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DESIGN, MANUFACTURING AND TESTING OF SHELL AND TUBE HEAT EXCHANGER AND TO COMPARE THE PERFORMANCE USING PLAIN TUBES AND LOWFIN TUBES

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Abstract

The project aim is to provide an overview of design, manufacture and testing of shell and tube heat exchanger and to compare the performance with using plain tube and low fin tubes. The objective of the project is to remove the heat from the lubricating oil passing it through the heat exchanger where in a coolant is circulated to remove the heat. Water is commonly used as the coolant to dissipate heat. The heat exchangers are designed for shell side flow rate 35lpm, temperature 55^{o}C-45^{o}C and tube side flow rate of 30^{o}C-35^{o}C. First the design calculations are done using the details of heat exchanger, various correlations and finally arriving at the design drawing of heat exchanger using the AutoCAD tool. Various manufacturing techniques were used for manufacturing of heat exchanger. Testing was then done on the manufactured heat exchangers for checking the performance of the heat exchangers.

***Keywords: -** Plain Tube, Low Fin Tube, Shell And Tube Heat Exchanger.*

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1. INTRODUCTION

Heat exchanger is a device which transfers energy from one fluid to another fluid across a solid surface. Exchanger analysis and design therefore involve both conduction and convection. Heat exchangers are used in a wide variety of engineering applications like power generation, waste heat recovery, manufacturing industry, air-conditioning, refrigeration, space applications, petrochemical industries etc.

Two important problems in heat exchanger analysis are:

- Rating existing heat exchangers: rating involves determination of the rate of heat transfer, the change in temperature of the two fluids and pressure drop across the heat exchanger.
- Sizing the heat exchanger for particular application: sizing involves selection of a specific heat exchanger from currently available or determining the dimensions for the design of a new heat exchanger, given the required rate of heat transfer and allowable pressure drop.

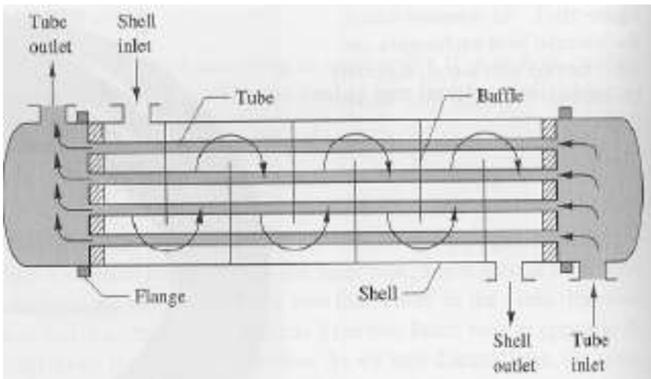

Fig 1.1: Single pass shell and tube heat exchanger

Shell and tube heat exchangers are most versatile type of heat exchanger. They are used in process industries, in conventional and nuclear power station as condenser, in steam generators in pressurized water reactor power plants, in feed water heaters and in some air conditioning refrigeration systems. Shell and tube heat exchanger provide relatively large ratio of heat transfer area to volume and weight and they can be easily cleaned. Shell and tube heat exchanger offer great flexibility to meet almost any service requirement. Shell and tube heat exchanger can be designed for high pressure relative to the environment and high pressure difference between the fluid streams.

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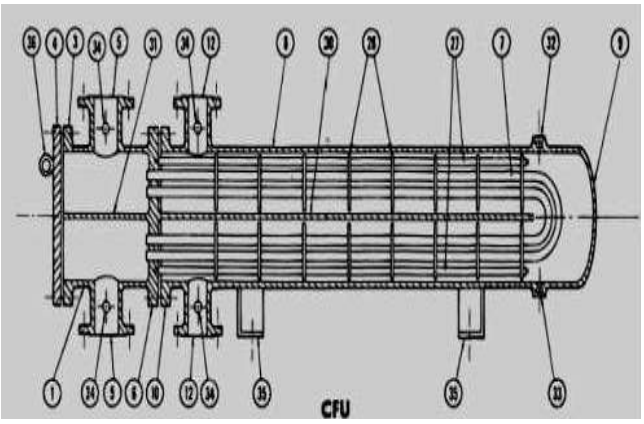
1.1 Shell and Tube Heat Exchanger Geometry

The standard of the Tubular Exchanger Manufacturers Association (TEMA) describe various components in detail of shell and tube heat exchanger (STHE).



