ENHANCEMENT OF HEAT TRANSFER OF A SHELL & TUBE HEAT EXCHANGER

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ABSTRACT

This Paper Consists of extensive thermal analysis of the effect of severs loading condition on the performance of the heat exchanger. A simplified model of shell and tube heat exchanger has been design using Kim method to cool the water from 70 Degree Celsius to 6 Degree Celsius by using water at room temperature.

The Heat Exchanger containing 5 tubes diameter 1.9 cm. and the tube length is 98.5 cm. The shell is 100.5 cm length the diameter 5 cm

This heat Exchanger is experimented with various shell side and tube side inlet temperature to see its effect on the performance of the heat exchanger at counter and parallel flow condition.

We have also Experimented the heat exchanger under various shell side flow condition. All these Observations along with their discussion have been discussed in detail inside the paper.

ACKNOWLEDGEMENT

All praises and thanks to “Almighty Allah” for continuous this research. I would like to express very great apperception to **Md. Sojib Kaisar,** lecturer of Department of Mechanical Engineering, Sonargaon University (SU), for his valuable and constructive suggestions during the planning and development of research works. His willingness to give valuable time generously has been very much aperients. Special thanks should be given to Md. Mostofa Hossain, Associate professor, Department of Mechanical Engineering, Sonargaon University (SU) for his professional guides & valuable support on this thesis project.

Finally, the authors remain thankful to others related to this thesis for support and encouragement to complete this work successfully.

DECLERATION

We hereby declare that, this thesis paper has been done by under the supervision of, **Md. Sojib Kaisar,** Lecturer & Coordinator of Department of Mechanical Engineering, Sonargaon University (SU). We also declare that neither this thesis paper not any part of thesis paper has been submitted else wise for award for any degree.

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CHAPTER 1

INTRODUCTION

A Heat exchanger is a piece of equipment that continually transfers heat from one medium to another in order to carry process energy. Heat exchangers are device used to transfer heat from one fluid to another while preventing the two from mixing. Heat exchanger manufacturers can make three main types: shell and tube heat exchangers, air-cooled heat exchangers and plate heat exchangers. Generally, a metal wall partition, acting as a conductor, is between the two fluids. A hot solution flowing on one side of the barrier transfers its heat to a cooler solution flowing on the other side. Thermal energy only flows from the hotter to the cooler in an attempt to each equilibrium. The surface area of a heat exchanger affects its speed and efficiency: the larger a heat exchangers surface area, the faster and more efficient the heat transfers. Heat exchanger is a device in which heat is transferred between two streams of fluids at different temperatures, which are separated from each other by the help of conductive solid wall. A Heat exchanger is very important component in many engineering applications. Such as power plants, chemical processing plants, building heating, Refrigeration & air conditioning, space heating, petroleum refinery plants etc. Working criteria of double pipe heat exchanger are one fluid flows through the inner pipe & the other fluid flows through the annular space. Generally, Heat exchangers may be classified depending on the flow directions of the heat exchanger fluids. Heat exchangers are used extensively in fossil-fuel and nuclear power plants, gas turbines, heating and air-conditioning, refrigeration, and the chemical industry. The devices are given different names when they see a special purpose. Thus boilers, evaporators, super heaters, condensers, and coolers may all be considered heat exchangers. Heat exchangers are manufactured with various flow arrangements and in different designs.

1.1 Objective

Main objectives of the experiment are to draw temperature profile along the length of the heat exchanger, computing Logarithmic mean temperature difference (LMTD), calculating overall heat transfer coefficient for the heat exchanger and to estimate heat loss to the surroundings. To study and evaluate the effects of flow conditions and flow configurations on the rate of heat transfer through thin walled tubes. To determine the overall heat transfer coefficient for the double pipe heat exchanger for countercurrent flow and parallel (or co-current) flow.

CHAPTER 2

LITERATURE REVIEW

Enhancement of heat transfer through shell and tube exchangers stills taking high attention by researchers. The present work investigated the effect of shell diameter and tube length on heat transfer coefficient and pressure drop for shell side with both triangular and square pitches. In addition, the effect of baffle spacing and cutting space on heat transfer coefficient and pressure drop was studied. Moreover, standards fouling rates used for both shell and tube sides to estimate the reduced heat transfer. My project added new vision Enhancement of heat transfer through Pins & Box for Increasing shell diameter with a triangular pitch and pull-through floating head recorded 3% increasing in heat transfer coefficient for only 0,05 m increasing in shell diameter. While 2.8% increase in heat transfer coefficient for shell side by 0.05 m increasing in shell diameter with split-ring floating head and square pitch. Heat transfer coefficient for shell side reduced by 15.15% by increasing baffle space by 0.2 from shell diameter and the pressure drop by 41.25%. Increasing cutting space from 15% to 25% decreases heat transfer coefficient by 5.56% and the pressure drop diminished by 26.3%. Increasing tube length by 0.61 m leads to enhance the heat transfer coefficient by 31.9% and pressure drop by 14.11% for tube side. For shell side, increasing tube length by 0.61 m gives 2.2% increasing in heat transfer coefficient and 21.9% increasing for pressure drop. Fouling resistance change on shell side shows a high effect on heat transfer more than same rate change on the tube side. Based on the result, this study can help designers to quick understand of each parameter effect on heat transfer into shell and tube exchangers.

2.1Purpose of Use Double Pipe Heat Exchanger

Heat exchangers are a fundamental tool common across almost every industry, and for good reason.

These devices transfer, or "exchange" heat between two flows (liquid or gas) via a conductive barrier without physically mixing them. This heat is a form of energy, and engineers have developed systems where heat exchangers are used to efficiently transfer energy between pathways. Heat exchangers come in many varieties because there are many different ways to achieve this heat transfer; this article will highlight the double pipe heat exchanger, one of the most basic, but flexible configurations. We will first examine what makes a heat exchanger a double-pipe design, how they accomplish energy transfer, and what are the main advantages and applications of such a design.

The goal of any heat exchanger is to allow two flows to interact at some conductive barrier, where this barrier physically separates the flows but allows for thermal energy transfer. To get a basic understanding of the principles behind these designs, read our article on understanding heat exchangers, which examines the theory behind these devices.

The double pipe heat exchanger is, in its simplest form, one pipe held concentrically inside of a larger pipe (thus the name "double pipe"). The inner pipe acts as the conductive barrier, where one fluid flows through this inner pipe and another flow around it through the outer pipe, forming an annulus shape. The outside or "shell side" flow passes over the inside, or "tube side" flow, which will cause heat exchange through the inner tube's walls. They are also often referred to as hairpin, jacketed pipe, jacketed u-tube, and pipe-in-pipe exchangers. Inside, they can contain one tube or a tube bundle (similar to shell and tube heat exchangers), but the bundle must be < 30 tubes and the outer pipe must be < 200mm in diameter, or the heat exchanger qualifies as another design (See our article on shell and tube heat exchangers for more information). The inner tube(s) can also use longitudinal fins, which further increase the heat transfer between the two working fluids.

2.2Purpose of Use Helical Baffle

A New type of baffle, called the helical baffle, provides further improvement. This type of baffle was first developed by Lutcha and Namcansky. They investigated the flow field patterns produced by such helical baffle geometry with different helical angles. They found that these flows patterns were very close to plug flow condition, which was expected to reduce shell-side pressure drop and to improve heat transfer performance. Stehlik et al. compared heat transfer and pressure drop correction factors for a heat exchanger with an optimized segmental baffle based on the bell-Delaware method, with those for a heat exchanger with helical baffle. Kraaletal. Discussed the performance of heat exchangers with the helical baffles based on test results of varies baffle geometries. One of the most important geometric factors of the STHXSB is the helix angle. Recently a comprehensive comparison between test data of shell side heat transfer coefficient versus shell-side pressure drop was provided for first helical baffle measure for oil-water heat exchanger. It is found that based on the heat transfer per unit shell side fluid pumping power or unit shell-side fluid pressure drop. The case of 40 helix angle behaves the best. The flow pattern in shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to geometry of the continuous helical baffles, which result in a significant increase in the heat transfer coefficient per pressure drop in the heat exchanger. Properly designed continuous helical baffle can reduce fouling in the shell side and prevent the flow-induced vibration as well. The performance of the proposed STHXs was studied experimentally in this work. The use o continuous helical baffles result in nearly 10% increase in heat transfer coefficient compared with the conventional segmental baffles for the same shell-side pressure drop. Based on the experimental data, the non-dimensional correlations for heat transfer coefficient and pressure drop was developed for the proposed continuous helical baffles heat exchanger with different shell configurations, which might useful for industrial applications and further study of continuous helical baffle heat exchanger.

