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Theme

Enhancement Heat Transfer in a double pipe Heat Exchanger through Varied Fin Geometries under Turbulent Flow Conditions

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DEDICACE

We dedicate this humble work: to our mothers and fathers

To our brothers and sisters and to all our families, each in his name to

All the professors of the Mechanical Engineering Department,

Especially Prof. Dr. Deghoum Khalil

Head of the Mechanical Engineering Department

To all members of the evaluation committee, professors and doctors to

My dearest friends and all my colleagues.

Thanks

First of all, we thank Allah, who helped us complete the memorandum and illuminated our path and success in our scientific thesis.

We thank the good parents who gave us all the incentives to complete this note

We also thank Dr. Deghoum Khalil.

We thank all the professors and employees of Hama Al-Akhdar University

For what they have provided for education in our university, especially

The dean and professors of the Faculty of Science and Technology,

Especially the Mechanics Department, and the head of the department

For all. . Masters.

Also, don't forget our sincere thanks to all your classmates

Abstract

Double-pipe heat exchangers have gained significant economic importance. It is estimated that nearly all of the generated thermal energy passes through a heat exchanger at least once. The thermal-hydraulic properties of a double-pipe heat exchanger were analyzed with the aim of improving its performance. Three main pipe configurations were studied: smooth cylindrical, smooth triangular, and smooth trapezoidal with varied convex arrangements. Hot and cold water were the fluids used in this study. The governing equations were solved using the finite volume method based on the SIMPLE algorithm for pressure-velocity coupling. The standard model was used to describe the turbulence phenomenon. Simulations were performed using the "ANSYS FLUENT" code. The results indicated that the type of pipe and the arrangement of the corrugations significantly affect the thermal-hydraulic performance of the heat exchanger.

Keywords: corrugated, heat transfer, heat exchanger, double pipe, turbulent flow.

ملخص

اكتسبت المبادلات الحرارية ذات الأنابيب المزدوجة أهمية اقتصادية كبيرة. تشير التقديرات إلى أن جميع الطاقة الحرارية المولدة تقريبًا تمر عبر مبادل حراري مرة واحدة على الأقل. تم تحليل الخصائص الحرارية الهيدروليكية لمبادل حراري مزدوج الأنبوب بهدف تحسين أدائه. تم دراسة ثلاث تشكيلات للأنابيب الرئيسية: أسطوانية ملساء، مثلثية ملساء، وشبه منحرفه ملساء ذات ترتيبات محدبة ومتنوعة. وكانت المياه الساخنة والباردة هي السوائل المستخدمة في هذه الدراسة. تم حل المعادلات الحاكمة باستخدام طريقة الحجم المحدود المعتمدة على خوارزمية اقتران السرعة والضغط البسيطة. تم استخدام النموذج القياسي لوصف ظاهرة الاضطراب. تم إجراء عمليات المحاكاة باستخدام كود "ANSYS FLUENT". أشارت النتائج إلى أن نوع الأنبوب وترتيب التموج يؤثران بشكل كبير على الأداء الحراري الهيدروليكي للمبادل الحراري.

الكلمات المفتاحية المموجة: نقل الحرارة، المبادل الحراري، أنبوب مزدوج، التدفق المضطرب

Résumé

Les échangeurs de chaleur à double tuyau ont acquis une importance économique considérable. On estime que presque toute l'énergie thermique générée passe par un échangeur de chaleur au moins une fois. Les propriétés thermo-hydrauliques d'un échangeur de chaleur à double tuyau ont été analysées dans le but d'améliorer ses performances. Trois configurations principales de tuyaux ont été étudiées : cylindrique lisse, triangulaire lisse, et trapézoïdale lisse avec des arrangements convexes variés. L'eau chaude et froide étaient les fluides utilisés dans cette étude. Les équations régissant ont été résolues en utilisant la méthode des volumes finis basée sur l'algorithme SIMPLE pour le couplage pression-vitesse. Le modèle standard a été utilisé pour décrire le phénomène de turbulence. Les simulations ont été réalisées à l'aide du code "ANSYS FLUENT". Les résultats ont indiqué que le type de tuyau et l'arrangement des ondulations influencent de manière significative les performances thermo-hydrauliques de l'échangeur de chaleur.

Mots-clés : ondulé, transfert de chaleur, échangeur de chaleur, double tuyau, écoulement turbulent.

Summary

List of figures

List of tables

General Introduction

General introduction

Over time, the development of techniques related to energy has paralleled the evolution of humanity. Within the energy domain, thermal energy holds a distinctive position; actively participating in most energy processes either directly or indirectly throughout transformations.

The fields of application within thermal sciences appear extensive and crucial. Two particular areas merit emphasis: the conversion of energy into thermal energy and vice versa, and the transfer of thermal energy. The former pertains to thermal machines, while the latter involves heat exchangers. Heat exchanges manifest across various sectors of human activity. In many of these endeavors, heat transfer must occur without altering the media involved. Specialized equipment, known as heat exchangers, becomes imperative in such scenarios. These thermodynamic systems are integral to industrial units where heat extraction processes occur.

In industrial contexts, the heat exchanger assumes a pivotal role in energy management policies. A significant portion of thermal energy utilized in industrial processes undergoes at least one passage through a heat exchanger, both within the processes themselves and in the thermal energy recovery systems associated with these processes. As a fundamental tool for thermal and energy engineers, the heat exchanger facilitates temperature control within a system or product by exchanging heat between two environments.

Heat exchangers, as devices facilitating thermal energy flow between fluids at different temperatures, find application in diverse fields including energy production, food and chemical industries, electronics, environmental technology, residual heat recovery, industrial processes, and air conditioning, refrigeration, and space applications. The primary technological focus of heat exchangers lies in optimizing heat exchange between two fluids while minimizing pressure losses. The selection of a heat exchanger for a specific application is contingent upon various parameters such as the temperature and pressure range of fluids, physical properties, aggressiveness of fluids, and maintenance considerations. A well-designed and appropriately sized heat exchanger contributes to process efficiency and energy savings. The multitude of application areas for heat exchangers results in a variety of geometric shapes (tubular, plates, fins, etc.). The use of heat pipes as the main component of the exchange wall is particularly noteworthy. The concentric double-tube heat exchanger represents the simplest form within this family, while the tubular exchanger involves an assembly of two concentric tubes, with the inner tube conveying the first liquid and the outer tube coated with the second liquid. The flow of the two fluids can be co-current or countercurrent. Market constraints related to these exchanges express a need for reduced investment costs, space efficiency, and improved energy efficiency, prompting the development of increasingly compact heat exchangers and the exploration of various technologies for heat exchange intensification.

This study is part of a comparative energy study between three Types of double tube heat exchangers with concentric tubes Different geometric shapes: a smooth cylindrical central tube, a spiral conical central tube, and corrugated conical central tube. A series of numerical simulations were performed for to analyze and compare the thermal and dynamic properties of these three. Numerical simulation was performed by Ansys fluent.

This study includes three different chapters:

- Chapter One: Generalities about Heat Exchangers
- Chapter Two: Mathematical Model
- Chapter Three: Results and Discussion

Chapitre I. : General information

I.1. Introduction:

In order to prevent direct fluid mixing, a heat exchanger helps transport heat between a heat source and a heat sink, frequently through a solid wall. This widely utilized technology is found in many different industrial industries and is mostly used to chill or heat liquids or gases that are difficult to process directly. Even though heat exchangers have a straightforward working concept, research is still ongoing in the fields of computation, sizing, and optimization because the underlying physical phenomenon has not yet been fully understood. Therefore, the goal of this chapter will be to provide a deeper understanding of the various technical and theoretical elements related to heat exchangers by an extensive bibliographic study.I. Heat exchanger classification criteria.[1]

I.2. Bibliographic search on heat exchangers:

Chao Lou Ke Wei Song[2]:

The paper introduces a double pipe heat exchanger with two co-twisting oval pipes featuring unequal twist pitches. In the laminar regime, the study numerically investigates fluid flow and heat transfer characteristics, focusing on twist pitch ratios from 1.0 to 2.0. Results reveal that heat transfer initially increases, then decreases with the twist pitch ratio. The corresponding increase in flow resistance is comparatively less. The optimal twist pitch ratio for maximum heat transfer enhancement is found to be 1.5, achieving a 97.0% increase in Nusselt number with a modest 43.7% increase in friction factor. The highest thermal performance factor is 1.75 times that of a simple straight annular pipe, establishing the optimal twist pitch ratio as 1.5 for the best thermal performance. Fitted correlations are provided with deviations within acceptable limits.

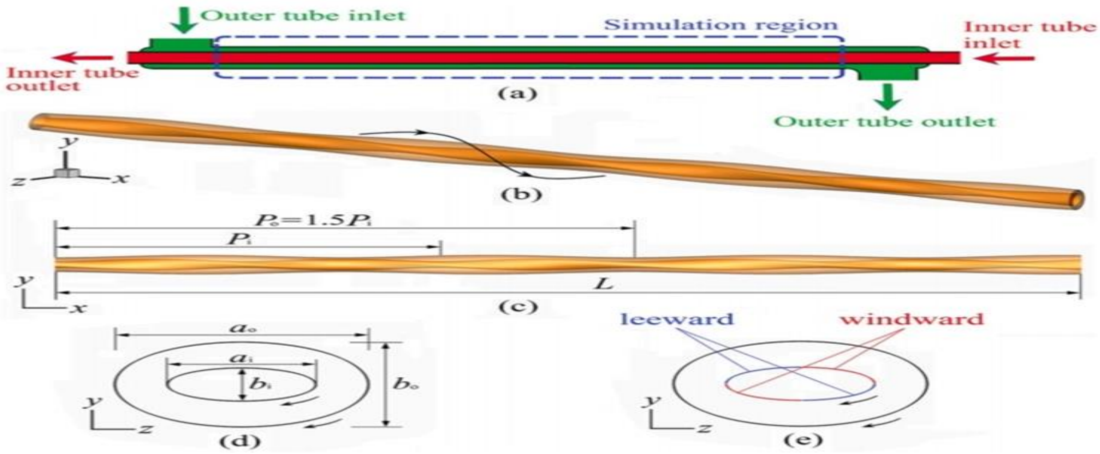


Figure I.1 : Schematic illustration of physical model

Milady Setareh Majid Saffar Aval[3]:

This study investigates the enhancement of heat transfer in a double-pipe heat exchanger using both experimental and numerical methods. A novel experimental setup with two concentric pipes is utilized, incorporating a bolted Langevin ultrasonic transducer to introduce ultrasonic vibrations (26.7 kHz) into the inner pipe. Numerical simulations using Open FOAM software are employed to understand the mechanisms underlying heat transfer enhancement. The study examines the influence of fluid flow rates for both hot and cold fluids, as well as acoustic power, on heat transfer and pressure drop. A comparison of overall heat transfer coefficient and pressure drop is conducted between scenarios with and without ultrasonic vibrations. Results indicate that ultrasonic vibration is more effective at lower fluid flow rates, resulting in a 60% heat transfer enhancement for fluid flow rates of 0.5 L/min and a 20% enhancement for rates of 1 and 1.5 L/min at an acoustic power of 120 W. Numerical findings attribute the improvement in heat transfer to cross-stream flows generated by ultrasonic wave propagation into the cold fluid.

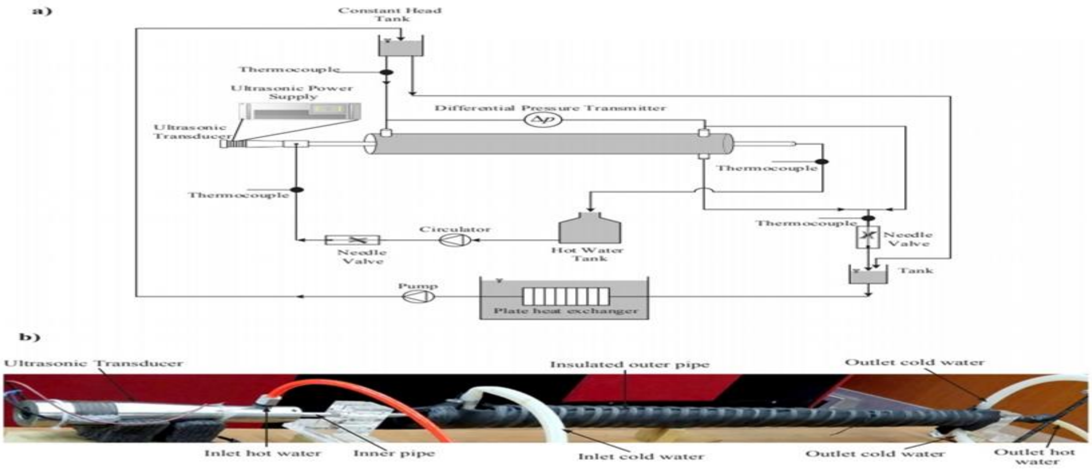


Figure I.2 : (a) Schematic view, (b) Real view (ultrasonic transducer and double-pipe heat exchanger).

Mojtaba Bezaatpour, Mohammad Goharkhah[4]:

The paper proposes a novel method to improve convective heat transfer in heat exchangers while minimizing pressure drop by utilizing an external magnetic field to induce a swirling flow in the magnetic working fluid. Through three-dimensional numerical simulations in a double-pipe mini heat exchanger, the method demonstrates a significant enhancement in heat transfer by up to 320% with only a minimal increase in pressure drop. This enhancement is attributed to the induced swirling flow disrupting the thermal boundary layer, enhancing flow mixing, and reducing flow resistance. The study suggests optimal operating conditions including low Reynolds numbers, high magnetic field intensities, and high nanofluid concentrations to achieve a balanced improvement in heat transfer and pressure drop.

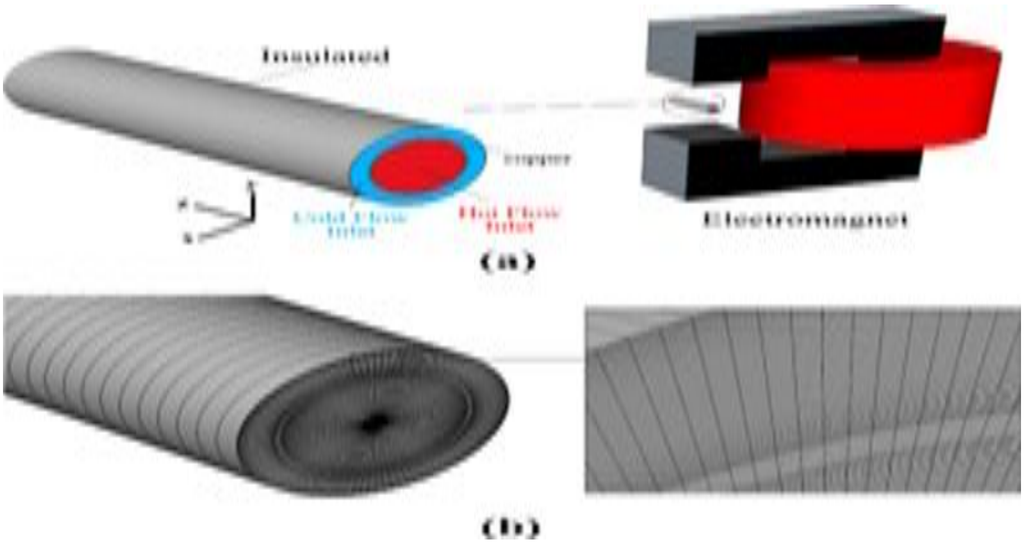


Figure I.3 : a) Schematic of the double-pipe mini heat exchanger and electromagnet.

Tete GuiGuobiao Ou[5]:

In this study, large eddy simulation was used to study the heat transfer characteristics of supercritical water (SCW) in a double-tube heat exchanger. The simulation revealed that the peak heat transfer coefficient increased from 3197.5 $W\cdot m^{-2}\cdot K^{-1}$ to 3260.5 $W\cdot m^{-2}\cdot K^{-1}$ and 3479.3 $W\cdot m^{-2}\cdot K^{-1}$ as the pressure decreased from 27 MPa to 25 MPa and 23 MPa, respectively.

The difference between the pseudo-critical temperature and the temperature at the peak of the heat transfer coefficient decreased from 3.1 K to 0.9 K due to the temperature gradient and variable properties of the SCW.

In addition, lowering the tube inlet temperature from 633 K to 613 K and 593 K resulted in a decrease in the peak heat transfer coefficient from 3430.5 $W^{-}m^{2}\cdot K^{-1}\ to$ 3283.0 $W^{-2}\cdot K^{-1}\ and$ 3229.7 $W\cdot m.^{-2}\cdot K^{-1}$, respectively, is attributed to the buoyant force.

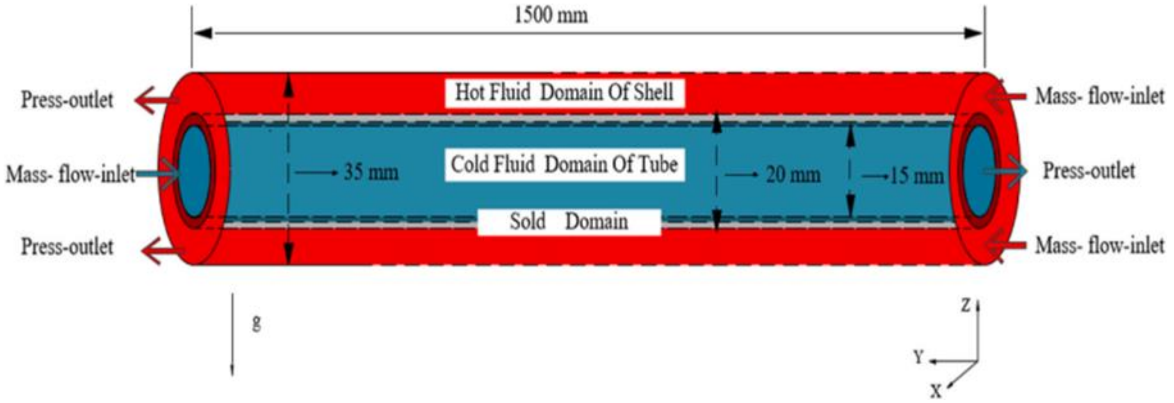


Figure I.4 : Size and structure of the DPHE.

Basim O. Hasan, Enas A. Jwair[6]:

Experimental investigations were conducted to examine the influence of surface enhancement on crystallization fouling in a double pipe heat exchanger operating under forced convective heat transfer. Moreover, it substantially reduced fouling resistance. Sodium sulfate at its saturation concentration was utilized, leading to precipitation on the outer surface of the tube due to countercurrent flow of the hot fluid. Notably, installing the coiled wire insert on the outer surface of the inner tube was more effective in reducing fouling resistance compared to installing it on the inside surface.

