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To Study the Effect of Solute on the Rate of Heat Transfer

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Abstract: Heat exchanger plays very important energy role in the industries. In this study the effect of liquid on HT flow rate was studied using a lab scale shell and tube heat exchanger (length-39 cm, shell diameter 9 cm, tube diameter 0.62 cm). Also the effect of cold and hot fluid on heat transfer rate, effect of mass concentration of fluid (liquid) was studied. This work deals with the experimental investigation of thermal conductivity and specific heat capacity of fluids as a function of a temperature and concentration of liquid with respect to water. Also, coolants in heat exchanger are used to access their feasibility and performance in heat transfer devices. Overall good results were obtained with experimental work results on thermal conductivity and heat capacity of liquids as well as the estimation of heat transfer areas in a model shell and tube heat exchanger reveal that aqueous chemicals possess superior thermal conductivity and heat capacity and require less heat transfer areas as compared to those of their base on other liquids. This novel class of liquids shows great potential for advanced heat transfer applications. The enhancement heat transfer of the heat transfer devices can be done by changing the fluid transport.

Keyword: Heat transfer, Shell and Tube Heat Exchanger, optimization.

I. INTRODCUTION

Shell and tube heat exchanger are one of the most widely used type of heat exchanger in the process industries (65%of the market) and are commonly found in oil refineries, nuclear power plants and other large scale chemical processes[5]. Additionally, they can be found in many engines and are used to cool hydraulic fluid and oil. In this application, two separated fluids at different temperatures flow through the heat exchangers: one through the tubes (tube side) and other though the shell around the tubes (shell side). Several design parameters and operating conditions influence the optimal performance of shell and tube heat exchangers.

A. Heat Transfer

Heat exchangers are one of the mostly used equipment in the process industries. Heat exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose [6].

Process fluids, usually are heated or cooled before the process or undergo a phase change. Heat exchangers are typically classified according to flow arrangements and type of construction. In the first classification, flow can be counter current or co-current (also called parallel). Different heat exchangers are named according to their application. For example, heat exchangers being used to condense are known condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger. Heat exchangers can also be classified based on their configuration as tubular, plate and shell & tube heat exchangers.

B. Design Parameter

1. Tube length
2. Tube diameter
3. Tube material
4. Shell size and material
5. Tube sheet layout
6. Number of tubes
7. Tube head
8. Low rate of hot and cold stream
9. Heat capacity and heat transfer coefficient
10. Tube and shell pressure
11. Tube and shell thickness
12. Arrangement of tubes
13. Desired temperature range
14. Temperature measurement system
15. Baffle size and position (75% of internal diameter)

C. Thermal Considerations

Thermal design of a shell and tube heat exchanger typically includes the determination of heat transfer area, number of tubes, tube layout, number of shell and tube passes, type of heat exchanger (fixed tube sheet, removable tube bundle etc), tube pitch, number of baffles, its type and size, shell and tube side pressure drop etc.

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i Tube pitch, tube-layout and tube-count:
Tube pitch is the shortest centre to centre distance between the adjacent tubes. The tubes are generally placed in square or triangular patterns (pitch) as shown in the Figure 1.1. The widely used tube layouts are illustrated in Table 1.1**.** The number of tubes that can be accommodated in a given shell ID is called tube count. The tube count depends on the factors like shell ID, OD of tube, tube pitch, tube layout, number of tube passes and type of heat exchanger and design pressure.

ii Tube passes:
The number of passes is chosen to get the required tube side fluid velocity to obtain greater heat transfer co-efficient and also to reduce scale formation. The tube passes vary from 1 to 16. The tube passes of 1, 2 and 4 are common in application. The partition built into exchanger head known as partition plate (also called pass partition) is used to direct the tube side flow.

TABLE I COMMON TUBE LAYOUTS

Tube OD, inch	Pitch Type	Tube pitch, inch
¾ 1	Square	1 ¼
¾ ¾	Triangular	15/16 1

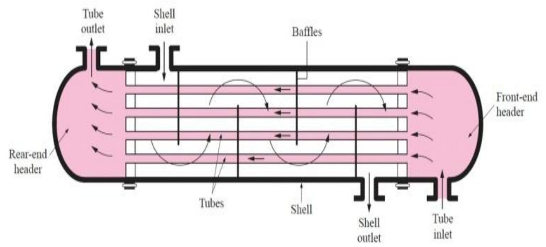

Fig 1**.** Basic flow arrangement of single pass shell and tube heat exchanger.