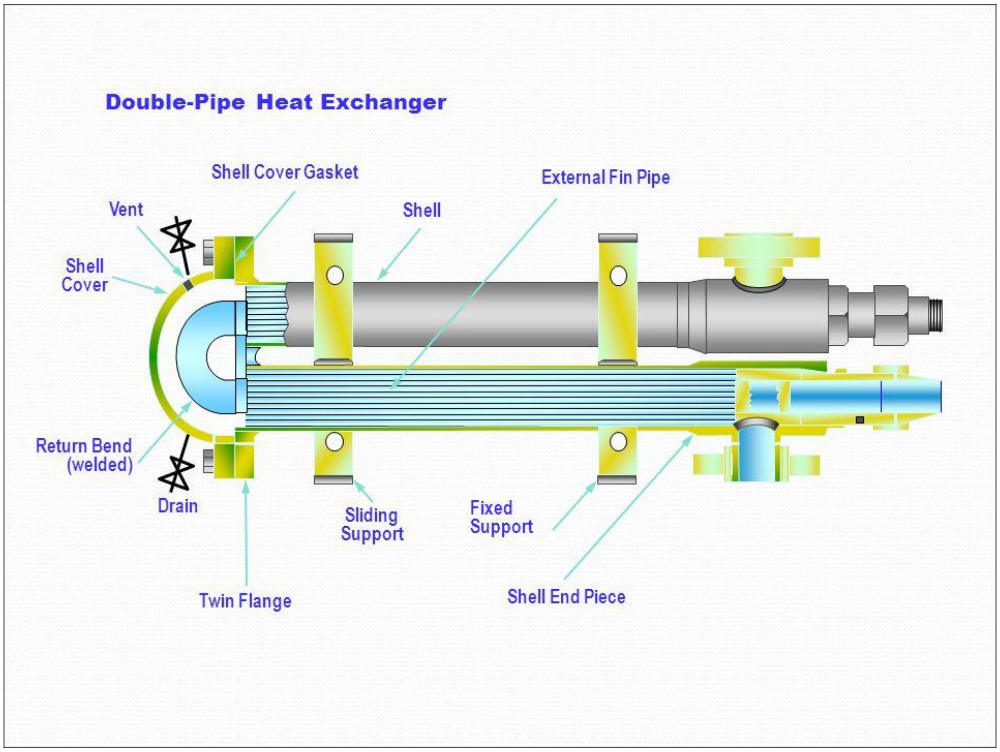

Figure- 2.1: Pattern in the in the shell side of the heat exchanger.

2.3Computational Fluid Dynamics

CFD is a sophisticated computationally-based design and analysis technique software gives you the power to simulate flows of gases and liquids, heat and mass transfer, moving bodies, multiphase physics, chemical reaction, fluid-structure interaction and acoustics through computer modeling. This software can also build a virtual prototype of the system or device before can be apply to real-world physics and chemistry to the model, and the software will provide with images and data, which predict the performance of that design.

Computational fluid dynamics (CFD) is useful in a wide variety of applications and use in industry. CFD is one of the branches of fluid mechanics that uses numerical methods and algorithm can be used to solve and analyze problems that involve fluid flows and also simulate the flow over a piping, vehicle or machinery. Computers are used to perform the millions of calculations required to simulate the interaction of fluids and gases with the complex surfaces used in engineering. Onwards the aerospace industry has integrated CFD techniques in to the design, R & D and manufacture of aircraft and jet engines. More recently the methods have been applied to the design of internal combustion engine, combustion chambers of gas turbine and furnaces also fluid flows and heat transfer in heat exchanger (figure- 2.1). Furthermore, motor vehicle manufactures now routinely predict drag forces, under bonnet air flows and surrounding car environment with CFD. Increasingly CFD is becoming a vital component in the design of industrial products and processes.

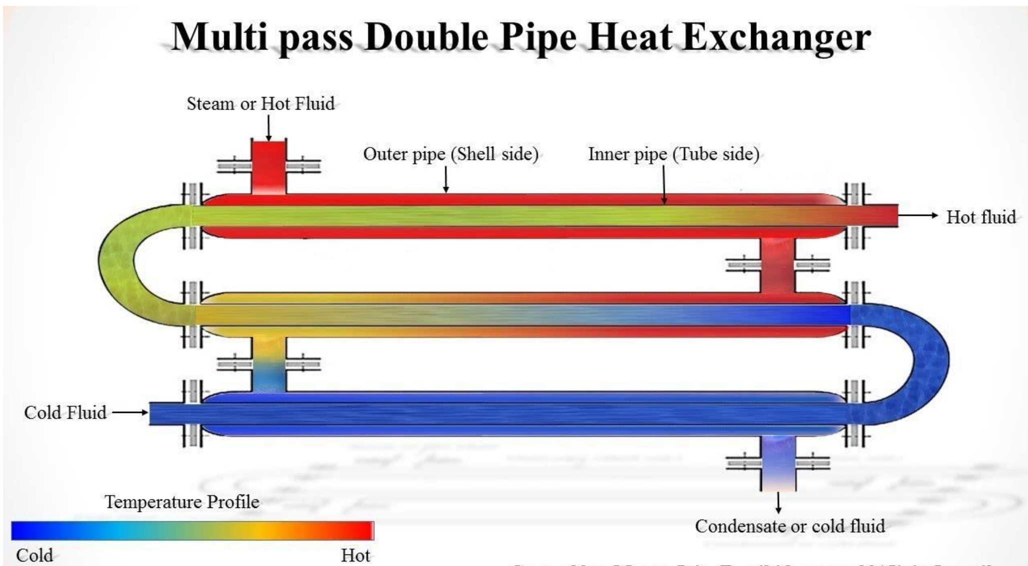

Figure- 2.2: Fluid flow simulation for shell and tube exchanger

2.4 ANSYS

Ansys is the finite element analysis code widely use in computer aided engineering (CAE) field. ANSYS software help us to construct computer models of structure, machine, components or system, apply operating loads and other design criteria, study physical response such as stress level temperature distribution, pressure etc.

In Analysis Following Basic step is followed:

- During preprocessing the geometry of the problem is defined. Volume occupied by fluid is divided into discrete cells (the mesh may be uniform or non-uniform. The physical modeling is defined. Boundary condition is defined. This involves specifying the fluid behavior of the problem. For transient problem boundary condition are also defined.
- The simulation is started and the equations are solved interactively as steady state or transient.
- Finally, a post procedure is used for the analysis and visualization of the resulting problem.

CHAPTER 3

SHELL AND TUBE HEAT EXCHANGER

By far the most common type of heat exchangers are to be encountered in the thermal applications in shell-and-tube heat exchangers. These are available in a variety of configurations with numerous construction features and with differing materials for specific applications. This chapter explains the basics of exchanger thermal design, covering such topics as Shell-and-tube heat exchanger components; classification of constructions.

3.1 Theory

The natural laws of physics always allow the driving energy in a system to flow until equilibrium is reached. As long as there is a temperature difference, heat leaves the hottest fluid and will be transferred to the colder fluid. A heat exchanger is a piece of machinery designed solely for the transfer of heat energy between two mediums, it is therefore necessary that it has large contact surface areas of martial separating each medium.

The theory of heat transfers from one media to another, or from one fluid to another, is determined by several basic rules

- Heat will always be transferred from a hot product to a cold product.
- There must always be a temperature difference between the products.
- The heat lost by the hot product is equal to the amount of heat gained by the cold product, except for energy losses to the surrounding area.

3.2 About Shell and Tube Heat Exchangers

Shell and tube type heat exchanger consist of a bundle of parallel sanitary tubes with the ends expanded in tube sheets. The bundle is contained in a cylindrical shell. Connections are such that the tubes can contain either the product or the media, depending upon the application. The major Limitation is that they cannot be used to regenerate, but they can transfer a large amount heat due to the large surface.

3.3 Advantages and Disadvantages

The double pipe heat exchanger is one of the easiest designs to fabricate, add on to, and repair thanks to its simple design. They have some unique advantages over some of the more complicated heat exchanger designs, as well as some important disadvantages, so this article will show buyers when they should – and shouldn't – consider using one of these systems:

Below is a list of the main advantages of using a double pipe heat exchanger:

- They can handle both high pressures and high temperatures well
- Their parts have been standardized due to their popularity, allowing for easy part sourcing and repair
- They are one of the most flexible designs, allowing for easy addition/removal of parts
- They have a small footprint that requires little to no maintenance space while still having good heat transfer

It is important to understand the downsides of such a design, however, which include:

- They are limited to lower heat duties than other, larger designs
- Even though they are able to be used in parallel flow, they are more often only used in counter flow regimes, which restricts some applications
- Leaking can occur, especially when paired with more units
- The tubes are easily fouled and difficult to clean without disassembling the whole heat exchanger

- If the budget and space exist for a shell and tube exchanger, then a double pipe design is often a less efficient method of heat transfer.

3.4 Different Application of Heat exchanger

Although they are not always known by the name “heat exchanger” these devices are quite common and aren’t always industrial-types. For instance, a car’s radiator is a useful device for transferring heat from the engine to the air Other examples of commercial uses for heat exchangers include spa and swimming pool heating, home radiators, hot water radiators, refrigerators and air conditioners. Whether in commercial or industrial use heat exchangers are vital as energy and money saving devices since most mechanical, chemical and energy systems require heat transferable of some sort.

Custom heat exchangers perform a crucial role in the design, operation and maintenance of heating and air-conditioning system, vehicle design, power plants, refrigeration, chemical and industrial engineering system. They are also important in settings such as food processing, industrial engineer process pharmaceutical, pulp and paper and the steel industry. All power generation industries need them. Other Industries that use heat exchangers include aerospace, Chemical, Marine, semiconductor, petrochemical, electronic, automobile, Water treatment facilities and textiles.

