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Salahaddin University-Erbil
College of Engineering
Chemical-Petrochemical Engineering Department

CFD Simulation of Shell and Tube Heat Exchanger

A Project Submitted to the Chemical-Petrochemical Engineering Department
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in the Partial Fulfillment of the Requirement for the Degree of Bachelor of Science
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Abstract

Heat exchangers are very important equipment in several industries, making it crucial to analyze the internal flow inside them. The research primarily focuses on the widespread usage of shell and tube heat exchangers in oil refineries. In this study, the practical system on the Bazian Oil Refinery Plant has been selected and investigated through the Aspen (EDR) simulation tool.

Six crucial parameters have been selected and investigated. Firstly, Effects of inlet hot fluid temperature on outlet of a cold temperature, the results show that increasing inlet temperature of the hot fluid leads to increase the value of the cold fluid temperature at outlet of the system.

Secondly, Effects of inlet cold fluid temperature on the outlet of hot fluid has studied, as a result, the hot fluid outlet temperature reaches maximum when the inlet temperature of the cold fluid is maximum.

Next, variation of hot fluid flow rate on the heat transfer rate between fluids has been investigated, the maximum transfer rate from hot fluid to cold fluid is achieved incase the flow rate is reached the highest value.

Another parameter that was investigated was the cold fluid flow rate variation influence on the heat transfer heat rate between fluids, results show that, increasing cold flowrate value leads to reduce transfer rate between both fluids.

Finally, Effects of baffle cut on the fluid velocity and pressure drop inside the shell has studied, the results illustrate that, increasing baffle cut will reduce the pressure drop and velocity together.

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Finally, I'd want to thank everyone who assisted and led me through this great research.

Supervisor’s Certificate

I certify that the engineering project titled **"CFD simulation of Shell and tube Heat Exchanger”** was done under my supervision at the Chemical-Petrochemical Engineering Department, College of Engineering - Salahaddin University–Erbil. In the partial fulfillment of the requirement for the degree of Bachelor of Science in Chemical-Petrochemical Engineering

Supervisor

Signature:

Name: Dr. Hardi Siwaily

Date: / /

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Nomenclature

EDR	(Exchanger, Design and rating)
CFD	(Computational fluid dynamics)
HVAC	(Heating, ventilation, and air conditioning)
U	(Overall Heat Transfer Coefficient)
LMTD	(Log Mean Temperature Difference)
EE	(energy equations)
ME	(Mass equations)
EmoC	(Equation of Mass Conservation)
EenT	(Equation of Energy Transport)
ERANS	(Equations of Reynolds Averaged Navier Stokes)
EcoT	(equation of continuity transport)
TEME	(Tubular Exchanger)
ASTM	(American Society for Testing and Materials)
Apl	(American petroleum institute)
∂	(partial derivative)
P	(density)
T	(time)

CHAPTER ONE: INTRODUCTION

1.1. Introduction

A shell and tube heat exchanger are a fundamental component in various industrial processes, utilized for efficient heat transfer between two fluid streams. Its design consists of a bundle of tubes enclosed within a cylindrical shell. One fluid flow through the tubes, while the other flows around them in the shell. This arrangement allows for the exchange of heat between the fluids without them coming into direct contact, making it suitable for applications where contamination or mixing must be avoided(Afrianto et al., 2014).

The basic principle behind a shell and tube heat exchanger involves maximizing the surface area for heat transfer while ensuring efficient flow patterns to promote thermal exchange. Typically, one fluid (often referred to as the process fluid) enters the tubes, where it either gains or loses heat depending on the specific application. Meanwhile, the other fluid (commonly known as the service fluid) flows around the outside of the tubes, facilitating the transfer of heat with the process fluid.

Shell and tube heat exchangers are versatile and find applications across numerous industries, including chemical processing, oil and gas refining, power generation, HVAC systems, and food processing. They offer several advantages such as high heat transfer rates, scalability, ease of maintenance, and compatibility with a wide range of fluids and operating conditions(Afrianto et al., 2014).

The design of shell and tube heat exchangers can vary based on factors such as the required heat transfer rate, pressure and temperature constraints, fluid properties, space limitations, and maintenance considerations. Engineers can customize these heat exchangers with different tube arrangements, materials of construction, and additional features like baffles and fins to optimize performance for specific applications(Afrianto et al., 2014).

Overall, shell and tube heat exchangers play a crucial role in thermal management processes, facilitating efficient energy utilization, temperature control, and productivity across various industrial sectors.

1.2. Theory

The theory behind shell and tube heat exchangers involves principles of heat transfer, fluid mechanics, and thermodynamics. Here's a concise overview:

1. Heat Transfer:

The primary function of a shell and tube heat exchanger is to transfer heat from one fluid stream to another. Heat transfer occurs through the walls of the tubes, which separate the two fluid streams. The rate of heat transfer is governed by principles of conduction through the tube walls and convection between the fluids and the tube walls(Aitani, 1996).

2. Fluid Mechanics:

The flow of fluids through the heat exchanger affects its performance. Both the shell side and tube side fluid flow patterns are important considerations. Proper design ensures adequate turbulence and mixing to maximize heat transfer while minimizing pressure drop. Baffles, dividers, and tube arrangements are often used to promote turbulent flow and enhance heat transfer efficiency(Aitani, 1996).

3. Thermodynamics:

The temperature difference between the two fluid streams, known as the temperature driving force, drives heat transfer in the heat exchanger. The effectiveness of heat transfer is influenced by factors such as the specific heat capacities of the fluids, flow rates, and overall heat transfer coefficients. Thermodynamic principles dictate the direction and magnitude of heat transfer between the fluids(Aitani, 1996).

4. Overall Heat Transfer Coefficient (U):

The overall heat transfer coefficient represents the combined resistance to heat transfer across the tube walls, fluid films, and any fouling or deposits. It is a critical parameter in heat exchanger design and is influenced by factors such as fluid properties, flow velocities, surface roughness, and fouling factors.

5. Log Mean Temperature Difference (LMTD):

The LMTD is a key concept used to calculate the effectiveness of a heat exchanger. It accounts for the temperature difference between the hot and cold fluids at different points along the length of the exchanger. The LMTD is used in conjunction with the heat exchanger's surface area and overall heat transfer coefficient to determine the rate of heat transfer(Aitani, 1996).

6. Fouling and Maintenance:

Fouling, the accumulation of deposits on the heat exchanger surfaces, can significantly degrade heat transfer efficiency over time. Proper maintenance and periodic cleaning are essential to mitigate fouling effects and maintain optimal heat exchanger performance(Aitani, 1996).

Understanding these principles allows engineers to design and optimize shell and tube heat exchangers for specific applications, ensuring efficient heat transfer, minimal pressure drop, and reliable operation over the exchanger's lifespan.

1.3. Types of shell and tube heat exchanger

Shell and tube heat exchangers come in various types, each designed to meet specific requirements and operating conditions. Here are some common types:

1. U-Tube Heat Exchangers:

In U-tube heat exchangers, the tubes are bent into a U-shape within the shell. One end of the U-tube bundle is fixed to a tube sheet, while the other end is free to expand and contract due to thermal expansion. This design allows for thermal expansion without the need for expansion joints(Arani and Moradi, 2019).

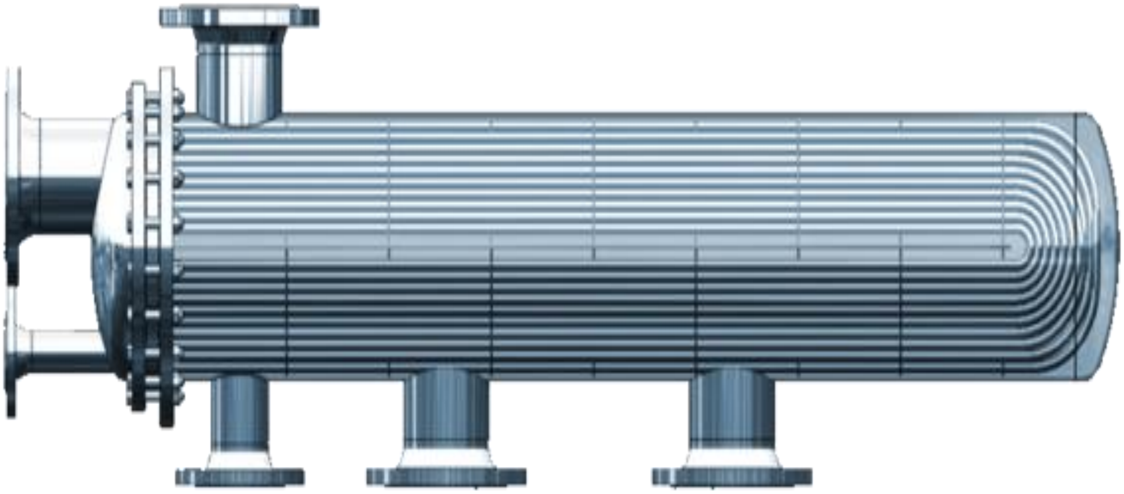


Fig. 1.1. U-tube shell and tube heat exchanger(Arani and Moradi, 2019).

2. Fixed Tube Sheet Heat Exchangers:

In this type, the tube bundle is firmly fixed at both ends to tube sheets within the shell. The tube sheets prevent the tubes from moving or vibrating, ensuring structural integrity. Fixed tube sheet heat exchangers are commonly used in applications where thermal expansion is minimal(Arani and Moradi, 2019).

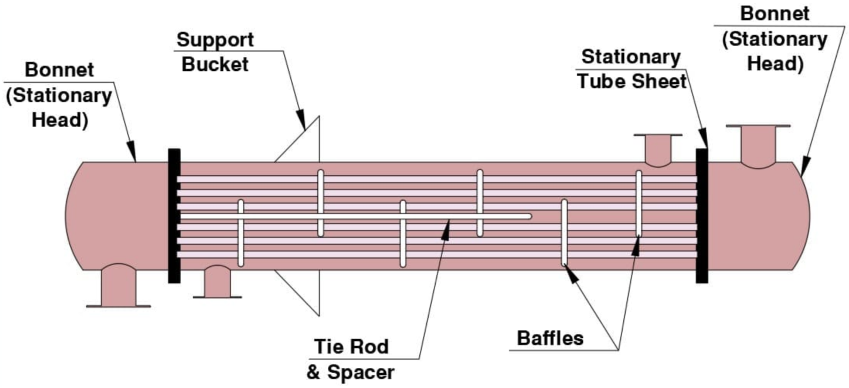


Fig. 1.2. Fixed-tube shell and tube heat exchanger(Arani and Moradi, 2019).

