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Design of Heat Exchanger with Effectiveness Improvement Techniques by using Fins and Inserts

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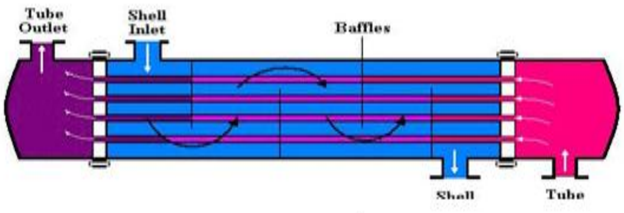
***Abstract* - Engineers are continually being asked to improve processes and increase efficiency. These requests may arise as a result of need to increase throughput, increase probability, or accommodate capital limitations. The processes which use heat transfer equipment must frequently be improved for these reasons. This paper provides method for increasing efficiency of shell and tube heat exchanger performance by using rough surfaces and grooved tubes to increase surface area for heat transfer. External grooved surface on outside of tube (fins) make heat transfer faster because of more surface area. This paper also provides methods to improve turbulence inside the tubes of heat exchangers by using inserts Main purpose of any heat exchanger is to exchange heat between hot fluid and cold fluid and reduce the temperature of hot water by giving its heat to the cold water. Due to this, heat exchanger finds its use in most of the devices working on thermal principles. Heat can be exchanged naturally between two substances at different temperatures but heat exchanger boosts the speed of heat transfer and is hence has a very important part in industries. The heat exchanger used for this project is of shell and tube type which is one of the most commonly used heat exchangers of today.**

Keywords: Heat exchanger, thermal principles

1. INTRODUCTION

Heat transfer is a device in which heat exchanges from one fluid to another fluid.

Heat transfer takes place due to purely convection. Ultimate goal of this project is to enhance convective heat transfer rate.



Examples of Heat exchangers

i. Preheaters and Intercoolers
ii. Condensers and boilers in steam plant
iii. Regenerators
iv. Radiators used in automobile
v. Boiler

2. LITERATURE REVIEW

Many authors worked on these heat exchanger devices some of the papers has been studied

R. Hosseini et al. According to these authors heat transfer coefficient and pressure drop obtained from the experiment when their study focused on different copper tubes (micro-fins, smooth and corrugated).Also, experimental obtained data validated with analytical data. Higher Nusselt number and pressure drop have been observed with respect to analytical method based on Bell's method.[1]

Andre L.H. et al. In their studies involved various problem solving parameter according to nature of problem that includes heat transfer area, restrictions ,selection of different equations for solving pressure drop and velocity bound, this was reduced thermal stresses developed by the heat exchanger was reduced.

Jiangfeng Guo et al. in this study involved design variable parameter of shell and tube heat exchanger and to solve these algorithms applied the optimization problem. Observed from experiment that effectiveness of heat transfer increases drastically.

3. PROJECT OBJECTIVES

The objectives of this project are:

- To design a shell and tube heat exchanger.
- To increase heat transfer rate by making inner surface of tube rough and increasing outer surface area of tube by grooving.

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- To use inserts to increase turbulence inside the tubes.
- To conclude effect of roughness grooved surface and inserts on efficiency of heat exchanger.

4. PROJECT SCOPE

Since heat exchangers are widely used in every field it is necessary to find out different methods to improve their efficiency and that too in minimum cost. Efficiency of heat exchanger depends on various factors, heat transfer rate being one of them. This project is mainly concentrating on how to improve heat transfer rate of heat exchanger by using rough and grooved surfaces. Another factor for improving efficiency is turbulence of fluid experienced in tubes. Increasing turbulence to make heat transfer faster by convection is objective of this project. These simple techniques can improve efficiency of heat exchanger drastically with minimum cost.

5. DESIGN

- The heat exchanger used in this project is of shell and tube type. It consists of a shell which is made up of Polyvinylchloride (PVC). The internal diameter of PVC pipe is 110mm.
- The tubes are finned type and made up of copper. This Heat Exchanger consists of five copper tubes each having an internal diameter of 12.6mm. Copper is a very good conductor of heat and finned copper tubes means more dissipation of heat to the surrounding i.e. cold water in this case.
- The hot water is supposed to flow through the finned copper tubes and loose its heat to the cold water in the PVC shell as it progresses through the tube.
- A total of four holes are drilled on the PVC pipe, two for inlet and two for outlet of hot and cold water.
- The inlet and outlet of hot water are drilled at the opposite extreme ends of the PVC shell and are at an angle of 90 degrees with each other.
- The hot and cold water inlets and outlets are separated from each other with the help of two circular baffles, one in between the two inlets and one in between the two outlets.
- The baffle has a diameter equal to that of PVC pipe and consists of five holes of the same external diameter as of copper tubes for them to pass through it. Also 2 semi-circular baffles are placed in between the two circular baffles at 1/3rd of the distance between two circular baffles.

