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Theme:

STUDY OF THE PERFORMANCE OF A HORIZONTAL AIR-GROUND GEOTHERMAL EXCHANGER WITH AN ADIABATIC OUTLET.

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First, we thank Allah for granting us success in our study and completing this note.

To our parents, we really appreciate your unwavering support and patience.

Our sincere thanks to our supervisor, Mr. Mabrouk Mohamed Drid, for his invaluable advice and guidance.

Finally, we express our gratitude to our classmates for the unforgettable journey that we shared.

With depth

[Bettahar Abdelouahab , BEZZIOU IHEB]

DÉDICACE

To our beloved families,

Thank you for your unwavering love and support. This devotion is dedicated to you, especially my grandmother, and to all who have brought smiles into our lives.

With heartfelt gratitude,

[Bettahar Abdelouahab , BEZZIOU IHEB]

Summary

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Nomenclature

Thermal conductivity constant	λ	(W/m◦C)
Density	ρ	(kg/m3)
Specific heat at constant pressure	Cp	(J/kg◦C)
Conductive heat flux	Q_{cond}	(W/m2)
Temperature	T	(◦C)
Convective heat flux	Q_{conv}	(W/m2)
Overall horizontal length	Hx	(m)
Evaporative heat flux	Q_{evap}	(W/m2)
Overall vertical length	Hy	(m)
Solar irradiance	Gb	(W/m2)
Vertical velocity component	v	(m/s)
Horizontal velocity component	u	(m/s)
Horizontal element size	Δx	(m)
Pressure	P	(Pa)
Vertical element size	Δy	(m)
Soil-to-air convection coefficient	h_{Sup}	(W/m2◦C)
Horizontal nodal distance	δ_x	(m)
Emissivity coefficient	ε	
Vertical nodal distance	δ_x	(m)
Absorptivity coefficient	α	
Source term	g	(W)
Dynamic viscosity	µ	(Pa·s)
Pipe diameter	D	(m)
Duct thickness	e	(m)
Duct length	L	(m)
Heat convection coefficient	h	(W / m2 K)
Thermal conductivity of solid	λ_s	(W / m K)
Thermal conductivity of the fluid	λ	(W / m K)
Heat flux	Q	(QW)
Transfer coefficient by convection	h_{cv}	(W.m-2K -1
Solid/fluid exchange surface	s	(m2)
Inside radius of duct	r	(m)
Time	t	(s)
Stefan Boltzmann Constant	σ	(cm ^{3})
the volumetric water	θ	

Introduction general

General Introduction :

Modern existence depends on energy, and during the past century, energy demand has grown significantly. But because of the release of greenhouse gases like carbon dioxide, which contribute to climate change, the rising demand for energy has had a detrimental effect on the environment. Growing interest in clean energy sources that don't hurt the environment has been observed during the past several years. Geothermal power is a type of renewable energy.

In hot places that are outside the electrical grid, like southern Algeria, cooling requirements rise to fulfill the thermal requirements of structures and industrial infrastructures. Since positive cooling modes are so energy-intensive, it is necessary to adopt strategies and methods to cut costs. The air-to-ground heat exchanger, one of these technologies, is a passive cooling system based on geothermal energy that aids in bringing down the temperature inside both residential and commercial buildings.

The process itself does not represent a harm to the environment; availability and availability of sources (and if the source is renewable, it is preferable); the cost of running this energy must be acceptable. Among these are geothermal energy, geothermal cooling and heating, hydraulic biomass, and solar energy.

The findings of this research will advance understanding of geothermal energy as a useful and sustainable cooling technique in addition to providing insight into the effectiveness of the horizontal air-ground geothermal exchanger. The study results may be used by decision-makers in engineering, architecture, and policy to develop and implement sustainable cooling strategies in places with limited access to the electrical grid. By using less energy and non-renewable resources, we may contribute to a more resilient and sustainable future.

Investigating the performance of a horizontal air-ground geothermal exchanger with an adiabatic outlet is crucial given the growing need for cooling solutions in regions with limited access to the electrical grid.

We can lessen the detrimental impacts of energy consumption on the environment while providing durable and cost-effective cooling solutions by using geothermal energy and developing efficient cooling technology. Our research, we are certain, will contribute to the development of a greener and more sustainable future for coming generations.

In this research, we will make a comparison between the effectiveness of the air-to-ground heat exchanger with and without an adiabatic outlet with changing the Reynolds number.

To achieve the objective of this work, we have addressed this problem in the third basic chapters:

The first chapter will include a bibliographic study on the underground heat exchanger and its working mechanism and a view of some ancient studies.

The second chapter will begin with definitions about thermal transport and fluid flow characteristics, and then to thermal and sporting modulation of the ground air exchanger with a heat output.

Chapter III will be devoted to numerical simulation with Anays software, showing the way it works and showing results and explanations of temperature, air speed and Reynolds numbers.

Our study ends with a general conclusion.

Chapter I: Generality and bibliographic research

I.1 Introduction:

It is a renewable energy source that is derived from underground heat. Additionally, we may utilize this energy to heat and cool buildings, as well as in spas and hot springs, in addition to using it to generate electricity. Deep under the Earth's core, a chemical and nuclear reaction that has been occurring for billions of years is the cause of the heat there. Heat is one of the most frequent by-products of these interactions, and it slowly moves across the planet until it reaches locations where we can access the ground. Any heat we spend will be restored or replenished because those processes that occur deep under the Earth's core will continue to take place. We can utilize geothermal energy indefinitely, along with sun, wind, and hydropower. This makes it a renewable energy source. In this chapter, we are interested in the study of air/soil heat exchangers. The objective is to conduct a bibliographic review summarizing the theoretical, analytical, and preparatory and experiments of certain researchers working in this exchanger.

I.2 History:

Utilizing the waters of hot springs has allowed for the long-standing usage of geothermal energy, a renewable energy source. More than 10,000 years ago, American Indians began using the hot springs to prepare their food. The waters of geothermal systems were once thought by some scientists to have their origins in volcanic activity deep within the earth. Recent research, however, using hydrogen and oxygen isotopes in it revealed that at least 95% of this water is generated from the atmosphere. The Larderello field's natural steam eruption has been taken use of since 1904 by an Italian enterprise. Since then, geothermal energy has gained popularity and value in many nations throughout the world, including Japan, Iceland, New Zealand, and the United States of America. These nations have used geothermal energy as an alternative source of energy for things like power production and house heating. With the advancement of heat exchanger technology, the usage of geothermal energy is gradually growing.[1] Peter Ritter von Rittinger created the heat pump in 1855 after Lord Kelvin had first described it in 1853. In 1912, Heinrich Zoelly obtained a patent for the method of using it to extract heat from the ground. The first direct exchange ground source heat pump was created by Robert C. Webber in the late 1940s after he experimented with a freezer. [However, sources dispute on the precise year of his creation.] A National Historic Mechanical Engineering Landmark by ASME, the first successful commercial project was installed in the Commonwealth Building in Portland, Oregon, in 1948. The first residential open loop version was created in 1948 by Ohio State University professor Carl Nielsen. Ground source heat pumps gained popularity in Sweden following the 1973 oil crisis, and its adoption has been slowly spreading internationally ever since. Before the invention of polybutylene pipe in 1979, closed loop systems were the only viable option on the market. There are more than a million units installed worldwide as of 2004, offering 12 GW of thermal capacity with an annual growth rate of 10%. As of 2011/2004, 80,000 and 27,000 units, respectively, are installed annually in the US and Sweden. Between 2006 and 2011, a geothermal heat pump accounted for more than 40% of the market share for new detached homes in Finland.[2]