3. Floating Head Heat Exchangers:

In floating head heat exchangers, one tube sheet is fixed, while the other is allowed to move freely. This allows for differential thermal expansion between the shell and the tube bundle, reducing stress on the tubes. Floating head heat exchangers are often used in applications with high temperature differentials or thermal cycling.

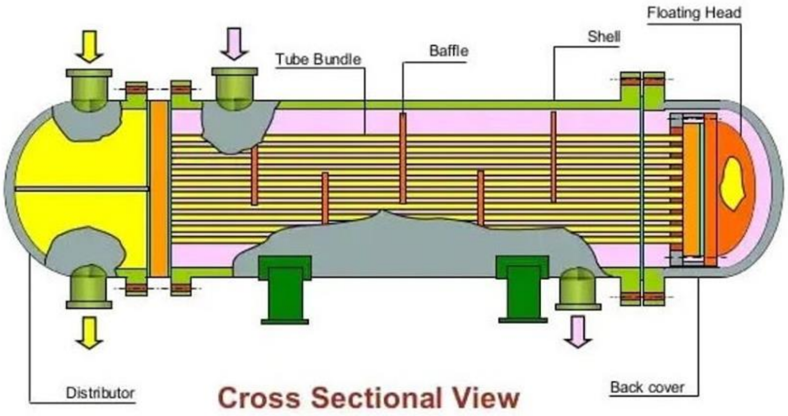


Fig. 1.3. Floating Head shell and tube heat exchanger(Arani and Moradi, 2019).

4. Kettle Reboilers:

Kettle reboilers are a specialized type of shell and tube heat exchanger used in distillation processes. They consist of a shell side vapor zone and a tube side liquid zone. The liquid to be vaporized flows through the tubes, while the vapor rises through the shell, providing heat for the distillation process(Arani and Moradi, 2019).

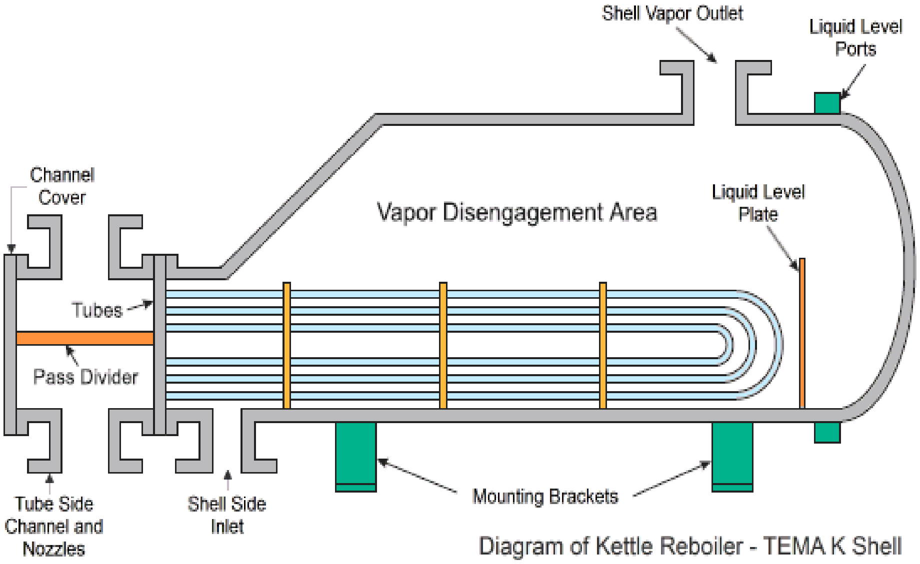


Fig. 1.4. Floating Head shell and tube heat exchanger(Arani and Moradi, 2019).

5. Double Pipe Heat Exchangers:

Although not strictly shell and tube, double pipe heat exchangers are a simple and compact variation. They consist of concentric tubes where one fluid flows through the inner tube, and the other flows through the annular space between the inner and outer tubes. Double pipe heat exchangers are often used in applications where space is limited or for low flow rate processes(Arani and Moradi, 2019).

Fig. 1.5. Double Pipe shell and tube heat exchanger(Arani and Moradi, 2019).

6. Multi-Pass Shell and Tube Heat Exchangers:

In multi-pass heat exchangers, the fluid is directed through the shell side and passes over the tube bundle multiple times before exiting. This design increases the heat transfer area and enhances efficiency, particularly in applications with limited space or where high heat transfer rates are required(Arani and Moradi, 2019).

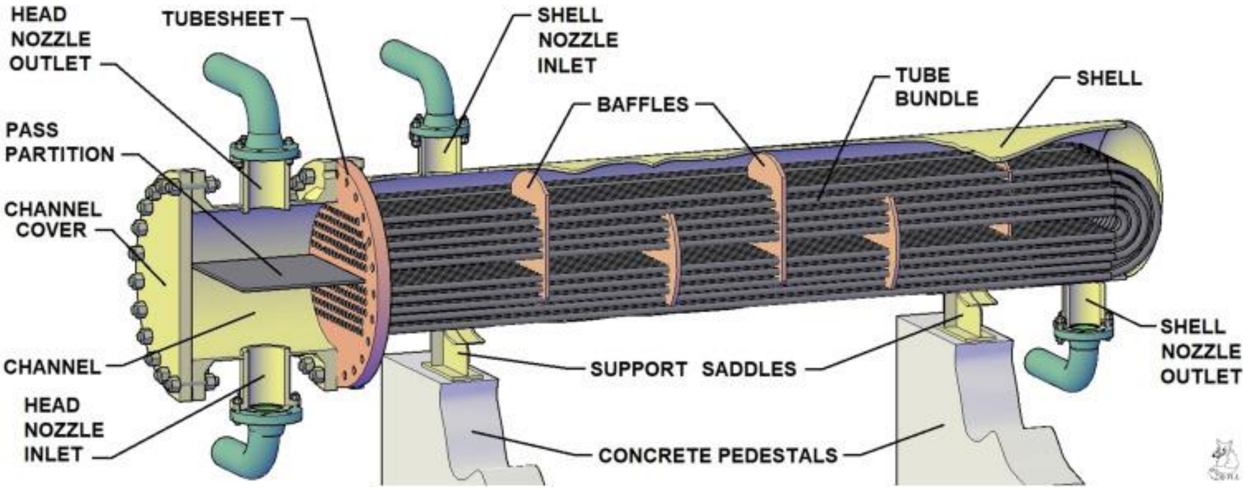


Fig. 1.6. Multi-Pass shell and tube heat exchanger(Arani and Moradi, 2019).

1.3.2 Applications of shell and tube heat exchangers.

Shell and tube heat exchangers are widely used across various industries due to their versatility, efficiency, and reliability. Some common applications include:

1. Chemical Processing:

Shell and tube heat exchangers play a crucial role in chemical processing industries for tasks such as heating or cooling process fluids, condensing vapors, or recovering waste heat. They are used in processes such as distillation, evaporation, chemical reaction cooling, and solvent recovery(Bachmann et al., 2014).

2. Oil and Gas Refining:

In oil refineries and petrochemical plants, shell and tube heat exchangers are utilized for tasks like heating crude oil, cooling refined products, condensing hydrocarbon vapors, and preheating feed streams to distillation columns. They are also employed in gas processing plants for natural gas cooling and liquefaction(Bachmann et al., 2014).

3. Power Generation:

Shell and tube heat exchangers are integral components of power generation systems, where they are used for steam condensation, turbine cooling, and heat recovery from exhaust gases. They play a critical role in thermal power plants, nuclear power plants, and combined-cycle power plants(Bachmann et al., 2014).

4. HVAC Systems:

Heating, ventilation, and air conditioning (HVAC) systems often incorporate shell and tube heat exchangers for tasks such as heating or cooling water, exchanging heat between air streams, and recovering energy from exhaust air. They are commonly found in chillers, boilers, heat pumps, and air handling units(Bachmann et al., 2014).

5. Food and Beverage Processing:

In food processing facilities, shell and tube heat exchangers are employed for tasks such as pasteurization, sterilization, and product cooling. They help maintain precise temperature control during various stages of food and beverage production, ensuring product quality and safety(Bachmann et al., 2014).

6. Marine and Aerospace Applications:

Shell and tube heat exchangers are used in marine propulsion systems, such as shipboard steam propulsion plants and marine diesel engines, for seawater cooling and steam condensation. They are also utilized in aircraft systems for engine cooling and environmental control(Bachmann et al., 2014).

7. Chemical Reactor Cooling:

Shell and tube heat exchangers are often employed to maintain optimal operating temperatures in chemical reactors by removing heat generated during exothermic reactions. They help control reaction rates, improve product quality, and ensure the safety of the process(Bachmann et al., 2014).

8. Waste Heat Recovery:

Shell and tube heat exchangers are utilized in waste heat recovery systems to capture and reuse thermal energy that would otherwise be lost to the environment. They can recover heat from exhaust gases, industrial processes, and other sources, thereby improving energy efficiency and reducing operating costs(Bachmann et al., 2014).

1.4. CFD Simulation of Shell and Tube heat exchangers.

Computational Fluid Dynamics (CFD) is a powerful tool used to analyze and optimize the performance of shell and tube heat exchangers. Here's how CFD can be applied to simulate and improve the efficiency of these heat exchangers:

1. Geometry Modeling:

The first step in CFD analysis involves creating a digital model of the shell and tube heat exchanger geometry. This includes accurately representing the shell, tubes, baffles, tube sheets, inlet/outlet ports, and any other internal components. Advanced CAD software is typically used for geometry modeling(Brief and Oiestad, 1964).

2. Mesh Generation:

Once the geometry is created, it needs to be discretized into a mesh of small computational cells. The mesh should be refined near the surfaces of the tubes and other areas where fluid flow is complex to capture detailed flow behavior accurately. Meshing software is employed to generate a high-quality mesh suitable for CFD simulation(Ansys, 2018).

3. Boundary Conditions:

Boundary conditions define the fluid flow and thermal conditions at the inlet and outlet ports of the heat exchanger. This includes specifying the inlet velocities, temperatures, pressures, and fluid properties for both the shell side and tube side fluids. Additionally, thermal boundary conditions such as heat flux or temperature can be applied to the tube walls to simulate heat transfer.