The study focused on evaluating the impact of surface enhancement on heat transfer coefficient and fouling resistance for both smooth and enhanced surfaces. The experiments involved using a hot fluid (salt solution) at 40 C and Reynolds number ranging from 5300 to 20,000, while a cold fluid (distilled water) at 10 C with Reynolds number ranging from 13,000 to 22,000 was circulated through the inner tube. Surface enhancement was achieved by incorporating a coiled wire insert either inside or outside the inner tube.

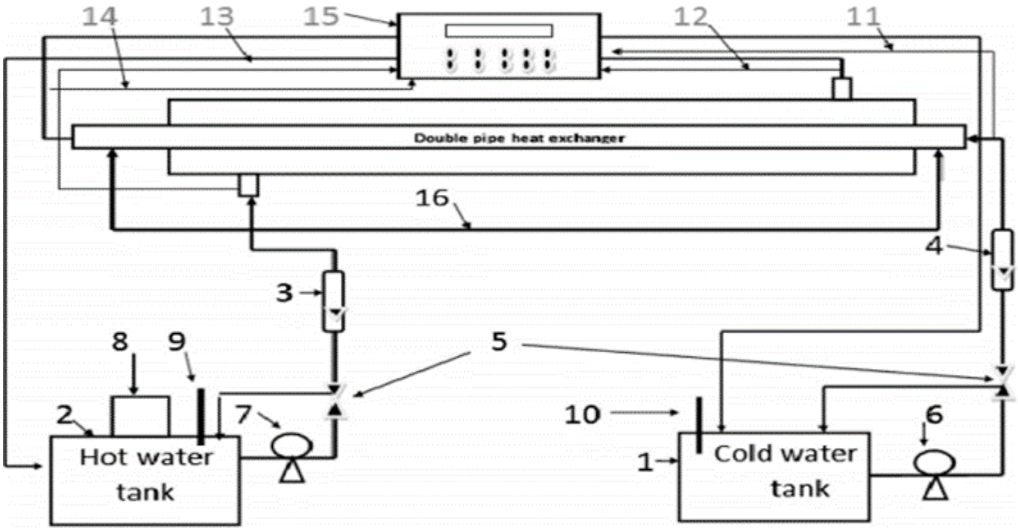
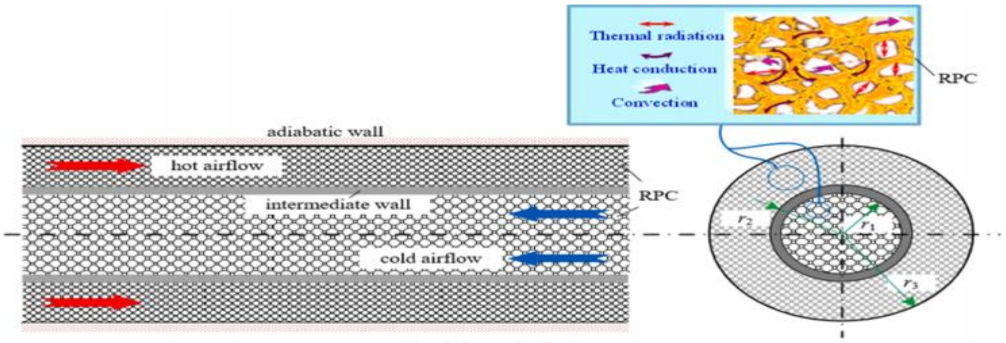


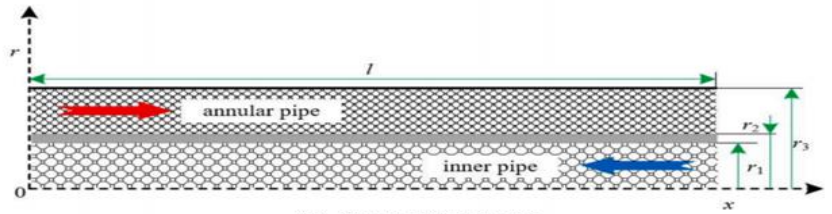
Figure I.5 : Schematic diagram of the experimental rig

Zhen-huan Li, Lin-yang we[7]:

This study employs a multi-objective optimization model, combining support vector regression (SVR) and non-dominated sorting genetic algorithm (NSGA-II), to enhance the performance of a double-pipe heat exchanger (DPHE) filled with porous foam for high-temperature applications. A comprehensive conjugated heat transfer model considers the Local Thermal Non-equilibrium (LTNE) effect, interfacial wall coupling, and employs Monte Carlo method for radioactive heat transfer.



(a) Schematic diagram



(b) Computational domain

Figure I.6 : Schematic diagram of the foam filled counter flow double-pipe heat exchanger.

Mohammed Flyyih Hasan, Merdin Danıs[8]:

This study numerically investigates heat transfer enhancement in a double pipe heat exchanger with an extended surface on the inner tube's outer surface, utilizing Alumina Nano fluid. Water and hot de-ionized water with varying mass flow rates and Reynolds numbers flow through the annuli, while hot de-ionized water flows through the inner tube. Al2O3 nanoparticles with volume concentrations of 1%, 3%, and 5% were used. Computational Fluid Dynamics, utilizing the Semi-Implicit Method for Pressure Linked Equations, was employed for numerical analysis. Simulated results indicate that the use of a finned tube heat exchanger led to an improvement ratio between 2.3 and 3.1. The convective heat transfer coefficient increased numerically with higher volume concentrations and Reynolds numbers. At a 5% volume concentration, the heat transfer coefficient and thermal conductivity rose by 20% and 4.7%, respectively.

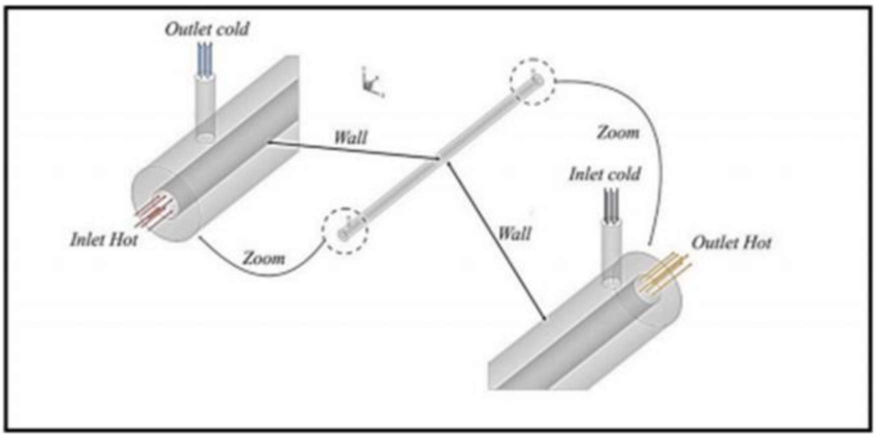


Figure I.7 : The model geometry used in the simulations of plain tube.

H.A. Mohammed, Husam[9]:

This numerical study investigates the impact of louvered strip inserts in a circular double pipe heat exchanger using various nano fluids. Utilizing a finite volume method, the study explores two louvered strip insert arrangements, considering different slant angles and pitches, and covers four types of nanoparticles (Al2O3, CuO, SiO2, and ZnO) with varying volume fractions and nanoparticle diameters in water. Results show that the forward louvered strip arrangement significantly enhances heat transfer, with a maximum improvement of 411%. SiO2 nanofluid exhibits the highest Nusselt number, and the Nusselt number increases with decreasing nanoparticle diameter and slightly with increasing volume fraction. The study also reveals a substantial increase in skin friction coefficient for the enhanced tube and provides a performance evaluation criterion ranging from 1.28 to 1.56.

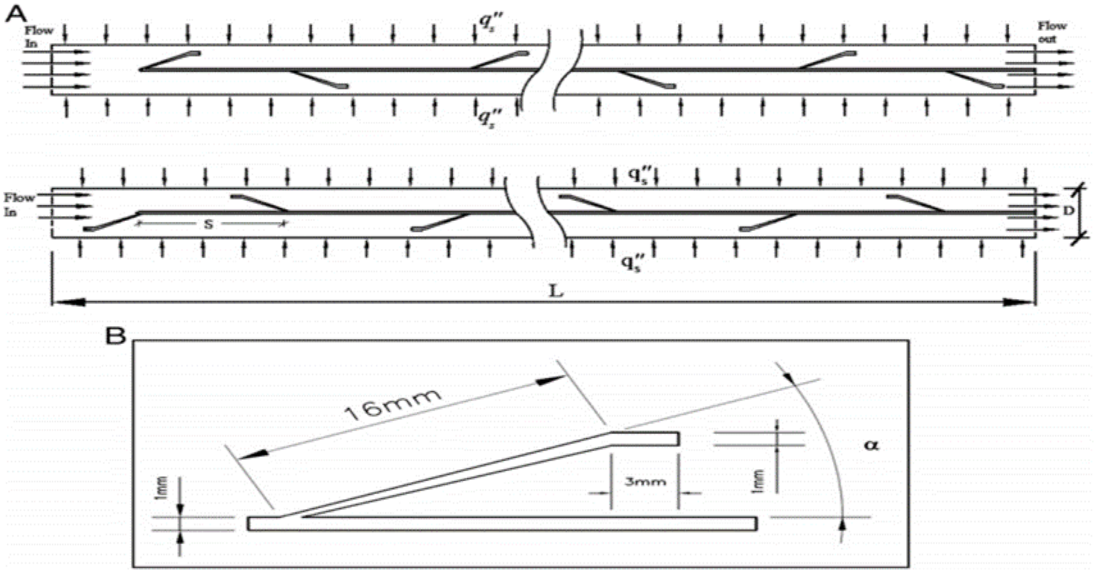


Figure I.8 : (A) Schematic diagram of a circular tube fitted with for war and backward arrangements of louvered strip inserts, and (B) geometry details of louvered strip insert.

I.3. Definition:

Heat exchangers are devices designed to transfer heat between two fluids at different temperatures. Typically, the fluids do not directly contact each other; instead, heat exchange occurs through a separating surface. The primary heat transfer mechanism within this surface is conduction, while convection almost always dominates on the surfaces in contact with the fluids. While most heat exchangers involve single-phase fluids, either gaseous or liquid, there are three main categories where phase changes occur: evaporators, where a liquid is transformed into vapor; condensers, where vapor is condensed into a liquid; and vapor condensers, involving phase changes in both liquids.[1]

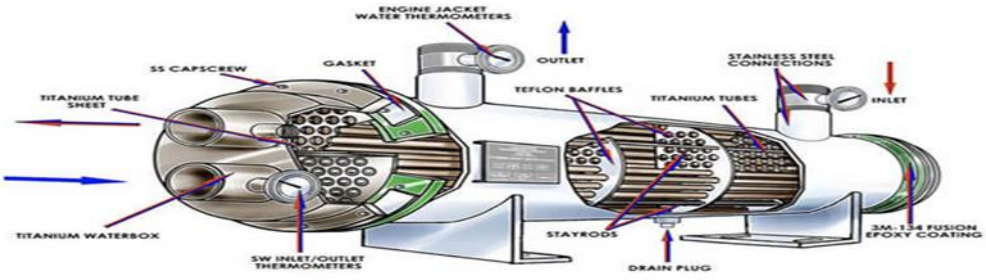


Figure I.9: Heat exchanger[10]

I.4. Criteria for classification of heat exchangers:

Heat exchangers can be categorized using a number of factors, the most significant of which are as follows:

I.4.1. Classification according to the nature of the wall material:

I.4.1.1.Exchange:

The classification of heat exchangers based on the nature of the wall material refers to the materials used in constructing the separating walls between the heat transfer media. Examples of this classification include**.[11]**

I.4.1.2.Metallic Heat Exchangers:

The separating wall is made of metallic materials such as stainless steel or aluminum**.[11]**

I.4.1.3.Plastic Heat Exchangers:

Polymers and plastics are used in constructing the separating walls, making them a lightweight and electrically non-conductive option.[11]

I.4.1.4.Composite Heat Exchangers:

Multiple-material compositions are used, such as walls containing layers of both metal and plastic. The wall materials vary based on their mechanical and thermal properties, and they are chosen according to operational conditions and design requirements to achieve optimal performance in the heat exchanger**.[11]**

I.4.2. Functional classification:

The main reason for utilizing a heat exchanger in a system or process determines how to classify them depending on their function. Several instances of functional classification include**.[11]**

I.4.2.1.Cooling Heat Exchangers:

Used to cool heat transfer media by transferring heat from the hot medium to the cold medium.[11]

I.4.2.2.Heating Heat Exchangers:

Aimed at increasing the temperature of the heat transfer medium by transferring heat from another medium.[11]

I.4.2.3.Temperature Control Heat Exchangers:

The heat transfer medium can be effectively controlled with precision using this particular method.[11]

I.4.2.4.Chemical Process Heat Exchangers:

This particular application involves the utilization of chemical processes for various purposes, including but not limited to cooling, heating, and chemical exchange.[11]

I.4.2.5.Power Generation Heat Exchangers:

Employed in generating thermal energy, such as steam boilers in power generation plants. This classification helps understand the primary role played by the heat exchanger in a specific system or process.[11]

I.4.3. Classification according to the heat transfer process:

Heat exchangers are classified into several main types based on the heat transfer process, including:

- **Direct Heat Exchange:**

Where heat transfer occurs directly between two heat transfer media without an effective separation between them**.[11]**

- **Indirect Heat Exchange:**

Involving a separating wall that prevents direct contact between the exchanging heat materials.[11]

- **Single-phase Heat Exchange:**

Occurs when the heat transfer medium is in a single state, whether liquid or gas.[11]

- **Multiphase Heat Exchange:**

Occurs when the state of the heat transfers medium changes between liquid and gas during the heat exchange process.

These classifications depend on the specific context and application of the heat exchanger.[11]

I.4.4. Classification according to contact:

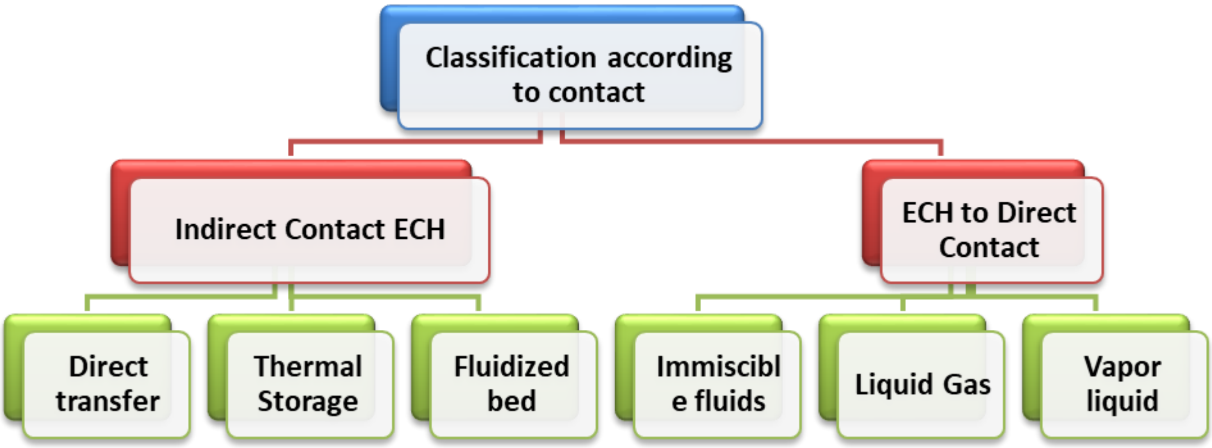


Figure I.10 : General Flowchart of Heat Exchanger.

I.4.5. Classification according to the number of fluids:

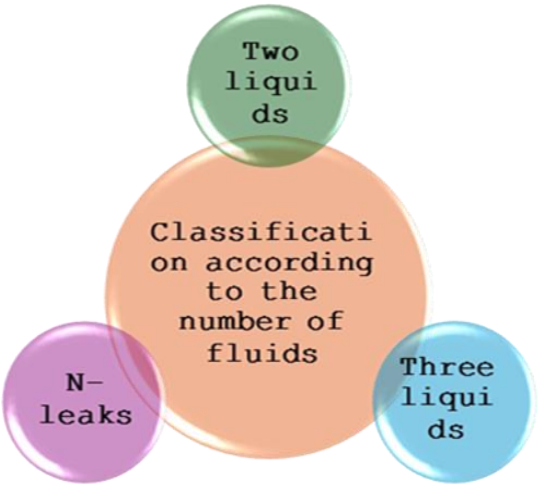


Figure I.11 : General Flowchart of Heat Exchanger.

I.5. Classification by design method:

The heat exchanger is defined by the exchange principle occurring between two liquids, leading to a wide range of diverse designs, including the following[12]:

I.5.1. Tubular exchangers:

Due to historical and economic factors, heat exchangers that utilize tubes as the primary component of the exchange wall are predominant. These can be categorized based on the number of tubes and their arrangement, always engineered to maximize efficiency for specific applications:

A. Single-tube exchanger:

It is a type of heat exchanger, as it consists of one tube through which the thermal medium passes. This tube is designed to exchange heat with another medium that circulates outside the tube, allowing efficient heat transfer between the two mediums.

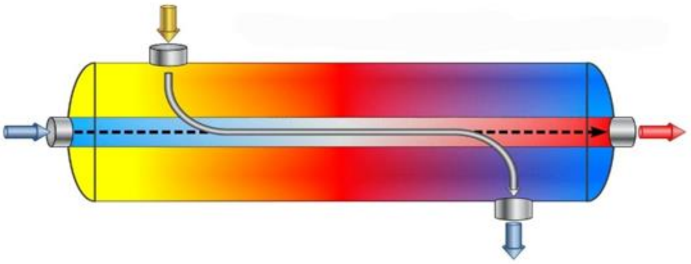


Figure I.12 : Single-pipe exchanger[13]

B. Coaxial exchanger:

It is a type of heat exchanger consisting of an inner tube containing a heat medium, surrounded by an outer tube containing another heat medium. Heat exchange occurs between the thermal media passing inside the two tubes through the wall separating them. This type of heat exchanger is used in a variety of applications to achieve highly efficient heat transfer between liquids or gases.[14]

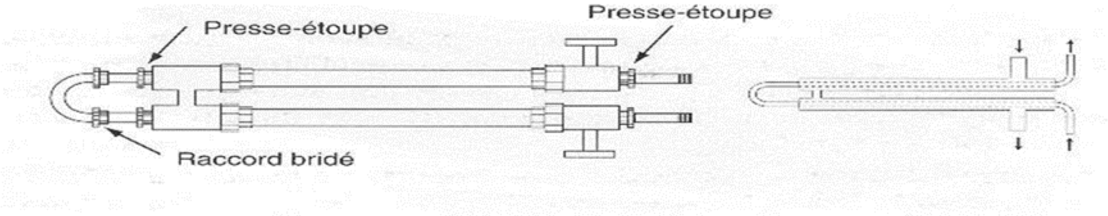


Figure I.13 : Coaxial exchanger[15]

C. Tube and shell exchanger:

This particular device, renowned for its widespread popularity, adheres to the beam principle encased within a calendar. This construction has been consistently applied in the manufacturing of condensers and reboilers. The apparatus comprises a bundle of tubes secured between two tubular plates and equipped with multiple baffles.