6. ASSEMBLED MODEL OF SHELL AND TUBE HEAT EXCHANGER

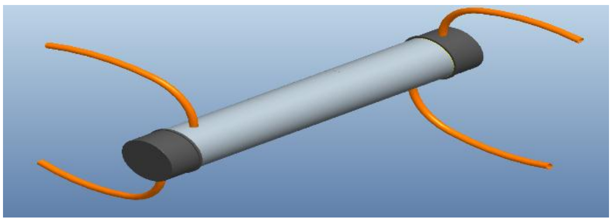

Fig 6.1 Assembled view of heat exchanger

7. RESULTS AND DISCUSSION

7.1 theoretical calculations (by LMTD approach)

7.1.1 without fins

i. Mass flow rate for cold water = 293.04 kg/hr ($\dot{m}c$) = 0.0814 kg/

ii. Mass flow rate for cold water = 195.36 kg/hr ($\dot{m}h$) = 0.05426 kg/s

Inlet cold water temperature (tci) = 200

iii. Inlet hot water temperature (thi) = 700

iv. Outlet hot water temperature (t_{ho}) = 40^0C

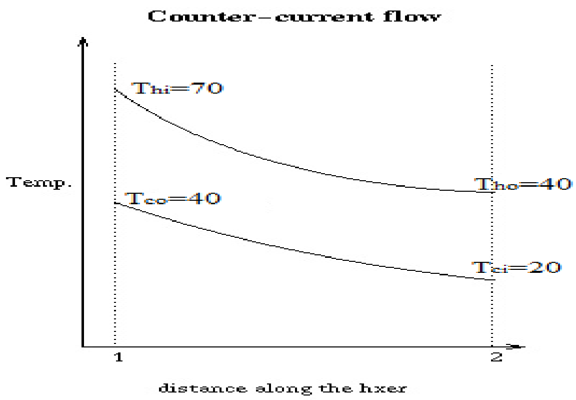

Fig 7.1 LMTD diagram

LMTD,

$$\theta_m = \frac{\theta_1 - \theta_2}{\ln(\theta_1/\theta_2)}$$

$$= \frac{30-20}{\ln(30/20)}$$

= 24.66

v. Heat of water,

$Q_h = \dot{m}_h * c_{ph} * (t_{hi} - t_{ho})$
= 0.05426*4200*(70-40)
= 6836.76 W

Assuming complete heat transfer to cold water,

$Q_c = \dot{m}_c * c_{pc} * (t_{co} - t_{ci})$

6836.76=0.0814*4200*(t_{co}-20)...............
[∵ $Q_h = Q_C$] t_{co} = 40^0C

vi. Number of tubes (n) = 5

Diameter of each copper tube (d) = 15.8×10^{-3} mm

Length of pipe = 0.6 m

Q_1 = UAθm
= 900× (5×0.6×π×15.8×10^{-3})×6..............
[where, A= n×πd²×L]
Q_1= 3304.941 W..................... (I)

Table no. 6.1Mass flow rate

(II) Calculations

Flow (litre = 1) Time (Seconds)		Hot (^{0}C)		Cold (^{0}C)	
$\dot{m}_h$	$\dot{m}_c$	Inlet	Outlet	Inlet	Outlet
108 s	20 s	67	40	28	35
69.65 s	14 s	70	50	28	34
60 s	12 s	65	49	28	33
43.47 s	10.2 s	70	52	28	32
22.22 s	7.57 s	70	54	28	31

i. $\dot{m}_h = 9.259\times10^{-3}$ kg/s

$\dot{m}_c = 0.05$ kg/s

$c_c = c_h = 4200$ J/kgK

$C_c = C_{max} = 210$ J/kgK.............. ($\because C_c = \dot{m}_c \times c_c$)

