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Research Article

Performance improvement of heat exchanger using slotted baffle

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Abstract

Heat exchangers are very important heat and mass exchange apparatus in various process industries. Among all types of the heat exchanger shell and tube heat exchangers are commonly and effectively used in industries or applications. Heat exchanger performance can be improved by using various augmentation techniques. Generally in shell and tube heat exchanger segmental baffles are used. The purpose of baffle is to guide the flow and support for tubes. In this study the performance improvement of heat exchanger is done using slotted baffle instead of segmented baffle as segmental baffle have problems like flow induced vibrations etc. Present study aims at developing a heat exchanger model with slotted baffle and comparing the results experimentally with the heat exchanger having segmental baffle.

Keywords: *Heat Exchanger, Shell and Tube, Slotted baffle, Segmental baffle.*

1. Introduction

Heat exchangers are device used for transfer of heat between two fluids at different temperature. In the majority of the heat exchangers, a solid wall separates the two fluids so that they are not in direct contact with each other. A shell and tube heat exchanger is a very good example of heat exchanger. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside the shell. A shell and tube heat exchangers are probably most common type of heat exchangers applicable for wide range of operating temperature and pressure.

Heat exchanger performance can be improved by using various augmentation techniques. Generally in shell and tube heat exchanger segmental baffles are used. In this study the performance improvement of heat exchanger is done using slotted baffle instead of segmented baffle. Present study aims at developing a heat exchanger model with slotted baffle and comparing it experimentally with the heat exchanger having segmental baffle for performance improvement. For this study some literature review is done as follows.

Sunilkumar Shinde and Mustansir Hatim Pancha (2012). In this study author has given the comparative study of segmental baffle and continuous helical baffle. The comparison is done using Kern method. This paper gives the mathematical formulae for comparison.

Bin Gao, Qincheng Bi, *et. al.* (2015). In this author has performed the experimental study on shell and tube heat exchanger for checking the performance with discontinuous helical baffle. Study gives us some drawbacks of segmental baffle which are overcome by helical baffle.

Alok Vyas and Prashant Sharma (2013). In this paper author has discussed about the experimental study to improve performance of tubular heat exchanger. In this paper some thermal design factors that are to be taken into account while designing the tubes of the tubular heat exchanger has been discussed.

The main objectives of this study are: - Development of experimental set up, Experimentation, Comparison of results of segmental baffle with that of slotted baffles.

2. Development of Model

Design data

Table 1 Properties of fluid

Properties	Hot fluid	Cold fluid
Inlet temp	60^0C	30^0C
Outlet temp	53^0C	35^0C
Density (ρ)	984.1KG/M3	994.09
Dynamic viscosity(μ)	4.715×10^{-4}	7.22×10^{-4}
Thermal conductivity(k)	0.65167	0.62416
Specific heat(cp)	4.065×10^3	4.068×10^3
Prandlt No(PR)	2.9421	4.7085

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Tube outside diameter (Do): 19 mm
Tube inside diameter (Di): 18.2 mm
Length of the tubes (L): 1 m
Baffle spacing (L_b):250 mm
Assume mass flow rate 1Kg/sec

Calculations:

$$Q=[mCp(\Delta t)]cold$$

$$=[1*4.068\times10^3*(35\text{-}30)]$$

$$\boxed{Q = 20.34\ Kw}$$

Let select U=300 (Kern method)[1][5]
We know that,

$$Q=UA\theta_m$$

Where θm=Log mean temp. Difference=24

$$\therefore \quad Q=300*A*24$$

$$\boxed{A=2.825\ m^2}$$

But $A = \pi*d_o*L*n$
n = 47.20

∴ No of tubes=48

Tube side Heat transfer coefficient:

$Ac= (\pi/4)*d_i^2*n=0.01211\ m^2$

Gs=ṁc/Ac=82.5

$$hi = 0.023 \times \frac{k}{di} \times \left(\frac{Gs \times di}{\mu}\right)^{0.8} \times \left(\frac{\mu \times Cp}{K}\right)^{0.4}$$

$$\boxed{hi=806.89 W/m^2k}$$

Shell side Heat transfer coefficient:
Let selecting square pitch
For square pitch,

$$de = \frac{4 \times (Pt^2 - \left(\frac{\pi}{4}\right) \times do^2)}{\pi \times do}$$

Where Pt=Pitch=1.25*do=23.81 mm

$$\boxed{de=18.84\ mm}$$

Let Diameter of shell Ds=250 mm

Length of baffle span Lb=250 mm

$$As = \frac{(Pt - do) \times Ds \times Lb}{Pt}$$

∴As=0.012494

Gs= ṁc/Ac=57.464

$$\frac{ho\times de}{k} = 0.36 \times \left(\frac{de\times Gs}{\mu}\right)^{0.55} \times \left(\frac{Cp\times\mu}{K}\right)^{0.33} \times \left(\frac{\mu}{\mu w}\right)^{0.14}$$

$$\boxed{ho=1254.43\ W/m^2k}$$

$$\frac{1}{U} = \left(\frac{1}{hi} \times \frac{do}{di}\right) + \left(\frac{1}{ho}\right) + 0.0004 + 0.0004$$

∴ U =343.19

But

$$Q=UA\theta_m$$

∴ Required area=2.4694 m^2

This is less than available area so design is safe.