At both ends of the device, distribution boxes are affixed to facilitate the fluid's circulation within the bundle through several passes. The beam is housed within a calendar, accommodating inlet and outlet pipes for the second fluid circulating outside the tubes, following the designated path outlined by the baffles

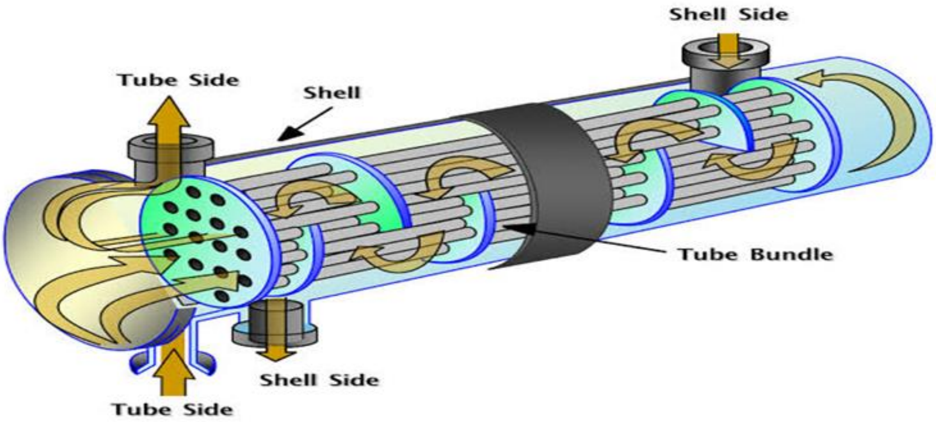


Figure I.14: Tube and shell exchange[16]

All components involved in the exchanger construction adhere to standardization set by TEMA (Tubular Exchanger Manufacturers Association), which defines the mechanical and thermal characteristics corresponding to various operating conditions. The maximum capacity achieved with this configuration, measured in exchange surface per cubic meter, is approximately 500 m^2/m^3.

❖ Baffles:

It is a term referring to metal plates or fins placed inside the shell of the heat exchanger. These baffles direct the flow of the fluid and increase its velocity, while also reducing vibrations. There are various types of baffles:[17]

1. **Straight baffles:**

Flat plates placed perpendicular to the fluid flow path.

2. **Curved baffles:**

Curved plates placed at an angle to the fluid flow path.

3. **Slotted baffles:**

Plates with openings that allow the fluid to flow through.

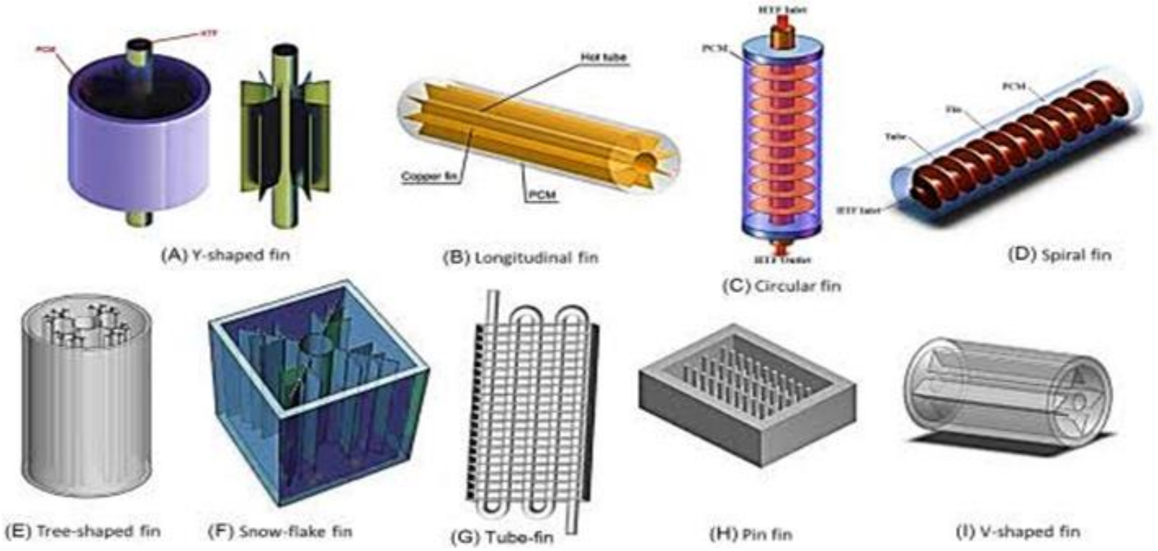


Figure I.15 : A group of types of barriers[18]

I.6. Varieties of tubular shell exchangers:

I.6.1. Exchangers with U-tubes:

Tube bundle "U" heat exchangers are widely used for producing hot water or industrial processes due to their low cost and strength. The "U"-shaped tube bundle is formed and secured to a carbon steel tube sheet, allowing for easy removal by disassembling the front head. This design effectively handles high temperature liquids or steam.

The "U"-shaped tubes are available in various materials such as stainless steel AISI 316L, copper, and carbon steel, suitable for applications involving steam, hot water, or thermal oils. The tubes are connected to a tube sheet, and cleaning and draining connections are provided on the front head. The rear end can be customized to reduce vibration issues as needed.[19]

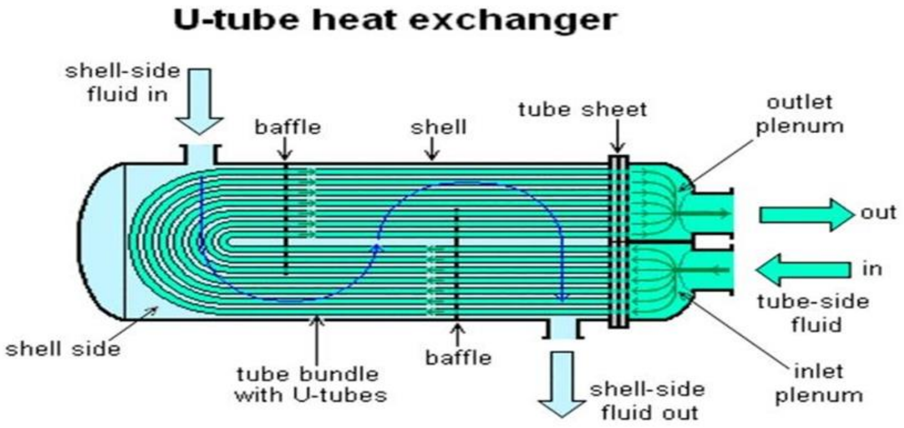


Figure I.16 : Exchanger with U-tube[20]

I.6.2. Floating head exchangers:

In this type of heat exchangers, one end of the tube plate is fixed on both sides with the housing, while the other end is free to move relative to the housing, known as the floating head. The floating head consists of a floating tube plate, a hook ring, and a floating head cover, which is a detachable connection allowing the tube bundle to be pulled through.

This design allows the tube bundle to move and expand freely without restrictions from the housing, reducing thermal stress. Despite the ease of cleaning between and inside the tubes without thermal stress, the structure is complex, and the cost is higher, with large equipment and significant material consumption.

The floating head cover cannot be inspected during operation. These structures are suitable for situations where the temperature difference between the shell bundle and the tube is significant or measuring the medium on the shell side is easy.[21]

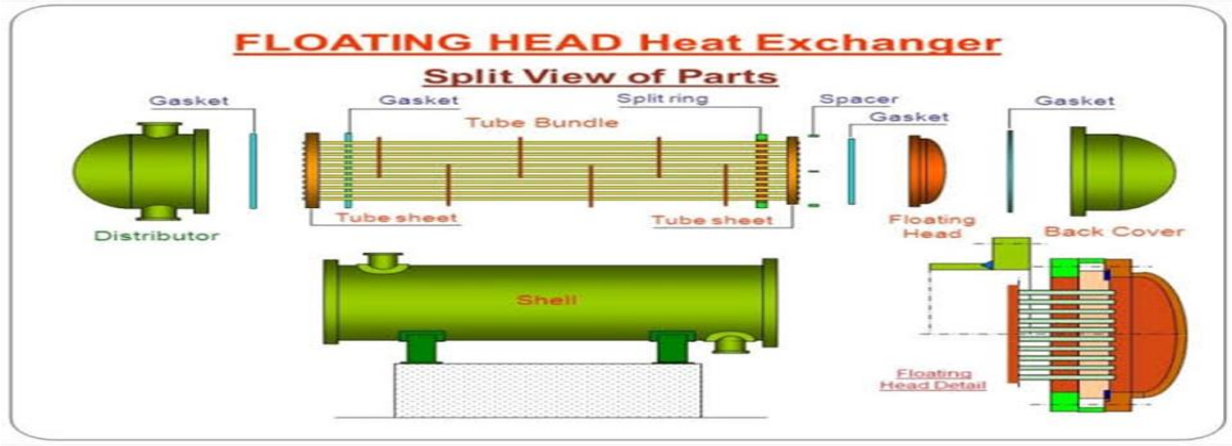


Figure I.17 : Floating head exchangers[20]

I.6.3. Plate exchangers:

A plate heat exchanger (PHE) is a compact type of heat exchanger that uses a series of thin metal plates to transfer heat between one fluid and another, usually fluids at different temperatures. Each panel consists of a concave, bounded tubular shell, in which the panels are arranged to create thin, rectangular channels for heat exchange. Operating fluid flows between these channels, and the plates are connected with gaskets to adjust the fluid flow. Different types of liquids are distributed onto the plates, with each type directed onto a separate plate. Heat is then exchanged between the cold and hot fluids across the plates, resulting in excellent thermal performance thanks to the large face area on the plates. They also have two types: primary surface exchangers and secondary surface exchangers.[22]

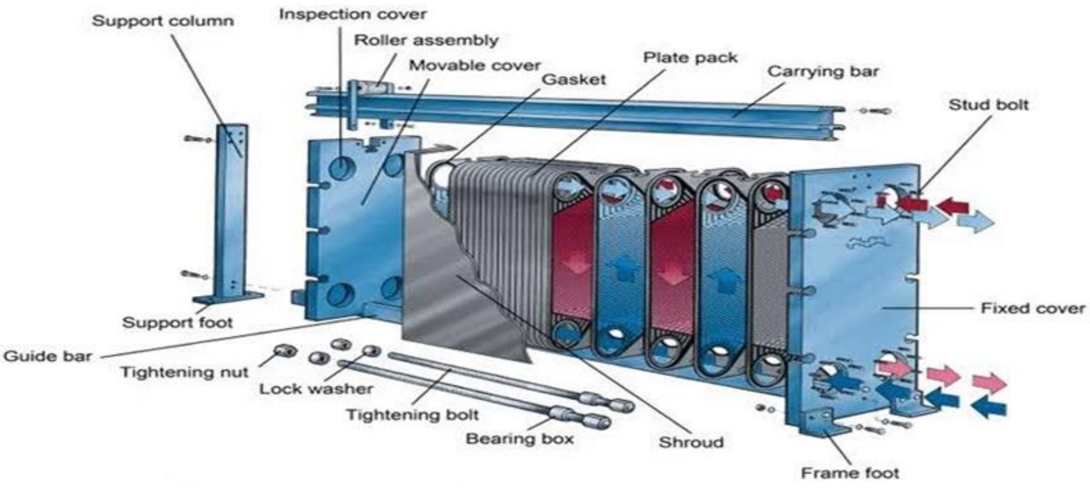


Figure I.18 : Plate exchangers[23]

I.6.4. Brazed plate exchanger:

Arc plate heat exchangers are systems where the plates have undulations or wrinkles, which increases heat transfer efficiency due to increased surface area. They are usually made of copper or titanium.[24]

Figure I.19 : Brazed plate exchanger[25]

I.7. Operational problems of heat exchangers:

The heat exchanger faces several operational problems during its operation over time. These problems are pollution, corrosion, vibration, and mechanical resistance.

I.8. Conclusion:

Heat exchangers are primarily used in industrial sectors (chemistry, petrochemicals, steel industry, agriculture and food, energy production, etc.), transportation (automobile, aviation), as well as in residential and educational sectors (heating, air conditioning, etc.). The selection of a heat exchanger for a specific application depends on several criteria, including the temperature and pressure range of the fluids, their physical and chemical properties, maintenance, and size. It is evident that having a properly matched, well-sized, and efficiently used heat exchanger contributes to increasing the efficiency and sustainability of industrial processes.

Chapitre II. : Mathematical modeling

II.1. Introduction:

Heat exchangers are devices that transfer heat from one fluid to another by radiation, convection or conduction. They play a very important role in industrial plants, helping to maximize efficiency. To do this, it is necessary to establish good calculation and sizing procedures for this device. This requires the use of correlations for thermal and hydraulic calculations. In This chapter, we present a math model.

II.2. Thermal quantities:

In order to successfully explain the phenomena of heat transfer from one medium to another, and more generally heat conservation in isolated systems, it is necessary to define a number of physical quantities. For a given quantity of matter, the addition of a quantity of heat induces a change in its temperature, or a change in the state of matter. Temperature is a physical quantity that characterizes the energy level of matter. These different notions will be explained below.

II.2.1. The temperature:

Hot and cold are assessed by sensations, which leads to an irrational evaluation of these quantities. Temperature characterizes the level of heat in a body, making it possible to say that one body is warmer or cooler than another. [3]

II.2.2. Temperature field:

At any point in space where matter is present, we define a scalar temperature function as a function of the point's coordinates and time. The set of instantaneous temperature values throughout space is called the "temperature field", $T(x; y; z; t)$.[26]

II.2.3. Heat flow:

Heat flows under the influence of a temperature gradient from high to low temperatures. The amount of heat transmitted per unit time and per unit area of the isothermal surface is called the heat flux densityφ .[26]

$$\varphi = \frac{1}{A} \cdot \frac{dQ}{dt} \tag{II.1}$$

The quantity of heat transmitted to surface S per unit time is called the heat fluxϕ:

$$\phi = \frac{dQ}{dt} \tag{II.2}$$

II.2.4. Heat:

Heat is a form of energy (energy of movement of molecules) that moves from a hot point (higher temperature) to a cold point (lower temperature).[26]

II.2.5. Specific heat:

By definition, the specific heat Cp corresponds to the quantity of heat required by a material of given mass to raise its temperature by one degree. In other words, the amount of heat exchanged between two bodies at temperatures $T1$ and $T2$ respectively ($T1>T2$) is expressed by :

$$Cp = \frac{1}{m} \cdot \frac{dQ}{dT} \tag{II.3}$$

II.2.6. Thermal conductance:

Thermal conductance is a physical quantity that characterizes the behavior of materials during heat transfer by conduction. This constant appears in Fourier's law. It represents the quantity of heat transferred per unit area and per unit time under a temperature gradient. Conductivity depends mainly on:

- ✓ The nature of the material.
- ✓ The temperature.
- ✓ Other parameters such as humidity and pressure.

So thermal conductivity λ characterizes the material's ability to transmit heat[27]

II.2.7. Contact resistance:

Contact between two solids is uniform only on a macroscopic scale. At a more local level, for example at the roughness scale, contact is discontinuous. This discontinuity in thermal conductivity at cross-sectional level generates a discontinuity in the temperature profile. This phenomenon can be modeled by introducing the contact resistance Rc, defined by the following relationship:

$$Rc = \frac{1}{hc} \tag{II.4}$$

Where $\boldsymbol{hc}$ is the heat transfer coefficients

II.3. Physical magnitudes:

II.3.1. Density (ρ):

The ratio of the mass of a material per unit volume. Also known as mass-volume[28]

II.3.2. Viscosity (μ):

Viscosity is the property of a fluid that tends to prevent it from flowing when subjected to a force. The more viscous the fluid (high viscosity), the more difficult its movement.[28]

II.3.3. Flow rate:

This is the quantity of fluid that flows or is supplied per unit of time. There are two types of flow; mass flow and volume flow. The mass flow rate $Q_m\ [Kg/S]$and the volumetric flow rate $\dot{m}[m/s]$

II.3.4. Reynolds number:

The REYNOLDS number is the ratio of the forces of inertia to the forces of viscosity, given by the following formula:

$$Re = \frac{UL}{V} = \frac{\rho UL}{\mu} \tag{II.5}$$

It characterizes the fluid flow regime.

The REYNOLDS experiment on flow in a cylindrical pipe reveals two flow regimes characterized by a parameter (REYNOLDS number).

For low flow rates, the regime is said to be laminar. Otherwise, it is turbulent.

- **Laminar regime:**

The fluid threads are parallel, and exchanges take place between the layers, which are of molecular origin (conduction).

The flow remains laminar as long as the REYNOLDS number remains below 2300.

- **Turbulent regime:**

Flow is disturbed, and fluid particle motion is random and three dimensional. The flow regime is considered turbulent if the REYNOLDS number reaches or exceeds 10000. The regime corresponding to a REYNOLDS number between 2300 and 10000 is said to be transient.[29]

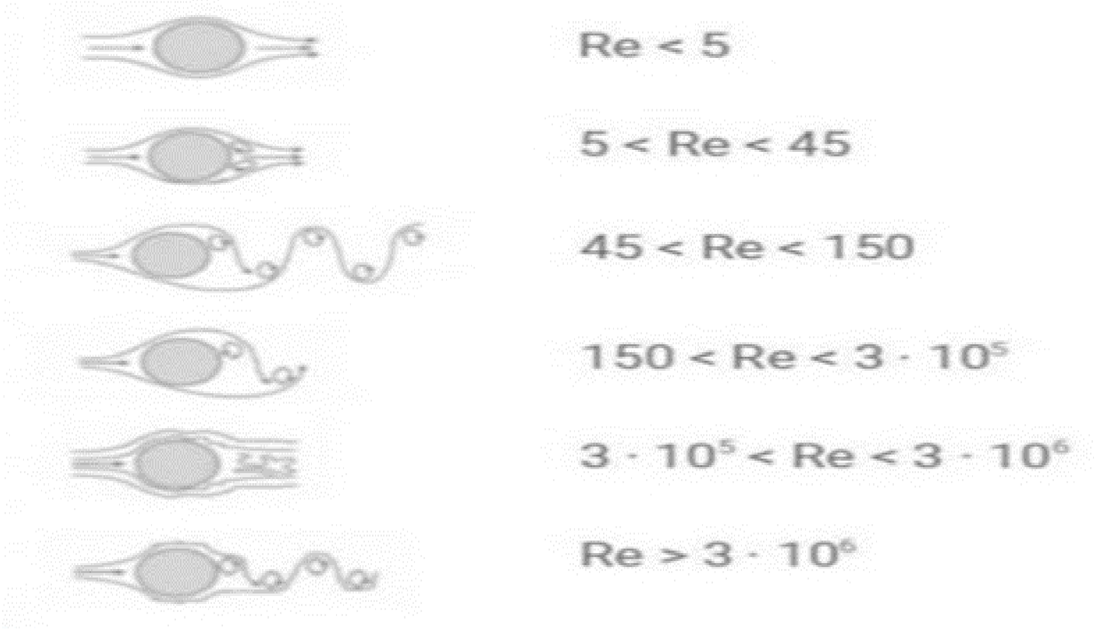


Figure II.1 : flow regimes[29]

II.3.5. Nusselt number:

This dimensionless number specifies the relative importance of the heat flux actually transmitted by convection compared with a reference conductive heat flux for the problem.

$$\mathrm{Nu} = \frac{\mathrm{h.L}}{\lambda_f} = \frac{\phi_{conv}}{\phi_{cond}} \quad \text{(II.6)}$$

h :Local or global exchange coefficient, depending on the case.