4. Solver Setup:

The CFD solver solves the governing equations of fluid flow and heat transfer within the heat exchanger domain. These equations include the Navier-Stokes equations for fluid flow, the energy equation for heat transfer, and any additional models for turbulence, buoyancy, and species transport if needed. Proper selection of solver settings and solution algorithms is critical for accurate and efficient simulation(Ansys, 2018).

5. Simulation:

With the boundary conditions and solver settings defined, the CFD simulation is run to solve the flow and heat transfer equations numerically. The solver calculates the velocity, pressure, temperature, and other flow properties throughout the heat exchanger domain over time steps. The simulation may require multiple iterations to converge to a stable solution(Ansys, 2018).

6. Post-Processing:

Once the simulation is complete, post-processing tools are used to analyze and visualize the results. This includes generating contour plots, velocity vectors, temperature distributions, pressure profiles, and other relevant data to evaluate the performance of the heat exchanger. Post-processing also helps identify areas of flow stagnation, recirculation, turbulence, or heat transfer inefficiency(Ansys, 2018).

7. Analysis and Optimization:

Based on the simulation results, engineers can analyze the performance of the shell and tube heat exchanger and identify opportunities for optimization. This may involve adjusting geometric parameters, modifying flow distribution, optimizing baffle configurations, or selecting alternative materials to improve heat transfer efficiency, minimize pressure drop, or reduce fouling effects(Brief and Oiestad, 1964).

Overall, CFD enables engineers to gain deep insights into the fluid flow and heat transfer behavior within shell and tube heat exchangers, facilitating the design, analysis, and optimization of these critical components in various industrial applications.

1.5. Simulation of shell and tube heat exchanger by using ASPEN EDR

Aspen Exchanger Design & Rating (Aspen EDR) is a software tool developed by AspenTech for the design, simulation, and rating of shell and tube heat exchangers. It is widely used in the engineering and process industries for optimizing the performance and efficiency of heat exchanger systems. Here's an overview of Aspen EDR's key features and capabilities:

1. Design:

Aspen EDR allows engineers to design shell and tube heat exchangers with ease. Users can input design specifications such as fluid properties, operating conditions, tube geometry, and heat transfer requirements. The software provides tools for selecting appropriate tube layouts, specifying baffle configurations, and optimizing the overall heat exchanger geometry.

2. Simulation:

Aspen EDR includes robust simulation capabilities to predict the thermal and hydraulic performance of the designed heat exchanger. It employs advanced heat transfer and fluid flow models to simulate the behavior of the fluids within the exchanger, taking into account factors such as turbulence, pressure drop, fouling, and phase change.

3. Rating:

The software allows users to rate existing heat exchangers based on actual operating conditions. Aspen EDR calculates key performance parameters such as heat transfer coefficients, pressure drops, and overall effectiveness to assess the performance of the exchanger under specific operating conditions. This helps engineers identify potential bottlenecks, optimize performance, and troubleshoot issues.

4. Optimization:

Aspen EDR offers optimization capabilities to improve the design and performance of heat exchangers. Users can explore various design options, adjust parameters, and evaluate the impact on performance metrics such as heat transfer rate, pressure drop, and surface area. Optimization algorithms help identify the most efficient design configurations to meet process requirements.

5. Integration:

Aspen EDR seamlessly integrates with other AspenTech software products, such as Aspen HYSYS and Aspen Plus, for comprehensive process simulation and optimization. This integration enables users to perform rigorous process simulations, including heat exchanger modeling, within a unified environment, streamlining the design and analysis workflow.

6. User Interface:

Aspen EDR features an intuitive user interface with interactive tools, visualization capabilities, and customizable workflows. The software provides graphical representations of heat exchanger geometry, fluid flow patterns, and temperature distributions, making it easy for users to interpret results and make informed design decisions.

Overall, Aspen EDR is a comprehensive software solution for the design, simulation, and rating of shell and tube heat exchangers, offering engineers powerful tools to optimize performance, reduce costs, and enhance process efficiency in a wide range of industrial applications

CHAPTER TWO: METHODOLOGY AND REVIEW

2.1. Introduction

A literature review and methodology of shell and tube heat exchangers encompasses a broad range of topics, including design methodologies, performance enhancement techniques, fouling mitigation strategies, optimization approaches, and applications across different industries. Here's a general overview of the key themes and findings typically covered in such a review:

1. Fundamental Principles:

The literature provides a comprehensive overview of the fundamental principles underlying shell and tube heat exchangers, including heat transfer mechanisms, fluid flow behavior, thermal resistance analysis, and performance evaluation metrics.

2. Design Considerations:

Various design aspects of shell and tube heat exchangers are discussed, such as geometric configurations, tube arrangements, baffle designs, materials of construction, and manufacturing techniques. The literature explores the influence of these design parameters on heat transfer efficiency, pressure drop, fouling propensity, and overall performance.

3. Heat Transfer Enhancement:

Researchers have investigated numerous techniques to enhance heat transfer rates in shell and tube heat exchangers, including surface modifications (e.g., fins, turbulators), flow manipulation (e.g., swirl flow, jet impingement), and advanced heat transfer fluids (e.g., nanofluids, phase change materials). The literature reviews the effectiveness of these enhancement methods and their practical applicability in different operating conditions.

4. Fouling and Fouling Mitigation:

Fouling, the accumulation of deposits on heat exchanger surfaces, is a significant challenge in shell and tube heat exchangers. Literature reviews often discuss the mechanisms of fouling, factors influencing fouling rates, and strategies for fouling mitigation, such as surface coatings, periodic cleaning protocols, and operating condition optimization.

4. Numerical Simulation and Modeling:

Computational Fluid Dynamics (CFD) has emerged as a valuable tool for simulating and analyzing the performance of shell and tube heat exchangers. The literature reviews advancements in numerical modeling techniques, turbulence modeling approaches, mesh generation methods, and validation studies to improve the accuracy and reliability of CFD simulations.

5. Experimental Investigations:

Experimental studies play a crucial role in validating theoretical models, benchmarking numerical simulations, and investigating heat exchanger performance under real-world conditions. Literature reviews often summarize key findings from experimental research, highlighting trends, challenges, and opportunities for further investigation.

6. Optimization and Performance Evaluation:

Optimization techniques are employed to maximize heat exchanger performance while minimizing energy consumption, pressure drop, and fouling effects. Literature reviews discuss optimization methodologies, including mathematical modeling, genetic algorithms, and artificial intelligence techniques, and their application to shell and tube heat exchangers.

7. Applications and Case Studies:

The literature provides numerous examples of shell and tube heat exchanger applications across various industries, including chemical processing, oil and gas refining, power generation, HVAC systems, and food processing. Case studies illustrate the practical implementation of heat exchangers in specific processes, highlighting design challenges, performance improvements, and lessons learned.

By synthesizing and analyzing the findings from existing literature, researchers gain valuable insights into the current state-of-the-art, recent advancements, and future research directions in the field of shell and tube heat exchangers. This knowledge serves as a foundation for further investigation and innovation in heat transfer technology.

2.2. Review

The foundational text by (Taborek et al., 1983) covers the theory and practical aspects of heat exchangers, including shell and tube configurations, design principles, and performance evaluation.

(Kandlikar et al., 2005) provides insights into heat transfer and fluid flow phenomena relevant to microscale heat exchangers, offering perspectives on compact shell and tube designs.

(Mukherjee, 1998) outlines the fundamentals of shell and tube heat exchanger design, discussing geometric considerations, fluid flow patterns, and thermal performance analysis.

(Bott, 1995) examines fouling mechanisms, factors influencing fouling rates, and mitigation strategies in shell and tube heat exchangers, offering insights into fouling management.

(Rad et al., 2015) comprehensive review evaluates various heat transfer enhancement techniques in shell and tube heat exchangers, including surface modifications, flow manipulation, and advanced heat transfer fluids.

(Leoni et al., 2017) discussed the application of Computational Fluid Dynamics (CFD) in simulating shell and tube heat exchangers, highlighting numerical modeling techniques and validation studies.

(Rasheed et al., 2021) summarizes experimental and numerical studies on shell and tube heat exchangers, discussing key findings, challenges, and future research directions.

(Yang et al., 2014) explores optimization methodologies applied to shell and tube heat exchangers, including mathematical modeling, genetic algorithms, and artificial intelligence techniques.

(Silaipillayarputhur and Khurshid, 2019) highlights recent advancements in shell and tube heat exchanger technology, covering topics such as heat transfer enhancement, fouling mitigation, and optimization strategies.

(Master et al., 2006) discussed the applications of shell and tube heat exchangers in various process industries, offering insights into design considerations and performance requirements.

(Bachmann et al., 2014) studied recent advancements in heat transfer enhancement techniques, focusing on surface modifications, additives, and flow control strategies in shell and tube heat exchangers.

(Afrianto et al., 2014) conducted experimental study evaluates the effectiveness of heat transfer enhancement techniques, such as twisted tape inserts, wire coils, and surface roughness modifications, in shell and tube heat exchangers.

(Aitani, 1996) numerical study employs Computational Fluid Dynamics (CFD) to simulate fluid flow and heat transfer phenomena in shell and tube heat exchangers, investigating the influence of geometric parameters and operating conditions.

(Arani and Moradi, 2019) investigated optimization study applies genetic algorithms to optimize the design of shell and tube heat exchangers, considering multiple objectives such as heat transfer efficiency, pressure drop, and cost.

(Brief and Oiestad, 1964) explored the use of nanofluids to enhance heat transfer in shell and tube heat exchangers, summarizing recent research findings and potential applications.

(Costa and Queiroz, 2008) discussed the design and fabrication of compact shell and tube heat exchangers for aerospace applications, highlighting challenges and considerations specific to high-performance, lightweight designs.

(Crespo et al., 2015) investigates the transient behavior of shell and tube heat exchangers during startup and shutdown operations, analyzing temperature profiles, thermal stresses, and thermal efficiency under varying operating conditions.

(Freudenrich, 2001) studied the integration of shell and tube heat exchangers with plate heat exchanger technologies to create hybrid heat exchanger systems, offering advantages in terms of compactness, efficiency, and flexibility.

(Gangwar et al., 2019) conducted experimental study evaluates the performance of shell and tube heat exchangers under non-Newtonian fluid flow conditions, exploring the influence of fluid rheology on heat transfer characteristics.