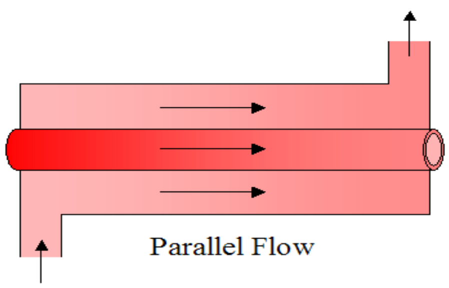

Fig 2. Schematic diagram of parallel flow shell and tube heat exchanger.

iii. Tube sheet:
The tubes are fixed with tube sheet that form the barrier between the tube and shell fluids. The tubes can be fixed with the tube sheet using ferrule and a soft metal packing ring. The tubes are attached to tube sheet with two or more grooves in the tube sheet wall by, tube rolling. The tube metal is forced to move into the grooves forming an excellent tight seal. This is the most common type of fixing arrangement in large industrial exchangers. The tube sheet thickness should be greater than the tube outside diameter to make a good sea. The recommended standards (IS:4503 or TEMA) should be followed to select the minimum tube sheet thickness.

iv. Baffles:
Baffles are used to increase the fluid velocity by diverting the flow across the tube bundle to obtain higher transfer co-efficient. The distance between adjacent baffles is called baffle-spacing. The baffle spacing of 0.2 to 1 times of the inside shell diameter is commonly used. Baffles are held in positioned by means of baffle spacers. Closer baffle spacing gives greater transfer co-efficient by inducing higher turbulence. The pressure drop is more with closer baffle spacing [6]. In case of cut-segmental baffle, a segment (called baffle cut) is removed to form the baffle expressed as a percentage of the baffle diameter. Baffle cuts from 15 to 45% are normally used. A baffle cut of 20 to 25% provide a good heat-transfer with the reasonable pressure drop. The % cut for segmental baffle refers to the cut away height from its diameter.

D. Applications

- Chemical processes.
- Petrochemical and refining.
- Food and diary.
- Power generation.
- Nuclear.
- Paper and pulp.
- High pressure applications.
- Fuel oil pre-heaters.
- Ammonia exchangers.

II. LITERATURE SURVEY

A shell and tube heat exchanger is a device in which heat energy is transferred from hot fluid to cold fluid across the solid surface of tubes, hence this process consists the both heat transfer due to conduction and convection. To calculate the parameter that gives the actual idea for how the heat is being transferred in the equipment the LMTD method can be used if the user already knows the temperature values of the inlet and the outlet cold and hot fluids.
The basic things that affects the process performance of the heat exchanger and influence the plant size, plant layout ,length of pipe runs and the strength of supporting structures is the choice of the heat exchanger to be used. Variations in the tube diameter, tube pitch, shell type, no of tube passes, baffle spacing, baffle cut etc. incorporates the various design options to the designer. The main objective of this study is the optimal design. Thus the optimal design of heat exchanger can be posed as a large scale, discrete, combinatorial problem.

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Most of the traditional optimization techniques based on the gradient methods have the possibility of getting trapped at local optimum depending upon the degree of the non-linearity and initial guess. The shell and tube heat exchangers are required in industries where the high temperatures and high pressures demands are significant and can be applied for the process where the large amount of fluid is to be heated or cooled. Due to their design these exchanger offers the large heat transfer area and can also provide the high heat transfer efficiency in comparison with others. Based on this observational correlation to find the film heat transfer coefficients will be developed during any process refining of the chemical manufacturing the heat exchangers are widely used [1].

Shell and tube heat exchangers can be used at so many industrial divisions such as boilers, oil coolers, pre-heaters, condensers etc, they are widely used in process operations as well as the refrigeration and air conditioning industries[2]. The shell and tube heat exchanger offers the unique advantage over the variants in applications like the case for any dissertation work [3]. Heat exchangers are one of the most important devices of mechanical systems in modern Society. Most industrial processes involve the transfer of heat and more often they require the heat transfer process to be controlled. A heat exchanger is the heat exchanged between two media, one being cold and the other being hot. There are different types of heat exchanger, but the type which is widely used in industrial application is the shell and tube. In this study, experiments conducted based on fully replicable five-factor, five-level central composite design. Regression models are developed to analyse the effects of shell and tube heat exchange process parameter such as inlet temperature of hot fluid and flow rates of cold and hot fluid. The output parameters of a heat exchanger are used for analysing the direct and interactive effects of heat exchange process parameters [4].

III. MATERIALS & METHODS

A. Potassium Hydroxide Solution

Potassium hydroxide is an inorganic compound commonly known as caustic potash. It is a prototypical strong base. It has many industrial and niche applications in which most exploit its reactivity toward acids and its corrosive nature.