In forced convection, the Nusselt number is linked to the Reynolds number and the Prandtl number.

II.3.6. Prandtl number:

It characterizes the influence of the nature of the fluid on heat transfer by convection:

$$\mathrm{Pr} = \frac{C_p.\mu}{\lambda} \qquad \text{(II.7)}$$

II.4. Modes of heat transfer:

II.4.1. Heat conduction[27]:

Conduction is mainly the transfer of heat from hot to cold parts of the same body, or from one body to another, without any parallel movement of the material. This mode can take place in both solids and fluids. Conduction is reacted by Fourier's law:

$$\phi = -\lambda.\overrightarrow{grad} \qquad \text{(II.8)}$$

If a body at temperature T_1 is connected to a body at temperature T_2 by a thermal body of section S and thickness$e$. The heat flow between the two objects is given by:

$$\phi = \lambda . A . \frac{(T_1 - T_2)}{e} \quad \text{(II.9)}$$

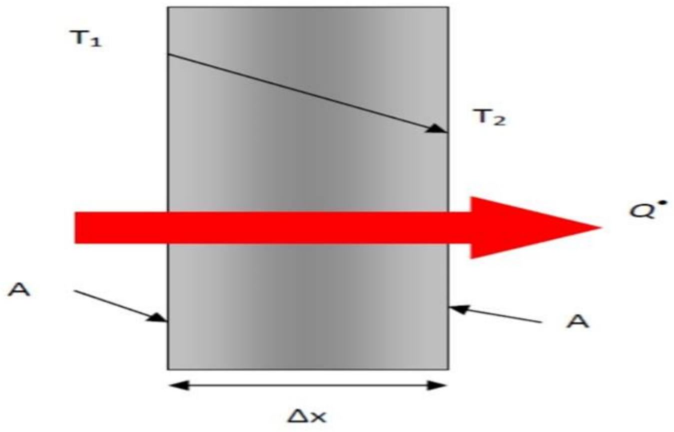


Figure II.2 : conduction of heat through a wall[27]

II.4.2. Heat convection[27]:

The term convection is used to describe the transfer of energy between a solid surface and a fluid moving relative to it. For this transfer, energy transfer by conduction always takes place, but the dominant mode is that due to the motion of fluid particles.

$$\phi = h . A . (T_1 - T_2) \quad \text{(II.10)}$$

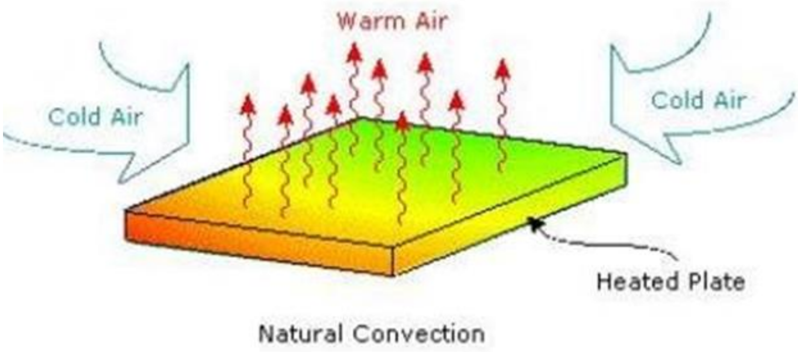


Figure II.3 : Thermal convection phenomenon[27]

- **Natural convection:**

Also called free convection, it is caused by mass forces in the fluid, due to differences in temperature and therefore in the density of the fluid.

- **Forced convection:**

When fluid movement is created by a pressure difference (pump, blower) or an applied speed.

II.4.3. Radiation:

Along with conduction and convection, thermal radiation is the third mode of heat transfer anybody with a temperature above 0 K emits thermal radiation. Unlike conduction and convection, where energy is transported by the presence of matter (in fluid or solid form), heat transfer by radiation takes place in the form of electromagnetic waves and can be observed between two bodies placed in a vacuum. It is characterized by Stephan-Boltzmann law. [27]

$$\phi = \sigma . A . T^4 \tag{II.11}$$

$\sigma = 5{,}67.10^{-8}[N.m^{-2}.K]$ **:** Stephan Boltzmann's constant.

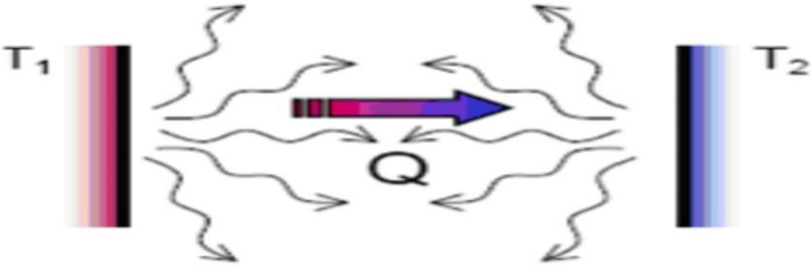


Figure II.4 : Thermal radiation phenomenon[27]

II.5. Study of an exchanger:

When designing a heat exchanger, the aim is always to obtain a given exchange capacity, with the smallest possible exchange surface and the lowest possible pressure drop, in other words, the lowest investment and operating costs. Constraints such as size, weight, corrosion and standardization all play their part, which means that the parameters available are generally far more numerous than the equations, with certain imperatives being essentially technological or economic in nature. The complete design of a heat exchanger therefore calls on a variety of disciplines (thermal, fluid mechanics, technology, etc.).

II.5.1. Overall heat transfer coefficient:

The heat transfer coefficient represents the "force" with which power is transmitted between the wall and the fluid. This coefficient can be small, meaning that the heat is transmitted in a non-efficient way. On the other hand, it can be very large, leading to highly efficient heat transfer.

This coefficient is directly affected by the physical properties of the fluids.

$$\phi = h . A . (T_h - T_c) \tag{II.12}$$

The methods used to design and calculate heat exchangers are either analytical or numerical.

II.5.2. Analytical methods:

There are two methods of calculation:

■ Logarithmic mean temperature difference method, known as the DTLM method.

■Number of transfer units' method, also known as the NUT method, also used in chemical engineering for mass transfer. [30]

II.5.2.1.DTLM Method:

This method is used to determine the exchange surface S, given the power exchanged and the inlet and outlet temperatures of the two fluids, hot and cold**.**

A simple shell-and-tube heat exchanger consists of two coaxial cylindrical tubes. One fluid (generally the hot fluid) circulates in the inner tube, and the other in the annular space between the two tubes. Heat transfer from the hot fluid to the cold fluid takes place through the inner tube wall. The hot fluid enters the exchanger at temperature $T_{h1}$and leaves at T_{h2} .Cold fluid enters at T_{c1} and leaves at T_{c2} .Heat flow can be evaluated in different ways. [26]

- For full exchanger length:

$$\phi = \mathrm{h.A.}(\mathrm{T_h} - \mathrm{T_c}) \tag{II.13}$$

- Heat transfer in an exchanger section of length dx and cross section:

$$d\phi = \mathrm{h.}(\mathrm{T_h} - \mathrm{T_c}).\mathrm{ds} \tag{II.14}$$

- Heat loss through hot fluid:

$$d\phi = -\dot{m}_h \,.\, C_{P_h}.\, dT_h \tag{II.15}$$

- Heat gain through cold fluid:

$$d\phi = \dot{m}_c \,.\, C_{P_c}.\, dT_c \tag{II.16}$$

According to the last equations, we can write:

$$\frac{\mathrm{d}(\mathrm{T_h} - \mathrm{T_c})}{(\mathrm{T_h} - \mathrm{T_c})} = -\mathrm{h.}\left[\frac{1}{\dot{\mathrm{m}}_\mathrm{h}.\mathrm{C}_{\mathrm{p_h}}} + \frac{1}{\dot{\mathrm{m}}_\mathrm{c}.\mathrm{C}_{\mathrm{p_c}}}\right].\mathrm{dA} \tag{II.17}$$

By integration, we obtain:

$$\log\frac{(T_h^2 - T_C^2)}{(T_h^1 - T_C^1)} = -h.\left[\frac{1}{\dot{m}_h.C_{p_h}} + \frac{1}{\dot{m}_c.C_{p_c}}\right].A \tag{II.18}$$

So:

$$\phi = h.A(\Delta T)_{1m} \tag{II.19}$$

With:

$$(\Delta T)_{1m} = \frac{\Delta T_1 - \Delta T_2}{\log\left(\frac{\Delta T_1}{\Delta T_2}\right)} \qquad \text{(II.20)}$$

ΔT_1 And ΔT_2 :Fluid temperature differences at each end.

$(\Delta T)_{1m}$: This is the average logarithmic temperature difference between the two fluids over the entire heat exchanger. The surface area can then be calculated:

$$A = \int \frac{d\phi}{h.(T_1 - T_2)} \qquad \text{(II.21)}$$

T_1AndT_2 are the fluid temperatures on either side of the wall.

In general, the exchange surface can only be calculated if the following assumptions are made:

✓A characteristic mean temperature is defined.

✓The overall exchange coefficient h determined at the characteristic exchange temperature is assumed to be constant.

The surface area is given by:

$$A = \frac{\phi}{h.F.(\Delta T)_{1m}} \qquad \text{(II.23)}$$

In practice, we prefer to express the DTLM from the mean logarithmic difference of a counter current exchanger calculated with the same fluid inlet and outlet temperatures, multiplied by a corrective factor F.[26]

This corrective factor F is 1 in the case of a counter-current exchanger. The calculations can be performed as follows:

- ➥ Determination of average characteristic temperature from inlet and outlet temperatures.
- ➥ Calculating exchange capacity.
- ➥ Calculation of DTLM and corrective coefficient$F$.
- ➥ Calculating the exchange surface.

- **Heat exchanger efficiency:**

The efficiency of an exchanger is defined as the ratio of the heat flow actually transferred in the exchanger to the maximum heat flow that would be transferred under the same inlet temperature conditions for the two fluids in an infinitely long tubular exchanger operating in counter current. [26]

- **Calculation of maximum heat flow:**

The maximum heat flow is calculated by the following equation:

$$\phi_{\max} = \left(\dot{m}.C_p\right)_{\min}.\left(T_h^1 - T_C^2\right) \tag{II.24}$$

If:

$$\left(\dot{m}.C_p\right)_{\min} = \left(\dot{m}.C_p\right)_h \tag{II.25}$$

$$\phi_{\max} = \left(\dot{m}.C_p\right)_h.\left(T_h^1 - T_c^2\right) \tag{II.26}$$

$$\phi = \left(\dot{m}.C_p\right)_h.\left(T_h^1 - T_h^2\right) \tag{II.27}$$

Then efficiency is defined by:

$$\eta = \frac{T_h^1 - T_h^2}{T_h^1 - T_c^1} \tag{II.28}$$

If:

$$\left(\dot{m}.C_p\right)_{\min} = \left(\dot{m}.C_P\right)_c \tag{II.29}$$

$$\phi_{\max} = \left(\dot{m}.C_p\right)_c.\left(T_h^1 - T_c^2\right) \tag{II.30}$$

$$\phi = \left(\dot{m}.C_p\right)_c.\left(T_c^2 - T_c^2\right) \tag{II.31}$$

Efficiency is Witten:

$$\eta = \frac{T_c^2 - T_c^1}{T_h^1 - T_c^1} \tag{II.32}$$

II.5.2.2. NUT Method:

The NUT method provides an elegant and rapid response to most of the problems that arise in exchanger engineering studies. These can be into two main classes:

- ➢ Design problems in which inlet temperatures and an outlet temperature are outlet

temperature is imposed, the flow rates being known. The question is to select the most the most appropriate exchanger model, and find its size, i.e. the exchange surface area required to obtain the desired outlet temperature. [26]

The method to be used consists in determining the NUT, then the efficiency, and finally to calculate the required exchange surface. The calculation procedure can be as follows:

➥Estimation of outlet temperatures.
➥Calculation of overall heat transfer coefficient.
➥Determination of NUT and exchanger efficiency.
➥Calculating output temperatures.

- ➢ Performance problems where the data are the exchanger model and size exchanger, flow rates and inlet temperatures. The aim is to determine the power and outlet temperatures. The method enables NUT to be calculated from the initial data. From which the efficiency value and the two outlet temperatures are deduced.[26]

Imbalance ratio: this is the ratio of thermal flows:

$$R = \frac{(\dot{m}.c_p)_c}{(\dot{m}.c_p)_h} \tag{II.33}$$

- **Number of transfer units:**

  The number of transfer units is the dimensionless number given by:

$$NUT = \frac{h.A}{\dot{m}.c_p} \tag{II.34}$$

The number of transfer units on the hot side:

$$NUT_h = \frac{h.A}{\left(\dot{m}.c_{p_h}\right)} \tag{II.35}$$

The number of transfer units on the cold side:

$$NUT_c = \frac{h.A}{(\dot{m}.c_{p_c})} \tag{II.36}$$

In practice, only the NUT corresponding to the minimum thermal flow is useful. We NUT without specifying an index:

$$NUT = \frac{h.A}{(\dot{m}.c_p)_{min}} \tag{II.37}$$

The idea behind the NUT method is to express the exchanger's η efficiency as a function of the two parameters R and NUT for each exchanger configuration. Parameters R and NUT for each exchanger configuration. We then have a general function that is independent of specific temperature or flow conditions. Temperature or flow rate conditions, which can be used to quickly calculate the flows involved without outlet temperatures. [26]

In this case, all we need to do is calculate R and then NUT, since we know the characteristics of the exchanger and the flow rates. Of the heat exchanger and the flow rates, which allows us to calculate η from equation:

$$\eta = \frac{1-exp\left(-NUT(1-R)\right)}{1-R} \tag{II.38}$$

All that remains is to calculate the flux using the equation:

$$\phi = \eta.\phi_{max} \tag{II.39}$$

Output temperatures will be deducted:

$$\phi_h = \dot{m}_h . c_{p_h}(T_h^2 - T_h^1) \quad \text{(II.40)}$$

$$\phi_c = \dot{m}_c . c_{p_c}(T_c^2 - T_C^1) \quad \text{(II.41)}$$

The number of transfer units NUT for a given problem, where the different temperatures at the exchanger terminals are known, characterizes the thermal service required temperatures are known, characterizes the thermal service required. [26]

For single-pass traffic, this number is defined by:

$$NUT = \frac{h.A}{(\dot{m}.c_p)_{min}} \quad \text{(II.42)}$$

If the number of transfer units is too small$(NUT < 1)$, the exchanger is not very efficient, whatever the direction of circulation. On the other hand, if the number of transfer units is large enough$(NUT = from\ 5\ to\ 10)$, the heat exchanger is highly efficient. [26]

- **Relationship between efficiency $\boldsymbol{\eta}$ and $\boldsymbol{NUT}$:**

The relationship between efficiency and the number of NUT transfer units is given by equation:

$$NUT = -ln(1 - \eta) \quad \text{(II.43)}$$

II.6. Conclusion:

When sizing a heat exchanger for a specific application, there are several criteria to consider. Heat output is always the main concern, but the final choice of exchanger may depend on other parameters such as pressure losses, overall dimensions, mass, fouling, wall temperature not to be exceeded, materials used...etc. As far as exchanger sizing is concerned, we can conclude that both methods lead to the same results. However, the NUT method is used for sizing refrigeration systems where outlet temperatures are not known.

The most interesting studies use numerical modeling to predict malfunctions and study the performance of these devices. The following chapter presents the mathematical models used to simulate heat exchangers and numerically study all the phenomena involved.

Chapitre III. : *Simulation and Interpretations*

III.1. Introduction:

The aim of this chapter is to study a simulation on a double pipe heat exchanger with different geometries to optimize the heat transfer in the heat exchanger for better efficiency by Ansys fluent.

III.2. Geometry Of the Heat Exchanger:

Table III.1: Geometric parameters.