I.3 Background of geothermal heat exchangers:

For heating, cooling, and hot water in residential, commercial, and industrial buildings, geothermal heat exchangers use the earth's thermal energy. They take use of the constant temperatures beneath to boost energy efficiency and cut greenhouse gas emissions.

Figure I-1: Geothermal heat exchangers

I.3.1 Significance of studying horizontal air-ground systems with adiabatic outlets:

To increase their efficiency, improve system design, and better understand how they behave in practical applications, researchers must examine the performance of horizontal air-ground geothermal heat exchangers with adiabatic outputs. Adiabatic outputs are essential for system stability and for achieving the necessary heat transfer properties.

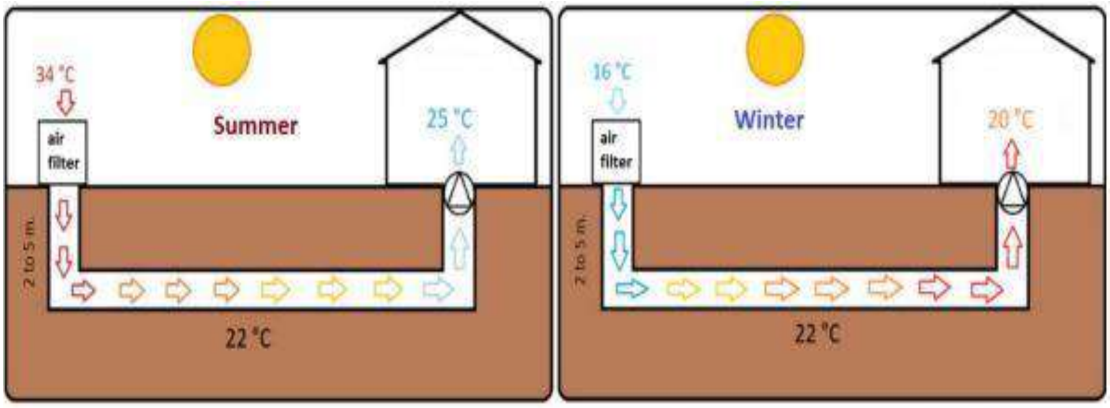


Figure I-2: Basic principle of operation of a ground-to-air heat exchange

I.3.2 Geothermal heat pump :

Using electricity, heat pumps transfer heat from one location to another. Refrigerators and air conditioners are two typical heat pump examples. Buildings may be heated and cooled using heat pumps. Year-round, the temperature at about 30 feet below the surface ranges between roughly 50°F (10°C) and 59°F (15°C). This implies that in the majority of American regions, soil temperatures are typically warmer in the winter and cooler in the summer than the surrounding air. These stable subsurface temperatures are used by geothermal heat pumps to effectively exchange heat, cooling homes in the summer and heating them in the winter.

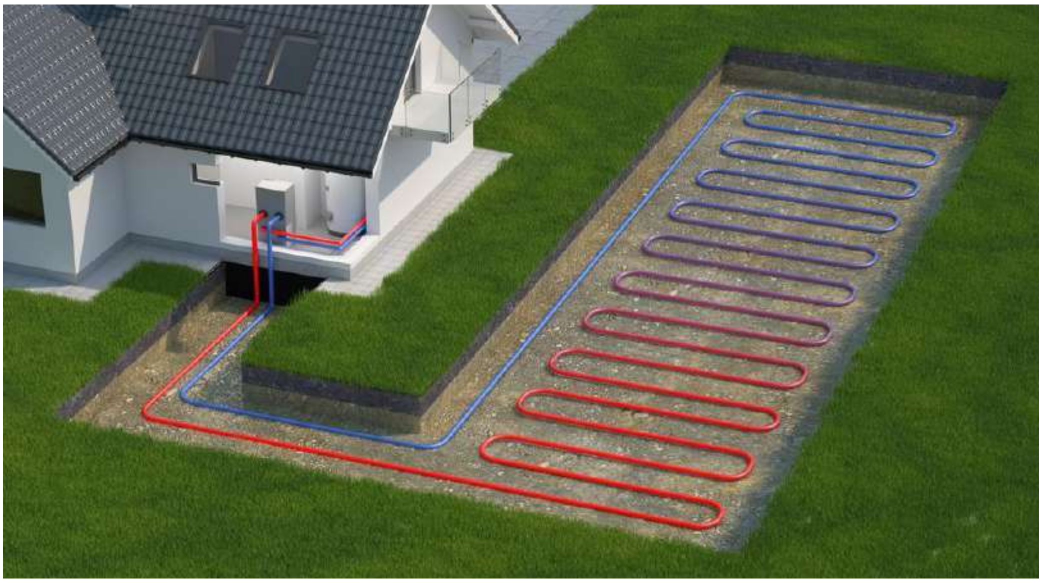


Figure I-3: Model of Geothermal heat pump

I.3.2.1 Geothermal heat pump system :

A geothermal heat pump system includes:

I.3.2.1.1 An underground heat collector :

A geothermal heat pump employs a network of interconnected pipes installed in the ground close to a structure to use the earth as a heat source and sink (thermal storage). Both a vertical and a horizontal burial of the loop is possible. Depending on whether the ambient (outside) air is warmer or cooler than the soil, the fluid it circulates either absorbs or deposits heat to the area.

I.3.2.1.2 A heat pump:

A geothermal heat pump concentrates and transmits heat from the fluids in the collector to the structure when the surrounding air is cooler than the earth. The heat pump takes heat from the structure and deposits it underground when outside temperatures are warmer than the ground..