3.5 Classification of Heat Exchanger

Generally, Heat exchangers may be classified depending on the flow directions of the heat exchanger fluids. So, there are three types of heat exchangers based on fluid flow direction-

I. Parallel flow heat exchanger: -Where the two fluid streams flow in the same directions.
II. Counter –current or counter flow heat exchanger: -Where the two fluid streams flow in the opposite directions.
III. Cross flow heat exchanger: -where one fluid flows through the heat transfer matrix at right angle to the flow path on the other fluid.

3.6 History

Highly Use of Heat Exchanger Industry. Because it is enables re-usable by using wasted condensed, if a result comprehensive amount cost reduces. Then choose Shell and tube heat exchangers. Shell and tube heat exchangers are considered one among the most effective type of heat exchangers. These heat exchanges have a cylindrical shell with a bundle of tubes. But my project added additional part of pins & box because this is provably that heat transferred efficiency enchantment. The tubes are made from thermally conductive materials, which allow heat exchange between the hot fluids flowing outside the tubes and the coolant flowing through the tubes. These heat exchangers offer an optimal cooling solution to different applications including:

1. Hydraulic
2. Leisure

3. Marine
4. Rail
5. Industrial

Shell and tube heat exchangers are widely used in applications, which require cooling, or heating large volume of process fluids or gases. There are several different types of shell and tube heat exchanger designs to meet several processes needs in virtually every industry.

3.7 Important Parts of Shell and Tube Heat Exchangers

The following are the four most crucial parts of a shell and tube heat exchanger:

Tube Bundle: A tube bundle consists of tube sheets and tubes. The tube bundle is held together by baffles, and tie rods.

Shell: The tube bundle is included in a shell.

Front Header: A front header, which is also referred to as a stationary header, is the part from where the fluid enters the tube side of the exchanger.

Rear Header: A rear header is apart from where the tube side fluid leaves the exchanger or where it is returned to the front header

3.8 Benefits of Using Shell and Tube Heat Exchangers

Shell and tube heat exchangers are extensively used in several industries, particularly in refineries, owing to the various advantages they offer over other heat exchangers. Shell and tube heat exchangers have more heat transfer efficiency. These heat exchangers are an optimal solution for swimming pool heating, mining machinery, hydraulic power packs, etc. These heat exchangers can be easily dismantled. Thus, cleaning and repairing is easy. The heat exchangers are compact in size. The capacity of these heat exchangers can be increased by adding plates in pairs. These exchangers are affordable compared to the plate type coolers. As the pressure test is relatively simple, one can easily locate tube leaks and fix them and also this heat exchanger can be used in systems, which have higher operating temperatures and pressures.

CHAPTER 4
FABRICATIONAND DESIGN OF SHELL AND TUBE HEAT EXCHANGRER

The classical approach to shell-and-tube Heat Exchanger design involves a significant amount of trial-and-error because an acceptable design needs to satisfy a number of constraints. Typically, a designer chooses various geometrical parameters such as tube length, shell diameter and baffle spacing based on experience to arrive at a possible design. If the design does not satisfy the constraints, a new set of geometrical parameters must be chosen. Even if the constraints are satisfied, the design may not be optimal. In this project, a methodology is proposed that calculates the approximate free flow areas on tube and shell side for specified pressure drops. Once these are obtained, geometrical dimensions can be tried to satisfy heat transfer requirements.

4.1 Mechanical Design of shell and Tube Heat Exchanger

Designers and fabricators of heat exchanger often treat thermal design and mechanical design as two discrete and separable functions. The interaction between these two is essential in some cases like thermal stresses in multiple passes fixed tube heat exchanger, effect of flexing of tube sheets. Therefore, a designer alert to the mutual influence of these two designs and hence hydro-mechanical design is also done.

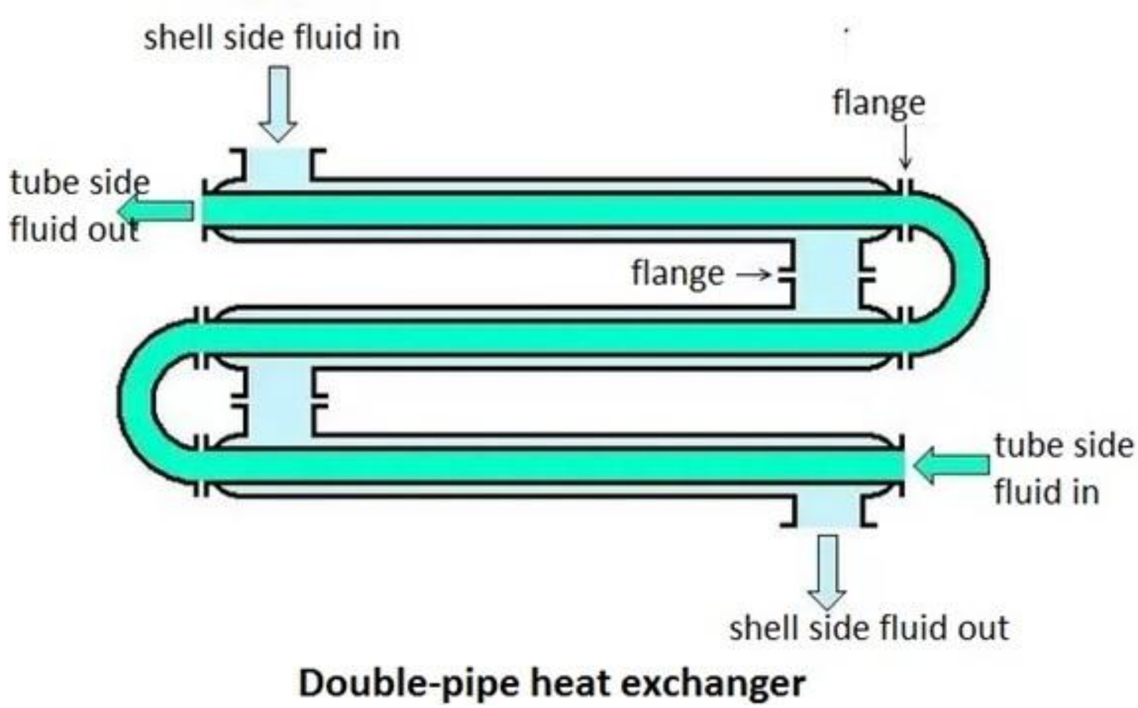

Figure- 4.1: Design of Shell and tube Heat Exchanger.

4.2 Constructional Details of Shell and tube Heat Exchanger

It is essential for the designer to have a good knowledge of the mechanical features of shell-and-tube heat exchangers and how they influence thermal design. The principal components of shell-and-tube heat exchangers are:

- Shell
- Shell cover
- Tubes
- Channel
- Channel cover

- Tube sheet
- Copper nickel Alloys
- Carbon steel
- Stainless steel
- Baffles
- Nozzles

Other components include tie-rods spacers; pass partition plates, impingement plate, longitudinal baffles, sealing strips, supports, titanium and foundation. The tubular exchanger manufacturer is Association, has introduced a standardized nomenclature for shell-and-tube heat exchangers. A three-letter code has been used to designate the overall configurations. The three important elements of any shell-and-tube heat exchangers are front head, the shell and rear head design respectively. The standards of Tubular Exchanger Manufactures Associations (TEMA) describes the various components of varies class of shell-and-tube heat exchanger in detail.

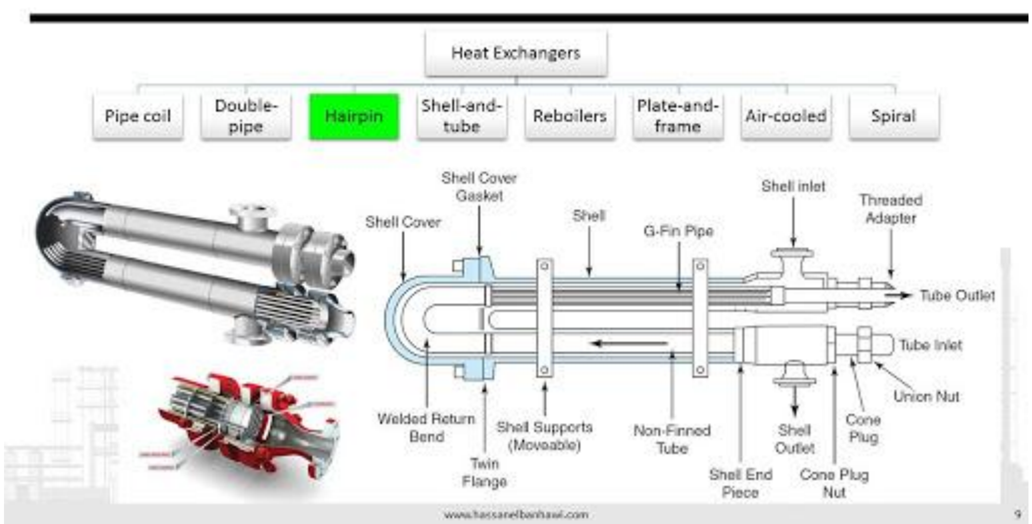

Figure- 4.2: Constructional Design of Shell and tube heat exchanger.

4.3 Materials Used

Different materials are used for manufacturing heat exchangers based on the applications. Here is the most frequently used tube side materials are Cupronickel Alloys, Titanium, Carbon Steel, Brass Alloys, Motor, Weir, Plug Stainless Steel etc.

Heat Exchanger Steam Inlet Line must be needed insulation & valve open slowly. Valve opens before checking the line. Heat exchange expectation line needed insulation so we expect properly outputted.