SN.	PARAMETER	DESCRIPTION
1	Inner dia. of inner tube	10.00 mm
2	Outer dia. of inner tube	12.00 mm
3	Inner dia. of outer tube	40.00 mm
4	Outer dia. of outer tube	42.00 mm
5	Length of both tubes	1000.00 mm

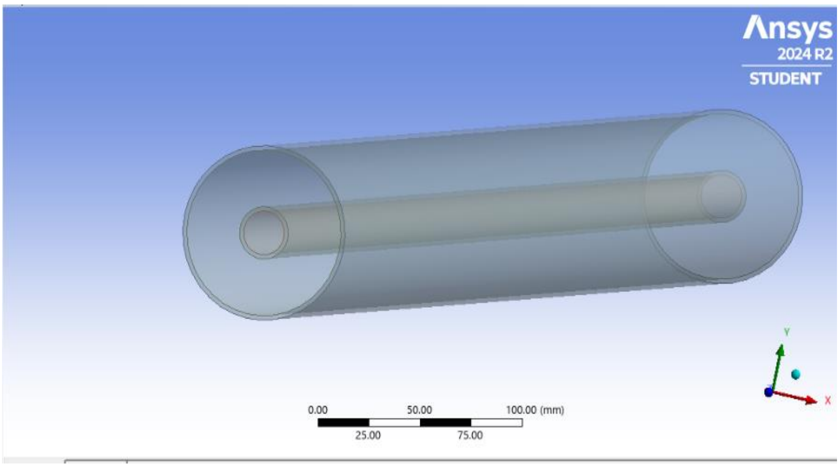


Figure III.1: Geometry of double pipe heat exchanger simple

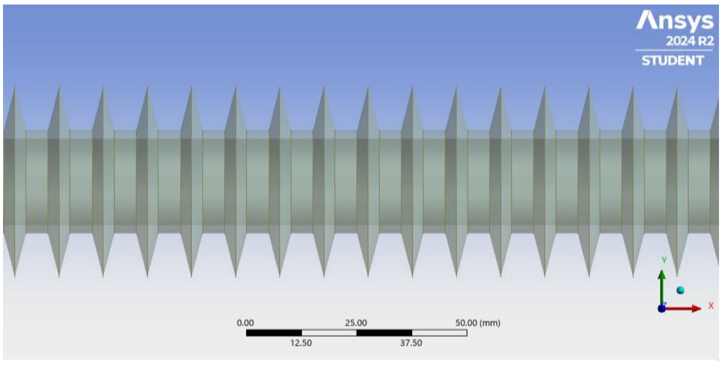


Figure III.2: Geometry of double pipe heat exchanger triangle

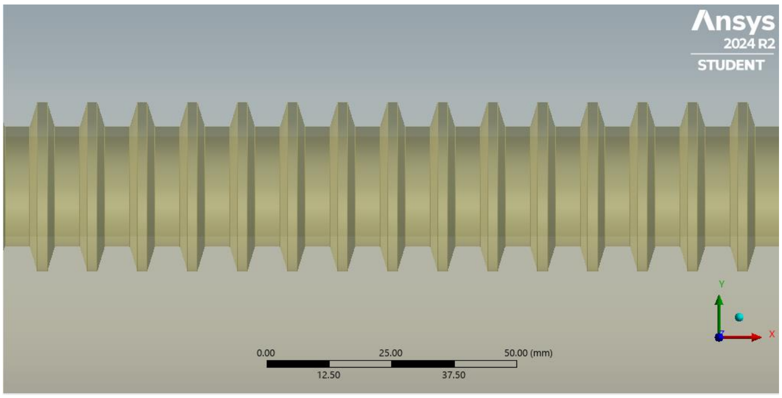


Figure III.3: Geometry of double pipe heat exchanger trapezoid

Named Selections - The different surfaces of the solid are named as per required inlets and outlets for inner and outer fluids.

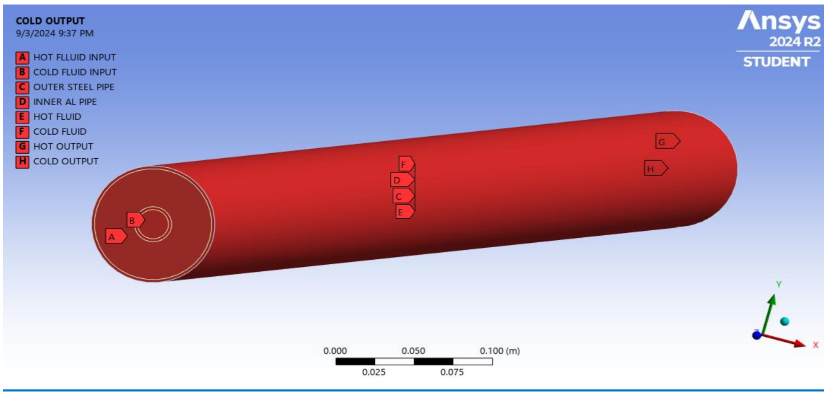


Figure III.4: Named selections for the geometry

III.3. Mesh:

Table III.2: Mesh report.

Domain	Nodes	Elements
Cold fluid	34104	24300
Hot fluid	31262	27540
Inner pipe	17864	9720
Outer pipe	22736	11745
Total	105966	73305

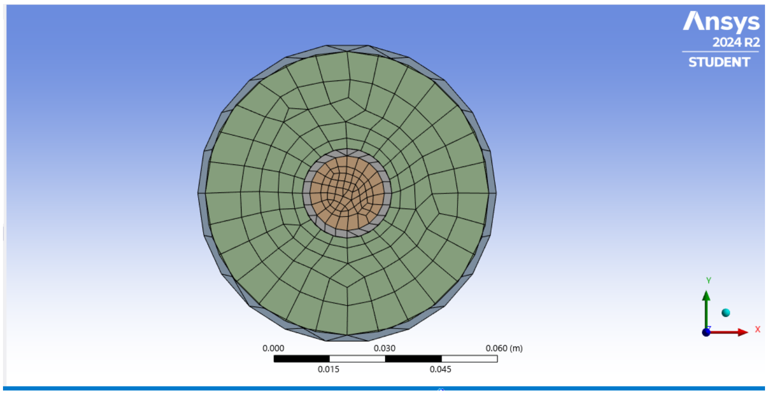


Figure III.5: *Meshing obtained*

III.4. SETUP AND SOLUTION:

Problem Setup - The mesh is checked and quality is obtained. The analysis type is changed to pressure-based type. The velocity formulation is changed to absolute and time to steady state.

Models - Energy is set to ON positions. Viscous model is selected as “k-Ɛ model” and it is kept as realizable.

Materials - The create/edit option is clicked to add water-liquid and copper, galvanized iron to the list of fluid and solid respectively from the fluent database.

Cell zone conditions - Inner and outer fluid assigned as water and inner and outer solid pipe assigned as material copper and galvanized iron respectively.

Wall treatment – near wall treatment is set as enhanced wall treatment Boundary Conditions - Boundary condition is used according to the need of the model. The inlet and outlet conditions are defined as mass flow inlet and pressure outlet.

Measure of convergence - It is tried to have a nice convergence throughout the simulation and hence criteria is made strict so as to get an accurate result. For That's the reason residuals are given as per the table 4 that follows.

Table III.3: Boundary conditions for parallel flow

Sr. No.	Boundary type	Conditions	Mass flow rate (kg/sec)	Temperature (kelvin)
Hot inlet	Mass flow inlet		0.2	330K
Hot outlet	Pressure outlet		_	_
Cold inlet	Mass flow inlet		0.005	289K
Cold outlet	Pressure outlet		_	_

Table III.4: Measure of convergence.

Variable	Residual

X – Velocity	10^{-6}
Y – Velocity	10^{-6}
Z - Velocity	10^{-6}
Continuity	10^{-6}
Turbulent Kinetic Energy	10^{-6}
Energy	10^{-6}

Run Calculation - The number of iterations is set to100 and the solution is calculated.

III.5. RESULTS AND DISCUSSION:

III.5.1. Definition of ANSYS software

ANSYS, an abbreviation for "Analysis System," is a collection of engineering simulation software created by ANSYS Inc. This software is utilized for finite element analysis (FEA) and computational fluid dynamics (CFD). It enables engineers and designers across different industries to simulate the performance of their products under real-world conditions before they are physically constructed or manufactured. ANSYS achieves this by analyzing a variety of issues related to mechanical product design and civil structure design using numerical techniques.

III.5.2. Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) is a branch of fluid mechanics that uses numerical methods and algorithms to analyze and solve problems involving fluid flows, heat transfer, and related phenomena. CFD involves the simulation of fluid behavior by solving the equations of fluid motion (typically the Navier-Stokes equations) on a computer, allowing engineers and scientists to predict how fluids will behave in a variety of real-world scenarios, such as in aerodynamics, weather forecasting, and industrial processes.

III.5.3. Fluid Fluent

Fluid Fluent (or ANSYS Fluent) is a specific CFD software within the ANSYS suite. It is one of the tools engineers and researchers use to perform CFD simulations. Fluent allows users to model fluid flow, heat transfer, and related phenomena in a wide range of engineering applications.

There are many indicators that we rely on to judge the effectiveness of heat exchangers, some of the most important of which are:

III.5.3.1.The temperature

Temperature directly affects the efficiency of heat transfer in heat exchangers. The greater the temperature difference between the two mediums (such as the fluids exchanging heat), the more heat is transferred, thus improving the heat exchanger's performance.

- **For double pipe heat exchanger simple**

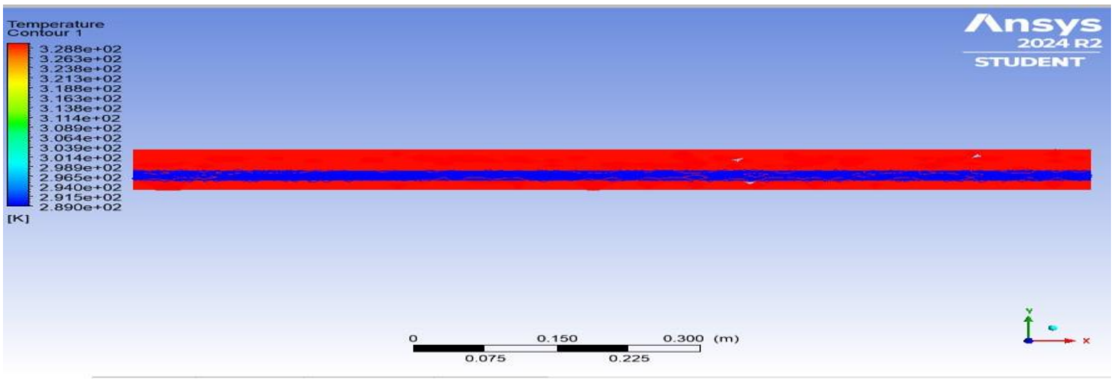


Figure III.6: the temperature distribution of a double pipe heat exchanger simple.

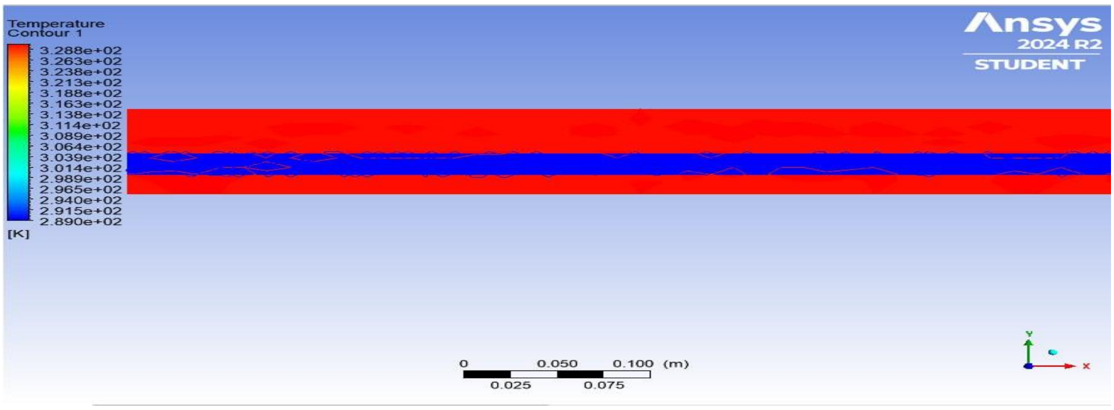


Figure III.7: the temperature distribution of a double pipe heat exchanger simple in the inlet section.

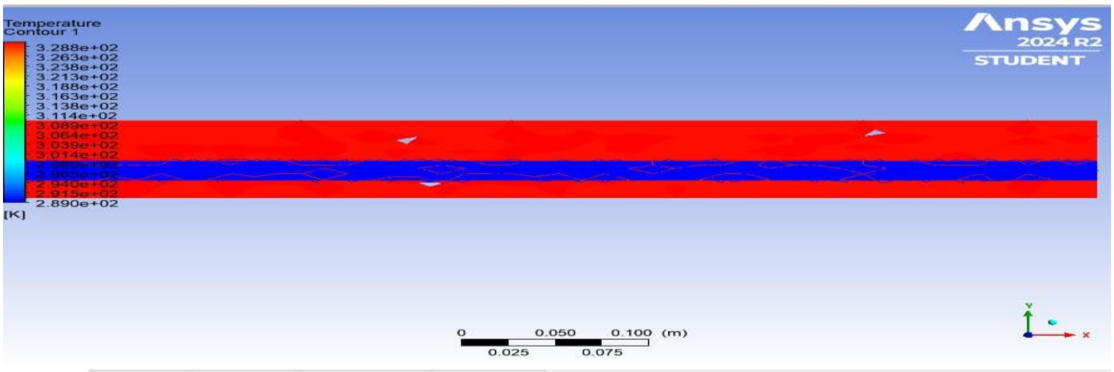


Figure III.8: the temperature distribution of a double pipe heat exchange simple in the outlet section.

Comment and analysis:

As shown in ***Figure III.***, the cold-water outlet temperature is estimated to be 290 K after entering at 289 K and the hot water outlet temperature is estimated to be 328.8 K. The difference between the cold water inlet temperature (289 K) and its outlet temperature (290 K) indicates that there is a weak heat exchange process between the hot and cold water, which enabled us to raise the cold water temperature by 1 K, which indicates that there is no large contact surface between the two liquids and also that there are no obstacles to the flow such as fins, which is an important factor for improving the performance and efficiency of the heat exchanger. This simple design of the double-tube heat exchanger provides us with a basis for improving the heat exchanger design in order to increase the contact surface.

For double pipe triangle heat exchanger

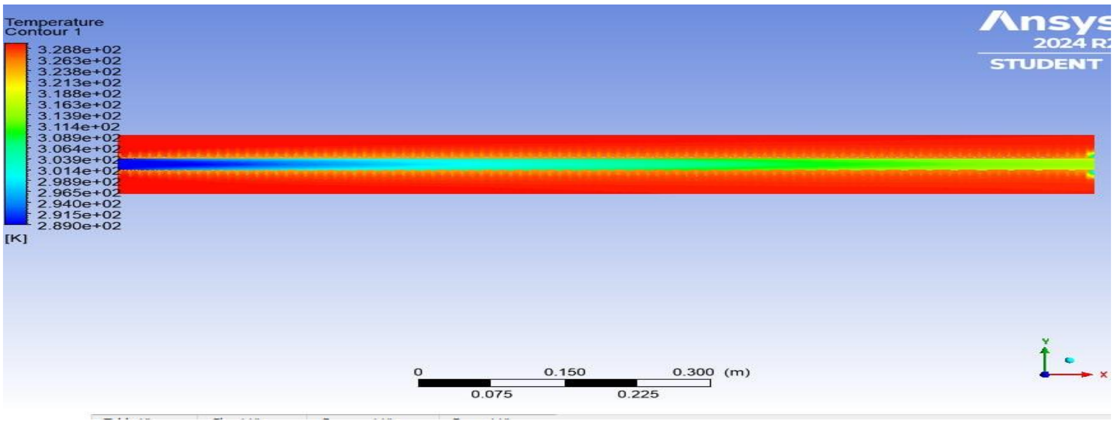


Figure III.9: the temperature distribution of a double pipe triangle heat exchanger.

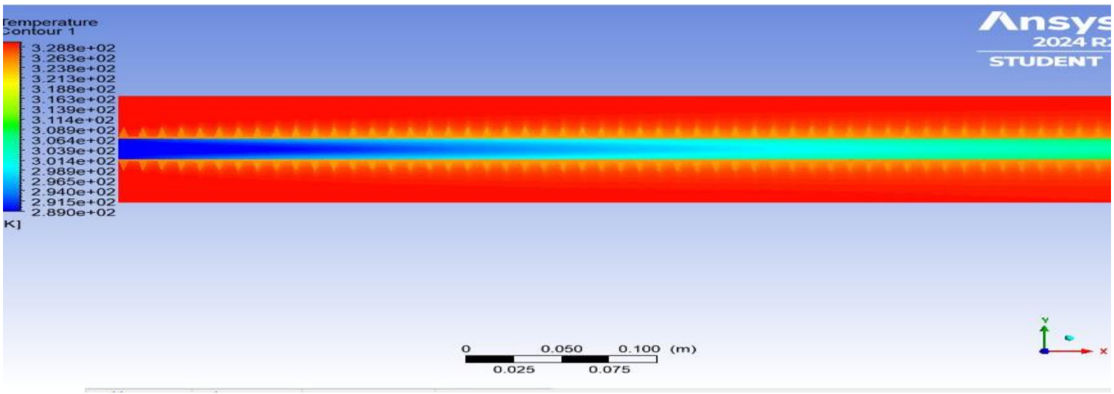


Figure III.10: the temperature distribution of a double pipe triangle heat exchanger in the inlet section.

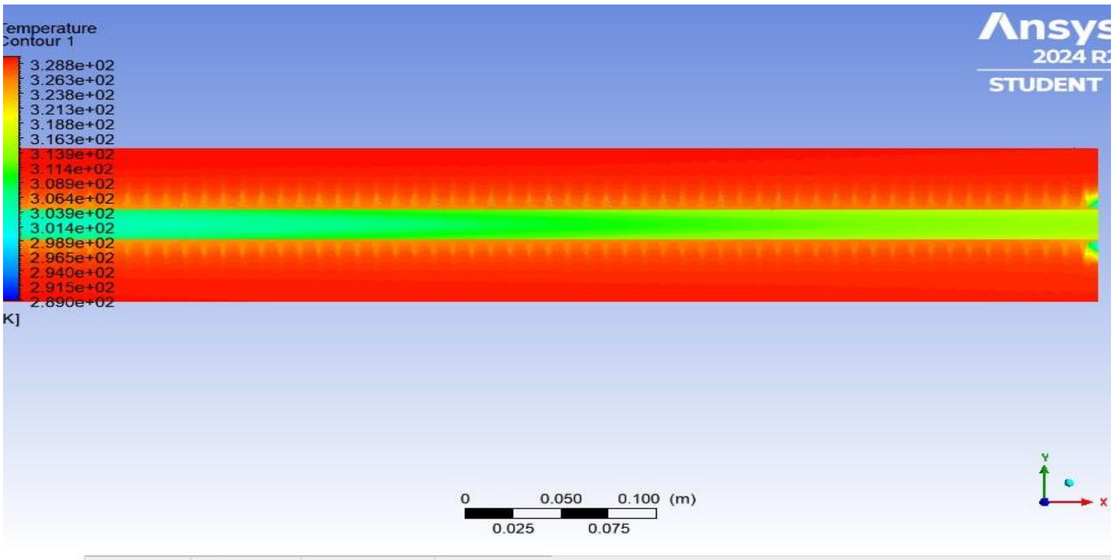


Figure III.11: the temperature distribution of a double pipe triangle heat exchanger in the outlet.

<u>Comment and analysis:</u>

As we can see from , the cold-water outlet temperature is estimated at 295.6 Kelvin after entering at a temperature of 289 Kelvin, and the hot water inlet temperature is estimated at 328.8 Kelvin. The difference between the cold-water inlet temperature (289 Kelvin) and its outlet temperature (295.6 Kelvin) indicates an effective heat exchange process between the hot and cold water, which enabled us to raise the cold-water temperature by 6.6 Kelvin, which indicates that the new contact surface (the trapezoidal heat exchanger) is good, but we notice that it is low compared to the triangular exchanger. Based on the results we obtained, it becomes clear to us that it is the main reason for the increase in the difference in the cold-water temperature, which indicates an improvement in the performance and efficiency of the heat exchanger.