I.3.2.1.3 A heat distribution subsystem:

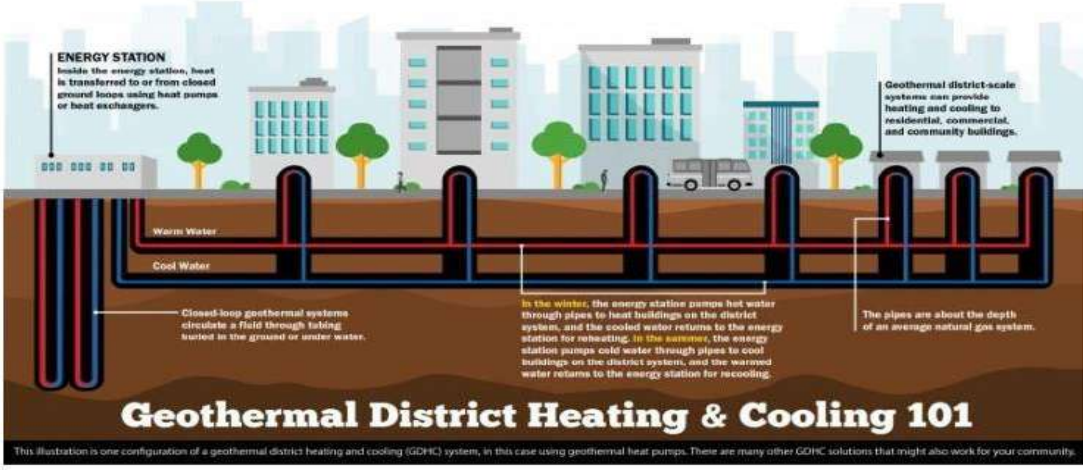
Conventional ductwork is generally used to distribute heated or cooled air from the geothermal heat pump throughout the building.

I.3.3 Geothermal heat pump uses:

- Used to heat and cool a single house, single business, or an entire community (college campus, neighborhood, etc.)
- Implemented as part of new construction or retroactively added for existing buildings
- Installed in urban or rural environments. Some systems can supply homes and businesses with hot water. [3]

I.3.4 The difference between a geothermal heat pump and an air source heat pump :

Compared to air-source heat pumps, geothermal heat pumps are distinct. While air-source heat pumps exchange heat from the air, geothermal heat pump systems do the opposite. Geothermal systems do not rely on the temperature of the outside air, and they have been found to be quieter, last longer, and require less maintenance than air-source systems. Generally speaking, geothermal systems are more expensive than air source systems, however the higher costs are frequently offset by energy savings..[3]



Geothermal heat pumps can be scaled up to meet an entire community's heating and cooling needs on a single network, as depicted in this graphic. Other geothermal heating and cooling technologies such as district heating can also be used in a community system.

Figure I-4: Geothermal district Heating & cooling

I.3.5 Analysis of horizontal air-ground geothermal heat exchangers:

Horizontal air-ground geothermal heat exchangers consist of a network of pipes buried in the ground, through which a heat transfer fluid, often air, circulates. The heat exchanger interacts with the surrounding soil, utilizing its thermal properties to exchange heat with the fluid. Analyzing the design, operating principles, and performance characteristics of horizontal air-ground geothermal heat exchangers is vital for optimizing their efficiency.

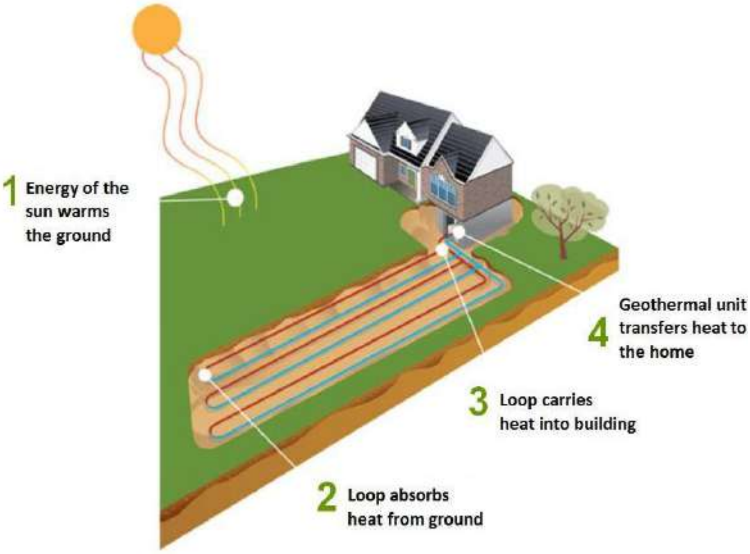


Figure I-5: Analysis of horizontal air-ground geothermal heat exchangers

I.3.6 Geothermal energy sources:

Geothermal energy is obtained from different sources, including volcanic activity, hotsprings, and geothermal reservoirs. The heat held beneath the Earth's surface is accessible through wells and utilized to generate energy or offer direct heating for home, commercial, andindustrial applications.

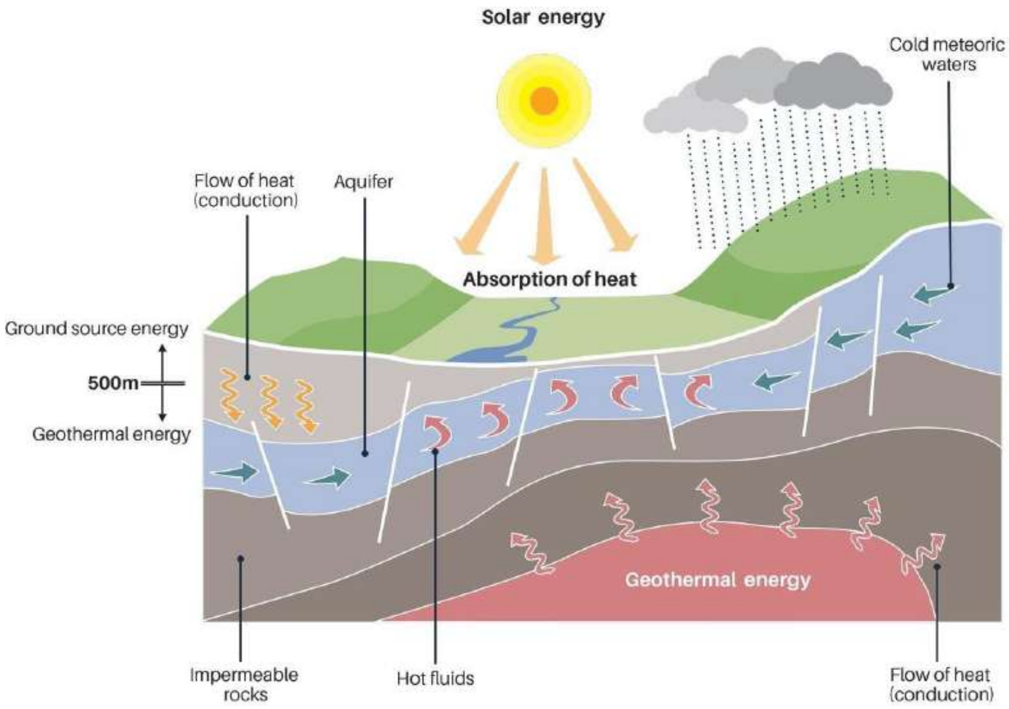


Figure I-6: Geothermal energy sources

The boundaries of the tectonic plates get the bulk of the heat from the Earth's core ,Plate tectonics refers to the movement and interaction of Earth's hard outer layer, or lithospheric plates. This movement causes in many geologic events like as earthquakes, volcanic activity, and the creation of mountain ranges. In the context of geothermal energy, plate tectonics plays a crucial influence in the occurrence of geothermal reservoirs, which are subterranean pools of hot water or steam that may be tapped into for energy generation. The heat within these reservoirs is created by the movement and friction of tectonic plates, adding to the Earth's total temperature. [4]