4.4 Apparatus

Following equipment's are necessary for performing the excrement:

Pressure Gauge, Flow meter, Thermocouple, Condensed collect Bucket, Glass wool, Rockwool etc.

4.5 Assumptions

Followings assumptions are made for the study of heat transfer in a counter flow heat exchanger:

Flow is considered to be steady; Specific heat of the fluids does not vary with temp. Overall heat transfer coefficient remains constant along the heat transfer. Overall heat transfer coefficient determined based on ideals condition.

4.6 Precaution

During performing the experiment, the following precautionary measures should be taken:

Thermocouple reading should be taken when the steady state is reached. Inlet & outlet temperature of water are to be recorded when there is no fluctuation of temperature. Otherwise the average temperature may be taken.

4.7 Copper Tube Heat Exchanger

Tube are available a variety of diameters, wall thickness, length and materials of construction. The heat exchanger containing 5 tubes of outer diameters 1.5 cm and inner diameter 1.3 cm. The tube length is 90 cm.

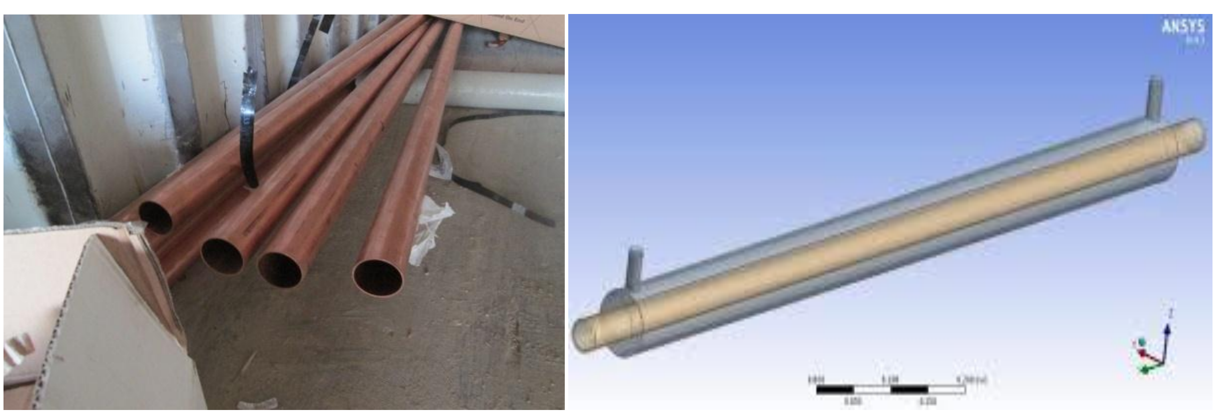

Figure-4.3: Copper Tube

4.8 Shell of Heat Exchanger

The shell is a container for the shell fluid. Usually, it is cylindrical in shape with a circular cross section, although shells of different shapes are used in specific supplication. The shell is 50 mm longed inner diameters are 48 mm.

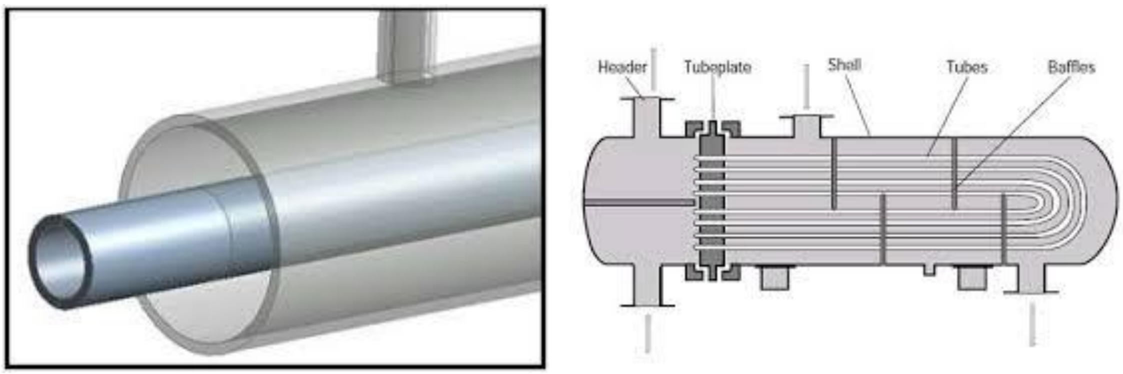

Figure- 4.4: Cylindrical type Shell construction Design.

4.9 Calculation of Heat Transfer Coefficient

Flow across banks of tubes is, from both constructional and physical considerations, one of the most effective means of heat transfer. However, it is recognized quite early that ideal tube bank correlations, if applied to shell-and-tube heat exchangers, needed substantial correlations. In 1951, Tinker presented what has become a classical paper on flow though the tube bundles shell-and-tube heat exchanger. He pointed out that a number of differing paths existed for the flow and argued that the assumption that all of the fluid passed through the whole of the bundle was false. This was clearly demonstrated by his observations of the performance of exchangers handling highly viscose oils. Then he proceeded to propose a flow model based on variety of flow paths cross flow, bundle bypass, tube-baffle leakage. These paths are shown in the figure below. The contribution become watershed in shell-and-tube that exchanger technology. Up until that, simple correlations, similar to those used for tubes, had been produced and used for shell side performance. Following Tinker's work researches concentrated on developing the sophisticated performance model for heat exchanger which recognized the existence of flow paths.

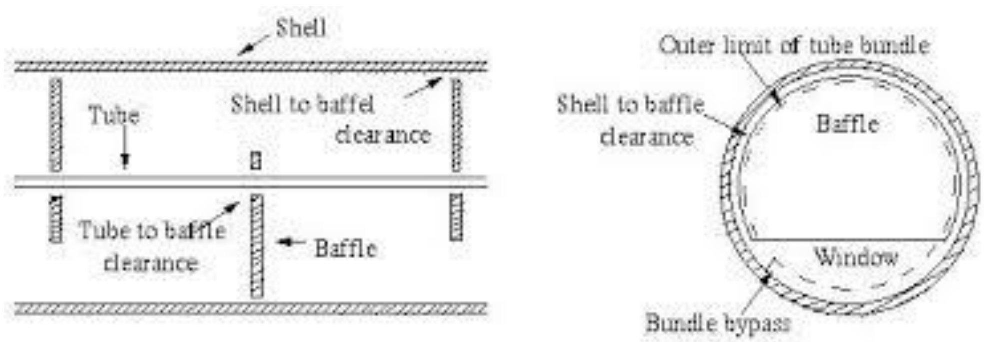

Figure- 4.5: Mechanical Clearances in shell and tube heat Exchanger.

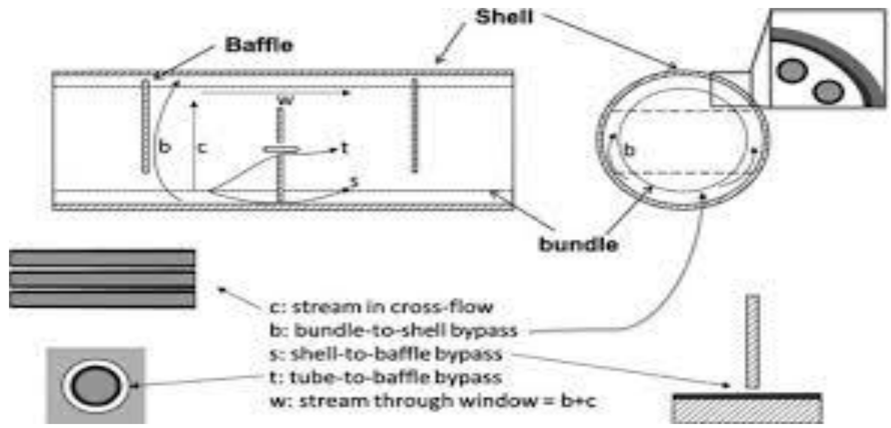

Figure- 4.6: Shell and baffle Model

4.10 FABRICATION

Shell and tube heat exchanger considers one of the most common types of exchangers widely used in the industrial processes. This exchanger consists of a vessel with different sizes contains a number of tubes inside. Heat transfers between these tubes together and with the shell side through tube walls. Shell and tube exchangers characterize by easy to manufacture in different sizes and flow configurations . The rate of transferred heat depends on several factors such as feed temperature and pressure, shell diameter, a number of tubes, tube geometry, baffle spacing and cutting spacing. design of shell and tube heat exchanger in details and tested the effect of shell diameter on overall heat transfer coefficient by using different bundle diameters . Concluded that baffle spacing, and pitch type can play a vital role in enhancing heat transfer into exchangers. In the same effect of baffle material on heat transfer coefficient and pressure drop by using different materials of constructions to recommend stainless steel as the best choice. Tested the effects of distance, width, profile, and layout of the baffle on the overall heat transfer of exchanger. Investigated experimentally using a corrugated shell and corrugated tube instead of smooth shell and tube to improve the heat transfer through the exchanger .examined the effect of geometry parameters on the heat transfer and entropy generation. Experimentally studied the effect of using helix angles on the performance of shell-and-tube heat Exchanger. Each part in exchanger has a direct effect on the total transferred heat, therefore, it is important to choose carefully all the parameters

Figure-4.7: Design of Shell & Tube Heat exchanger box With Pins

This paper will design shell and tube heat exchanger by using different parameters to study the effect of baffle spacing, cutting space, shell diameter, tube length, fouling rate on heat transfer coefficient and pressure drop for shell and tube sides. The properties estimated by using Cold water in shell side and hot Fluid (Steam) in tube side. In the design of shell and tube exchanger cannot avoid trial and error process to reach requested result. Therefore, study the effect of each parameter of design can lead to quick prediction and effective design.