For double pipe trapezoid heat exchanger

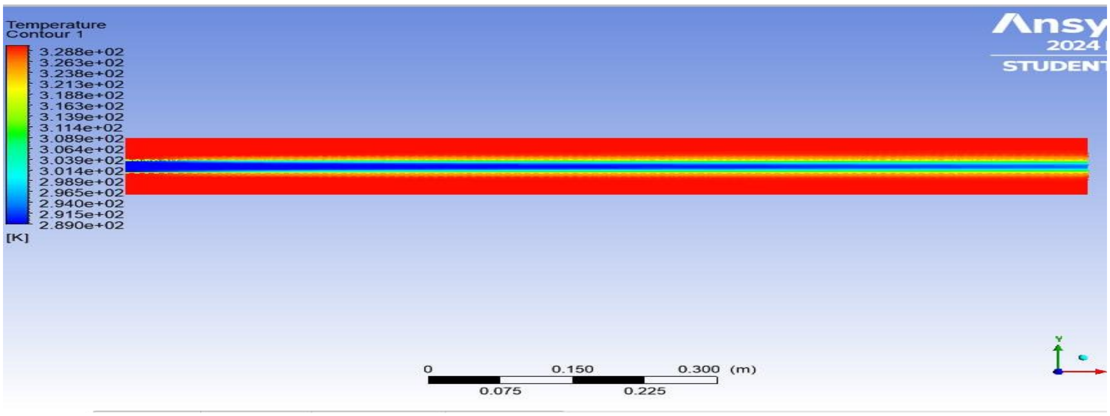


Figure III.12: the temperature distribution of a double pipe trapezoid heat exchanger.

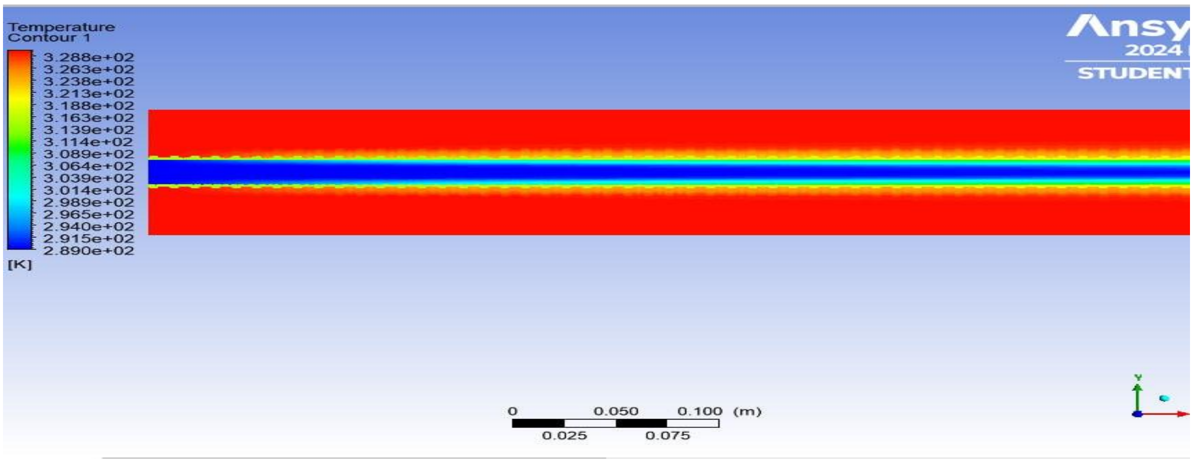


Figure III.13: the temperature distribution of a double pipe trapezoid heat exchanger in the inlet section.

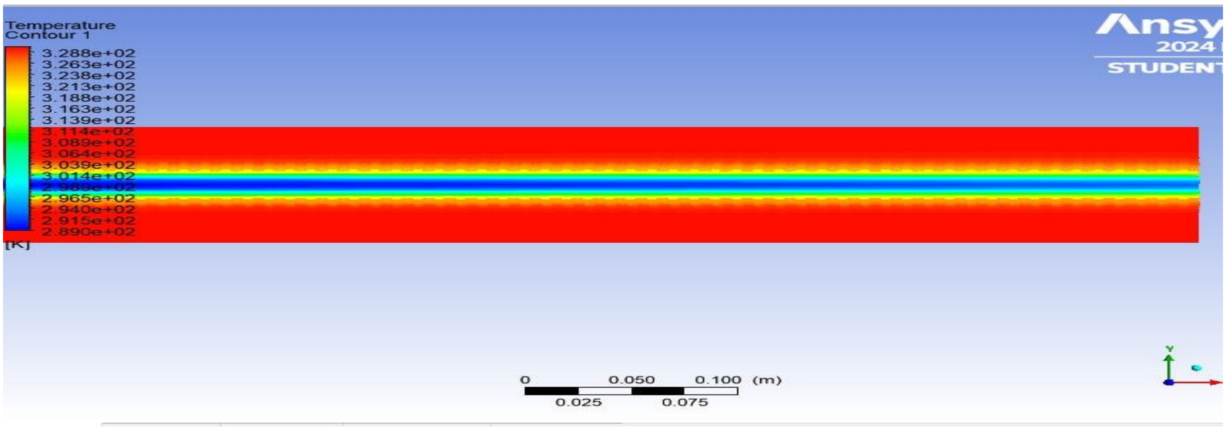


Figure III.14: the temperature distribution of a double pipe trapezoid heat exchanger in the outlet.

Comment and analysis:

As we can see from ***Figure III.12*** the exit temperature of cold water is estimated at 317 K after entering it at a temperature of 289 K and the entry temperature of hot water is estimated at 328.8 K. The difference between the entry temperature of the cold water (289 K) and its exit temperature (317 K) indicates that there is an effective heat exchange process between the hot and cold water, which enabled us to raise the temperature of the cold water by 28 K, which indicates that the new contact surface (trapezoid heat exchanger)

Based on the results we obtained, it appears to us that it is the main reason for a significant increase in the difference in cold water temperature, and this indicates that there is a very noticeable improvement in the performance and efficiency of the heat exchanger. Which also confirms that improving the geometry and design of the fins is a means of increasing the contact surface.

Compare the results obtained

The aim of this title is to investigate the importance of improvement in the geometry and design of fins for the three types of heat exchangers. Where ***Figure III.15*** shows the temperature values for each type along the heat exchangers.

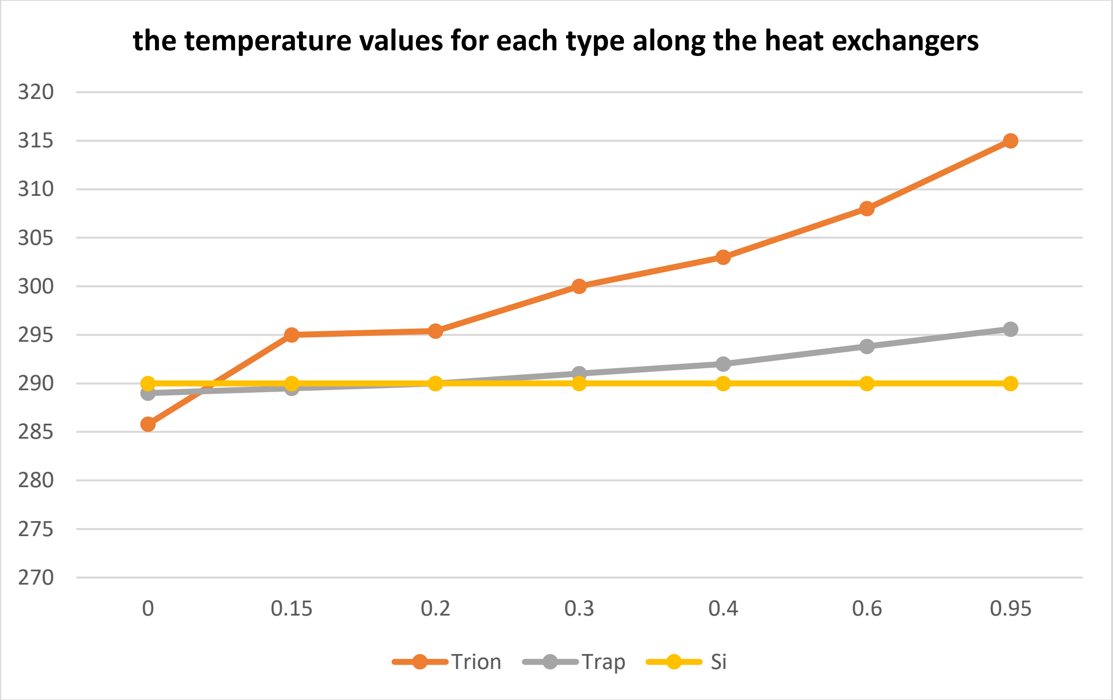


Figure III.15: Graphic curve representing temperature changes as a function of distance x for the three types of heat exchangers.

As it is clear from ***Figure III.15***, all the obtained curves are an increasing linear function and all the heat exchangers have the same cold water inlet temperature, which is 289 Kelvin. We notice that the curve for the simple heat exchanger has a cold-water outlet temperature of 290 Kelvin and as we concluded previously, the temperature difference reached 1 Kelvin. As we also notice regarding the heat exchanger curve (trapezoid), the water outlet temperature is estimated at 295.6 Kelvin and the temperature difference reached 6.6 Kelvin. As for the heat exchanger curve (triangular), the water outlet temperature is 315 Kelvin and the temperature difference was 26 Kelvin. The curve for the simple heat exchanger indicates limited efficiency in heat transfer. The temperature difference between the inlet and outlet (1 Kelvin) is relatively small, indicating that the surface available for heat transfer between the hot and cold water is limited, and therefore a large amount of thermal energy is not exchanged. The trapezoidal fin heat exchanger introduced trapezoidal fins resulting in an increase in the cold-water outlet temperature (295.6 K) with a temperature difference of 6.6 K. This increase indicates that the trapezoidal fins provide a larger surface area for heat transfer between the hot and cold water compared to the first exchanger. The fins increase the flow turbulence and improve the heat transfer process, which contributes to increasing the efficiency of the exchanger. The triangular fin heat exchanger showed the highest heat transfer efficiency, as the cold-water outlet temperature reached 315 K, with a large temperature difference of 26 K. The triangular fins, due to their unique shape, provide the largest surface area for heat transfer and significantly increase the flow turbulence, which significantly enhances the heat transfer efficiency. These results indicate that the triangular design provides more effective heat exchange than other designs.

III.5.3.2.The velocity

Fluid velocity is a primary factor affecting the sympathetic exchanger of the couple. Increased speed in heat transfer, but may lead to increased pressure drop and energy consumption. Therefore, the radiant speed must be chosen to achieve high voltage, operational costs and dynamism of the heat exchanger.

- **For double pipe heat exchanger simple**

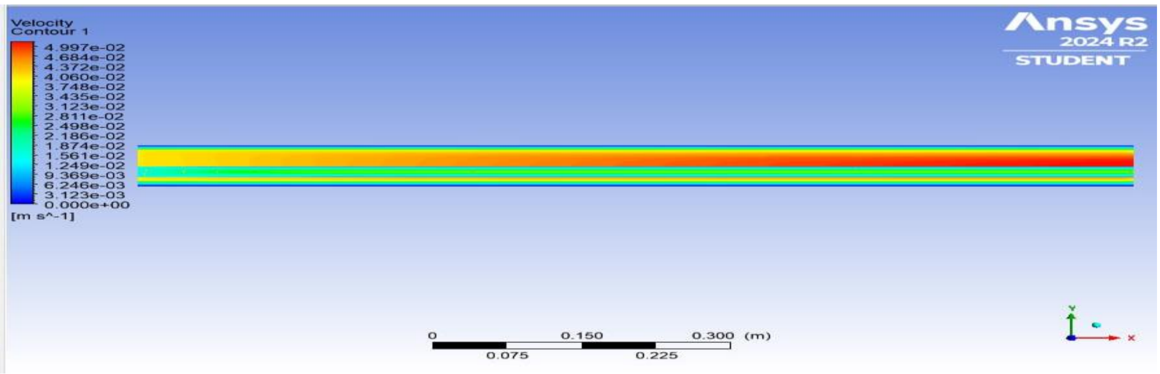


Figure III.16: the velocity distribution of a double pipe heat exchanger simple.

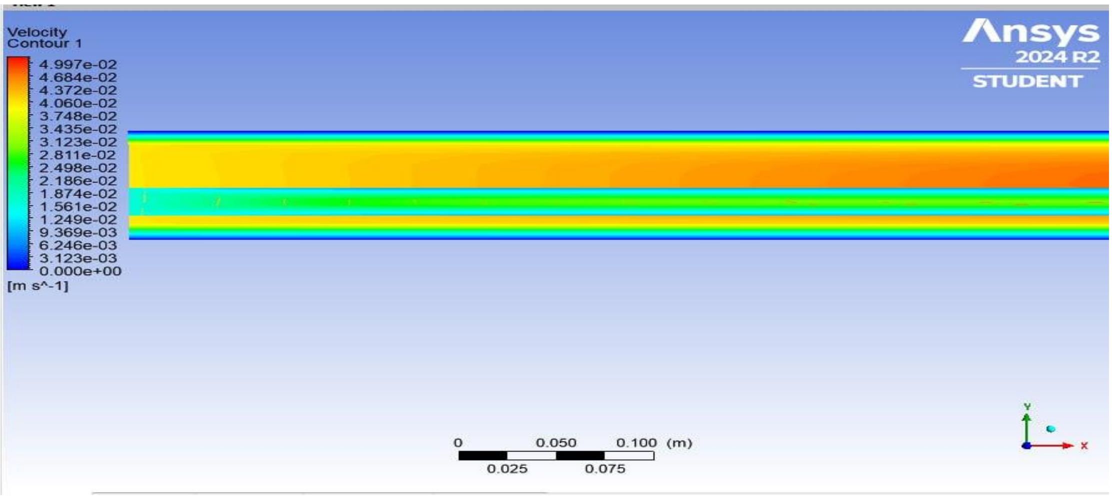


Figure III.17: the velocity distribution of a double pipe heat exchanger simple in the inlet section.

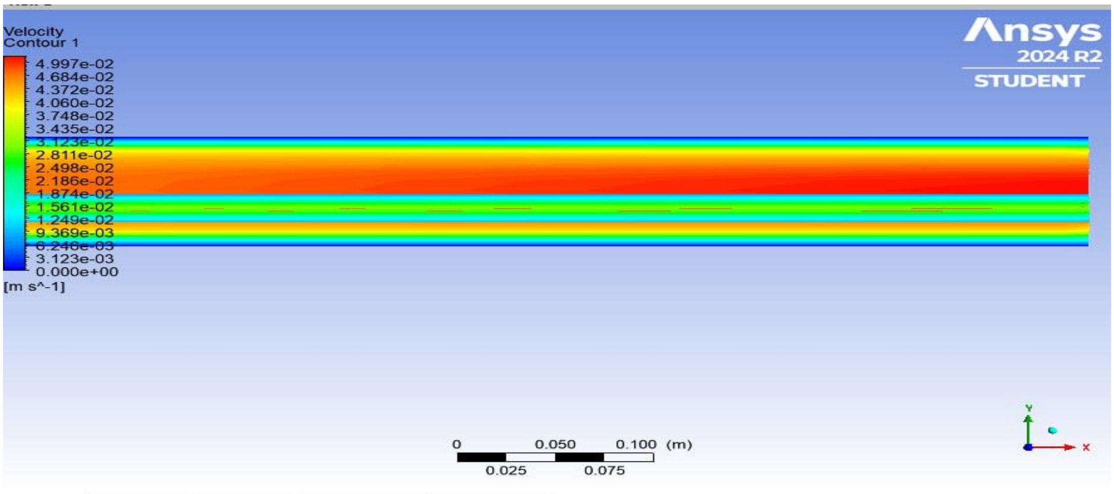


Figure III.18: the velocity distribution of a double pipe heat exchanger simple in the outlet section.

Comment and analysis:

As we can see from ***Figure III.16*** which represents the distribution of fluid velocities inside the simple heat exchanger and as the value of the velocity of cold water at the outlet is 0.022 and also as we can see that the velocity of water is zero at the inner walls of the tube. The value of the velocity obtained at the outlet shows that there is a significant heat exchange because the value of the velocity obtained is a good value and I predict a weak heat exchange between the two fluids. The increase in velocity affects by causing a disturbance in the flow inside the heat exchanger. This disturbance enhances heat transfer by reducing the thermal boundary layer that forms on the surface of the tubes or plates, what is known as the law of “sliding”, which leads to an increase in the rate of heat transfer between the two fluids.

