Experimental Analysis on Shell and Tube Heat Exchanger with Different Fluid Flows

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ABSTRACT

Heat exchanger plays a major role in industrial process heating. Heat is transported among liquids by conduction and convection over the partitions of the heat exchanger. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment.

A heat Exchanger may be defined as equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running costs. Shell and Tube heat exchanger are the basic types of heat exchanger one of the fluids flow through a number of tubes enclosed by a shell. The outer fluid is forced through a shell and it flows over the outside surface of the tubes.

In this research, overall performance of a shell and tube heat exchanger operated with water(hot)-–water(cold), kerosene(hot)-water(cold), and Transformer oil (hot)-water(cold) were experimentally investigated. At different mass flow rates Heat transfer rate Q, Overall heat transfer coefficient (U) have been observed for different combination of fluids. And also Reynolds Number (Re) calculated to observe the type of flow.

Also the outlet temperature of cold fluid increases, outlet temperature of hot fluid decreases and overall heat transfer coefficient increases with increase mass flow rate. The overall heat transfer coefficient of Transformer oil was found to be more when comparison of kerosene and water. The overall heat transfer coefficient of kerosene was found to be more when comparison of water. Reynolds Number also found to be more for Transformer oil when comparison of kerosene and water. For all the cases of different combination of fluids type of flow have been observed as laminar flow.

Keywords: Heat transfer rate, overall heat transfer coefficient, Reynolds Number, Shell-and-tube heat exchanger.

I.INTRODUCTION

1.1 Definition of heat exchanger:

Heat exchanger is a device, such as an automobile radiator, used to transfer heat from a fluid on one side of a barrier to a fluid on the other side without bringing the fluid into direct contact (Fogiel, 1999). Usually, this barrier is made from metal which has good thermal conductivity in order to transfer heat effectively from one fluid to another fluid. Besides that, heat exchanger can be defined as any of several devices that transfer heat from a hot to a cold fluid. In engineering practical, generally, the hot fluid is needed to cool by the cold fluid.

For example, the hot vapor is needed to be cool by water in condenser practical. Moreover, heat exchanger is defined as a device used to exchange heat from one medium to another often through metal walls, usually to extract heat from a medium flowing between two surfaces. In automotive practice, radiator is used as heat exchanger to cool hot water from engine by air surrounding same like intercooler which used as heat exchanger to cool hot air for engine intake manifold by air surrounding. Usually, this device is made from aluminum since it is lightweight and good thermal conductivity.

1.2 FUNCTION OF HEAT EXCHANGER

Heat exchanger is a special equipment type because when heat exchanger is directly fired by a combustion process, it becomes furnace, boiler, heater, tube-still heater and engine. Vice versa, when heat exchanger make a change in phase in one of flowing fluid such as condensation of steam to water, it becomes a chiller, evaporator, sublimate, distillation-column reboiler, still, condenser or cooler-condenser. Heat exchanger may be designed for chemical reactions or energy-generation processes which become an integral part of reaction system such as a nuclear reactor, catalytic reactor or polymer (Fogiel, 1999). Normally, heat exchanger is used only for the transfer and useful elimination or recovery of heat without changed in phase. The fluids on either side of the barrier usually liquids but they can be gasses such as steam, air and hydrocarbon vapor or can be liquid metals such as sodium or mercury. In some application, heat exchanger fluids may use fused salts.

1.3. Applications of Heat exchangers

Industries	Applications
Food and Beverages	Ovens, cookers, Food processing and pre-heating, Milk pasteurization, beer cooling and pasteurization, juices and syrup pasteurization, cooling or chilling the final product to desired temperatures.
Petroleum	Brine cooling, crude oil pre-heating, crude oil heat treatment, Fluid interchanger cooling, and acid gas condenser.
Hydro carbon processing	Preheating of methanol, liquid hydrocarbon product cooling, feed pre-heaters, Recovery or removal of carbon dioxide, production of ammonia.
Polymer	Production of polypropylene, Reactor jacket cooling for the production of polyvinyl chloride.
Pharmaceutical	Purification of water and steam, For point of use cooling on Water For Injection ring.
Automotive	Pickling, Rinsing, Priming, Painting.
Power	Cooling circuit, Radiators, Oil coolers, air conditioners and heaters, energy recovery.
Marine	Marine cooling systems, Fresh water distiller, Diesel fuel pre-heating,

	central cooling, Cooling of lubrication oil.