In this experiment instead of segmental baffle slotted baffles are used which is shown in figure below.

Figure 1 Slotted baffle

These baffles are placed at 90^0 to each other while fitting pipes into it so that flow gets turbulence.

3. Experimental setup

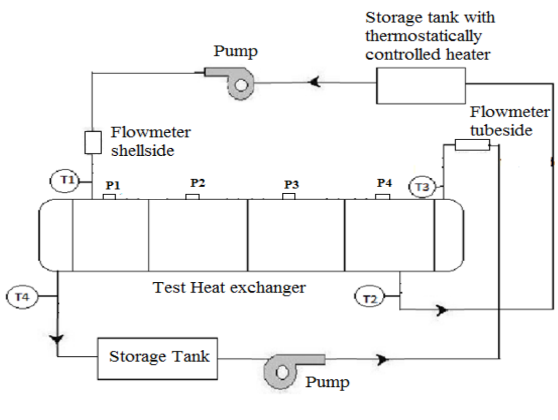

Figure 2 Line diagram of Experimental setup

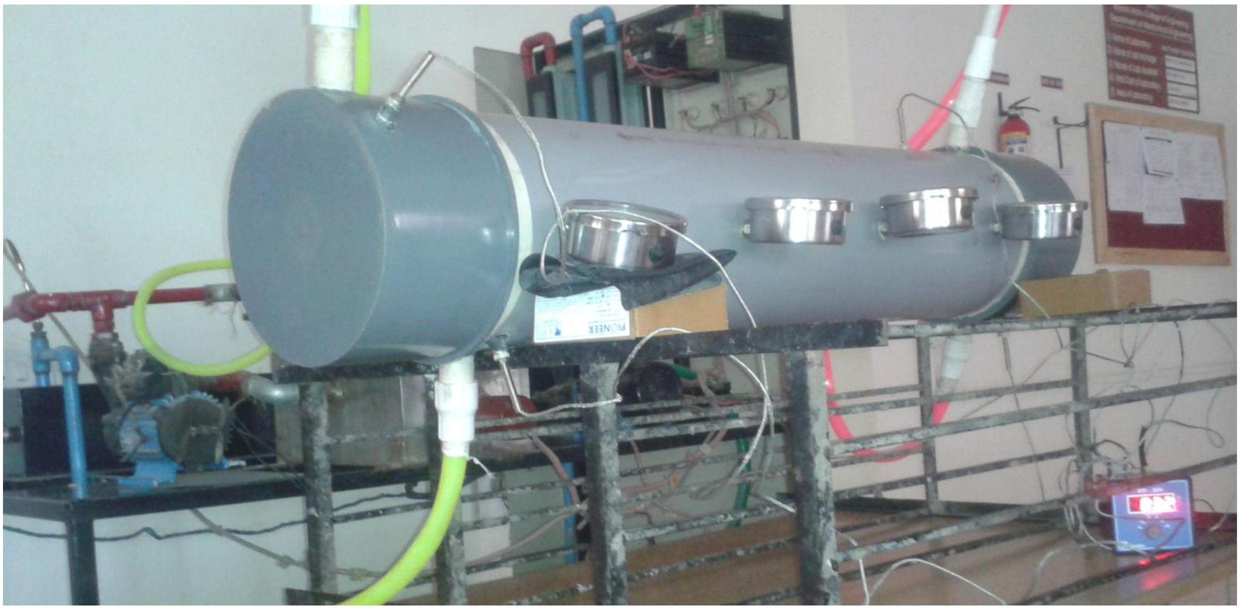

Figure 3 Working Experimental Setup

The experimental setup for testing of heat exchanger is as shown in figure above.

Hot water is flowing on shell side of the HEX from top side of the shell of HEX and leaves the shell from bottom side. Hot water from storage tank is taken through a water pump towards the HEX. Flow of water is controlled by using a flow control valve. Flow rate of the water is measured through a Rotameter. For getting hot water a thermostatically controlled water heater is used. This is a immersion type of heater. It is fixed in the storage tank permanently. Various water temperatures can be achieved and maintained by using this heater.

Cold water is used as working fluid in this heat exchanger. Cooling water at atmospheric temperature is stored in storage tank placed near Heat exchanger. It is pumped to the heat exchanger though pump and enter tube side from top and leaves tube side from bottom side of the heat exchanger. Flow of the water is controlled though a valve. Due to flow of Hot and cold water heat exchange takes place in exchanger.