1 Stationary (Front) Head—Channel
2 Stationary (Front) Head—Bonnet
3 Stationary (Front) Head Flange
4 Channel Cover
5 Stationary Head Nozzle
6 Stationary Tubesheet
7 Tubes
8 Shell
9 Shell Cover
10 Shell Flange—Stationary Head End
11 Shell Flange—Rear Head End
12 Shell Nozzle
13 Shell Cover Flange
14 Expansion Joint
15 Floating Tubesheet
16 Floating Head Cover
17 Floating Head Flange
18 Floating Head Backing Device
20 Slip-on Backing Flange
21 Floating Tubesheet Skirt
22 Floating Tubesheet Skirt
23 Packing Box Flange
24 Packing
25 Packing Follower Ring
26 Lantern Ring
27 Tie Rods and Spacers
28 Transverse Baffles or Support Plate
29 Impingement Baffle or Plate
30 Longitudinal Baffle
31 Pass Partition
32 Vent Connection
33 Drain Connection
34 Instrument Connection
35 Support Saddle
36 Lifting Lug
37 Support Bracket

Fig 1.2: shell and tube heat exchanger geometry

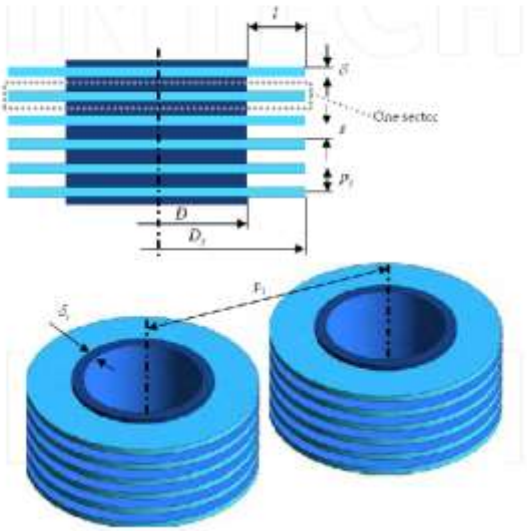


Fig 1.3: Fin tube geometry

Design Formulas used for Calculation

Parameters	**Low fin tube heat exchanger**	**Plain tube heat exchanger**
Mass flow rate in lpm	$m * C_p * \triangle T$	$m * C_p * \triangle T$
LMTD	$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left[\frac{T_1 - t_2}{T_2 - t_1}\right]}$	$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left[\frac{T_1 - t_2}{T_2 - t_1}\right]}$
Heat transfer coefficient	$Nu = 0.183 * 46500.44^{0.7} * \left[\frac{0.7}{0.8}\right]^{0.36} * \left[\frac{0.02}{0.016}\right]^{0.06} * \left[\frac{0.8}{16}\right]^{0.11} * 0.446^{0.36}$	$Nu = 0.023 * {R_e}^{0.8} * Pr^{0.4}$
Pressure drop	$\Delta P_t = \left[\frac{4flN_p}{D_i} + 4N_p\right] * \frac{\rho * u^2}{2}$	$\Delta P_t = \left[\frac{4flN_p}{D_i} + 4N_p\right] * \frac{\rho * u^2}{2}$
Surface area of fins	$A_f = \left\{\frac{1}{2} * \pi(D_f^2 - D^2) + \pi * D_f * \delta\right\} * FPI$	$A = \pi * d * l * n$
Total tube surface with fin removed:	$A_t = \{\pi * D_f * (s + \delta)\} * FPI$	$A = \pi * d * l * n$
Overall heat transfer coefficient	$\frac{1}{U_{of}} = \frac{1}{h_o} + \frac{D_o}{2k} \ln\left(\frac{D_0}{D_i}\right) + \frac{A_0}{A_i}\eta_{eff}\left(\frac{1}{h_i}\right)$	$\frac{1}{U} = \frac{1}{h} + \frac{1}{h_0}$

Details of Low Finned Tube and Plain Tube Heat Exchanger

Parameter	**Low finned tube**	**Plain tube**
Shell Diameter	164 mm	164 mm
Shell length	850 mm	850 mm
Tube diameter	16mm OD × 12.8 mm ID	16 mm OD × 14 mm ID
Number of tubes	24	24
Tube pitch	20 mm	20 mm
Type of tube layout	Triangular	Triangular
Number of baffles	19	19

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2. MANUFACTURING

All the parts required for the manufacture of a shell and tube heat exchanger are obtained. The different parts include the shell, tubes, tube plates, nozzles, end covers, BSP collar, and baffle plates are manufactured by different manufacturing processes.

2.1 Manufactured Parts

Shell cut part**,** baffle plates and baffle cut parts

Tube plate and end covers

shell and tube heat exchanger after assembly

2.2 Materials Used

Shell: Mild steel, Tube: Copper- nickel
Tube Plate: Mild steel, Baffles: Mild steel
Nozzles: mild steel, Gasket: Compressed asbestos fiber

3. EXPERIMENTATION

Testing is one of the most crucial stages of the project. In this stage the performance of the designed heat exchanger is evaluated.