CHAPTER THREE: MATHEMATICAL ANALYSIS

3.1 Fundamental of mathematical calculations

The calculation of energy, momentum, and continuity are the fundamental equations of CFD analysis. All fluid dynamics are based on the equations of these major physical rules. (Zhu et al., 2020):

1. Mass equations (ME)

2. The second law of Momentum Newton and

3. Energy equations (EE)

In this section, it's aimed to have a deep insight into these formulations of ME and EE to find the related proper dimensionless forms of them for modelling that are needed for the heat transfer process. Then, strategies based on the results, solutions, and modelling will be offered to set the correct CFD simulations.

When trying to analyze a kind of transport in a system, all mathematical relationships utilized to model any fluid flow largely contain the mass and momentum upkeep. Other equations, such as EE, are required to be solved to find a proper heat transfer mode (Wusiman, 2020).

3.1.1 Equation of Mass Conservation (EMaC)

The $EMaC$ is presented below (Wusiman, 2020):

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}\left(\rho_{u_i}\right) = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

3.1.2 Equation of Momentum Conservation ($EMoC$)

In the Navier–Stokes equation, $EMoC$ is labeled as below (Wusiman, 2020):

$$\frac{\partial}{\partial t}\left(\rho_{u_i}\right) + \frac{\partial}{\partial x_i}\left(\rho u_i u_i\right) = -\frac{\partial F}{\partial x_i} + \frac{\partial}{\partial x_i}\left(\mu \frac{\partial u_i}{\partial x_i}\right) + H_i \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

In the $EMoC$ presented in $Eq. 3-1$, ρ shows the symbol of density, u_i indicates the velocity of tensor notation, P is a symbol of medium pressure, μ shows the viscosity of dynamic state and H_i is a represent of the outside pressure (Wusiman, 2020).

3.1.2 Equation of Energy Transport (*EEnT*)

In Eq. 3-3, the statement shows the $EEnT$:

$$pc_p\left(\frac{\partial T}{\partial t}+u_i\frac{\partial T}{\partial x_i}\right)=\frac{\partial}{\partial x_i}\left(\tau\frac{\partial T}{\partial x_i}\right)+\emptyset \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

In this equation, T shows the energy under thermal circumstances, c_p is the symbol of $capacity$ $(specific\,heat)$, and τ is the conductivity under thermal circumstances, and $\emptyset$ is the viscous degeneracy or $\frac{internal\ heat\ generation}{unit\ volume\ rate}$.

On the other hand, modelling the combustion cases, we used the reduced transport equation for mixture division as below:

$$\frac{\partial}{\partial t}(pf)+\frac{\partial}{\partial x_i}(pu_i f)=\frac{\partial}{\partial x_i}\left(\frac{\mu}{\sigma}\frac{\partial f}{x_i}\right)+S_m+S_{user}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

where, m is viscosity and s is a constant(Wusiman, 2020).

3.2 Equations of Reynolds Averaged Navier Stokes (ERANS)

To originate ERANS forms of the fundamental mathematical equations, Reynolds decomposition is applied to mold the variables of flow into the time-averaged variables and shifting constituents. This results in the nonlinear statement $p\overline{u'_{\imath}u'_{J}}$ named as Reynolds stress. $p\overline{u'_{\imath}u'_{J}}$ Reynolds stress term is mostly answering the problems of turbulent quantity modelling and leads to two main models of turbulence equations, which are discussed below. of can be observed in Eq. 3-5(Reynolds, 1895):

$$\frac{\partial}{\partial t}(\rho u_i) + \frac{\partial}{\partial x_i}\left(\rho u_j u_i\right) + \frac{\partial}{\partial x_j}\left(\rho \overline{u'_\iota u'_J}\right) = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\tau_{ij} + F_i \ldots\ldots\ldots\ldots\ldots\ldots..3.5$$

In this equation, u and u_0 show the mean and the changeable variables of velocity, respectively. Stress tensor of Newtonian fluid τ_{ij} would be expressed as below:

$$\tau_{ij} = \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\frac{\partial u_k}{\partial x_k}\delta_{ij}\right) \ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots\ldots\ldots\ldots3.6$$

Then, Reynolds stress can be formulated as:

$$-p\overline{u'_\iota u'_J} = \mu_t\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}(pk + \mu_t\frac{\partial u_k}{\partial x_k})\delta_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots3.7$$

It can be stated that is the laminar viscosity and is the turbulent viscosity. The simplest form of whole-turbulence modelling is a kind of two-equation model. In this model, velocity and length of turbulent can be separately calculated based on two independent equations of $\kappa - \varepsilon$ model and $\kappa - \omega$ model (Deuflhard, 1974). The describe equations are shown below(Giacomelli et al., 2018):

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}\left(\rho k \mu_j\right) = \frac{\partial}{\partial x_j}\left[(\mu + \frac{\mu_t}{\sigma_k})\frac{\partial k}{\partial x_j}\right] + G_k - \rho\varepsilon - Y_M \ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.8$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_j}\left(\rho \varepsilon \mu_j\right) = \frac{\partial}{\partial x_j}\left[(\mu + \frac{\mu_t}{\sigma_\varepsilon})\frac{\partial \varepsilon}{\partial x_j}\right] + \rho C_1 S\varepsilon - \rho C_2 \frac{\varepsilon^2}{k+\sqrt{v\varepsilon}} \ \ldots\ldots\ldots\ldots.....3.9$$

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}\left(\rho k u_j\right) = \frac{\partial}{\partial x_j}\left[\Gamma_k \frac{\partial k}{\partial x_j}\right] + G_k - Y_k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots3.10$$

$$\frac{\partial}{\partial t}(\rho \omega) + \frac{\partial}{\partial x_j}\left(\rho \omega u_j\right) = \frac{\partial}{\partial x_j}\left[\Gamma_\omega \frac{\partial \omega}{\partial x_j}\right] + G_\omega - Y_\omega + D_\omega \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots3.11$$

If it's considered the conductivity of the thermal circumstances and the resulted heat of the chemical reaction as S_h, then the total form of $EEnT$ can be stated as below: (Ansys, 2018):

$$\frac{\partial}{\partial t}(\rho E)+\frac{\partial}{\partial x_i}(u_i(\rho E+\rho))=\frac{\partial}{\partial x_i}\left[k_{eff}\frac{\partial T}{\partial x_j}+u_i(\tau_{ij})_{eff}\right]+S_h \ldots\ldots\ldots\ldots\ldots 3.12$$

Eq. 3-13 shows the equation of continuity transport $(ECoT)$ or in the simple form, the equation of volume division, for the gas phase represented by(Giacomelli et al., 2018):

$$\frac{1}{p_g}\left[\frac{\partial}{\partial t}\left(\alpha_g\rho_g\right)+\frac{\partial}{\partial x_i}(\alpha_g\rho_g u_{ig})\right]=0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.13$$

In this equation in tensor notation,α_g considered as volume fraction,ρ_g as density and u_{ig} as gas phase velocity.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter presents the results of numerical recreations for the industrial applications displayed in Chapter 3, obtained from the analysis of using selected model base on the TEME standards. The results displayed in this chapter outline the precision and unwavering quality of the solutions from each solving method. This chapter also gives a detailed discourse on the examined topic.

4.2. Selection criteria according to TEMA standard.

Selecting a shell and tube heat exchanger based on the TEME (Tubular Exchanger Manufacturers Association) standard involves considering several factors to ensure optimal performance and reliability. Here's a step-by-step guide:

1. Determine Design Requirements:

- Define the process requirements, including fluid types, operating temperatures, pressures, flow rates, and heat transfer duties.

- Identify any special considerations, such as corrosive fluids, high fouling potential, temperature-sensitive materials, or space constraints.

2. Refer to TEME Standards:

- Consult the TEME standards, which provide guidelines and best practices for the design, construction, and testing of shell and tube heat exchangers.

- Review relevant sections of the standards, such as design criteria, materials of construction, fabrication tolerances, testing procedures, and performance verification.

3. Select Design Parameters:

- Determine the appropriate design parameters based on TEME recommendations, including tube diameter, tube length, tube layout (triangular or square pitch), shell diameter, baffle spacing, and tube bundle arrangement.
- Consider factors such as heat transfer coefficient, pressure drop, velocity limits, and fouling resistance when selecting design parameters.

4. Material Selection:

- Choose materials of construction for the shell, tubes, tube sheets, baffles, and other components based on TEME guidelines, considering factors such as fluid compatibility, corrosion resistance, thermal conductivity, and mechanical properties.
- Ensure compliance with relevant industry standards and codes, such as ASME, ASTM, or API, for material specifications and fabrication practices.

5. Performance Evaluation:

- Evaluate the performance of candidate heat exchanger designs using established methods and calculations recommended by TEME standards.
- Assess heat transfer efficiency, pressure drop, fouling propensity, thermal stresses, and other performance metrics to verify that design requirements are met.

6. Safety and Reliability:

- Consider safety and reliability aspects during the selection process, including pressure ratings, structural integrity, seismic design considerations, and compliance with applicable regulatory requirements (e.g., ASME Boiler and Pressure Vessel Code).
- Ensure that the selected heat exchanger design meets industry standards for safety, reliability, and environmental protection.

7. Cost Considerations:

- Evaluate the cost implications of different design options, including initial capital costs, operating expenses, maintenance requirements, and lifecycle costs.

- Optimize the design to achieve the best balance between performance, reliability, and cost-effectiveness while meeting project budget constraints.

8. Documentation and Compliance:

- Ensure that all design specifications, materials, fabrication procedures, and testing protocols comply with TEME standards and any other applicable regulations or contractual requirements.

- Maintain thorough documentation of the selection process, including design calculations, material certifications, inspection reports, and quality assurance records.

By following these steps and adhering to TEME standards, engineers can confidently select a shell and tube heat exchanger that meets the specific needs of their application while ensuring compliance with industry best practices and quality standards.

4.3.Simulation Details.

The Aspen Exchanger Design Rating (EDR) is a feature within the Aspen Plus and Aspen HYSYS software suites used in process engineering and simulation. It helps engineers design and analyze heat exchangers by providing ratings based on specified design conditions, such as flow rates, temperatures, pressures, and fluid properties. This feature assists in optimizing heat exchanger designs for efficiency and performance, also we use vertion 11 of aspen (EDR).