Figure-4.8: Shell and Tube Heat Exchanger with Using Fins and Box

4.11Working Procedure

Steps as mentioned bellow should be followed while performing the experiment -

First, the valve of the experimental setup is to be adjusting properly counter flow arrangement that is valve B&C are to be closed & valve A and D are to be opened. Next valve A&D are to be controlled to regulate the flow of cold water as per requirement

(APR). Then by opening the valve steam will be allowed to flow throw the HX & the steam pressure will be maintain at desired value by controlling the valve.

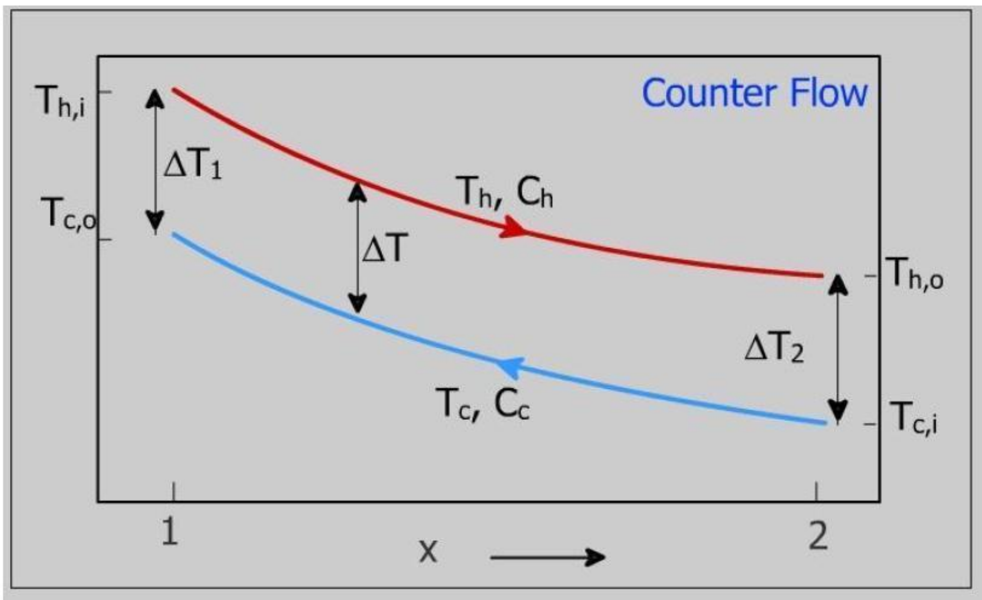

Figure-4.9: Heat exchangers counter flow

Now steady state has to be attained, which can be ensure by observing by outlet temp. Of the hot & cold fluids until they become nearly constant with time. After steady state is reached the temperature at the different location of HX is to be recorded by the thermocouple.

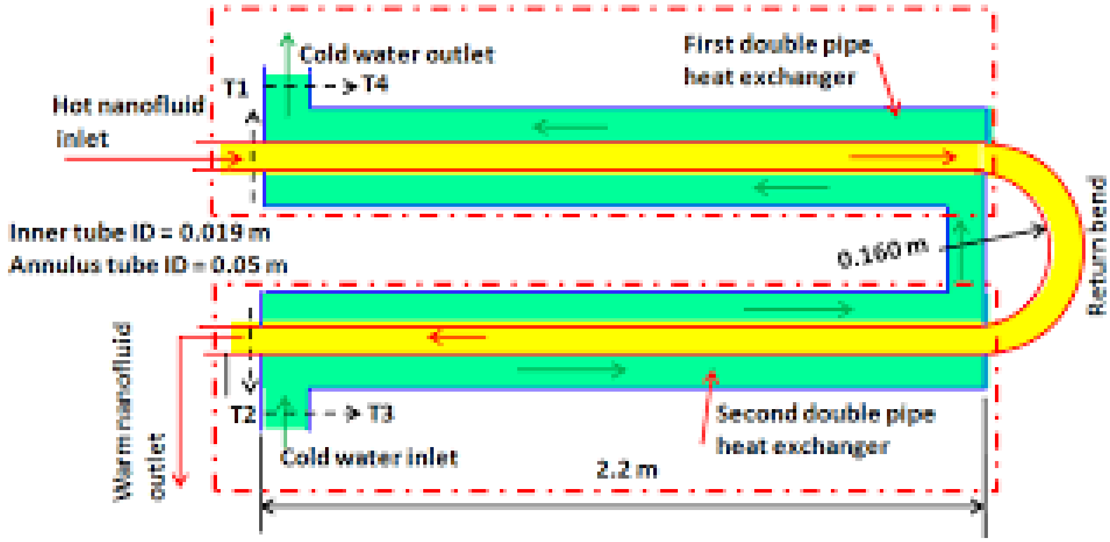

Figure-4.10: Counter flow Heat Exchanger Process

Then the mass flow rate of water is to be recorded by using bucket, platform scale & stopwatch.

Next the height of the condensate column from the condensate collector is to be recorded for a certain period. Then the temperature profile is to be drowning along the length of the HX.

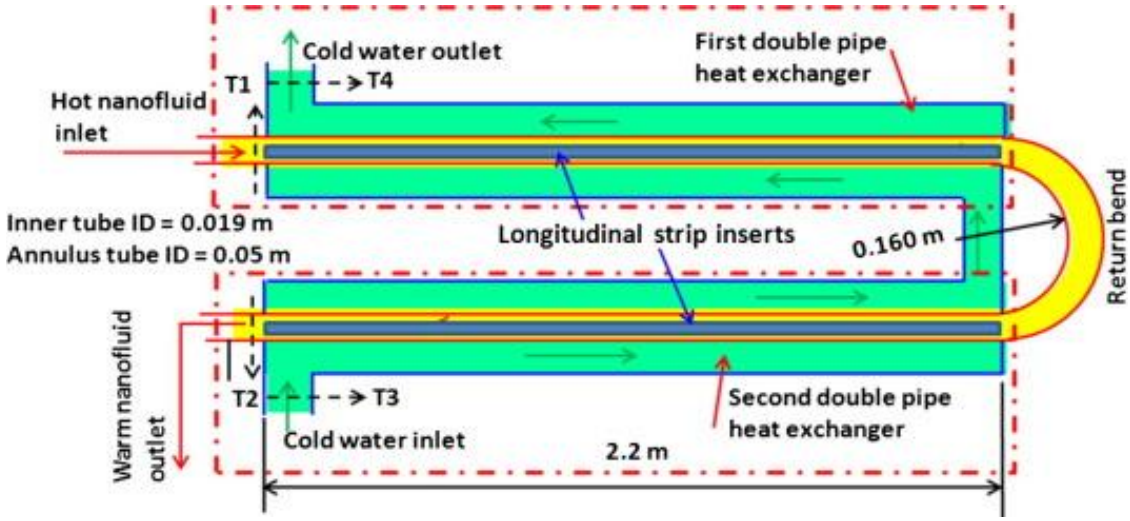

Figure-4.11: Heat transfer coefficient

Now LMTD, heat removed from steam, heat taken by water, overall heat transfer coefficient, heat loss from the HX are to be calculate by using the relevant equations.