Potassium hydroxide can be found in pure form by reacting sodium hydroxide with impure potassium. It is usually sold as translucent pellets, which will become tacky in air because KOH is hygroscopic. It typically contains varying amounts of water. Its dissolution in water is strongly exothermic. Concentrated aqueous solutions are sometimes called potassium Iyes. Even at high temperature solid KOH does not dehydrate readily.

B. Sodium Chloride Solution

Sodium chloride is also known as salt or halite is an ionic compound in 1:1 ratio of sodium and chloride ions. It is the salt most responsible for the salinity of seawater and of the extracellular fluid of many multicellular organisms. In the form of edible salt or table salt it is commonly used as condiment and food preservative. Large quantities of NaCl are used in many industrial processes, and it is as major source of sodium and chlorine compounds used as feed stocks for further chemical synthesis. A second major consumer of sodium chloride is de-icing of the roadways in sub-freezing weather.

C. Potassium Permanganate Solution

Potassium permanganate is am inorganic chemical compound consisting of K^+ and MnO^- and formerly known as permanganate of potash or Condy's crystal. It is a strong oxidizing agent. It dissolves in water to give intensely pink or purple solutions, the evaporation of which leaves prismatic purplish-black glistening crystals. It is on the WHO Model of essential medicines, the most important medications needed in a basic health system.

IV. EXPERIMENTAL SETUP

A. Experimental Apparatus and Method

For studying the enhancement of heat transfer coefficient, lab scale shell and Tube Heat exchanger was designed and fabricated itself in the workshop. The goal of this experiment for co-current operation of the equipment and flow rates (hot and cold fluids) specified by the instructor, determine:

a) The heat lost to the surroundings.
b) The overall efficiency.
c) The temperature efficiency for the hot and cold fluids.
d) The overall heat transfer coefficient U determined experimentally.
e) The overall heat transfer coefficient U determined theoretically. Compare with the experimental one.

A schematic diagram of the experimental apparatus is shown in Figure 3.1. In addition to the loop component, a full set of instruments for measuring and control of temperature and flow rate of all fluids are installed at all important points in

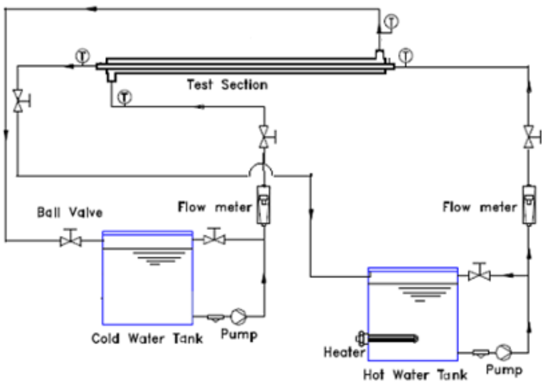

Fig.3.1.Schematic diagram of experimental apparatus

the circuit. The close-loops of hot and cold water consist of the 0.05 m^3 storage tanks, electric heaters controlled by

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adjusting the voltage using relay for hot water. The hot water is adjusted to the desired level and controlled by temperature controller. After the temperature of the cold and hot water are adjusted to achieve the desired level, the water of each loop is pumped out of the storage tanks, and is passed through a filter, flow meter, test section, and returned to the storage tanks.

The shell and tube heat exchanger consists of a number of tubes in parallel enclosed in a cylindrical shell shown in Figure 3.2 cold water in tubes and hot water in shell side. Heat is transferred between one fluid flowing through the tubes and another fluid flowing through the cylindrical shell around the tubes. Baffles are included inside the shell to increase the velocity and turbulence of the fluid to improve the heat transfer. The exchanger is designed to demonstrate liquid to liquid heat transfer in a 1-6 shell and tube heat exchanger (one shell and 6 tubes with two transverse baffles in the shell).

Fig 3.2.This is the original set up of equipment (for cold water in shell and hot water in tubes) on which experiment was conducted at J.D.I.E.T. Yavatmal.

B. Temperature measuring system

When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, there is a continuous current which flows in the thermoelectric circuit Rather than measuring the temperature of the reference junction and computing its equivalent voltage as we did with software compensation, we could insert a battery to cancel the offset voltage of the reference junction. The combination of this hardware compensation voltage and the reference junction voltage are equal to that of a 0°C junction. The compensation voltage, e, is a function of the temperature sensing resistor, RT. The voltage V is now referenced to 0°C, and may be read directly and converted to temperature by using the NBS tables. Another name for this circuit is the electronic ice point reference. These circuits are commercially available for use with any voltmeter and with a wide variety of thermocouples. The major drawback is that a unique ice point reference circuit is usually needed for each individual thermocouple type.

C. Experimental procedure

The designed shell and tube heat exchanger was run for achieving steady state flow rate of cold stream in a parallel flow arrangement for all experimentation. The details of experimental procedure are given below.

