KW

Tube Side:
Tubes: 0.75 in. Dia.
Fluid handled: cold water
Flow rate = 68.9 Kg/sec
Pressure = 14.7 psi
Temperature = 25^0C to 40^0C
1030 tubes each 16 ft long
4 passes
23.8 mm triangular pitch
Pressure Drop = 0.59 psi
Shell side:
Fluid handled = steam
Flow rate = 8060 Kg/hr
Pressure = 10 Kpa
Temperature = 45^0C to 50^0C
shell: 39 in. dia. 1 passes
Baffles spacing = 3.5 in.
Pressure drop = 0.109 psi
Utilities: Cold water
Ud assumed = 1000 W/m^2 ^{o}C Ud calculated=1100.97W/m^2 ^{o}C
Rd = 0.0005

Table 3
Result

Parameters	Before	After
Reynolds's No.	22392	26036
Overall Heat Transfer Coefficient	1000 W/m^2 ^{0}C	1100.29 W/m^2 ^{0}C

7. Conclusion

The purpose of our project is to increase the heat transfer coefficient by using the alternative equipment in double pipe heat exchanger. This project provides indirect benefits which reduce the thermal pollution. Thus the heat transfers for heat exchanger specific to double pipe heat Exchanger has been increased. Design of double pipe heat exchanger by using Solid- Works as been done based on the increased heat transfer coefficient. Temperature distribution in parallel flow & counter flow heat exchanger has been achieved and Overall heat transfer in parallel and counter flow to obtain increased effectiveness as been increased by changing the alternative material of tubes inside the heat exchanger. And also to increase the heat transfer coefficient of condenser by providing increased Reynolds number has been achieved.

References

[1] Anand Babu, K., Naveena, H.S. and Nagesh, R. (2017) 'Experimental Investigation for the heat transfer of a double pipe heat exchanger', International Journal of Mechanical Engineering and Technology (IJMET), Volume 8.
[2] Arturo Reyes-León, Miguel Toledo Velázquez. and Pedro Quinto-Diez. (2011) 'The Design of Heat Exchangers', Thermal and Hydraulic Engineering Laboratory SEPI-ESIME-IPN Professional Unit.
[3] Chamil Abeykoon. (2014) 'Improving the performance of shell-and-tube heat exchangers by the addition of swirl', Int. J. Process Systems Engineering, Vol. 2.
[4] Gábor Szepesi. and Károly Jármai. (2018) 'Optimal Design of Double-Pipe Heat Exchangers', University of Miskolc, Miskolc, Hungary.
[5] Haziqatulhanis Ibrahim. and Norazlanie Sazali. (2019) 'Factors Affecting Heat Transfer Efficiency of Nanofluids for Application in Plate Heat Exchanger' Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 60.
[6] HeydarMaddah. and MaliheZarei. (2014) 'Heat Transfer of Nanofluid in a Double Pipe Heat Exchanger', International Scholarly Research Notices Volume 2.
[7] Hussain H. Al-Kayiem. and Mohamed F. El-Rahman. (2011) 'Ribbed Double Pipe Heat Exchanger: Analytical Analysis', Journal of Engineering Science and Technology, Vol. 6.

[8] Israa Abdullah Hussien. (2018) 'Using The Nanofluid to Improve the Heat Transfer in The Double Pipe Heat Exchanger', International Journal of Civil Engineering and Technology (IJCIET), Volume 9.
[9] Jatinder. and Gautam Kocher. (2016) 'Heat Transfer and Flow Behavior Analysis of Double Pipe Heat Exchanger', International Journal of Science and Research (IJSR), volume 79.
[10] Kevin M. and Lunsford. (1998) 'Increasing Heat Exchanger Performance', Bryan Research and Engineering, Inc.
[11] Kuruva Umamahesh. and K. Venugopal. (2015) 'Design and Analysis of Double Pipe Heat Exchanger Using Computational Method', International Journal of Professional Engineering Studies, vol. 5.
[12] Kushal Kamboj. and Gurjeet Singh. (2016), "Heat transfer augmentation in double pipe heat exchanger using mechanical turbulators," Springer-Verlag Berlin Heidelberg, vol. 3.