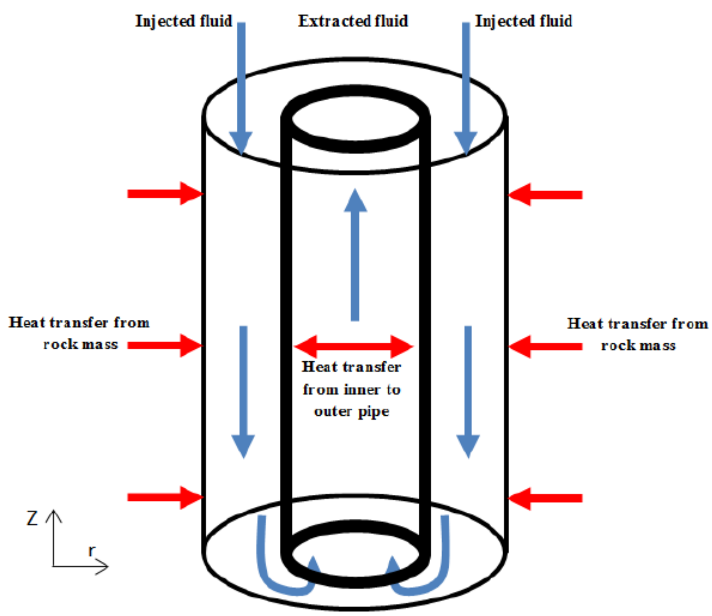

Figure-4.12: Heat Remove System

CHAPTER 5

MATHEMATICAL FORMULA AND RESULT

5.1 Experimental Data

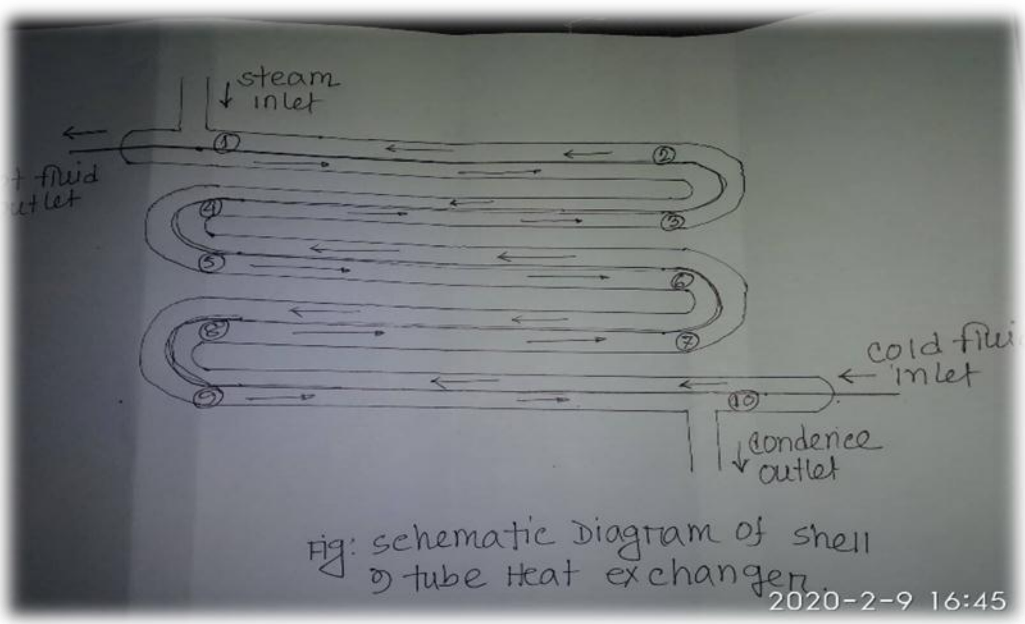

Figure-5.1: Schematic Diagram of Shell and tube Heat Exchanger

Distance(cm)	Thermocouple Reading		Remarks
	Water Temperature Tw °C	Steam Temperature Ts °C	
20	37.6	107	
40	35.8	96.7	
60	31.2	87	
80	28.7	75	
100	26.9	69.7	
120	25	65.7	

Table- 5.1: Experimental data

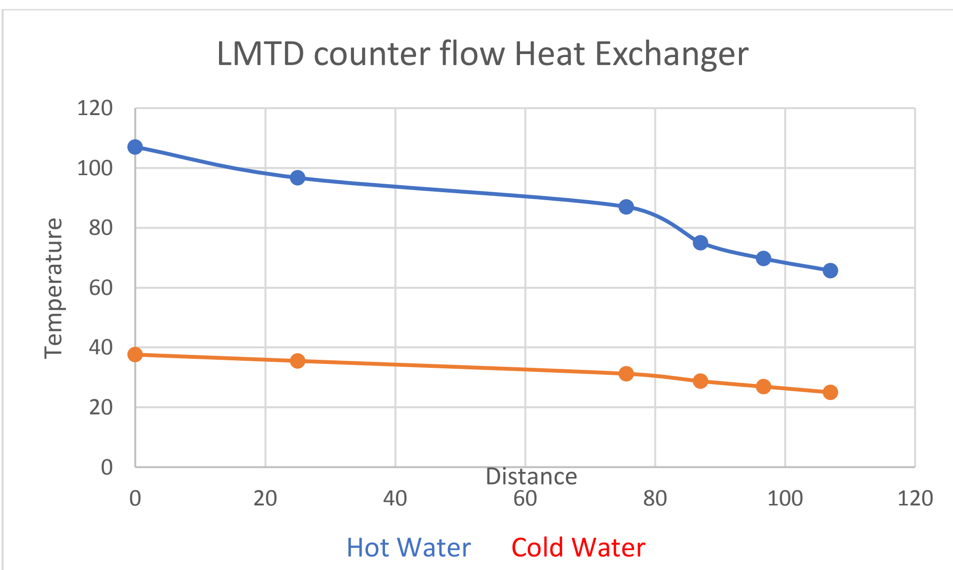

Figure- 5.2: Log Mean Temp Difference (LMTD) For Counter Flow Heat Exchanger

5.2 Mathematical Equation of Formula

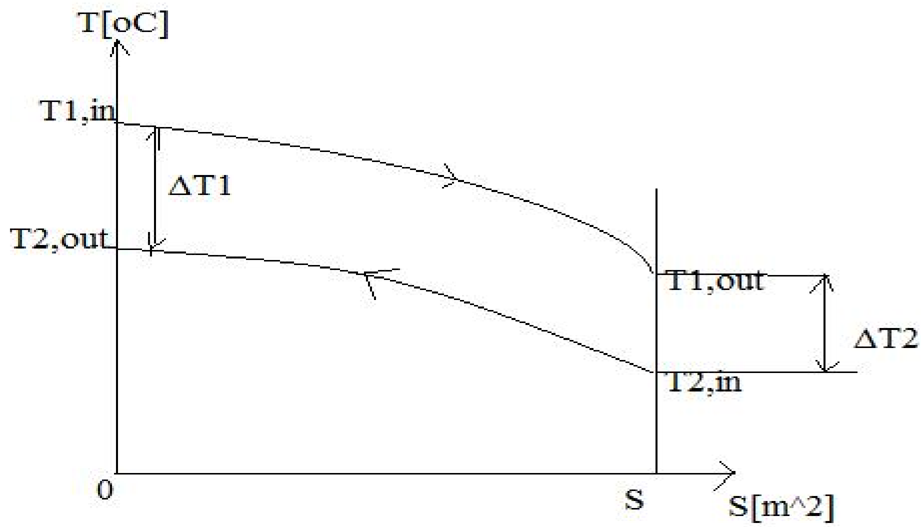

Figure 5.3: Counter Flow

$$\Delta T1 = Th1 - Tc2$$

$\Delta T2 = Th2 - Tc1$

Where,

ΔT1=Section 1, Temperature different

ΔT2= Section 2, Temperature different

Th1= Section 1, Hot fluid

Tc1= Section 1, cold fluid

Th2= Section 2, Hot fluid

Tc2= Section 2, cold fluid

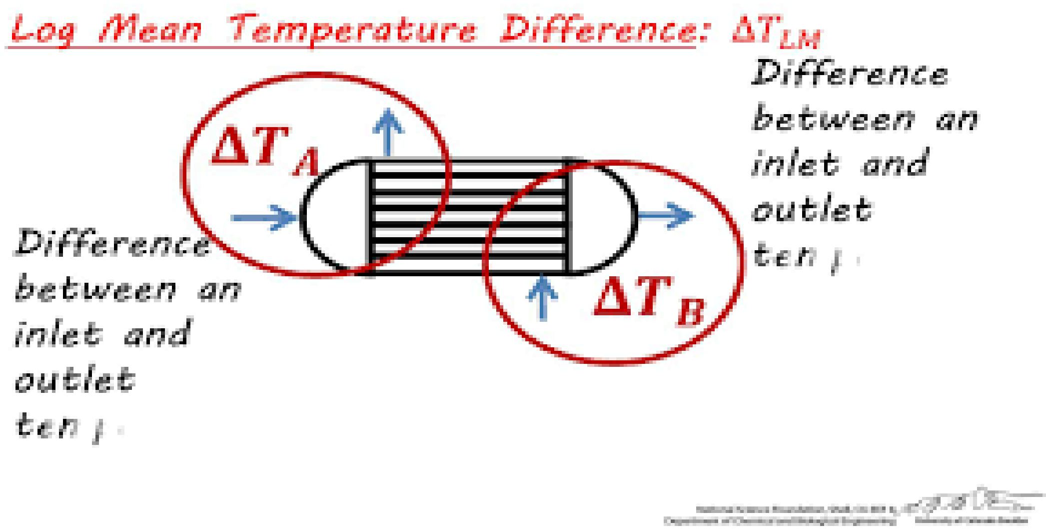

Figure 5.2: Log mean temp. difference of the two fluids

We Know that,

$$LMTD = (Th1 - Tc1) - (Th2 - Tc2)/\ln\{(Th1 - Tc1)/Th2 - Tc2)\}$$

$$or,\ LMTD = (\Delta T1) - (\Delta T2)/\ln\{(\Delta T1)/(\Delta T)\},$$

$$Or, LMTD, Tm = \Delta T1 - \frac{\Delta T2}{\ln\left(\frac{\Delta T1}{\Delta T2}\right)} \ldots\ldots\ldots\ldots 1$$

Where,

Tm = Log mean temp. difference of the two fluids, (˚c)

$Th1$ = temp. of hot fluid at section 1, (˚c)

$Th2$ = temp. of hot fluid at section 2, (˚c)

$Tc1 = \text{temp. of cold fluid at section } 1, (^{\circ}c)$

$Tc2 = \text{temp. of cold fluid at section } 2, (^{\circ}c)$

mass flow rate of water (cold fluid),

$$mw = \frac{m}{t}$$

Where,

$m = \text{mass flow rate (kg)}$

$t = \text{time(s)}$

mass flow rate of steam (hot fluid),

$$mw = \frac{v}{t}$$

Where,

$v = \text{volume (m3)}$

$t = \text{time(s)}$

Again We know,

Volume of the condensate collected (m3) is determined from,

$V = \pi h/4(d. -2t)2$ ……………………………...2

Where,

$\mathrm{h = height\ of\ condensate\ collected, (m)}$

d. =Outer diameter $\mathrm{of\ condensate\ collected, (m)}$

t=thickness $\mathrm{of\ condensate\ collected, (m)}$

Also, we know,

Heat removed from the hot fluid (steam) flowing express as;