The following are the has used to conduct the simulation:

Operating System: Windows 11 Home 64-bit (10.0, Build 22631)

System Manufacturer: LENOVO

System Model: 82K6

BIOS: H1CN49WW

Processor: 11th Gen Intel(R) Core(TM) i7-11800H @ 2.30GHz (16 CPUs), ~2.3GHz

Memory: 32768MB RAM

Page file: 22928MB used, 14470MB available

Name: Intel(R) UHD Graphics

Chip Type: Intel(R) UHD Graphics Family

Device Type: Full Display Device

Approx. Total Memory: 16395 MB

Display Memory (VRAM): 128 MB

Shared Memory: 16267 MB

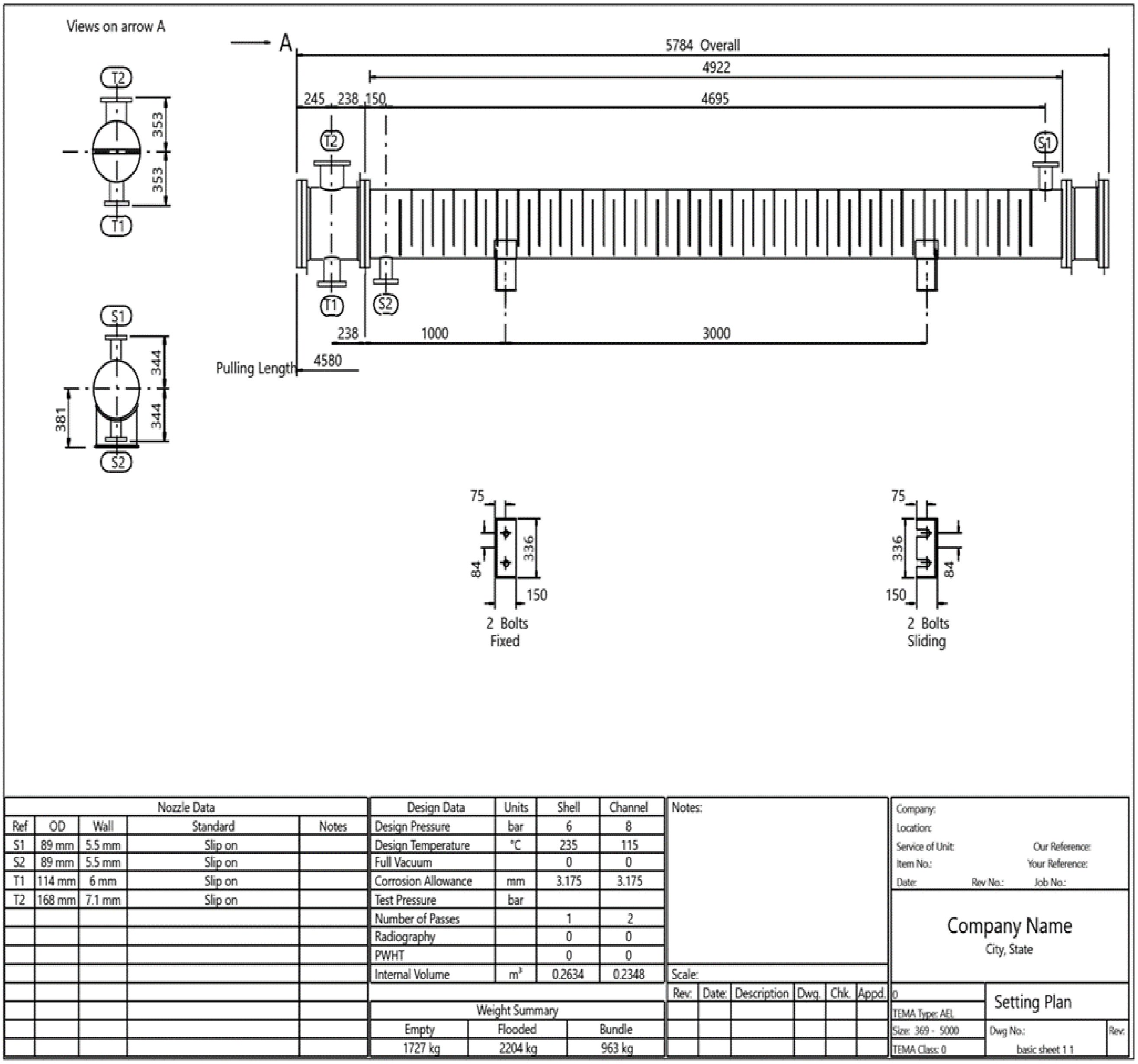
Table 4.1. CFD Simulation of a shell and tube heat exchanger

TEMA Sheet

Heat Exchanger Specification Sheet

1	Company:					
2	Location:					
3	Service of Unit: Our Reference:					
4	Item No.: Your Reference:					
5	Date: Rev No.: Job No.:					
6	Size: 369 - 5000 mm Type: AEL Horizontal Connected in: 1 parallel 1 series					
7	Surf/unit(eff.) 50.1 m² Shells/unit 1 Surf/shell(eff.) 50.1 m²					
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		Kerosene inlet->kerosene outlet		crude oil inlet->crude oil outlet	
11	Fluid quantity, Total	kg/h	20000		70000	
12	Vapor (In/Out)	kg/h	0	0	0	0
13	Liquid	kg/h	20000	20000	70000	70000
14	Noncondensable	kg/h	0	0	0	0
15						
16	Temperature (In/Out)	°C	200	93.81	40	76.93
17	Bubble / Dew point	°C	234.1 / 235.94	230.02 / 231.89	/	/
18	Density Vapor/Liquid	kg/m³	/ 613.85	/ 712.4	/ 803.45	/ 776.68
19	Viscosity	cp	/ 0.161	/ 0.3755	/ 1.9775	/ 1.0495
20	Molecular wt, Vap					
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	/ 2.765	/ 2.262	/ 1.983	/ 2.137
23	Thermal conductivity	W/(m-K)	/ 0.094	/ 0.1063	/ 0.1186	/ 0.1141
24	Latent heat	kJ/kg				
25	Pressure (abs)	kPa	500	464.462	650	622.689
26	Velocity (Mean/Max)	m/s	0.52 / 0.63		1.68 / 1.7	
27	Pressure drop, allow./calc.	kPa	80	35.538	80	27.311
28	Fouling resistance (min)	m²-K/W	0		0.00072 0.00092 Ao based	
29	Heat exchanged 1478.6 kW MTD (corrected) 76.17 °C					
30	Transfer rate, Service 387.6 Dirty 387.7 Clean 604.5 W/(m²-K)					
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**	
32			Shell Side	Tube Side		
33	Design/Vacuum/test pressure	kPa	600 / /	800 / /		
34	Design temperature / MDMT	°C	235 /	115 /		
35	Number passes per shell		1	2		
36	Corrosion allowance	mm	3.18	3.18		
37	Connections In	mm	1 76.2 / -	1 101.6 / -		
38	Size/Rating Out		1 76.2 / -	1 152.4 / -		
39	Nominal Intermediate		/ -	/ -		
40	Tube #: 170 OD: 19.05 Tks. Average 2.11 mm Length: 5000 mm Pitch: 23.81 mm Tube pattern:30					
41	Tube type: Plain Insert:None Fin#: #/m Material:Carbon Steel					
42	Shell Carbon Steel ID 14.53 OD 15.28 in				Shell cover -	
43	Channel or bonnet Carbon Steel				Channel cover Carbon Steel	
44	Tubesheet-stationary Carbon Steel -				Tubesheet-floating -	
45	Floating head cover -				Impingement protection None	
46	Baffle-cross Carbon Steel Type Single segmental Cut(%d) 17.33 Hori				Spacing: c/c 76 mm	
47	Baffle-long - Seal Type				Inlet 219.48 mm	
48	Supports-tube U-bend 0 Type					
49	Bypass seal Tube-tubesheet joint Expanded only (2 grooves)(App.A 'i')					
50	Expansion joint - Type None					
51	RhoV2-Inlet nozzle 2210 Bundle entrance 237 Bundle exit 204 kg/(m-s²)					
52	Gaskets - Shell side - Tube side Flat Metal Jacket Fibe					
53	Floating head -					
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service					
55	Weight/Shell 1727.1 Filled with water 2204 Bundle 962.6 kg					

The above table represents the real data from one of a Kurdistan regional refineries and which is used to verify the simulated cases using Aspen (EDR).



Nozzle Data				
Ref	OD	Wall	Standard	Notes
S1	89 mm	5.5 mm	Slip on	
S2	89 mm	5.5 mm	Slip on	
T1	114 mm	6 mm	Slip on	
T2	168 mm	7.1 mm	Slip on	

Design Data	Units	Shell	Channel
Design Pressure	bar	6	8
Design Temperature	°C	235	115
Full Vacuum		0	0
Corrosion Allowance	mm	3.175	3.175
Test Pressure	bar		
Number of Passes		1	2
Radiography		0	0
PWHT		0	0
Internal Volume	m^3	0.2634	0.2348

Weight Summary		
Empty	Flooded	Bundle
1727 kg	2204 kg	963 kg

Notes:

Scale:

Rev:	Date:	Description	Dwg.	Chk.	Appd.

Company:
Location:
Service of Unit: Our Reference:
Item No.: Your Reference:
Date: Rev No.: Job No.:

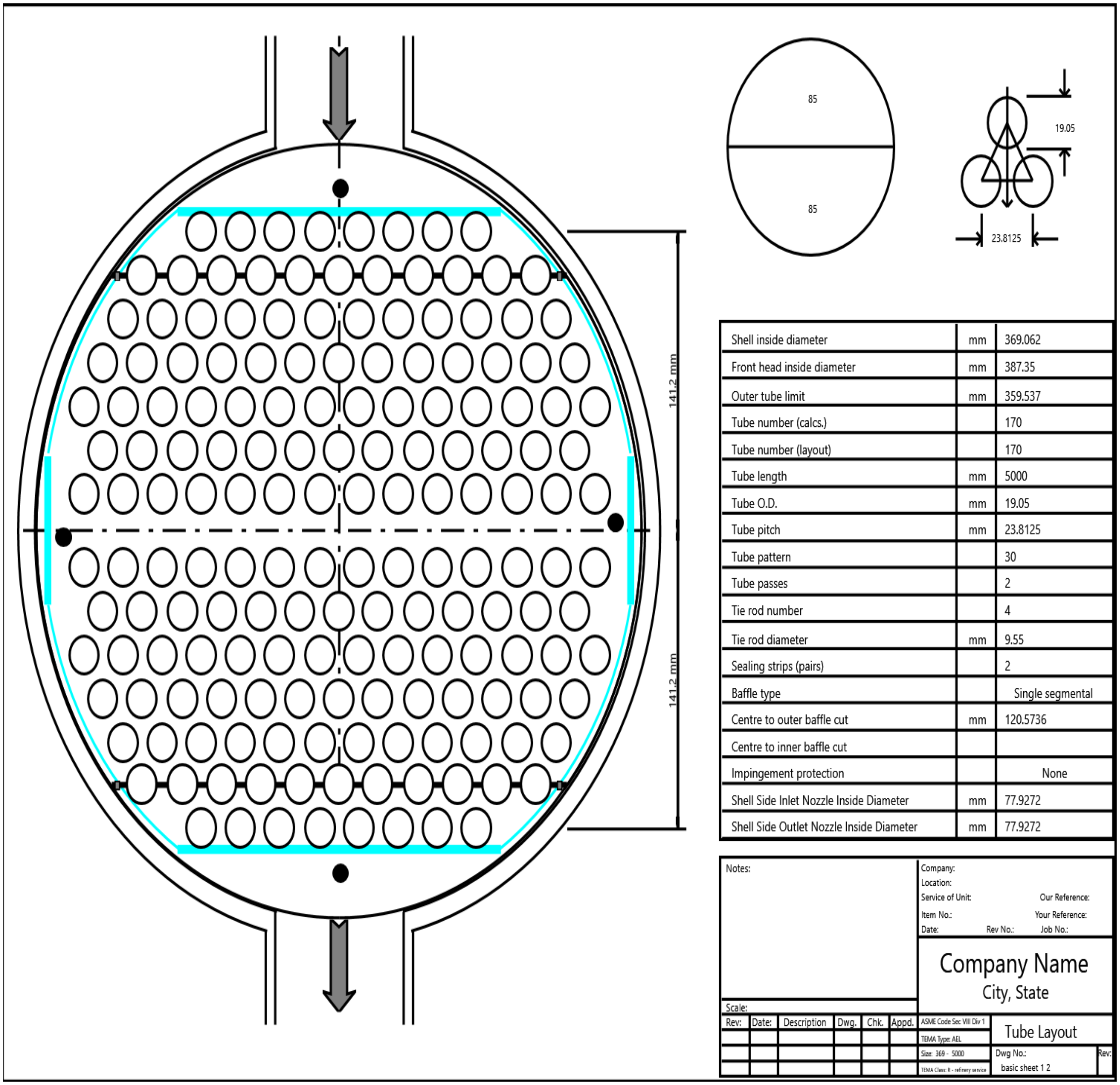
Company Name
City, State

0
TEMA Type: AEL
Size: 369 - 5000
TEMA Class: 0

Setting Plan
Dwg No.: basic sheet 1 1
Rev:

Fig. 4.1. The front view of the heat exchanger model characteristics.

This figure shows a specific aspect of our heat exchanger design based on the temperature, pressure, and flow rate data that we have collected. We are able to develop and rate our heat exchanger once we enter the data into used software. Consequently, the heat exchanger's layout, surface area, etc., will be displayed.



Shell inside diameter	mm	369.062
Front head inside diameter	mm	387.35
Outer tube limit	mm	359.537
Tube number (calcs.)		170
Tube number (layout)		170
Tube length	mm	5000
Tube O.D.	mm	19.05
Tube pitch	mm	23.8125
Tube pattern		30
Tube passes		2
Tie rod number		4
Tie rod diameter	mm	9.55
Sealing strips (pairs)		2
Baffle type		Single segmental
Centre to outer baffle cut	mm	120.5736
Centre to inner baffle cut		
Impingement protection		None
Shell Side Inlet Nozzle Inside Diameter	mm	77.9272
Shell Side Outlet Nozzle Inside Diameter	mm	77.9272

Notes:

Company:
Location:
Service of Unit: Our Reference:
Item No.: Your Reference:
Date: Rev No.: Job No.:

Company Name
City, State

Scale:

Rev:	Date:	Description	Dwg.	Chk.	Appd.

ASME Code Sec VIII Div 1
TEMA Type: AEL
Size: 369 - 5000
TEMA Class: R - refinery service

Tube Layout

Dwg No.: basic sheet 1 2
Rev:

Fig. 4.2 cross sectional view of the heat exchanger model characteristics.

The interior of the exchanger, which includes details about its length, internal diameter, and number of tubes, is depicted in the above figure.

4.4. Verification of details:

Verifying the designed model is a crucial step in performing simulation research. The data and dimensions for the practical example of the Bazian Oil Refinery Plant were derived from the aforementioned source.

The kerosene side stripper has a mass flow rate of 20,000 kg/hr and is at a temperature of 200 C. The goal is to cool it down to 90 C by exchanging heat with another stream of 70,000 kg/hr. The light crude oil, with an API gravity of 34, is transferred from storage at a temperature of 40 degrees Celsius. It enters the exchanger at a pressure of 5 bar, while the incoming crude oil enters at a slightly higher pressure of 6.5 bar.

Both streams can tolerate a pressure decrease of 0.8 bar. To account for fouling, it is necessary to incorporate a fouling factor of 0.0003 (W/m C). Considering the crude stream has a heat transfer coefficient of 0.0001 (W/m C) and the kerosene stream has a heat transfer coefficient of 0.0002 (W/m C), we need to design the heat exchanger with a maximum length of 5 m due to space limitations. Tubular Exchanger Manufacturing Associate (TEMA) Select one of the following options: A, E, L.

The viscosity of kerosene is 0.43 Nm/s m2, while the viscosity of crude oil is 3.2 Nm/s m2.

In order to validate the current findings, an operational instance was created and simulated using ASPEN (EDR) in this part. The results obtained from both the actual experiment and the simulation exhibit a high level of agreement, with a discrepancy of less than 1% between them.

4.5. Parametric Study

After verifying the methodology of the present study, which was recommended based on a literature review, various important parameters are explored and addressed as follows:

4.5.1 Effects of inlet hot fluid temperature on outlet of a cold temperature:

This section investigates the impact of increasing the temperature of the hot fluid, specifically kerosene, on the temperature of the cold fluid at the end of the heat exchanger.

The correlation between the temperature of the hot fluid in a heat exchanger and the temperature of the cold fluid is influenced by various factors, such as the heat exchanger's design, the flow rates of the fluids, and the thermal properties of both the fluids and the materials used in the exchanger.

as shown in figure 4.3, if the temperature on the hot side of the heat exchanger is increased, the temperature on the cold side will also increase, assuming all other variables remain unchanged. The reason for this phenomenon is that heat inherently moves from areas with higher temperatures to areas with lower temperatures, in accordance with the second rule of thermodynamics. After verifying the methodology of the current study, which was recommended based on a review of existing literature, we have investigated and discussed numerous important parameters as outlined below:

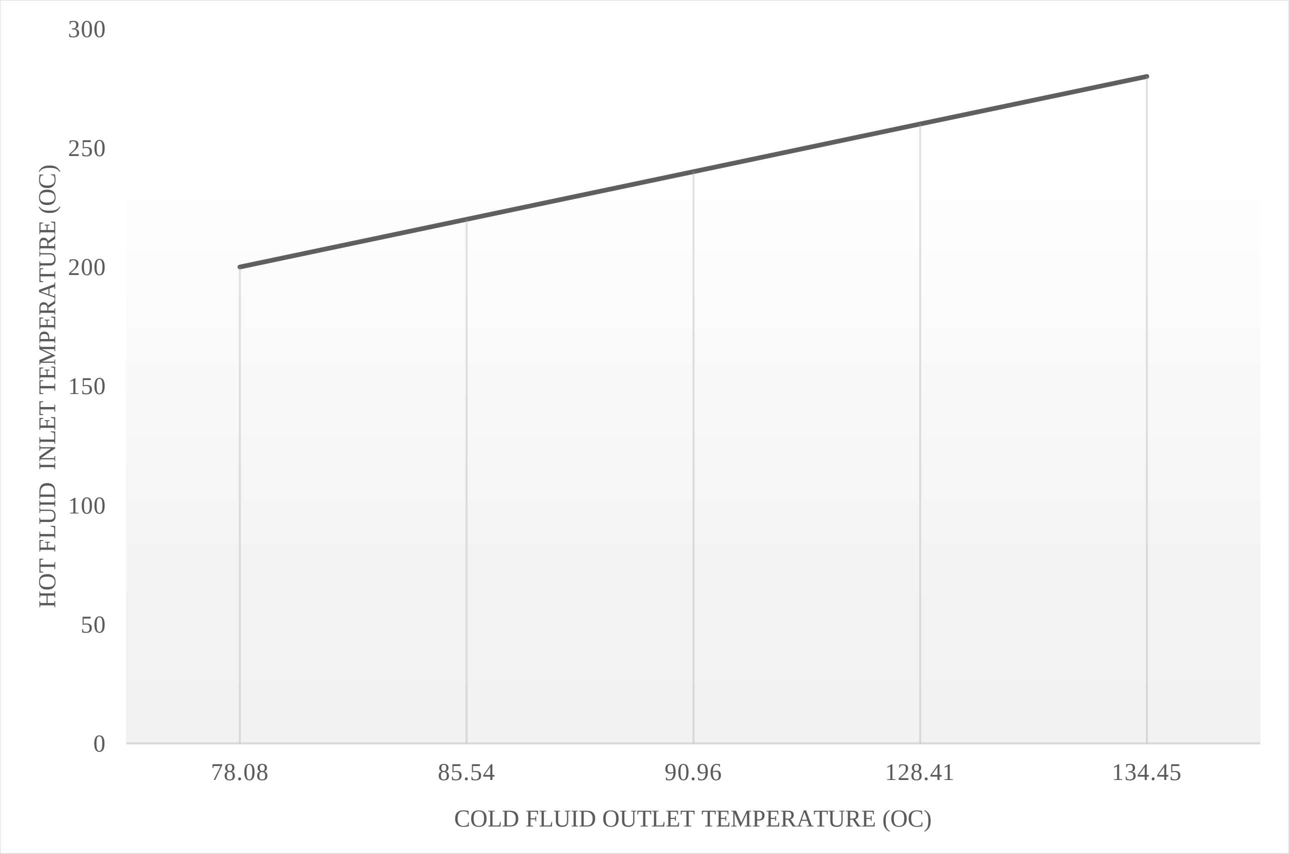


Fig. 4.3. Effects of inlet hot fluid temperature on outlet of a cold temperature.

4.5.2. Effects of inlet cold fluid temperature on the outlet of hot fluid:

The input temperature of the cold fluid plays a significant role in the functioning of a heat exchanger. In this section, the cold fluid's inlet temperature has been adjusted to demonstrate its impact on the output temperature of the hot fluid. Figure 4.4 demonstrates that a lower value of the heat exchanger input on the cold side will cause a drop in the temperature of the hot fluid, and vice versa. Reduced cold fluid temperatures at the lower entrance of a heat exchanger generally led to decreased hot fluid exit temperatures. This occurs because a lower temperature of the incoming fluid enables a higher rate of heat transfer from the hot fluid to the cold fluid.