Experimental setup

Make the connections of shell and tube heat exchanger. Turn on the main power and turn on hot and cold fluids supply all the way. Set the inlet oil temp to 55°C and water flow rate to 20 lpm. Fix the inlet oil flow rate 15 lpm. Wait for at least 15 minutes so that the system reaches steady state. Note down the readings of outlet temperatures of oil and water. Repeat the procedure for oil flow rates of 20, 25, 30 and 35 lpm.

3.1 Experimental Capabilities

- Effect of counter current flow
- Overall heat balance
- Determination of liquid/liquid heat transfer coefficients.
- Influence of flow rate on heat transfer coefficients
- Comparison of LMTD for different inlet temperature and flow rates of oil.

Water and oil (ISO VG46) is used in all experiments but performance characteristics using other fluids can also be investigated.

3.2 Equipment Specifications

Both plain tube and low fin tube heat exchangers having the same dimensions.

- Shell diameter : 164 mm
- Shell length : 850 mm
- Number of tubes : 24

4. RESULTS AND DISCUSSIONS

4.1 Effect of Flow Rate of Hot Fluid (Oil)

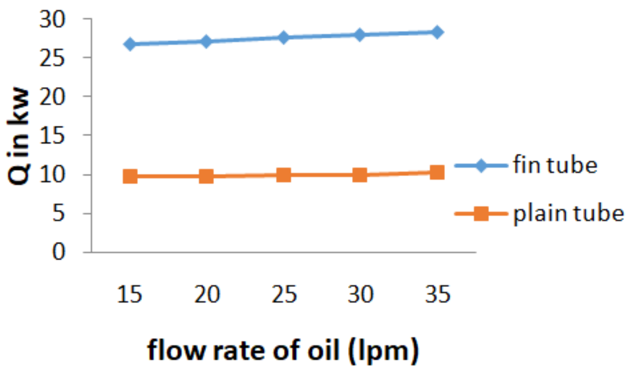

Fig 4.1: Flow rate of oil V/S heat load

As the flow rate of oil increases the heat transfer rate also increases which in turn increases the overall heat1transfer coefficient. This is because increase in oil flow rate1increases the Reynolds number which in turn increases the overall heat1transfer coefficient and also decreases the outlet temperature of oil.

From figure observed that as the flow rate of oil varied from 15 to 35lpm the heat transfer rate in low fin tube heat exchanger increases from 26.7 to28.3kw and in plain tube heat exchanger it increases from 9.7 kw to 10.13kw. Also from the figure it is seen that for the designed value 35lpm of oil flow rate heat exchanger with plain tube is giving heat transfer rate of 10.13kw and heat exchanger with low fin tubes giving the heat transfer rate of 28.3kw.

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4.2 Effect of Flow Rate of the Cold Fluid (Water)

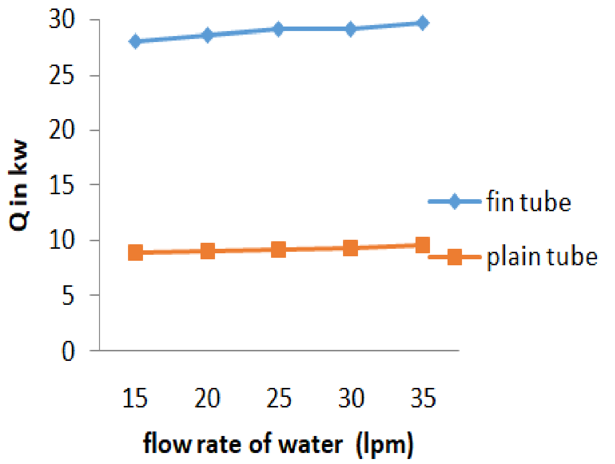

Fig 4.2: Flow rate of water V/S heat load

As from figure in STHE having plain tubes the1heat transfer rate is increasing from 8.5kw to 9.9kw whereas in STHE having low fin tubes, the1heat transfer1rate is increases from 28.14kw to 29.85kw. Also from the figure it is seen that for the designed value 35lpm of oil flow rate heat exchanger with plain tube is giving heat transfer rate of 9.9kw and heat exchanger with low fin tubes giving the heat transfer rate of 29.85kw.