1) In the experiments, the hot water flow rate was increased thus we took reading on these different flow rate 20LPH, 30LPH, 40LPH, 50LPH, etc. inlet cold solution and hot water temperatures were also varied.

2) The inlet hot water and cold solution temperatures were adjusted to achieve the desired level by using electric heaters controlled by temperature controllers. Before any data were recorded, the system was allowed to approach the steady state.

3) The experiments were performed for the concentric plain tube; the flow rates of the water are controlled and measured by two calibrated flow meters (rotameter).

4) The water and tube wall temperatures at the inlet are measured by calibrated thermometers, and outlet sections are measured by digital T thermocouples constantly.

5) For each section, two thermocouples are used to measure the hot water, cold solution and tube wall temperatures. All type T thermocouples are pre-calibrated with the thermo-well.

6) The solutions were prepared as follows: - a) KOH Solution was prepared 0.1N, 0.3N, and 0.5N by mixing 44.8gm, 84gm, and 140gm of KOH respectively with 7 litres of tap water

b) NaCl Solution was prepared 0.1N, 0.3N, 0.5N by mixing 40.90gm,105.19gm,175.32gm of NaCl with 7, 6, 6 litres of tap water respectively.

c) KMnO4 Solution was prepared 0.1N, 0.3N, and 0.5N by mixing 27.65gm, 82.965gm, and 138.21gm of KMnO4 with 8 litres of tap water respectively

7) Thus in this procedure we calculate all data for only pure tap water. Then we took reading subsequently for different amount of solute. Plug in the required connection using the socket.

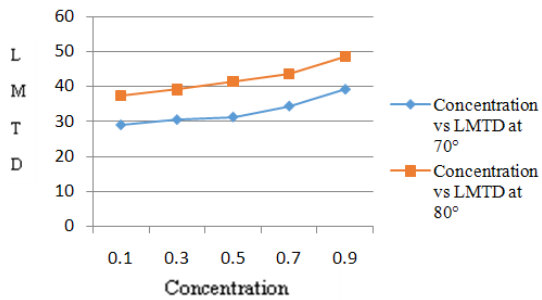
8) Allow the pressure of hot water to build up to minimum heat. Open the cold solution inlet valve so that hot water flows through shell at a particular flow rate.

9) Then open the cold solution inlet valve & adjust to a constant pressure & it flows in tube side of heat exchanger. Allow the cold solution to reach steady state. Afterward the inlet and outlet temperature of hot and cold fluid is noted down.

10) Note down flow rate of cold solution and also measure condensate collected for known interval of time. The procedure is repeated for different pressure of hot water.

V. RESULTS AND DISCUSSION

Potassium Hydroxide (KOH)



Fi.5.1.This graph shows that as the concentration increases Logarithmic Mean Temperature Difference (LMTD) also increases.

Sodium Chloride (NaCl)

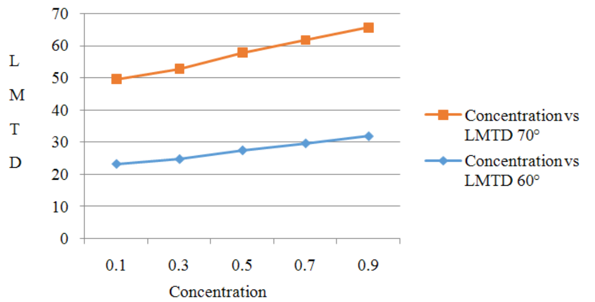


Fig.5.2.This graph shows that as the concentration increases Logarithmic Mean Temperature Difference (LMTD) also increases.

Potassium Permanganate ($KMnO^4$)

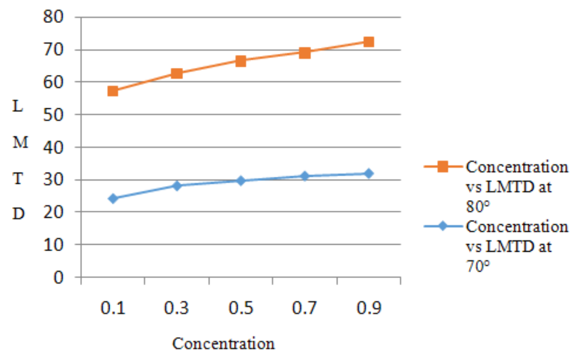


Fig.5.3.This graph shows that as the concentration increases Logarithmic Mean Temperature Difference (LMTD) also increases.

VI. CONCLUSION

In this project we have seen that the logarithmic mean temperature difference increases with respect to concentration since the heat transfer rate is directly proportional to LMTD. Therefore heat transfer rate ($Q = U A \Theta_m$) is increased and overall heat transfer rate and area remains constant.

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