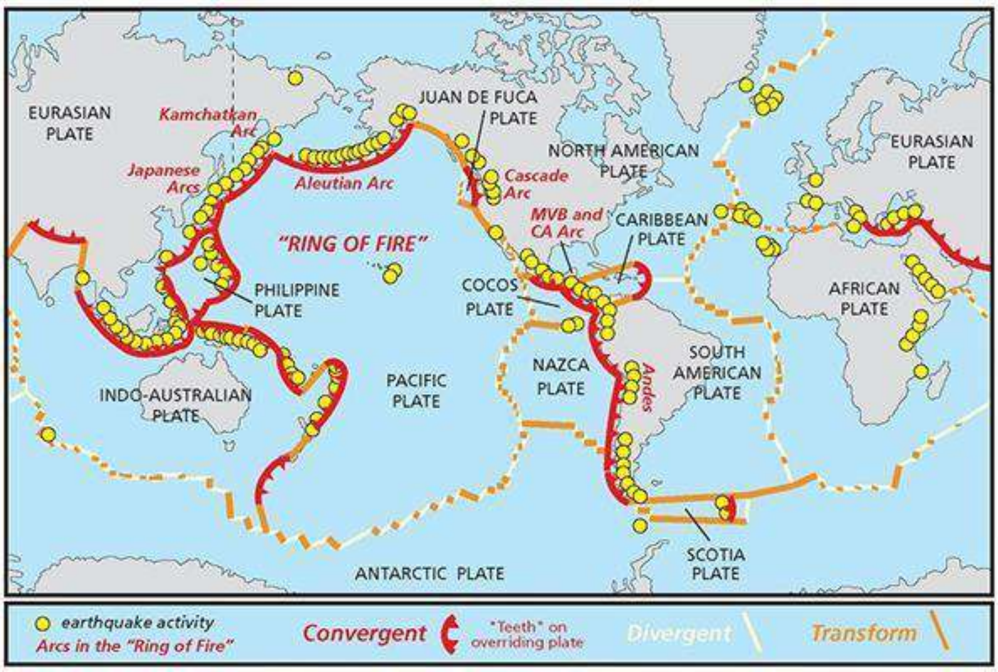


Figure I-7: A map of the world showing plate tectonics and plate boundaries

I.4 Geological gradient:

The geological gradient refers to the shift in temperature with growing depth within the Earth's crust. It illustrates how temperature increases as you walk deeper into the Earth. The geological gradient is an essential topic in understanding the distribution of heat inside the earth and its relevance to geothermal energy.

On average, the Earth's crust contains a geothermal gradient of around 25 to 30 degrees Celsius every kilometer (°C/km). This implies that for every kilometer you sink below the Earth's crust, the temperature climbs by around 25 to 30 degrees Celsius.

The region of the world under consideration has a greater impact on this temperature gradient. It can range from 3 degrees Celsius every 100 meters in sedimentary regions to 15 or even 30 degrees Celsius in volcanic regions and rift zones like Iceland or New Zealand. [5]

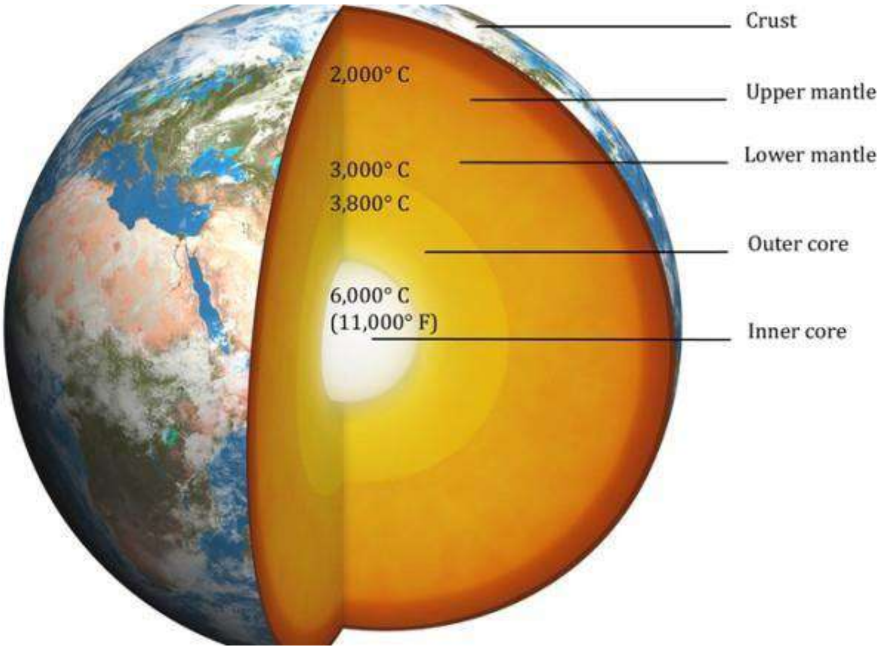


Figure I-8: Soil depths and temperatures

I.5 Soil thermal properties :

The primary thermal properties of soil, or any substance, are the heat capacity and the thermal conductivity. The heat capacity can be defined per unit mass, in which case it is often called the specific heat, or per unit volume, in which case it is called the volumetric heat capacity. Sometimes it is useful to consider the ratio of the thermal conductivity to the volumetric heat capacity, and this ratio is called the thermal diffusivity. We will define and consider each of these in turn below. Knowledge of the soil thermal properties is necessary to predict how soil temperatures vary in space and time. Sensors which measure soil thermal properties can be used monitor soil water content nondestructively. Soil thermal properties also play a role in several remote-sensing based approaches for estimating soil moisture across large regions.[6]