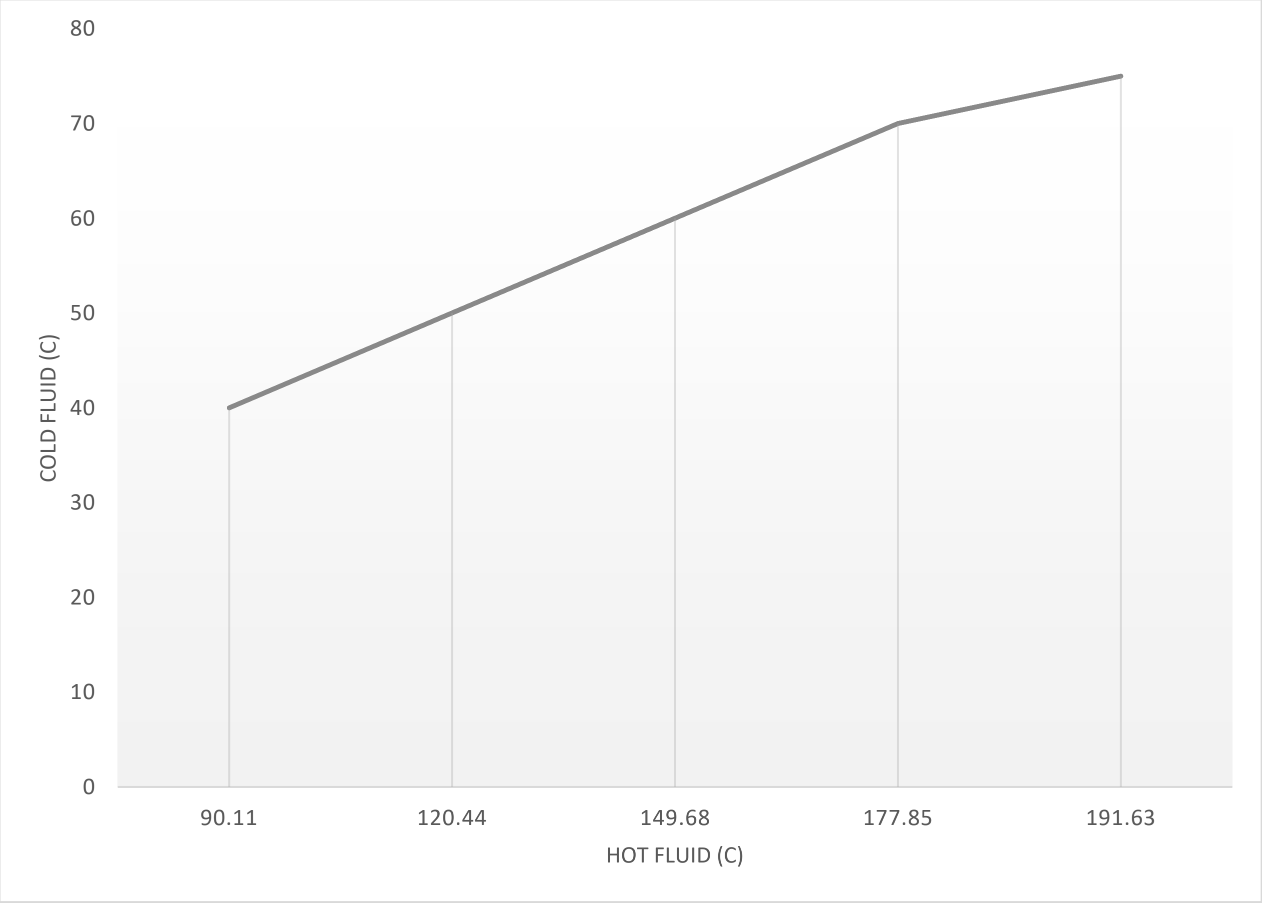


Fig. 4.4. Effects of inlet cold fluid temperature on the outlet of hot fluid.

As a result, there is a larger temperature difference, leading to a lower temperature of the outgoing hot fluid. On the other hand, if the entrance temperatures for cold fluids are increased, the output temperatures for hot fluids will also increase. Reduced temperatures of the incoming cold fluid generally led to decreased temperatures of the outgoing hot fluid in a heat exchanger. The reason for this is that when the incoming fluid is colder, it enables a higher rate of heat transfer from the hot fluid to the cold fluid. As a result, there is a larger temperature difference between the two fluids, leading to a lower temperature of the hot fluid at the output. On the other hand, if the entrance temperatures for cold fluids are increased, it will lead to greater output temperatures for hot fluids.

4.5.3. Effects of hot fluid flow rate on the heat transfer rate between fluids:

Another parameter that has been investigated is the impact of the flow rate of the heat exchanger on the effectiveness of the exchanger on the hot side. In this section, the flow rate of the hot fluid has been increased from 20000 kg/hr to 24000 kg/hr, with a steady increment of 1000 kg/hr.

The rate of heat transfer between fluids in a heat exchanger generally rises as the flow rate of the hot fluid increases. The reason for this is that a greater flow rate results in increased fluid contact with the heat exchange surface, hence enhancing heat transfer efficiency. Nevertheless, there is typically an ideal flow rate that, if exceeded, may not substantially improve heat transfer and could instead result in reduced benefits due to heightened pressure drop and turbulence.

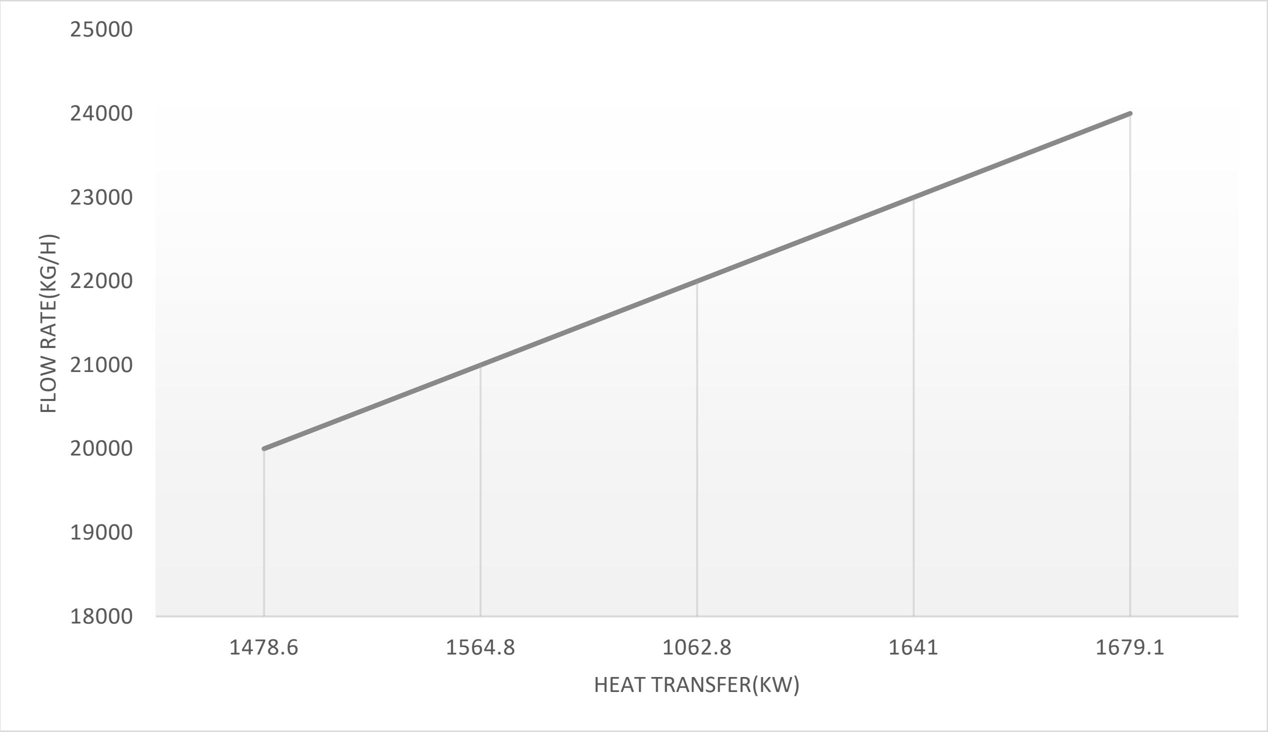


Fig. 4.5. Effects of hot fluid flow rate on the heat transfer rate between fluids.

4.5.4. Effects of cold fluid flow rate on the heat transfer heat rate between fluids:

Similar to previous section, the cold fluid flowrate also has a significant role on the system effectiveness, so, in current section the flow rate of the cold fluid has increased from 70000 kg/hr. to 74000 kg.hr with a constant rate of 1000 kg/hr.

As a result, which is illustrated in figure 4.6, increasing the cold fluid flow rate typically increases the heat transfer rate which led to increase system. This is because higher flow rates enhance the convective heat transfer coefficient, resulting in more efficient heat transfer between the fluids.