$C_h = C_{min} = 38.88$ J/kgK.............. ($\because C_c = \dot{m}_h \times c_c$)

$$\varepsilon = \frac{C_c(t_{co} - t_{ci})}{C_{min}(t_{hi} - t_{ci})}$$

$$= \frac{210(35-28)}{38.88(67-28)}$$

$$= 0.969$$

i. $\dot{m}_h = 14.3\times10^{-3}$ kg/s

$\dot{m}_c = 0.0714$kg/s

i. $\dot{m}_h = 14.3\times10^{-3}$ kg/s

$\dot{m}_c = 0.0714$kg/s

$c_c = c_h = 4200$ J/kgK

$C_c = C_{max} = 300$ J/kgK.............. ($\because C_c = \dot{m}_c \times c_c$)

$C_h = C_{min} = 60.06$ J/kgK..............

($\because C_c = \dot{m}_h \times c_c$)

$$\varepsilon = \frac{C_c(t_{co} - t_{ci})}{C_{min}(t_{hi} - t_{ci})}$$

$$= \frac{300(34-28)}{60.06(70-28)}$$

$= 0.7135$

ii. $\dot{m}_h = 16.6\times10^{-3}$ kg/s

$\dot{m}_c = 0.0833$ kg/s

$c_c = c_h = 4200$ J/kgK

$C_c = C_{max} = 350$ J/kgK.............. ($\because C_c = \dot{m}_c \times c_c$)

$C_h = C_{min} = 69.72$ J/kgK..............

($\because C_c = \dot{m}_h \times c_c$)

$$\varepsilon = \frac{C_c(t_{co} - t_{ci})}{C_{min}(t_{hi} - t_{ci})}$$

$$= \frac{350(33-28)}{69.72(65-28)}$$

$= 0.678$

iii. $\dot{m}_h = 0.023$ kg/s

$\dot{m}_c = 0.098$ kg/s

$c_c = c_h = 4200$ J/kgK

$C_c = C_{max} = 411.6$ J/kgK..............

($\because C_c = \dot{m}_c \times c_c$)

$C_h = C_{min} = 96.66$ J/kgK..............

($\because C_c = \dot{m}_h \times c_c$)

$$\varepsilon = \frac{C_c(t_{co} - t_{ci})}{C_{min}(t_{hi} - t_{ci})}$$

$$\frac{411.6(32-28)}{96.66(70-28)}$$

$= 0.4057$

i. $\dot{m}_h = 0.045$ kg/s

$\dot{m}_c = 0.132$ kg/s

$c_c = c_h = 4200$ J/kgK

$C_c = C_{max} = 554.4$ J/kgK..............

($\because C_c = \dot{m}_c \times c_c$)

$C_h = C_{min} = 189$ J/kgK..............

($\because C_c = \dot{m}_h \times c_c$)

$$\varepsilon = \frac{C_c(t_{co} - t_{ci})}{C_{min}(t_{hi} - t_{ci})}$$

$= 0.209$

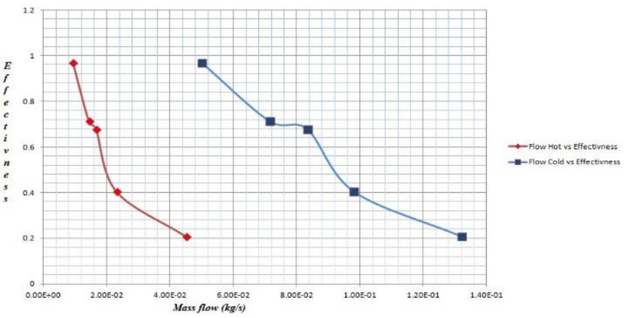

Fig 6.3 Mass flow vs Effectivness

Hence with increase in flow, effectiveness decreases.

7. CONCLUSION

- After all theoretical and practical calculations and testing prototype for different flows we can conclude following points:
- Copper already being good conductor of heat it accelerates heat transfer. Copper also has many qualities like rustproof, antifouling, corrosion free, cheap and easily available makes it very useful for heat exchanger
- Inserts are used in copper tubes. Inserts are twisted helically, such that water flowing through tubes moves in helically rotation and inserts push them towards the wall of copper tubes which helps in heat transfer. Also inserts increase turbulence of water inside the tubes.
- With external fins made on copper tubes, it increases contact surface (surface area) for convection heat transfer. Fins also make cold water turbulent while flowing from tubes surface. In result of this, we found 20.15% of increase in heat transfer theoretically.

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