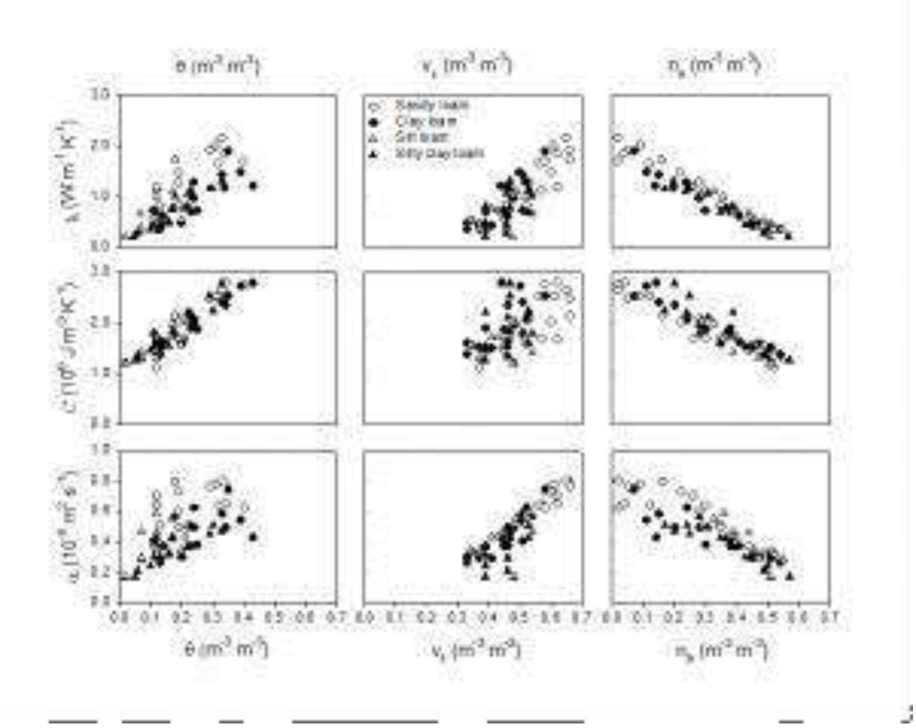


Figure I-9: Thermal conductivity (l), volumetric heat capacity (C), and thermal diffusivity (a) as influenced by volumetric water content (q), volume fraction of solids (vs), and air-filled porosity (na) across four different soils. Reproduced from Ochsner et al. (2007)

I.5.1 Thermal Conductivity:

The magnitude of the soil's conductive heat flow to the size of the temperature gradient (W m-1 °C-1) determines the soil's thermal conductivity (). Similar to how hydraulic conductivity measures the soil's capacity to "conduct" water, it is a measure of the soil's capacity to carry heat. Numerous soil properties, such as the following, affect soil thermal conductivity:

- air-filled porosity
- water content
- bulk density
- texture
- mineralogy
- organic matter content
- soil structure
- soil temperature

Quartz and air have by far the greatest and lowest thermal conductivities, respectively, among typical soil components (Table 1). All other factors being equal, sandy soils often have greater thermal conductivity values than other soils because the bulk of the sand-sized fraction in soils is frequently made up mostly of quartz. Air-filled porosity has a significant impact on soil thermal conductivity since air has a very low thermal conductivity. The thermal conductivity decreases as the air-filled porosity increases. Although not strictly linearly, soil heat conductivity rises as water content does. Because the water sticks to the mineral particles in dry soil, very minor increases in water content may significantly improve the thermal contact between the particles. This leads to a relatively considerable rise in the thermal conductivity. [6]

Table 1 : Thermal conductivity, density, and specific heat of common soil constituents at10 °C (after de Vries, 1963, Table 7.1; adapted from Horton and Ochsner, 2011).

Material	**Density** (*10^3 Kg m^{-3})	**Specific heat** (J Kg^{-1} K^{-1})	**Heat capacity** (*10^3 J K m^{-3})	**Thermal conductivity** (W m^{-1} K^{-1})
Quartz	2.65	733	1942	8.4
Soil minerals	2.65	733	1942	2.9
Soil organics	1.30	1926	2503	0.25
Water	1.00	4186	4186	0.6
Ice	0.90	2093	1883	2.5
Air	0.0012	1005	1.20	0.026

Specific heat and delayed crop development in soils managed with no tillage .(2)

I.6 Factors related to climatic conditions :

I.6.1 Ambient air temperature:

The air temperature, or ambient temperature (Ta), is an essential parameter of the thermal comfort. It intervenes in the evaluation of the heat balance of the individual at the level of convective, conductive and respiratory exchanges. In a room, the temperature of the air is not uniform, differences in air temperatures also occur in plan near cold surfaces and heating elements. [7]

I.6.2 Air humidity:

The humidity of the air can be expressed as the vapor pressure of water in certain volume of air, the humidity of the air inside the shelter influences the equipment in a direct and indirect. Air humidity does not have a big effect, it only has a significant effect when extremely high or extremely low . [8]

I.6.3 Air speed:

Wind is moving air or the agitation of air. It is an air displacement of high pressure areas to low pressure areas Air velocity plays a major role in convective and evaporative exchanges. Indeed, the convective exchanges between the outer surface of the walls and the outside air are function of the air speed in the vicinity of the walls.

I.6.4 Sunshine:

Sunshine (or duration of insolation), in meteorology, is the time during which a place is exposed to the sun. The outside air temperature reaches its maximum value in the middle of the afternoon, either at the time of maximum sunshine for the West orientation which is thus the most unfavorable. Among the vertical walls, it is the East and West walls that receive the most sunshine in summer. [8]

I.6.5 Heat Capacity:

Soil volumetric heat capacity (C) is the amount of energy required to raise the temperature of a unit volume of soil by one degree (J m^{-3} °C^{-1}). Unlike thermal conductivity, volumetric heat capacity increases strictly linearly as soil water content increases . Volumetric heat capacity is also a linear function of bulk density. The volumetric heat capacity can be calculatedby :

$$C = \rho_b c_s + \rho_w c_w \theta$$

where ρ_b is the soil bulk density (g cm^{-3}), *cs* is the specific heat of the soil solids (J g^{-1} °C^{-1}), ρ_w is the density of water (g cm^{-3}), c_w is the specific heat of water, and θ is the volumetric water content (cm^3). To increase the temperature of wetter, denser soil requires more energy thanto increase the temperature of drier, less dense soil, which has a lower volumetric heat capacity. This is one factor that can contribute to lower soil temperatures.

I.7 Literature review of relevant studies and research:

Literature review of relevant studies and research A comprehensive literature review will be conducted to analyze previous studies and research related to horizontal air-ground geothermal heat exchangers with adiabatic outlets. This review will identify key findings, methodologies, and advancements in the field, as well as any gaps or limitations that need to be addressed in the present study.

I.7.1 Biographical Study:

I.7.1.1 Overview of notable researchers and their contributions to geothermal heat exchanger studies :

This section will provide an overview of notable researchers who have made significant contributions to the field of geothermal heat exchangers. It will highlight their research findings, methodologies, and the impact of their work on the development and understanding of horizontal air-ground systems with adiabatic outlets.