$\mathrm{Qs = ms\ (h1 - h2)}$ …………………………….. 3

Where,

$\mathrm{ms = \ mass\ flow\ rate\ of\ steam, (kg/s)}$

$\mathrm{h1 \ = Enthalpy\ of\ steam\ at\ inlet, (kj/kg)}$

$\mathrm{h2 \ = Enthalpy\ of\ steam\ at\ outlet, (kj/kg)}$

Again, also we know,

Heat taken from the cold fluid (water) flowing express as;

$\mathrm{Qw = mwCp\,(Tw. - Tw1)\ \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 4}$

$\mathrm{Expression\ of\ heat\ transfer, Q(kw) for\ the\ counter\ flow\ HX\ can\ be\ obtain\ from,}$

$\mathrm{Q = UA.LMTD}$

Where,

A = total surface area of the HX, (m^2)

U = Over all heat transfer coefficient (kw/m2°C)

LMTD = Loag mean temperature defference, (°C)

For ideal case,

$Q = Qw = Qs$

Or, $U.A.LMTD = mwCp(Tw. - Twi)$

As a result heat loss can be obtain as,

$Qloss = Qs - Qw$

LMTD for counter flow heat exchanger

$$The\ total\ rate\ of\ heat\ transfer$$

$$Q = UA(Th - Tc)$$

$$The\ small\ amount\ of\ heat\ transfer$$

$$dQ = UdA\Delta T \ldots\ldots\ldots\ldots\ldots 1$$

$$Heat\ loss\ by\ hot\ fluid = Heat\ gained\ by\ cold\ Fluid$$

$$Q = mhcph(Thi - tho) = mccpc(Tco - Tci)$$

$$or, Q = ch((Thi - tho) = Cc(Tco - Tci)$$

$$Ch = Q/\,Thi - tho \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$\&\ Cc = Q/\,Tco - Tci \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

$$Now, For\ length\ "dx"\ the\ change\ of\ temperature$$

$$dT = dTh - dTc$$

$$or, dQ = Cc(-dTc)$$

$$or, dTc = -dQ/Cc$$

$$Another\ parts$$

$$dQ = -ChdTh$$

$$or, dTc = -dQ/Ch$$

$\therefore\ dT = -dQ/Ch - (-dQ/Cc)$

$\therefore\ dT = -dQ/Ch + dQ/Cc)$

$\therefore\ dT = -dQ(1/Ch - 1/Cc)$

$\therefore\ dT = -UdA\Delta T(1/Ch - 1/Cc)$

$$Separating\ the\ variavbles$$

$$dT/\Delta T = -UdA(1/Ch - 1/Cc)$$

$\therefore\ integrating\ both\ side$

$\therefore\ \int_{\Delta T1}^{\Delta T2} \frac{dT}{} \Delta T = -U \int dA \left(\frac{1}{Ch} - \frac{1}{Cc}\right)$

$\therefore\ ln[\Delta T2/\Delta T1] = -UA(1/Ch - 1/Cc)$

$\therefore\ ln[\Delta T2/\Delta T1] = -UA[(Thi - Tho/Q) - (Tco - Tci/Q)]$

$\therefore\ ln[\Delta T2/\Delta T1] = -UA/Q[(Thi - Tco) - (Tho - Tci)]$

$\therefore\ ln[\Delta T2/\Delta T1] = -UA/Q[(\Delta T1 - \Delta T2]$

$\therefore\ -ln[\Delta T2/\Delta T1] = -UA/Q[(\Delta T1 - \Delta T2]$

$\therefore\ \boldsymbol{Q = UA[(\Delta T1 - \Delta T2]/ ln[\Delta T2/\Delta T1]}$

$\therefore$ *This is the long mean temperature difference LMTD formula*

$\therefore$ *for a counter flow heat exchanger*.

Mathematical Calculation for LMTD Counter flow heat exchanger

Problem for counter flow heat exchanger

(All data put on previous calculation)

Q. $Cold\ Fluid\ (Water)\ mass\ mc\ = 62.04130 kg/s, Cp =$ $4.175 kj/kgk\ is\ heated\ from\ 25\ ℃\ to\ 43.7\ ℃\ by\ on\ Hot\ fluid\ mass\ mh =\ ,Thi =\ \ U =$ $3.21 kw/m2\ ℃\ , A = 16.13 m2$

$$Given\ data,$$

$$Cold\ Fluid\ (Water)$$

$$Mc\ = 62.04130 kg/s,$$

$$Cp = 4.175 kj/kgk$$

$$Tci = 25\ ℃$$

$$Tco = 43.7\ ℃$$

$$Hot\ fluid$$

$$Mh =\ 15 kg/s,$$

$$Thi =\ 107\ ℃$$

$$U = 3.21 kw/m2\ ℃\ ,$$

$$A = 16.13 m2$$

$$Solution, the\ total\ heat\ transfer\ is\ given\ by:\ -$$

$$Q = UA.LMTD \ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$Heat\ loss\ by\ hot\ fluid = Heat\ gained\ by\ cold\ Fluid$$

$$Heat\ removed\ from\ steam\ (hot\ fluid),$$

$$Qs = Ms(Thi - Tho)$$

$$= 15(107 - 65.7)$$

$$= 43.6kw$$

$$Heat\ taken\ by\ water\ (cold\ fluid),$$

$$Qw = mwCp(Tco - Tci)$$

$$= 17x4.21(43.7 - 25.0)$$

$$= 37.7kw$$

$$We\ know\ that,$$

$$Heat\ balance\ or\ heat\ loss\ Qloss = Qh - Qc$$

$$== 43.6 - 37.7$$

$$= 5.9kw$$

$$\boldsymbol{Loag\ mean\ temperature\ defference,}$$

$$LMTD = \frac{\Delta T1 - \Delta T2}{\ln\left(\frac{\Delta T1}{\Delta T2}\right)}$$

$$= (84.5 - \frac{9.1}{\ln\left(\frac{84.5}{9.5}\right)})$$

$$= 33.8268°C$$

5.3 Our Project Mathematical Calculation

Data given from our projects are bellows,

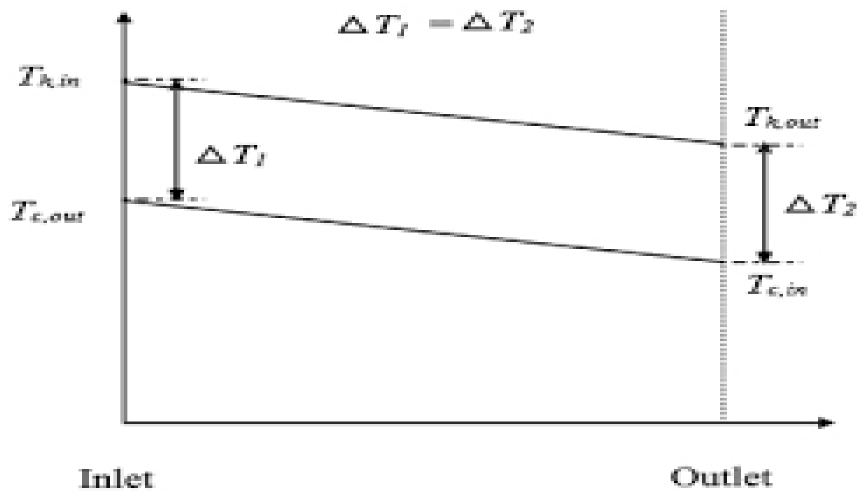

Figure 5.3 : Inlet Outlet pressur

$\text{Inlet temp. of steam, Tsi} = 107.6°\text{C}$

$\text{Outlet temp. of Condence, Tco} = 45.7°\text{C}$

$\text{Inlet Temp. of cold fluid, Tci} = 23.1°\text{C}$

$\text{Outlet temp. of hot fluid, Tho} = 37.6°\text{C}$

$\text{Mass of water collect, m} = 17\text{kg}$

$\text{time of water collection, t} = 75\text{s}$

$\text{Height of condensate collector, h} = 200\text{mm} = 0.2\text{m}$

$\text{Out side diameter of condensed collector, d.} = 200.7\text{mm} = 0.2007\text{m}$

$\text{Thickness of condensate collector} = 1.50\text{mm} = 0.0015\text{m}$

$\text{time of condensate collection, t} = 300\text{s}$

Density of condensate at condensate temperature of $45.7°\text{C}, \text{r} = 989.59\text{kg/m3}$