1.4 Shell-and-tube Heat exchanger:

Shell-and-tube heat exchangers are built of round tubes mounted in large cylindrical shells with the tube axis parallel to that of the shell. These are commonly used as oil coolers, power condensers, preheaters and steam generators in both fossil fuel and nuclear-based energy production applications. They are also widely used in process applications and in the air conditioning and refrigeration industry. Although they are not specially compact, their robustness and shape make them well suited for high pressure operations. They have larger heat transfer surface area-to-volume ratios than the most of common types of heat exchangers, and they are manufactured easily for a large variety of sizes and flow configurations. They can operate at high pressures, and their construction facilitates disassembly for periodic maintenance and cleaning. The shell-and-tube heat exchangers consist of a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the tubes and a second fluid flows within the space between the tubes and the shell. The simplest form of a horizontal shell-and-tube type condenser with various components is shown in fig (1.4). One fluid flows on the shell-side steam flows across between pair of baffles and then flows parallel to the tubes as it flows from one baffle compartment to the next. There are wide differences between shell-and-tube heat exchangers depending on the application. The most representative tube bundle types used in shell-and-tube heat exchangers are shown in figures,

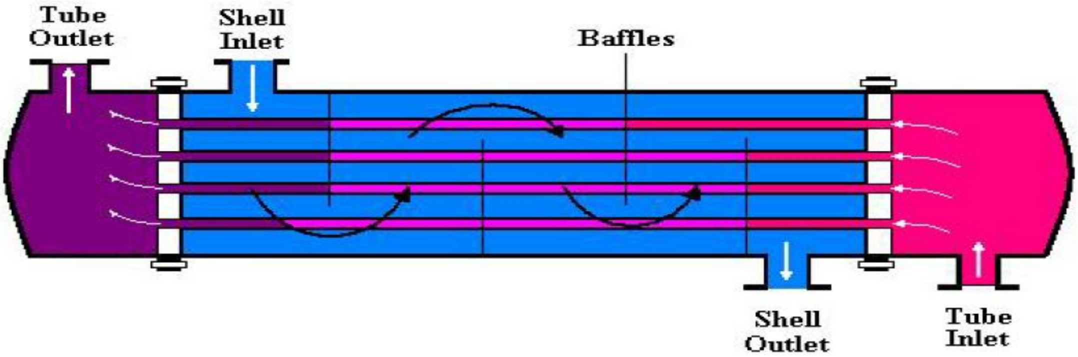


Fig1: Shell-and-tube heat exchanger

Analysis of heat exchanger depends on these governing parameters:

- Heat transfer rate(Q)-J/S or W
- Overall heat transfer coefficient(U)-W/M$^{2\ K}$
- Reynolds Number (Re).

Following data gives the brief view about the properties of the fluids that have been used in our analysis.

TRANSFORMER OIL –

Boiling point: 220 - 250ºC

Flash point: 140 ºC

Kinematic viscosity: 2.3 – 8.8Cst

Density: 2474 kg / m^3

KEROSENE –

Boiling point: 150 - 300ºC

Flash point: 160 ºC

Kinematic viscosity: 1.5 - 2Cst

Density: 2010 kg / m^3

II. LITERATURE SURVEY

M. Thirumarimurugan, T.Kannadasan and E.Ramasamy [1] have investigated heat transfer study on a solvent and solution by using Shell and Tube Heat Exchanger. In which Steam is taken as the hot fluid and Water and acetic acid-Water miscible solution taken as cold fluid. A series of runs were made between steam and water, steam and Acetic acid solution .The flow rate of the cold fluid is maintained from 120 to 720 lph and the volume fraction of Acetic acid is varied from 10-50%. Experimental results such as exchanger effectiveness, overall heat transfer coefficients were calculated. . MATLAB program was used to simulate a mathematical model for the outlet temperatures of both the Shell and Tube side fluids. From the comparisons it can be said that the mathematical model developed and simulated using MATLAB and compared with the experimental values for the system is very close. **DivyeshB.Patel1, Jayesh R. Parekh [2]** Heat exchangers are one of the most important heat transfer apparatus that find its use in industries like oil refining, chemical engineering etc. Shell and tube (U-tube) type of heat exchangers have been commonly and effectively used in industries over the year. In this paper, shell and tube (U-tube) heat exchanger is designed which includes thermal design, mechanical design and hydraulic design. Different types of methods are carried out for optimum design. According to design parameters experimental analysis is carried out, which reveal the clear idea about temperature difference and dimension of heat exchanger. General Design consideration and design procedure is also illustrated. **Jian-Fei Zhang, Ya-Ling He, Wen-Quan Tao [3]** developed a method for design and rating of shell-and-tube heat exchanger with helical baffles based on the public literatures and the widely used Bell–Delaware method for shell-and-tube heat exchanger with segmental baffles (STHXSB). The usage of tube-core with 40 deg middle overlapped helical baffles can reduce the over-all pressure drop by 46% and the heat transfer area is 13% lower. In case 3 pressure drop of the heat exchanger with 40 deg middle-overlapped helical baffles is equivalent, the heat transfer area reduced by 33%. In case 4 20 deg middle-overlapped helical baffles were adopted and the pressure drop is 33% lower than that of the original unit with 10% decrease in heat transfer area. And comparison result shows that all shell and tube heat exchanger with helical baffles have better performance than the original heat exchanger with segmental baffles.