*NESRINE HATRAF, the main objective is the study to evaluate the performance of an Air/ground exchanger. It is based on the study of the influence of the properties of the soil, thesite and the nature of the duct on the evolution of the air temperature along the exchanger thenthat obtained at the output which can be exploited. The difference with the outside temperaturedetermines the possibilities offered to the technique of cooling by geothermal energy to be usedin sites of varied climates in Algeria. [9]

Saffa Riffat: Saffa Riffat is an expert in sustainable energy systems and has contributed to the development of ground-source heat pump technology and geothermal heat exchangers. His work often focuses on improving the efficiency and performance of such systems. [10]

*Richard A. Beck: Richard A. Beck is a notable figure in the geothermal industry, known for his work on ground-source heat pump systems and geothermal heat exchangers. He has published various research papers on the performance and optimization of geothermal systems . [11]

*Marc A. Rosen: Marc A. Rosen is known for his research in the area of geothermal energy and ground-source heat pump systems. He has contributed to the optimization of heat exchanger design and the integration of geothermal systems into building heating and cooling. .(3)

*John W. Lund: John W. Lund is a well-respected expert in geothermal energy and heat exchangers. He has made substantial contributions to geothermal resource assessment, utilization, and the development of ground-source heat pump systems. His research has helped in the optimization of geothermal heat exchange systems. [12]

* These researchers have made significant contributions to the broader field of geothermal heat exchangers and related technologies. While I don't have specific information about the study you mentioned, you can search for their research papers, academic publications, and articles to explore their contributions in more detail. Additionally, to find specific studies related to a "horizontal air-ground geothermal exchanger with an adiabatic outlet," you may want to search academic databases or contact experts in the field for the most up-to-date information on this topic.

*The research work presented by BADER EDDINE DOUNANE and BOUBAKEUR HATHAT, The purpose of this work is to evaluate an air-soil exchanger system specific to climate zones. hot. They carried out the project by numerical simulation of a Turbulent flow in the air-ground exchanger; they used the FLUENT software for the numerical calculation. [13]

I.7.2 Analysis of key research papers and advancements in the field :

Selected key research papers will be analyzed to explore the advancements made in the study of horizontal air-ground geothermal heat exchangers. The analysis will focus on the methodologies employed, experimental setups, findings, and limitations, providing insights into the current state of knowledge in this area.

I.7.3 Identification of gaps or limitations in existing knowledge Through the biographical study:

Identifying gaps or limitations in the existing body of knowledge concerning horizontal air-ground geothermal heat exchangers requires a critical examination of the current research and literature. Some key areas of concern may include: [14,15]

Efficiency and Performance Variability : There might be gaps in understanding the factors contributing to the variability in efficiency and performance of horizontal geothermal heat exchangers. This could involve exploring the impact of soil properties, climate conditions, or system design on the overall performance.

Long-Term Durability: Assessing the long-term durability of these systems, particularly in different geological and climatic regions, is essential. Investigating potential issues related to corrosion, system degradation, or wear and tear can provide insights into limitations.

Optimal Sizing and Design: A gap might exist in the identification of the most optimal sizing and design criteria for horizontal geothermal heat exchangers. This includes determining the appropriate length, depth, and spacing of ground loops for maximum efficiency.

Environmental Impact: An analysis of the environmental impact of horizontal geothermal systems, including potential heat exchange fluid leaks or energy consumption, could be lacking. Understanding the ecological consequences is vital.

Cost and Economic Viability: Investigating the cost-effectiveness and economic viability of these systems in various regions may reveal gaps in our understanding of the financial barriers and benefits associated with their installation and operation.

Regulatory and Policy Frameworks:Identifying limitations in the regulatory and policy frameworks governing the installation and use of horizontal geothermal heat exchangers is crucial, as these can significantly impact their adoption and sustainability.

Technological Advancements: As technology evolves, there may be gaps in the research regarding the incorporation of cutting-edge materials and monitoring systems for improved performance and longevity.

Optimization and Control Strategies:Research might be lacking in terms of advanced control strategies and optimization techniques for horizontal geothermal systems, which could enhance their overall efficiency and reliability.

Climate Adaptation: Assessing how these systems perform under varying climate conditions, especially extreme weather events or changing climate patterns, is an essential aspect to explore.

Integration with other systems: Understanding how horizontal geothermal systems can be effectively integrated with other renewable energy sources or HVAC systems may reveal gaps in our knowledge of their full potential.

To address these gaps and limitations, further research, experimentation, and interdisciplinary collaboration are essential. Moreover, advances in monitoring technology, data analytics, and modeling can aid in a more comprehensive understanding of horizontal air-ground geothermal heat exchangers and their optimal utilization.

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Chapter II:

Mathematical Modeling

II.1 Introduction:

The double underground heat exchange, also known as a double U-tube ground heat exchanger or double loop geothermal system, is a form of geothermal heating and cooling system that leverages the Earth's stable subterranean temperatures to provide effective heating and cooling for structures.

In a twin subterranean heat exchange system, two sets of U-shaped pipes are placed underground. These pipes, often constructed of high-density polyethylene (HDPE) or copper, are buried in horizontal trenches or vertical boreholes, depending on the available space and geological circumstances of the site. The depth at which the pipes are buried can vary, although it is normally between 6 to 10 feet (1.8 to 3 meters).

The twin subterranean heat exchange system offers various benefits over standard heating and cooling techniques. It provides a continuous and sustainable source of energy, as the ground maintains at a reasonably stable temperature throughout the year. This lessens dependency on fossil fuels and helps to cut greenhouse gas emissions. Additionally, the system is very efficient and may give considerable energy savings compared to traditional HVAC systems.

And heat exchange is the transmission of thermal energy between things at different temperatures. It occurs until thermal equilibrium is attained, where both things have the same temperature and no further heat flows between them. Thermal equilibrium is based on the second rule of thermodynamics, indicating that heat travels from higher to lower temperatures. Once objects attain the same temperature, thermal equilibrium is established, and heat transmission stops.

II.2 Definitions:

II.2.1 Temperature field:

The change of temperature across time and space is used to calculate energy transfers:

T = f (x,y,z,t).A scalar known as the temperature field is the current temperature at any location in space. [16]

We'll separate these two situations:

- The speed is considered to be permanent or stationary in a temperature field that is independent of time.

- The speed of the temperature field's temporal evolution is described as variable or transitory.

II.2.2 Temperature gradient:

A surface known as an isothermal surface is created when all of the places in space that have the same temperature are combined. At the isothermal surface, the temperature variance per unit length is greatest along the normal. The temperature gradient is what distinguishes this variation:

$$\overrightarrow{grad}(T) = \vec{n}\frac{\partial T}{\partial n} \ldots\ldots\ldots\ldots (2.1)$$

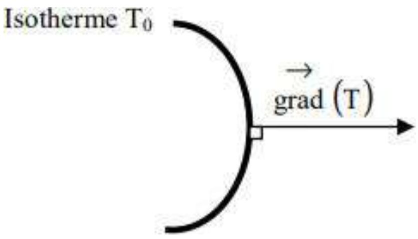


Figure II-1: Isotherm and thermal gradient

With:

$\vec{n}$: unit vector of normal

$\frac{\partial T}{\partial n}$: derived from temperature along normal.