For double pipe triangle heat exchanger

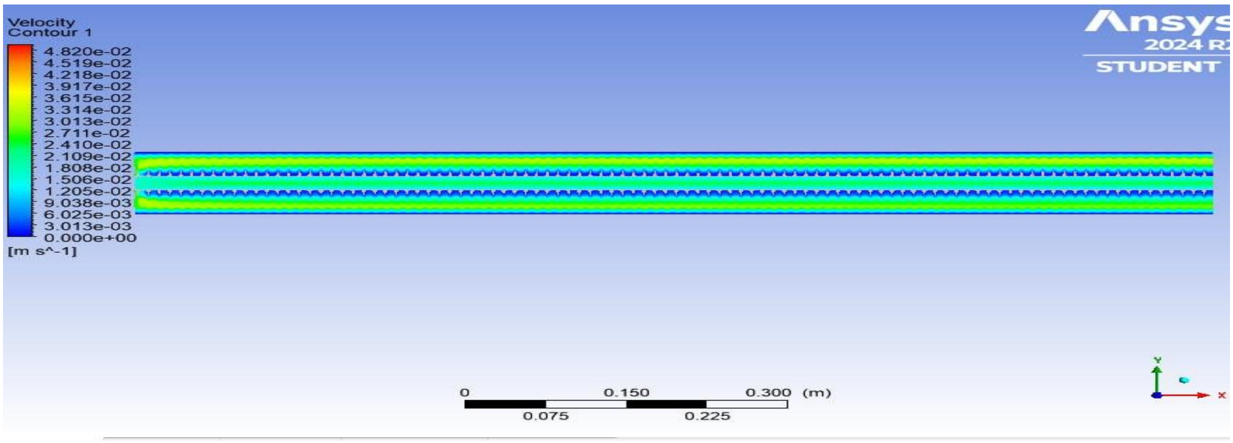


Figure III.19: the velocity distribution of a double pipe triangle heat exchanger.

section

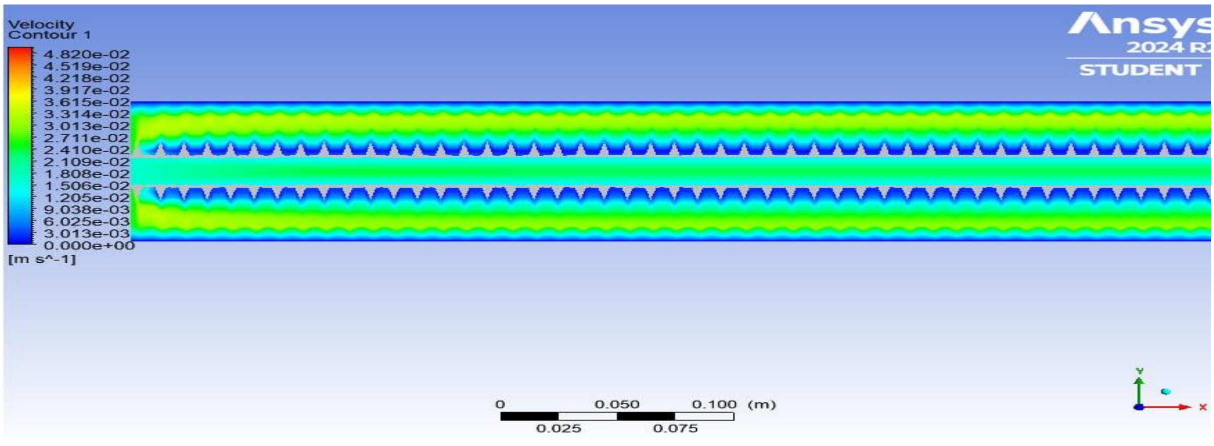


Figure III.20: the velocity distribution of a double pipe triangle heat exchanger in the inlet

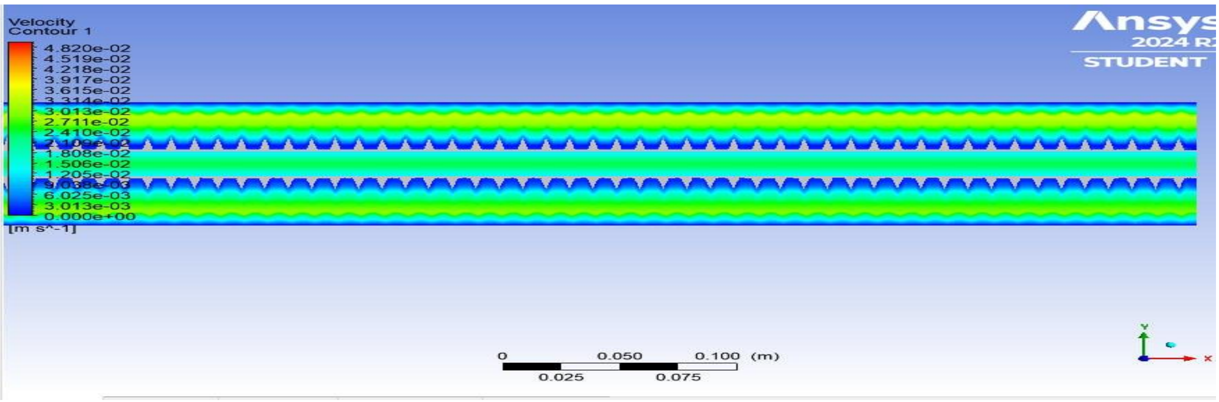


Figure III.21: the velocity distribution of a double pipe triangle heat exchanger in the outlet section

- Comment and analysis:

Figure III. which represents the distribution of fluid velocities inside the triangular heat exchanger and as we notice the value of the velocity of cold water at the outlet 0.0275 and also as we notice that the velocity of water is zero at the inner walls of the tube. The value of the velocity obtained at the outlet shows that there is a very good heat exchange because the value of the velocity obtained is high compared to the value obtained in the simple heat exchanger and this is due to the different design of the heat exchanger. This velocity led to an increase in the turbulence in the flow through the triangular fins which led to an enhancement in heat transfer by reducing the thermal boundary layer that forms on the surface of the tubes or plates, known as the law of "sliding", which leads to an increase in the rate of heat transfer between the two fluids.

- **For double pipe trapezoid heat exchanger**

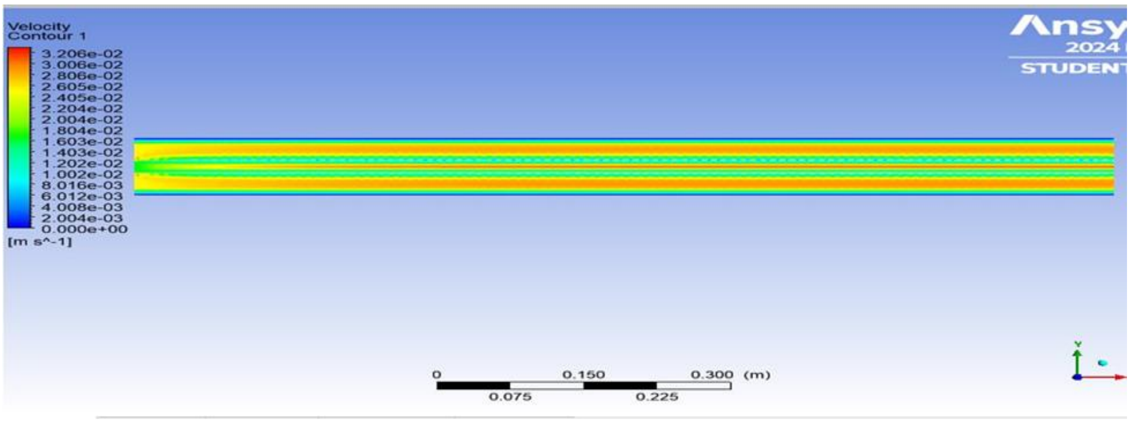


Figure III.22: the velocity distribution of a double pipe trapezoid heat exchanger.

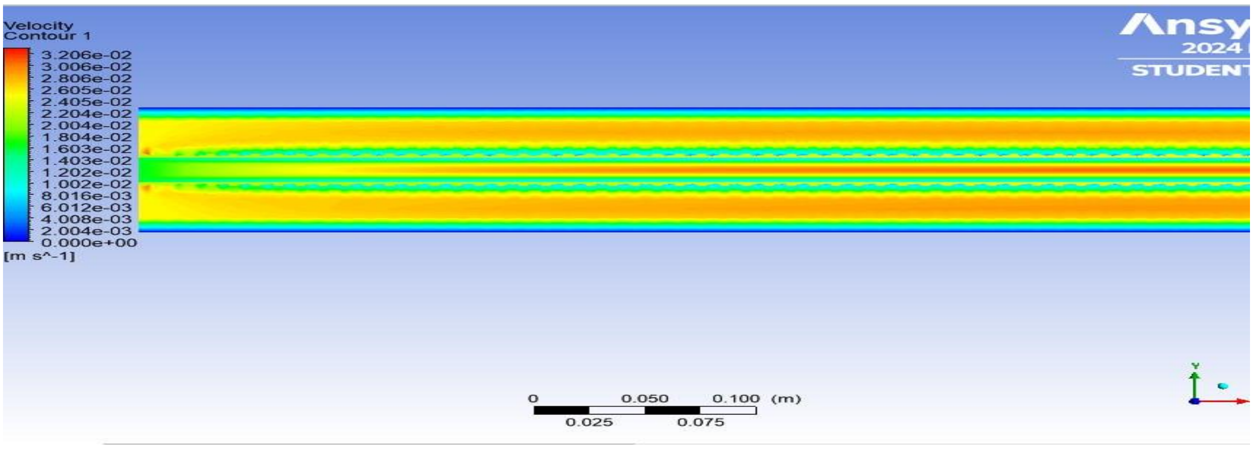


Figure III.23: the velocity distribution of a double pipe trapezoid heat exchanger in the inlet sectio

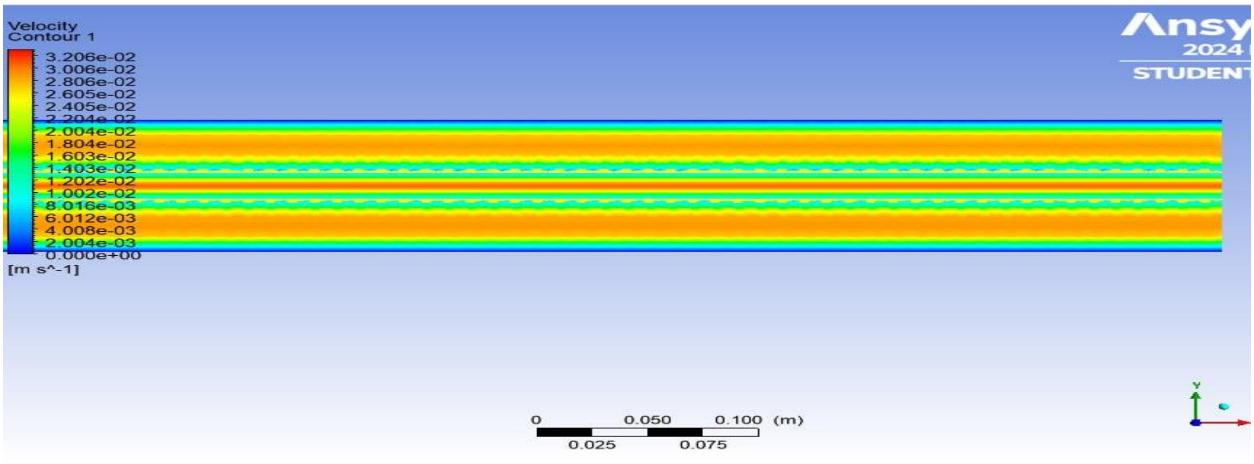


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Figure III.24: the velocity distribution of a double pipe trapezoid heat exchanger in the outlet section.

<u>Comment and analysis:</u>

By analyzing the fluid velocity distribution inside the trapezoidal fin heat exchanger as shown in ***s***ection. We notice that the velocity of cold water at the outlet is 0.0268 m/s. The velocity of water is zero at the inner walls of the tube. The high velocity value at the outlet reflects good heat exchange, because this velocity is lower compared to the value obtained in the triangular heat exchanger. This is due to the different design of the fins in the heat exchanger, which leads to increased turbulence in the flow thanks to the trapezoidal fins, which enhances heat transfer. This design reduces the thickness of the thermal boundary layer that forms on the surface of the tubes or plates, which is known as the "sliding" law, which contributes to increasing the efficiency of the heat exchanger.

<u>Compare the results obtained</u>

As is clear from ***Figure III.24***, all the obtained curves are an increasing linear function, where we notice that the curve for the simple heat exchanger, the exit velocity of cold water is estimated at 0.022 m/s, and we also notice that the velocity distribution is divided into two parts from [0.05 -, 0.1] is increasing and from m 0.1 the velocity is constant over the rest of the distance. As we also notice regarding the heat exchanger curve, the exit velocity of water is estimated at 0.0275 m/s and the distribution of its velocity is also divided into two parts, the first from [0.0,2] is increasing along the stage and from 0.2 to the end the velocity is constant no matter how much the distance increases. As for the heat exchanger curve, the exit velocity of water is 0.0268 m/s, which is slightly less than the curve for the triangle, and it is also divided into two stages from [0. 0.3] The curve is increasing and from 0.3 to the end it is constant. The reason for the increase of the three curves and then their stability is that at the start of operation, the speed is low, but as time passes and the fluid flows gradually, the speed gradually balances due to the improvement of the distribution of fluids through the pipes or channels in the heat exchanger. This process helps to achieve a stable and homogeneous flow. Also, after a period of operation, the system reaches a steady state, where the forces acting on the fluids such as pressure, flow, and viscosity are balanced. When the system reaches this state, the speed is constant because the operating conditions become stable. Increasing the speed of the fluid leads to more effective stirring, which reduces the thickness of the static boundary layer around the surfaces with which heat is exchanged. This enhances heat transfer between the fluid and the exchanger surface. High speed increases the heat exchange rate due to improved flow turbulence, which contributes to increasing the heat transfer coefficient. This means that heat can be transferred faster from the hot fluid to the cold fluid or vice versa.

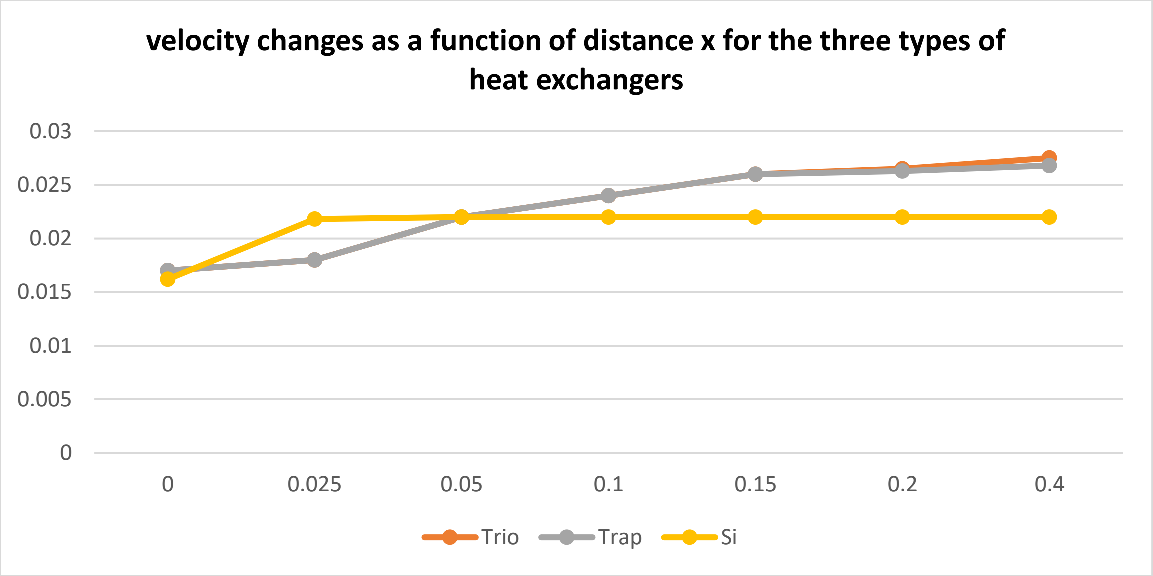

Figure III.25: Graphic carver representing velocity changes as a function of distance x for the three types of heat exchangers.

III.5.3.3.the pressure

- **For double pipe simple heat exchanger**

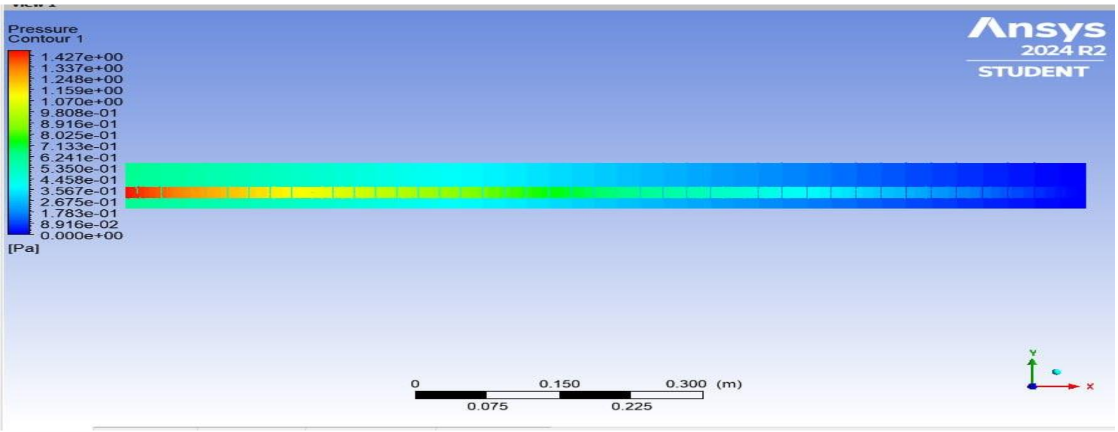

Figure III.26: the pressure distribution of a double pipe heat exchanger simple.

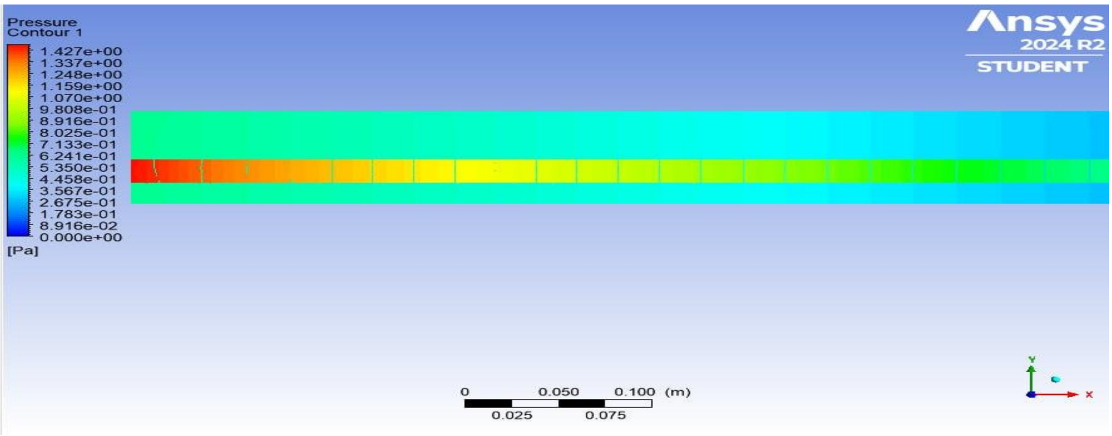

Figure III.27: Pressure distribution of a simple double tube heat exchanger from the inlet section.

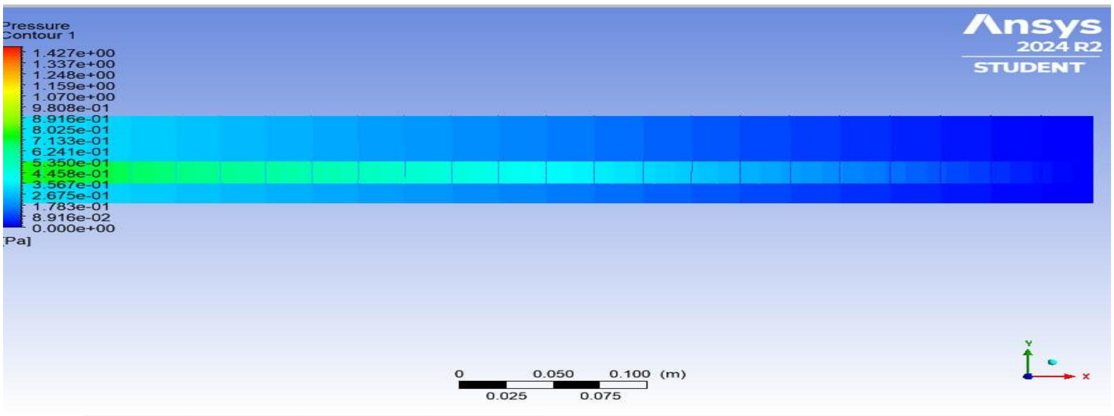

Figure III.28: Pressure distribution of a simple double tube heat exchanger from the outside section.