III. PROBLEM DEFINITION

Here we had calculated the overall heat transfer coefficient of heat exchanger by varying the mass flow rates.
The experimental analysis is carried out by taking the combination of different fluids are Kerosene (hot fluid) – water (cold fluid), Transformer oil (hot fluid) – water (cold fluid), water (hot fluid) – water (cold fluid).
The experimental is done on shell and tube heat exchanger.
Two reservoirs or tanks were constructed for storage of two fluids (i.e.., hot and cold fluids).
The analysis is done for laminar flow of both fluids.
The laminar flow is obtained by keeping constant mass flow rate.
Constant mass flow rate is obtained by operating the valves of tank (Opening and Closing of valves).
At different mass flow rates calculated the overall heat transfer coefficient, heat transfer rate and Reynolds number.
Whether the flow is laminar or turbulent is known by calculating Reynolds number. Reynolds number (R_e) is a dimensional less number. For our analysis we had considered only laminar flow.
So, if Reynolds number (R_e)

i.e., $R_e < 2200$

Then it is considered to be laminar.

Following formula is for calculation for Reynolds number.

$$R_e = \frac{\rho v d}{\mu} = m d_i/\mu A_c$$

ρ = Density of fluid

v = velocity of flow

d = diameter of outlet pipe

μ = dynamic viscosity(data from data book)

For the analysis of heat exchanger of following combinations of fluids had been used:-

Kerosene (hot fluid) – water (cold fluid)

Transformer oil (hot fluid) – water (cold fluid)

Water (hot fluid) – water (cold fluid)

For our analysis we have taken the combination of different fluids.

As the objective is to calculate the overall heat transfer coefficient of the heat exchanger so, the analysis is carried out by using fallowing formulae's.

First of all the temperatures of hot and fluids are noted down. Then the heat transfer rate of hot and cold fluid is calculated. Heat transfer rate is calculated by following formula

$$Q = mc_p\Delta T$$

m = mass flow rate

c_p= specific heat

ΔT = temperature difference

Now, the average heat transfer rate is calculated. After the calculating heat transfer rate Q has been calculated by following formula

Q_h = Heat rejected in hot water = $m_h Cp_h$ (Th_i –Th_o) watts

Q_c = Heat taken by cold water = m_c Cp_c[Tc_o– Tc_i] watts

Q = average heat transfer rate = (Q_h + $Q_{c)}$/2

Now, overall heat transfer coefficient (U) is calculated.

$$Q=A\ U\ \Delta T_m$$

$$\Delta T_m =(t_2-t_1)\sqrt{}(1+R^{2)}/ \log((2-p(1+R-\sqrt{}1+R^2)/2-p(1+R+\sqrt{}1+R^2))$$

$$R= T_1-T2/t_2-t1$$

$$P=\frac{t2-t1}{T1-t1}$$

inlet temperature of the shell-side (or hot) fluid$_1$ T_1
exit temperature of the shell-side (or hot) fluid 2:T_2
inlet temperature of the tube-side (or cold) fluid 1:t_1
exit temperature of the tube-side (or cold) fluid 2:t_2

Where,

A = surface area of heat exchanger= ($\pi d_o l$) N

Reynolds number is calculated by following formula

For tube side $R_e = md_i/\mu A_c$

d_i= 10 mm= 10*10^-3 m

μ=dynamic viscosity (from data book)

m= mass flow rate

Reynolds number is calculated by using different mass flow rates for shell side fluid and tube side fluid. It indicates the flow is laminar or turbulent. In this analysis, turbulent flow is considered for both shell side and tube side.

For tube side flow, Reynolds number is calculated by

Reynolds number (Re_t) = $\frac{\rho v d_i}{\mu} = \frac{\dot{m} d_i}{\mu A_c}$

$A_c = \frac{\Pi (d_i)^2}{4} \frac{N_t}{N_p}$

For shell side flow the Reynolds number is calculated by

Reynolds number (Re_s) = $\frac{\rho v d_i}{\mu} = \frac{\dot{m} d_e}{\mu A_c}$

Similarly, the calculations for each and every combination of fluids have been carried out. After calculating all the parameters, they are tabulated.

There after by observing the values, the graphs have been drawn.