II.2.3 Heat Flow:

A temperature gradient from high to low temperatures affects the movement of heat. Heat flux density is the quantity of heat transferred per unit of time and per unit of isothermal surface area:

$$\emptyset = \frac{1}{S}\frac{dQ}{dt}$$

Where S is the area of the surface (m^2).

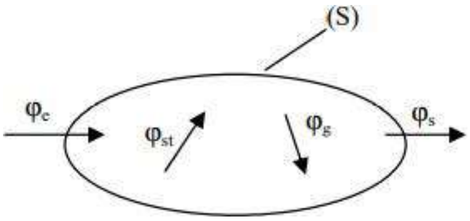
Heat flux is the amount of heat transmitted on the surface S per unit of time:

$$\varphi = \frac{dQ}{dt}$$

II.3 Formulation of a Heat Transfer Problem :

II.3.1 Energy balance:

A system (S) must first be described by its physical boundaries, after which an inventory of the numerous heat fluxes that affect the system's state and include the following must be created:



φ_{st} stored heat flux
φ_g heat flux generated
φ_e incoming heat flow
in the system (S)

φ_s outgoing heat flow

Figure II-2: Energy system and balance

The first principle of thermodynamics is then applied to establish the energy balance of the system (S):

$$\varphi_e + \varphi_g = \varphi_s + \varphi_{st} \quad \dots\dots\dots\dots (2.2)$$

II.3.2 Expression of energy flows:

Establishing the various energy flows manifestations is then necessary. We get the differential equation whose resolution enables us to determine the temperature evolution at each point of the system by incorporating these expressions into the energy balance.

II.3.2.1 Heat conduction:

A microscopic energy transport mode is thermal conduction (also known as thermal diffusion). The exchange of vibrational energy between the atoms of the crystalline network in non-metallic materials allows energy to be transferred across two zones with differing temperatures. Conduction electrons are also used to transmit heat energy in metals, improving the efficiency of the process. Thermal conduction moves quickly over short distances but moves relatively slowly over long ones.[17]

The theory of conduction is based on the Fourier hypothesis: the flux density is proportional to the temperature gradient:

$$\vec{\varphi} = -\lambda\, S\, \overrightarrow{grad}(T) \;\ldots\ldots\ldots\ldots\ldots\; (2.3)$$

Or in algebraic form:

$$\varphi = -\lambda\, S \frac{\partial T}{\partial x} \;\ldots\ldots\ldots\ldots\; (2.4)$$

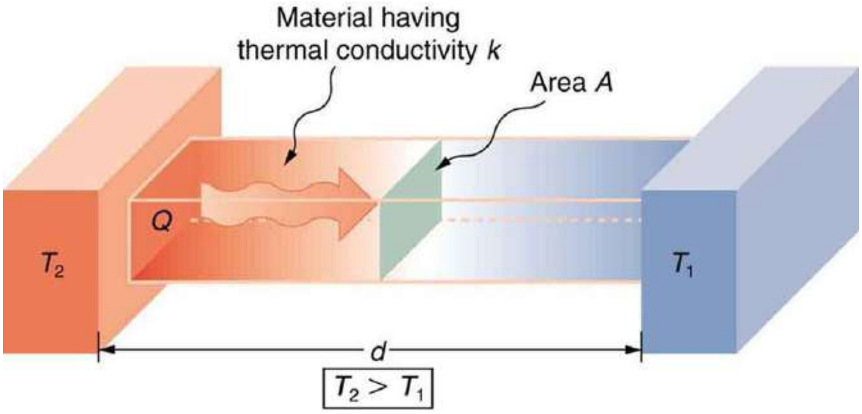


Figure II-3: Schematic representation of the conduction phenomenon.

With:

φ Heat flux transmitted by conduction (W)

λ Thermal conductivity of the medium (W m^{-1}°C^{-1})

x Space variable in flow direction (m)

S Area of heat flow passage section (m^2)

II.3.2.2 Heat convection:

It is the exchange of heat energy between a fluid and a solid through the displacement of the fluid.

- Convection can have one of two forms:

- Free or natural convection: In this case, the fluid is only moved as a result of density changes brought on by boundary temperature differences and a gravitational field.

- Forced convection is brought about by a fluid being circulated artificially (by a pump, turbine, or fan). Compared to natural convection, the transfer occurs more quickly.

This transfer mechanism is governed by Newton's law:

$$\varphi = h_c . A . (T_p - T_\infty) \text{ .... } (2.5)$$

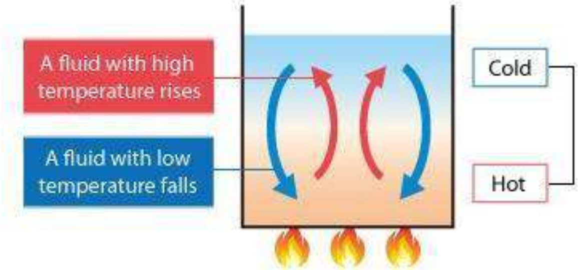


Figure II-4 : Phenomenon of convection in a liquid

II.3.2.3 Thermal radiation:

It is the third type of heat transmission and is only of an electromagnetic nature. Any object can absorb some of the background electromagnetic radiation (photons are absorbed by atoms and molecules).

On the other hand, every object continuously emits radiation. Due to thermal agitation, atoms and molecules constantly collide, and a portion of the energy from the collision is converted into electromagnetic radiation as the excited particles return to their initial state.

The "Stefan-Boltzmann" law states that at temperature T, a body's maximum heat flow density is given by:

$$\varphi = \sigma \varepsilon_p (T^4_p - T^4_\infty) \ldots\ldots\ldots\ldots\ldots (2.6)$$

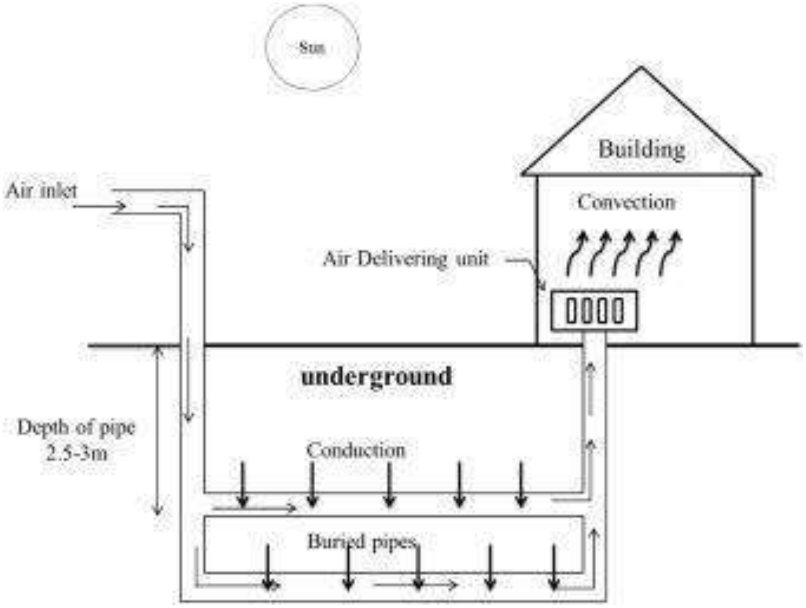


Figure II-5 : Working principle of EAHE

II.4 Flow characteristics:

Fluid mechanics, which studies fluid motions, has a very broad range of applications, including turbo machinery, aviation, combustion, and hydraulics.