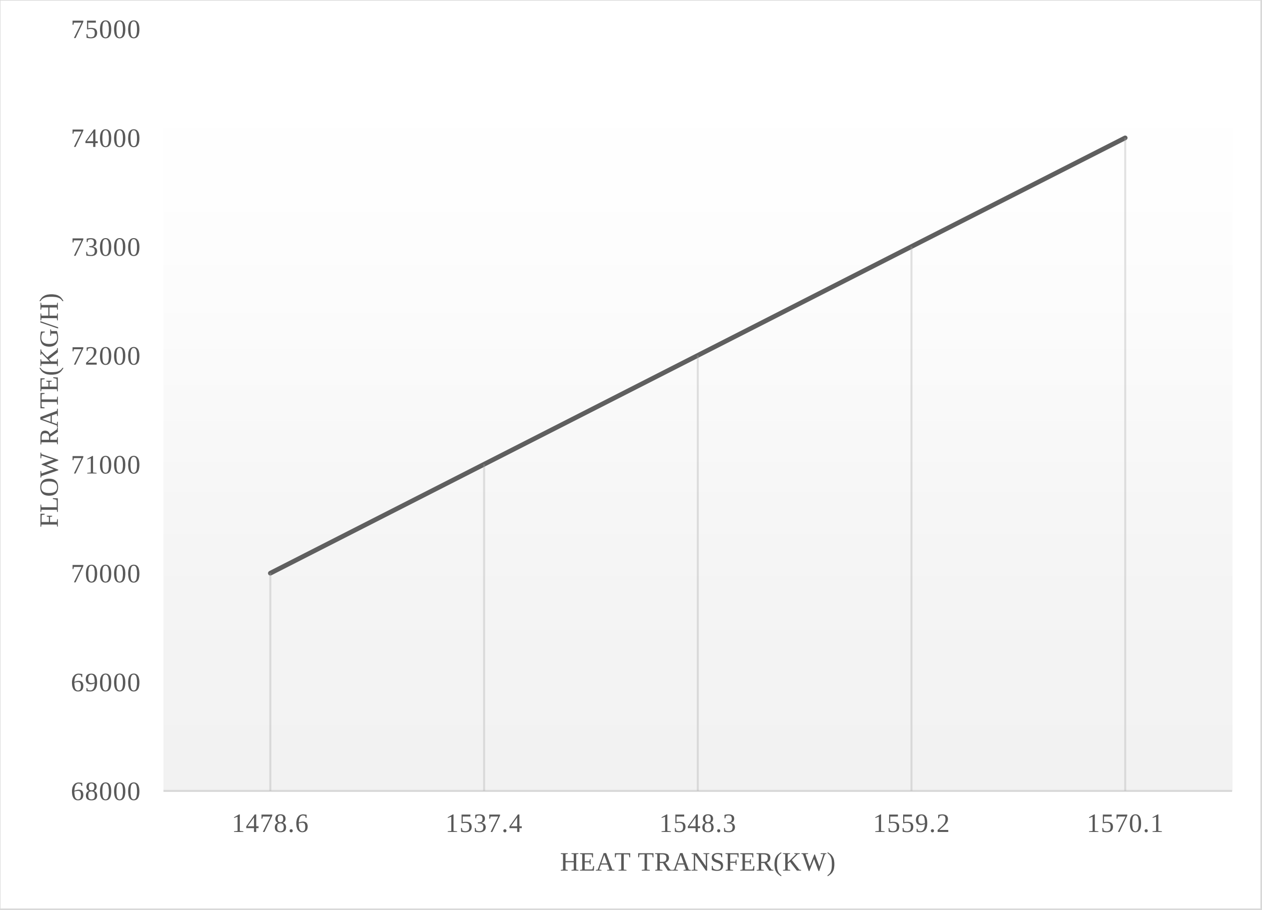


Fig. 4.6. Effects of cold fluid flow rate on the heat transfer heat rate between fluids.

4.5.5. Effects of baffle cut on the fluid velocity:

The baffle cut is an essential parameter. According to TEMA guidelines, it is recommended to adjust the baffle cut between 15% and 50% depending on the diameter of the shell.

For the purpose of illustrating the impact on the velocity of the shell side, chosen five distinct baffle cut percentages have selected: 17.33%, 25%, 35%, 40%, and 45%.

Consequently, A baffle, when inserted into a shell and tube heat exchanger, modifies the speed of the fluid by affecting the way it flows and the amount of pressure it experiences. A reduction in baffle size generally results in an increase in fluid velocity, which in turn leads to faster rates of heat transfer. However, it also causes bigger pressure decreases. Conversely, a bigger baffle cut diminishes the speed of the fluid, which can affect the efficiency of heat transmission but may result in a decrease in pressure drop. The trade-off between heat transfer performance and system energy consumption is depicted in figure 4.7. in this case, the maximum velocity has achieved at lowest baffle cut and the worst case was achieved in case of increasing baffle cut to maximum value.

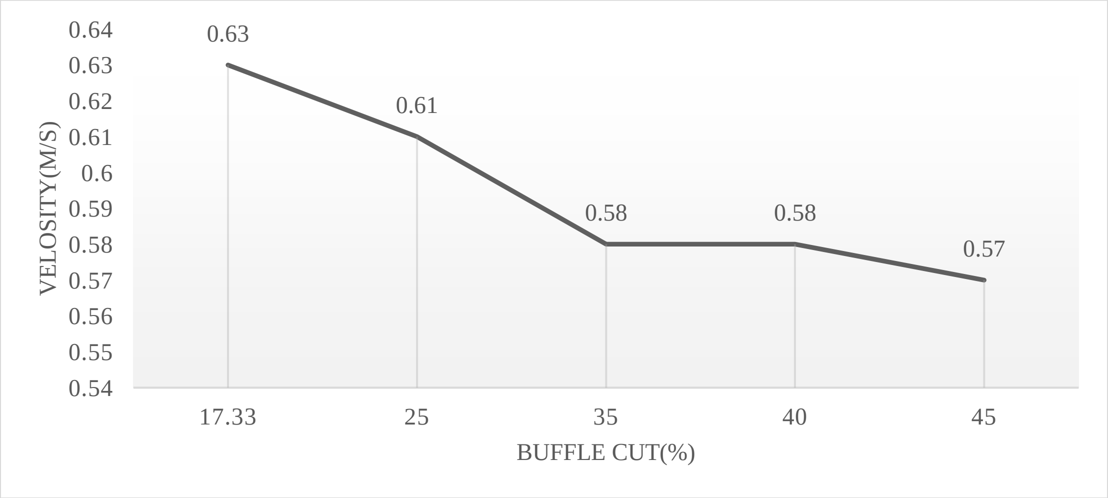


Fig. 4.7. Effects of baffle cut on the fluid velocity.

4.5.6. Effects of baffle cut on the pressure drop:

The baffle cut has a substantial impact on the pressure drop experienced on the shell side, which is comparable to the effect observed in the previous section. To demonstrate the effect on the pressure, drop of the shell side, five specific baffle cut percentages have been chosen: 17.33%, 25%, 35%, 40%, and 45%.

The impact of a baffle cut on the pressure drop in a shell and tube heat exchanger is contingent upon the precise configuration and positioning of the baffles. In general, a larger baffle cut, which refers to the percentage of the shell diameter occupied by the baffle, can lead to an increase in pressure drop. This is because it results in increased fluid velocity and turbulence. Conversely, reducing the baffle cut can lower pressure drop, but it may also impact heat transfer efficiency. The relationship between pressure drop and heat transfer performance must be carefully balanced. As shown in figure 4.8, the pressure drop reaches maximum value and minimum value in case of 17.33% and 45% respectively.

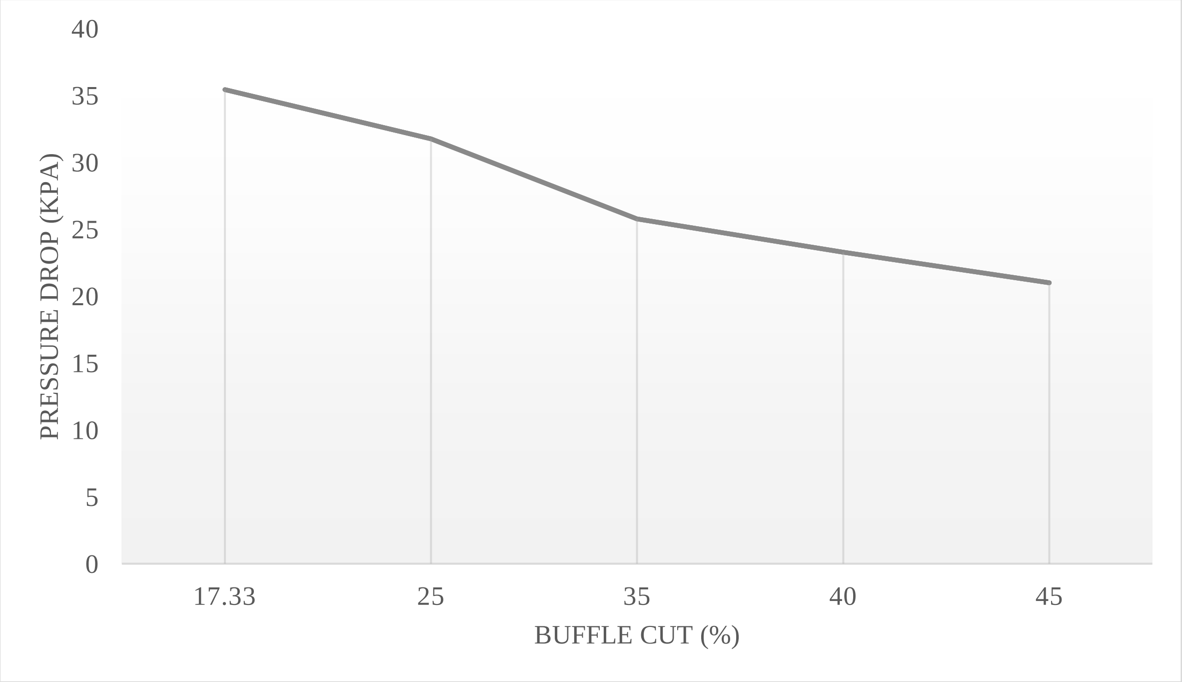


Fig. 4.8. Effects of baffle cut on the pressure drop.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

Heat exchangers play an important role on the development of the industrial innovations, therefore investigation on different areas of the heat exchangers are importanat.

In the current study, the results of the different parameters based on the international recommendations and limitations have been concluded as listed below:

1. Inlet temperature of the hot fluid increase from 200 to 250 ^{o}C and it will cause the cold fluid outlet temperature increases from 78 to 134.5 ^{o}C respectively.
2. The inlet value of cold fluid temperature also increased from 40 to 75 ^{o}C, which led to increase the effectiveness of the heat exchanger.
3. Hot and cold flowrate has increased seperatly, in both cases the transfer rate between fluid has affected, in the way that, increasing hot fluid flow will increase the transfer rate and increase the cold fluid flow led to reduce the transfer rate between both fluids.
4. The effects of the baffle cut on the pressure drop and flow velocity has investigated, five different recommended cased was exmined. It was concluded that increasing baffle cut led to reduce the pressure drop and flow velocity inside the shell.

5.2. RECOMMENDATIONS

1. Developing a comparable system is crucial for conducting more realistic parametric studies.
2. The simulation of various shell and tube heat exchanger designs, particularly the cattle type heat exchanger, is important due to its extensive application in high pressure environments.
3. Utilizing more suitable materials for the shell, tube, and baffles of the exchangers.
4. The implementation of a helical baffle to determine its impact on the efficacy of the exchange

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