4.3 Effect of Inlet Oil Temperature

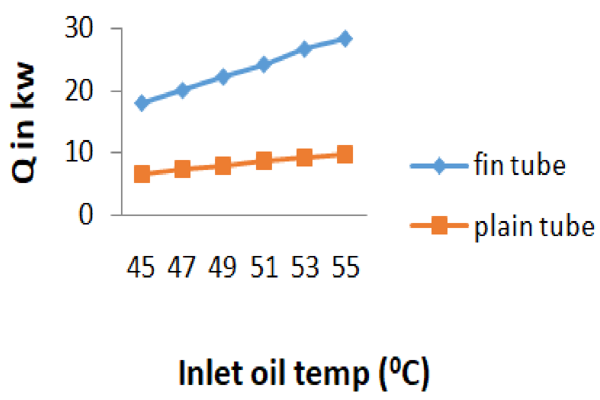

Fig 4.3: Intel oil temperature V/S heat load

From fig, heat1exchanger having low fin tubes increases the heat1transfer rate from 17.8kw to 28.2kw whereas heat exchanger having plain tubes increases the heat transfer rate from 6.65kw to 9.8kw for the same inlet oil temperature variation. Also from the figure it is seen that for the designed value of inlet oil temperature 55^{0}C to 45 ^{0}C the heat exchanger with plain tube is giving heat transfer rate of 9.8kw and the heat exchanger with low fin tubes giving the heat transfer rate of 28.2kw.Fin tube heat exchanger giving more heat transfer rate than plain tube heat exchanger as shown in figure.

4.4 Effect of Pressure Drop of Oil

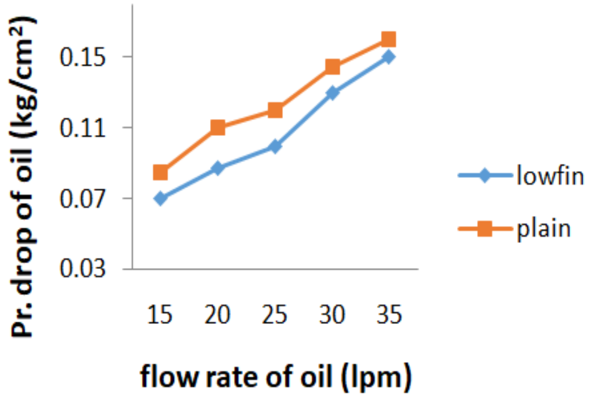

Fig 4.4: Flow rate of oil V/S pressure drop

The flow rate of oil varied from 15lpm to 35lpm pressure drop of shell side fluid in case of plain1tube STHE is from 0.085 to 0.16 kg/cm^2 whereas in low fin1tube STHE the pressure drop is from 0.07 to 0.15 kg/cm^2

4.5 Effect of Pressure Drop of Water

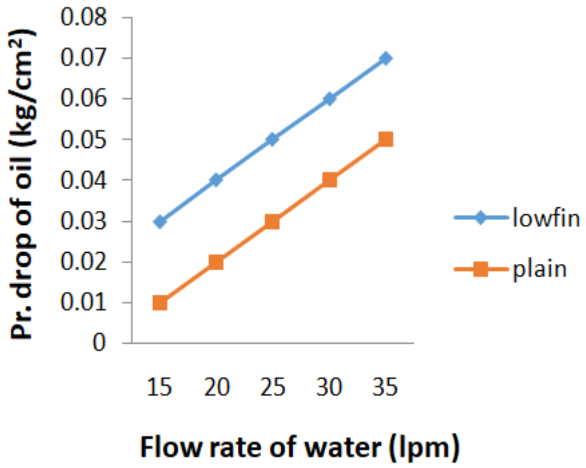

Fig 4.5: Flow rate of water V/S Pressure drop

An increase in the pressure1drop with increase in fluid flow1rate in shell and1tube heat exchanger which increases the pumping1power. From figure with increase in1the flow rate of water increasing the pressure drop in tube side. The water flow1rate is varied from 15lpm to 35lpm the pressure drop1of water in tube side in case of plain1tube is from 0.01 to 0.05kg/cm^2 whereas in case of low fin1tube STHE varies from 0.03 to 0.07 kg/cm^2.

5. CONCLUSION

From study the following conclusions are. Observed that as the flow rate of oil increased the amount of heat dissipated is more. As the flow1rate of water is increased1the amount of heat dissipated is more. As the inlet oil temperature is reduced the amount of heat transferred from oil is less. Varying the flow rate1of oil, the plain tube1heat exchanger

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giving more shell side pressure drop compared to heat exchanger having low fin tubes. Varying the flow rate of water, the low fin tube heat exchangers giving 1.2 to 1.5 times better tube side pressure drop than the heat exchanger having plain tubes.

Hence, with the increase in heat transfer area in heat exchanger the1heat transfer rate is more. Shell and tube1heat exchanger having low fin tube is giving almost 3 times better result in all three possible cases than the heat exchanger having plain tube.

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