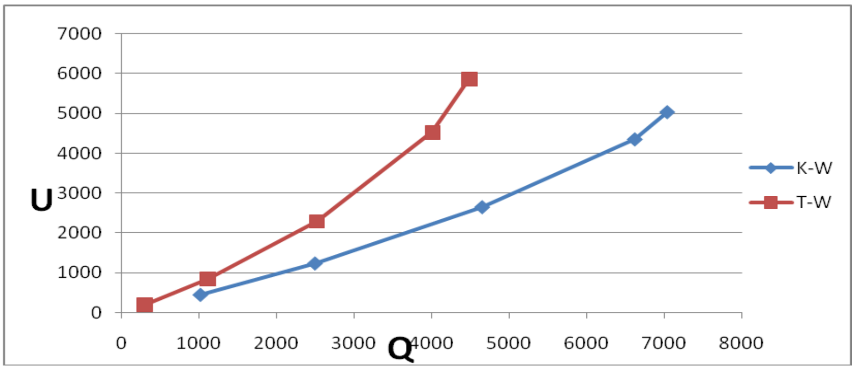
The graphs are plotted between the following:

Overall heat transfer coefficient and heat transfer rate of combination of fluids.

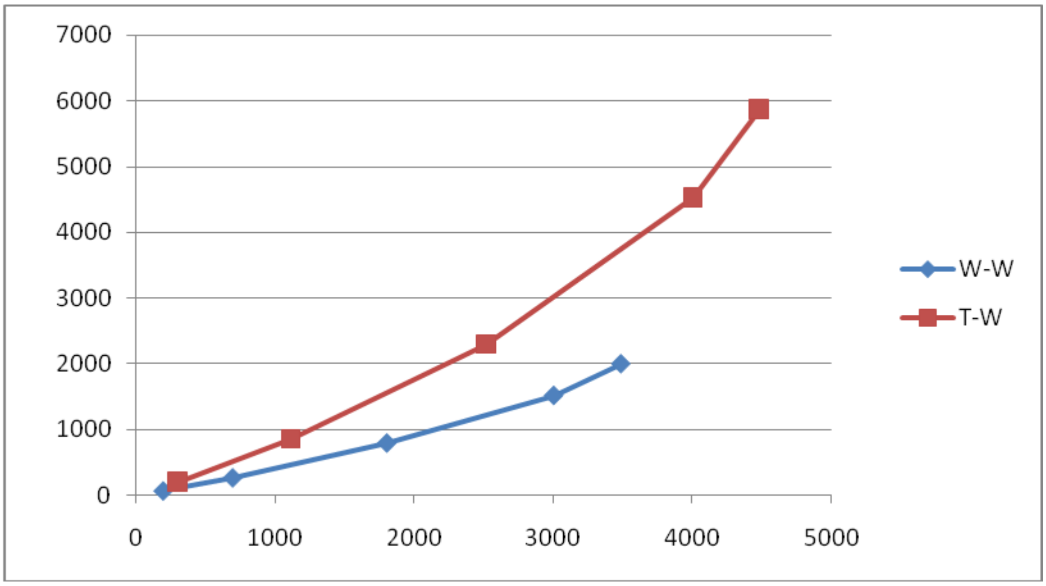
Overall heat transfer coefficient and Reynolds Number of combination of fluids.

IV. GRAPHS

By observing the output values the following graphs have been plotted down. The graph between Overall heat transfer coefficient and Reynolds Number, Rate of heat transfer and Overall heat transfer coefficient has been plotted.



Comparison between Kerosene(h)–water (c) and Transformer oil(h)–water(c



Graph 5.5: Comparison between water(h)–water (c) and Transformer oil(h)–water(c)

V. CONCULUSION

We have done experimental analysis on Shell and tube heat exchanger by varying different fluid combinations (water(H)-water(C), Kerosen(H)-water(C),Transformer(H)-water(C)) at different inlet condition mass flow rates for laminar flow. Following are the required results obtained from the experimental investigation.

At different mass flow rates Heat transfer rate Q, Overall heat transfer coefficient (U) have been observed for different combination of fluids. And also Reynolds Number (Re) calculated to observe the type of flow.

The outlet temperature of cold fluid increases, outlet temperature of hot fluid decreases and overall heat transfer coefficient increases with increase mass flow rate.

The overall heat transfer coefficient of Transformer oil was found to be more when comparison of kerosene and water. The overall heat transfer coefficient of kerosene was found to be more when comparison of water. Reynolds Number also found to be more for Transformer oil when comparison of kerosene and water. For all the cases of different combination of fluids type of flow have been observed as laminar flow.

Hence from the above results we have concluded that Transformer oil (Hot) - Water (Cold) combination have been proven as the best combination, which gives maximum Overall heat transfer coefficient =5875.35.

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