Comment and analysis

We notice through ***Figure III.26*** which represents the distribution of fluid pressure inside the simple heat exchanger and as the pressure value at the entrance is 1.427 PA and the pressure value at the exit is equal to the atmospheric pressure value and also as we notice that the pressure value gradually decreases from 1.427 PA to 0. The pressure value at the entrance shows that there is good heat exchange because the pressure value is high and does not predict poor heat exchange between the two fluids. This is because pressure affects the flow rate of fluids in the heat exchanger. Increasing pressure may help improve fluid flow, which enhances heat exchange effectively. The reason for its increase at the entrance is the increase in turbulent flow and after the fluids stabilize, the pressure gradually decreases.

For double pipe Triangular heat exchanger

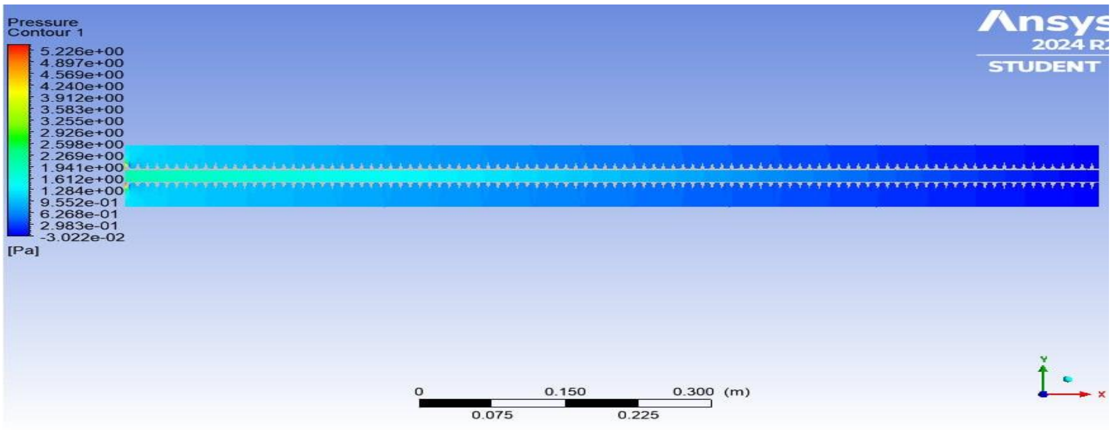

Figure III.29: the pressure distribution of a double pipe heat exchanger Triangle.

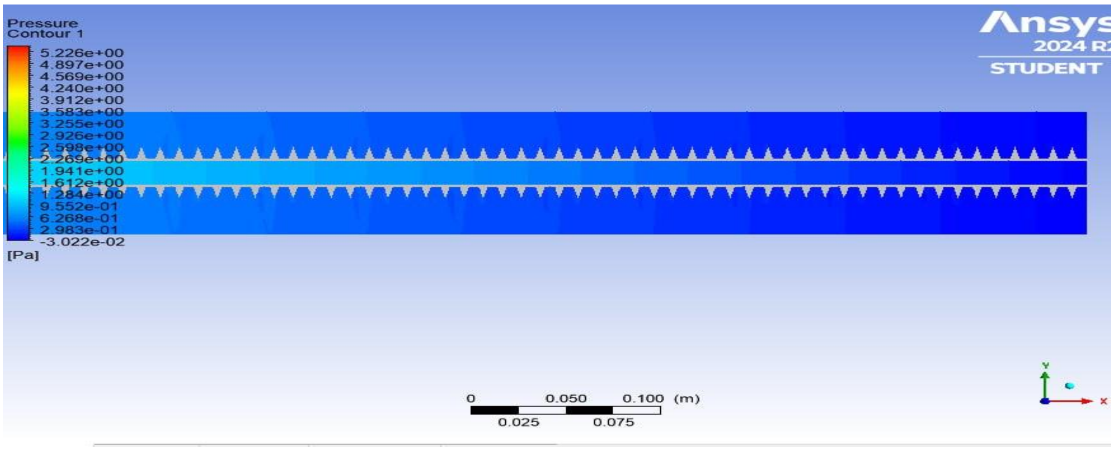

Figure III.30: Pressure distribution of a Triangle double tube heat exchanger from the outlet section.

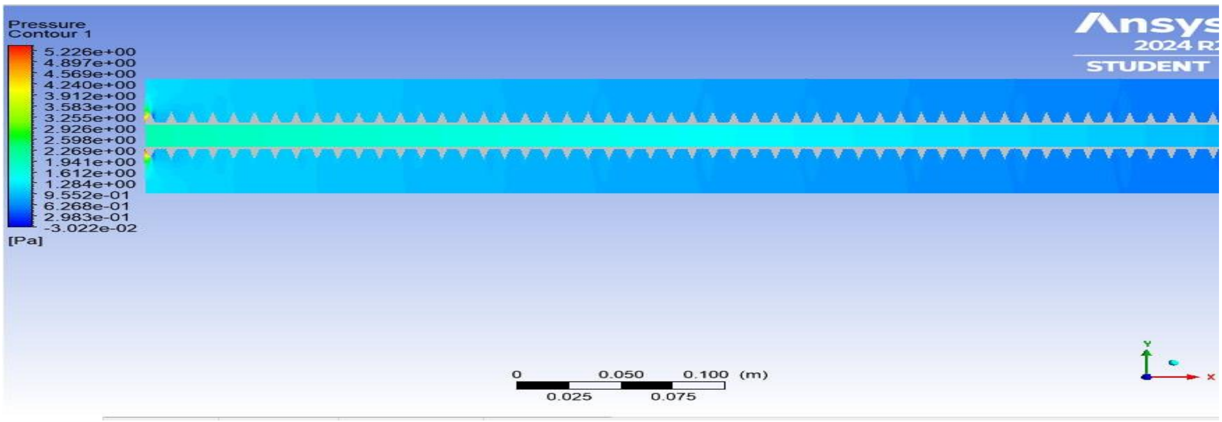

Figure III.31: Pressure distribution of a Triangle double tube heat exchanger from the inlet section.

Comment and analysis

We notice from ***Figure III.29*** which represents the distribution of fluid pressure inside the triangular heat exchanger that the pressure value at the inlet is 1.95 Pa and the pressure value at the outlet is equal to the atmospheric pressure value. We also notice that the pressure value gradually decreases from 1.95 Pa to 0. The pressure value at the inlet shows that there is good heat exchange because the high-pressure value increases the flow velocity and thus increases heat transfer. The reason for its increase at the inlet is the increase in turbulent flow due to the presence of triangular slits that affected the flow. After the fluids stabilize, the pressure gradually decreases to the normal level.

For double pipe trapezoid heat exchanger

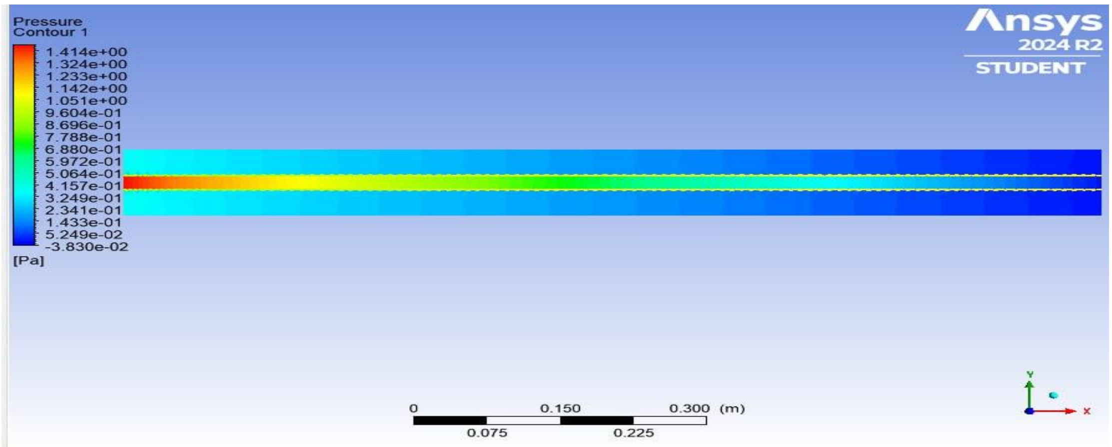

Figure III.32: the pressure distribution of a double pipe heat exchanger Trapezoid.

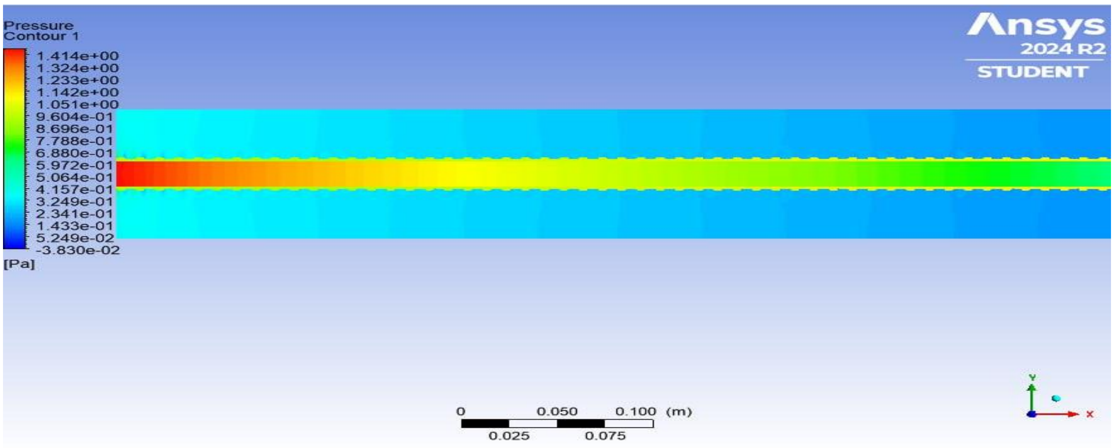

Figure III.33: Pressure distribution of a Trapezoid double tube heat exchanger from the inlet section.

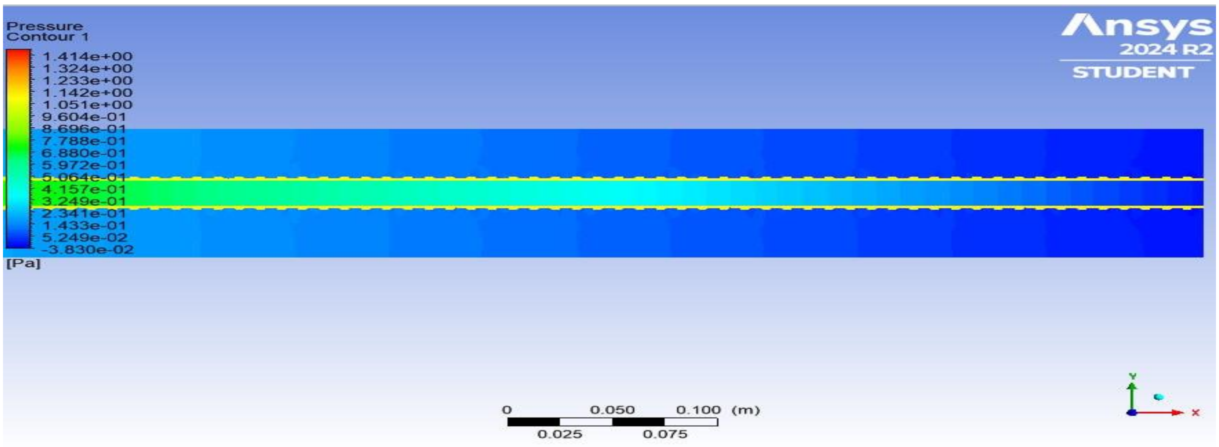

Figure III.34: Pressure distribution of a Trapezoid double tube heat exchanger from the outlet section.

Comment and analysis

From ***Figure III.31***, which illustrates the distribution of fluid pressure within the trapezoidal heat exchanger, we observe that the pressure at the inlet is 1.427 Pa, while at the outlet it equals atmospheric pressure. The pressure decreases gradually from 1.427 Pa to 0. The high pressure at the inlet suggests effective heat exchange, as elevated pressure enhances flow velocity and, consequently, heat transfer. This increase in pressure at the inlet is due to the enhanced turbulent flow caused by the trapezoidal fins, indicating a significant interaction between the fins and the fluid flow. Once the fluid flow stabilizes, the pressure progressively decreases to atmospheric levels.

Compare the results obtained

As is clear from ***Figure III.3III.5***, all the obtained curves are a decreasing linear function and all heat exchangers have the same gradient in the curves, as we notice that the curve of the simple heat exchanger, the pressure degree during its entry is the max estimated at 1.427 Pa, and as we noticed, it decreases to the value of atmospheric pressure. As for the heat exchanger with triangular fins, the value of the pressure during the entry is 1.95 Pa until this value decreases until it reaches the value of atmospheric pressure, i.e. it disappears. As we also have the curve of the heat exchanger with trapezoidal fins, the highest-pressure value is 1.427 Pa until this value gradually decreases to the value of atmospheric pressure, i.e. to 0, as we notice in Figure III.34 .

The high-pressure value for the three heat exchangers, the simple exchanger, the triangular fin exchanger, and the trapezoidal fin exchanger, indicates that the value of the turbulent flow is high and unstable during the entry, but for a limited period and then stabilizes inside the exchangers. Fins also have an effect on the pressure value as observed in the pressure value between the simple heat exchanger and the triangular and trapezoidal finned exchangers, where the fins increase the flow turbulence and velocity, which increases the pressure value. Increasing the pressure can increase the velocity of the fluids in the system if the pressure induces faster flow through the tubes. In the tubular heat exchanger, increasing the pressure may enhance the flow velocity, which improves heat exchange as observed in the triangular exchanger. Increasing the pressure can enhance heat exchange if it improves the flow of fluids around the tubes. Increasing the flow velocity may contribute to improving the heat transfer between the fluids and the nano-surfaces.

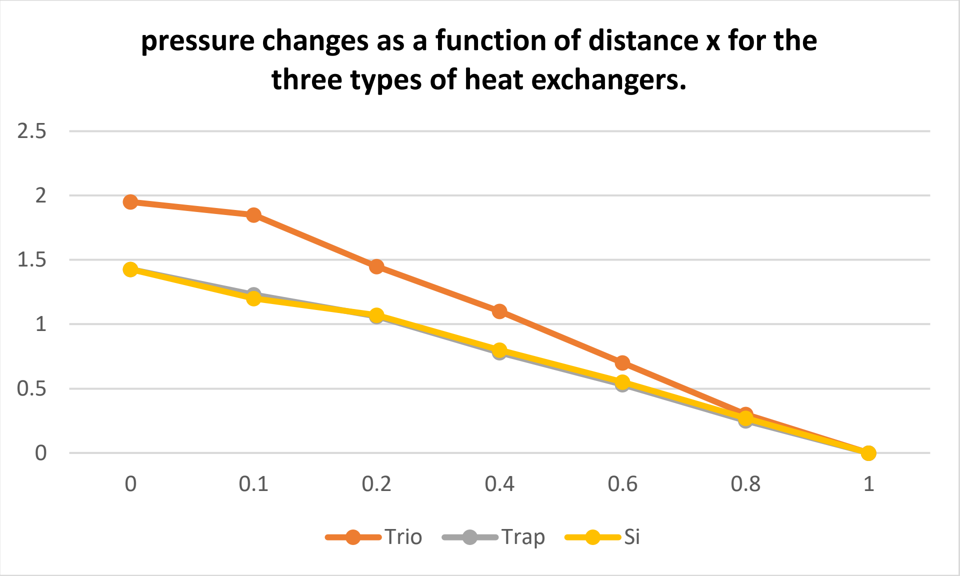

Figure III.3III.5: A graph representing pressure changes as a function of distance x for the three types of heat exchangers.

III.6. Study the efficiency of heat exchangers:

Its value is calculated in two different ways according to several references:

-Efficiency relative to heat flow:

$$\varepsilon(\%) = \frac{\varphi_{cold}}{\varphi_{hot}} \times 100$$

-Efficiency in relation to temperature:

$$\varepsilon(\%) = \frac{T_{c_1} - T_{c_2}}{T_{c_1} - T_{h_1}} \times 100$$

The temperature method was used and the following results were obtained:

$$\varepsilon_{trapezoid} = 45\%$$

$$\varepsilon_{triangle} = 65\%$$

From this we can conclude that a triangular heat exchanger has better efficiency than a simple trapezoidal heat exchanger

III.7. Conclusion:

In this chapter, we have presented the dynamic and thermal behaviors of the flow of two hot and cold fluids, in forced convection, in turbulent mode in a simple, triangular and trapezoidal tubular heat exchanger. The numerical results presented in this study prove that the use of corrugations (shapes of the exchange surface) contributes to the heat exchange and hence, despite the resulting pressure loss. The effects of this improvement are:

The geometric shape of the tubes plays a very important role in improving the heat transfer where the triangular shape was better in our study.

The numerical results presented in this study prove that the use of corrugations (shapes of the exchange surface) contributes to the heat exchange and hence, despite the resulting pressure loss. The effects of this improvement are:

General conclusion

General conclusion

In conclusion, by using various fin geometry under turbulent flow circumstances, this thesis has significantly advanced the optimization of heat transfer in a two-tube heat exchanger. Three distinct fin designs triangular, trapezoidal, and simple have been thoroughly compared, with an emphasis on how each affects important variables like temperature, pressure, and velocity.

The study's findings showed that, in comparison to the other designs, the heat exchanger with triangle fins performed best in terms of heat transmission and overall efficiency. The dynamic design of the triangle fins, which increases heat exchange efficacy and reduces the effect of turbulent flow, is responsible for this higher performance.

These results demonstrate the potential for increased efficiency through thoughtful engineering decisions and emphasize the significance of fin design in maximizing heat exchanger performance. Drawing from this work, we suggest more research to assess the impact of other variables such fluid types and operating circumstances, as well as investigating real-world applications in diverse industrial settings.

All things considered, this work has made a substantial contribution to our knowledge of heat exchanger efficiency and the function of fin engineering in improving thermal system performance, opening the door for future innovation and advancement in this important area.

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