For measurement of the pressure a pressure gauge is installed at each section of the Heat exchanger on shell side.

For temperature measurement RTD temperature sensors are used. They are connected to the digital temperature indicator which gives direct reading of the temperature.

4. Experimental Procedure

- Make all electrical and piping connections of heat exchanger and pump line etc.
- Shell priming is done by filling nearly 2/3 part of the shell of the heat exchanger.
- Set the heater to required temperature
- Start the mains supply of the setup
- Start heater
- Start pumps of shell and tube side
- Wait till the set temperature of heater is achieved.
- After reaching steady state start taking readings
- Take temperature readings by applying knob of the digital temperature indicator
- Take pressure reading directly from pressure gauge.
- Repeat the same procedure for various temperatures.
- After taking all readings switch off all devices and cut off mains power.
- At last drain out the water in shell and tube side

5. Results and discussion

After doing the experimental analysis following results were obtained. From observing the result table we can see the improvement in the heat transfer rate of the heat exchanger using slotted baffle instead of segmental baffle. Also the effectiveness of the heat exchanger increases for slotted baffle.

Table 2 Heat transfer rate and Effectiveness of heat exchanger with segmental baffle

Case no.	Q heat transfer rate	Effectiveness of hex
1	4.16328	0.6
2	6.24492	0.6
3	6.9388	0.588235294
4	7.63268	0.55
5	7.63268	0.5
6	9.02044	0.52
7	9.71432	0.482758621
8	10.4082	0.46875
9	10.4082	0.441176471
10	11.79596	0.447368421
11	12.48984	0.45
12	13.8776	0.465116279

Table 3 Heat transfer rate and Effectiveness of heat exchanger with slotted baffle

Case no.	Q heat transfer rate	Effectiveness of hex
1	4.16328	0.6
2	6.24492	0.6
3	6.9388	0.588235294
4	8.32656	0.6
5	8.32656	0.545454545
6	9.71432	0.583333333
7	11.79596	0.586206897
8	12.48984	0.5625
9	12.48984	0.529411765
10	14.57148	0.552631579
11	15.26536	0.536585366
12	16.65312	0.558139535

Comparison of the results for segmental baffle and slotted baffle heat exchanger

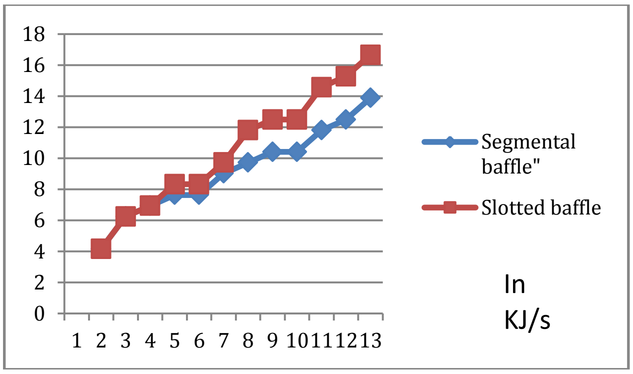

Figure 4 Comparison of heat transfer rate of heat exchanger using segmental baffle and slotted baffle

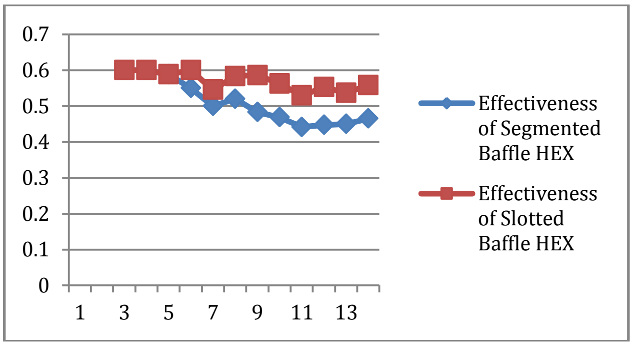

Figure 5 Comparison of effectiveness of heat exchanger using segmental baffle and slotted baffle

Figure 4 shows the variation of heat transfer rate of heat exchanger for segmental baffle and for slotted baffle. This is a plot of Heat transfer rates at various cases. Figure 5 shows the variation of effectiveness of heat exchanger for segmental baffle and for slotted baffle. This is plot of effectiveness of HEX at various cases.

Conclusion

After analyzing the results of the experimental analysis it is observed that heat transfer rate of the heat exchanger increases for slotted baffle that of segmental baffle. Also the effectiveness of heat exchanger increases for slotted baffle heat exchanger that of segmental baffle heat exchanger.

Nomenclature

HEX – Heat exchanger
Q – Heat transfer rate
m_h - Mass flow rate of hot fluid
m_c - Mass flow rate of cold fluid
Cp_h -Specific heat of hot water
Cp_c - Specific heat of cold water
ΔT_c- Temperature Difference for cold water
ΔT_h- Temperature Difference for hot water
θm=Log mean temp. Difference

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