$Enthalpy\ of\ hot\ fluid\ (super\ heated\ steam)at\ inlet\ with\ temp\ of$

$T1 = 133.6^{o}C, \&\ h1 = 2734.29kj/kg$

$Enthalpy\ of\ hot\ fluid\ (saturated\ water)at\ outlet\ with\ temp\ of$

$T2 = 46.6^{o}C, h2 = 193.73kj/kg$

Specific heat of water at average temp of water inlet & outlet

$= 33.8268°\text{C}, Cp = \frac{4.175kj}{kgK}$

$Diameter\ of\ steam\ pipe = 25.4mm$

$Length\ of\ steam\ pipe, L = 4.5m$

We know that,

$\boldsymbol{temp\ defference\ of\ hot}\ \&\ cold\ fluid\ at\ section\ 1,$

$\Delta T1 = (Th1 - Tc2) = (107.6 - 23.1) = 84.5°\text{C}$

$\boldsymbol{temp\ defference\ of\ hot}\ \&\ cold\ fluid\ at\ section\ 2,$

$\Delta T2 = (Th2 - Tc1) = (45.7 - 36.6) = 9.1°\text{C}$

We know that,

$\boldsymbol{Loag\ mean\ temperature\ defference,}$

$$LMTD = \frac{\Delta T1 - \Delta T2}{\ln\left(\frac{\Delta T1}{\Delta T2}\right)}$$

$$= (84.5 - \frac{9.1}{\ln\left(\frac{84.5}{9.5}\right)})$$

$$= 33.8268℃$$

$\boldsymbol{mass\ flow\ rate\ of\ water(cold\ fluid),}$

$$mw = \frac{m}{t}$$

$$\frac{\left(\frac{17}{75}\right)kg}{s}$$

$$= 0.227kg/s$$

Volume of condensate collected,

$$V(m3) = \frac{\pi h}{4(d^\circ - 2t)2}$$

$$= \frac{\pi x 0.20}{4(0.2007 - 2x0.0015)2}$$

$$= 18.808m3$$

$mass\ flow\ rate\ of\ steam(hot\ fluid),$

$$mw = \frac{v}{t}$$

$$= \frac{\left(\frac{18.808x989.59}{300}\right)kg}{s}$$

$$= 62.041303kg/s$$

Heat removed from steam (hot fluid),

$$Qs = ms(h1 - h2)$$

$$= 62.041303(2734.29 - 193.73)kw$$

$$= 43.70kw$$

Heat taken by water (cold fluid),

$$Qs = mwCp(Two - Twi)$$

$$= 0.740x4.175(41.9 - 29.8)kw$$

$$= 37.38kw$$

Also, we know,

$Over\ all\ heat\ transfer\ coefficient,$

$$U = \frac{Qw}{A.LMTD}$$

$$= Qw/\ (\pi DLxLMTD)$$

$$= 37.38/(3.1416x.0172x9.27x31.45)kw/m2℃$$

$$= 3.21\ kw/m2℃$$

$\boldsymbol{We\ know},$

$\boldsymbol{heat\ loss}, Qloss = Qs - Qw$

$= (45.7 - 37.6)kw$

$= 5.32kw$

5.4 Result Calculation

Inlet temp. of steam, Tsi $= 107.6°C$

Outlet temp. of Condence, Tco $= 45.7°C$

Inlet Temp. of cold fluid, Tci $= 23.1°C$

Outlet temp. of hot fluid, Tho $= 37.6°C$

Mass of water collect, m $= 17kg$

time of water collection, t $= 75s$

Height of condensate collector, h $= 200mm = 0.2m$

Out side diameter of condensed collector, d. $= 200.7mm = 0.2007m$

Thickness of condensate collector $= 1.50mm = 0.0015m$

time of condensate collection, t $= 300s$

CHAPTER 6
DISCUSSION

The pressure drop relationship has been applied to develop a specific relationship for a shell-and-tube heat exchanger based on the effectiveness-NTU approach. The bell's Delaware design method is used for estimating various parameters. The actual heat transfer coefficient is estimated and pressure drops are checked according to the HEDH method.

The flow rates, temperatures, allowable pressure drops, and physical properties of streams are fixed. It is required to determine the optimum area and optimum cost of shell-and-tube heat exchanger.

6.1 Discussion

The first objective in conducting this experiment was to evaluate and study the performance of the shell and tube heat exchanger at various operating conditions. Heat exchanger made up of a few tubes in parallel through which one fluid travel enclosed in a shell through which the other fluid is conducted. The shell side is provided with of baffles to promote high velocities and largely more efficient cross flow on the outsides of the tubes. Baffles are usually installed to increase the coefficient of the shell-side fluid by inducing turbulence and cross flow velocity component. In addition, the baffles physically support the tubes, reducing flow-induced tube vibration. The versatility and widespread use of this equipment has given rise to the development of industry wide standards. Baffle pitch normally starts from 0.2 until 1.0 times the inside diameter of the shell. Both the heat transfer coefficient and the pressure drop depend on the baffle pitch, so that its selection is part of the optimization of the heat exchanger. In order to simplify external piping, exchangers mostly are built with even numbers of tube passes. Process fluid streams may contain suspended matters or dissolved solids. When such a fluid flows through a heat exchanger over a long period of time, deposition of the tube surfaces and shell surfaces occurs. The surfaces may also be corroded by fluid slowly and the resulting corrosion products also get deposited on the surface. Formation of the deposit on a heat transfer surface is called fouling and the heat transfer resistance offered by the deposit is called the fouling factor or dirt factor commonly denoted by Rd. the dirt factor cannot be estimated. It can only be determined from the experimental data on heat transfer coefficient of a fouled exchanger and a clean exchanger of similar design operated at identical conditions. From the equation to gain Dirt factor, Q is referred to Q_w or Qs. But if there any error happened; the average value of U was taken by calculating $Q = Q_w = Q_s$. Next, the second objective was to determine the heat load, log mean temperature difference (LMTD) and overall heat transfer coefficient. To design a shell and a tube heat exchanger, it is necessary to relate the total heat transfer rate to fluid temperature (inlet and outlet), overall heat transfer coefficient (U) and the total surface area for the heat transfer (A). The formula below has been used in calculating heat load

6.2 The Design process of shell-and-tube heat exchanger proceeds through the following steps

- Process conditions (stream compositions, flow rates, temperatures, and pressures) must be specified.
- Required physical properties over the temperature and pressure ranges of interest must be obtained.
- The type of heat exchanger to be employed is chosen.

- A preliminary estimate of the size of the exchanger is made, using heat transfer coefficient appropriate to the fluids, the process, and the equipment.
- A first design is chosen; complete in all details necessary to carry out the design calculations.
- The design is now evaluated or rated, as to its ability to meet the process specifications with respect to both heat duty and pressure drop. To do this, heat transfer rate in shell-and-tube heat exchanger is calculated using equation.
- Temperature correction factor is determined using equations the calculated temperature correction factor should not be less than 0.75. the number shell passes and 1 and 2 Increases tube asses respectively. Effectiveness of shell-and-tube heat exchanger is obtained by using equation. Once effectiveness is available, overall number of transfer unit NTU is calculated from above equation. So, bisection method is used for the computation of NTU. The shell side friction factor, heat transfer j factor and baffle cut are set at standard initial value. The core velocity equation is used to find out the velocity on the shell side. This shell side velocity is then used to compute free flow area. Once free flow area is known, the shell diameter is known. The tube counts get fixed for determined shell diameter. The free flow is on tube side is also determined from core velocity equation. This can be obtained by tube count. These two free flow count areas are matched. Once this is achieved by the heat exchanger area. Heat transfer coefficient on tube and shell side is calculated. Once initial assumptions and details geometry coincide the design has been successfully accomplished.

- Based on this result a new configuration is chosen if necessary and the above step is repeated. If the first design was inadequate to meet the required heat load, it is usually necessary to increase the size of exchanger, while still remaining within specific pressure drop, tube length, shell diameter etc. This will sometimes mean going to multiple exchanger configurations. If the first design more than meets heat load requirements or does not use the entire allowable pressure drop a less expensive exchanger can usually be designed to fulfilled pressure requirement.

- The final design should meet process requirements (within the allowable error limits) at lowest cost. The lowest cost should include operation and maintenance costs and credit for ability to meet long term process changes as well as installed (capital) cost. Exchangers should not be selected entirely on a lowest first cost basis, which frequently result in future penalties.

CHAPTER 7
CONCLUSION

The study investigated the effect of change some parameters on heat transfer coefficient and pressure drop for shell and tube heat exchanger. The study concluded that as shell diameter increases the heat transfer coefficient and pressure drop increases. The pull-through head with triangular pitch can be the best choice to increase heat transfer coefficient. While, baffle spacing and cutting space reduced the heat transfer coefficient when increases. The fouling factor on shell side can affect the heat transfer heat more than that for tube side, therefore it is important to reduce fouling rate on shell side. The parameters selection has direct effect on both overall heat transfer coefficient and pressure drop.

- The methodology as presented in this work is based on Delaware method, which provides good predictions for shell side flow. It has been shown that how the basic algorithm can be applied using Delaware method.
- It must be emphasized heat exchanger had the potential danger of accepting a design that satisfies the dirt factor and pressure drop constraints without thoroughly investigating other option that may prove to be more promising. In Contrast, in this work a rapid algorithm is developed which takes care of all constraints.
- Targeting for area and cost is vital and well-established step in the design of heat exchanger networks by pinch technology. The targets proposed in this work allow the designer to determine the minimum area and cost (along with tube length shell diameter and baffle spacing etc.)

7.2 Future Scope of Work

With Shell-and-tube heat exchangers, the design and optimization methodology is restricted to applications involving single-phase turbulent flows with compressible fluids. This is because vaporization and condensation processes in this type of heat exchangers are often. However, the design method can also be used for two-phase heat transfer exchangers like compact heat exchangers with some little modifications in core velocity equation.

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