Typically, there are two sorts of flows:

- The use of external flows in aerodynamic design.
- Internal flows are beneficial when designing combustion, cooling, hydraulic, etc. systems.

II.4.1 Fluid flow rate:

A fluid particle travels along a route known as a current line in any flow. A current net or tube is made up of all current lines that are specified by real or imagined boundaries. Each fluid particle moving in a pipe as part of a fluid in motion flows at a specific speed along its "current line." The flow is referred to as stationary, permanent, or established when all variables—including velocity, pressure, viscosity, density, etc.—are independent of time. The regime is referred to as unstable or changeable if one of the parameters is not stable over time.

II.4.1.1 Laminar flow:

Remains known as silent laminar discharge, viscous laminar discharge, or Poise laminar discharge. As nested tubes that move at different speeds and parallel in every point in the direction of the flow, it happens at low speeds by blades or nets that maintain their individuality and slide on each other without mixing. The velocity is zero on the wall and gets to its maximum at the centre of the tube based to a parabolic variation. The laminar speed is expected to be below a Reynolds number of 2300 (between 2000 and 2500, per the authors).

II.4.1.2 Turbulent flow:

Additionally known as vortex or hydraulic flow. It happens at medium and high speeds, and the friction between the different fluid layers is what leads to the production of more or less haphazard vortices.

Similar to laminar flow, the flow rates are parallel. The turbulent regime will subsequently be acknowledged to have established itself above a Reynolds number value of 30,000 (the value of Re is not precisely defined; some authors choose a lower value while others acknowledge that values of Re of 5000 even 10000 are necessary for the turbulent regime to be perfectly reached).

In fact, the system is divided into the following categories:

- Weakly turbulent, with Reynolds numbers between 4000 and 10000
- "Highly turbulent" if Re is greater than 10000.

Since it corresponds to flows at high speeds compatible with industrial productivity restrictions, turbulent flow is quite common in industrial practice.

II.4.1.3 Intermediate flow (transition flow):

It is also known as transient flow, and with a Reynolds number between 2300 and 3000, there is an unstable flow that alternates between laminar and turbulent flow, absorbing tiny shocks until the flow returns to laminar. This regime is not very interesting for industrial applications.

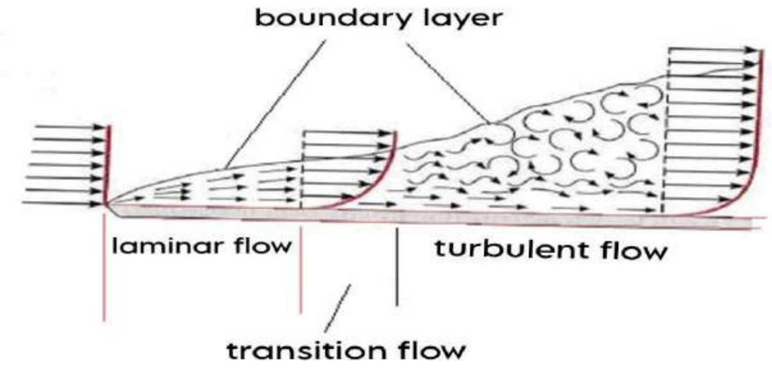


Figure II-6 : Flow System

II.5 Thermal modelling of an air-ground cooler:

The construction of the exchanger, the temperature of the air entering the tubes, and the temperature of the floor close to the tubes all affect how much heat is transferred from the floor to the air flowing through the tubes. The model is divided into two sections because the second temperature must necessarily be determined if the first temperature is a load that can be given by a meteorological data file. The temperature at any location on the ground is calculated in the first section (soil temperature "undisturbed") without the action of the exchanger. As a condition at the researched system's limits, this temperature is employed. The temperature of the air leaving the heat exchanger is determined by a second component, which is the heat exchanger model itself.

Only tube-level heat exchange is taken into account. The soil around the tubes is considered to have uniform qualities and the tubes are presumed to be identical. The tubes and the ground around them are represented by a mesh made up of many concentric cylindrical meshes in order to account for the dynamic and spatial features of heat exchange.

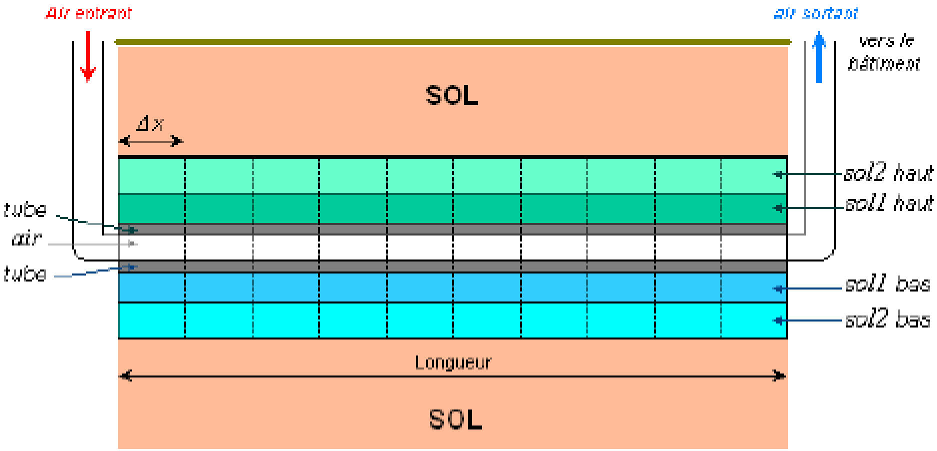


Figure II-7: Mesh appearance (longitudinal not cut)

II.6 Description of the problem:

The studied problem involves a U-shaped cylindrical pipe with a buried circular fixed section. The entire depth (Hy) of the system is 3 m, while the total length (Hx) is 20 m. The precise depths are stated as Hy1 = 2 m, Hy3 = 0.85 m, and Hx3 = 5 m. The lengths of Hx1 andHx5 are equivalent and specified as 0.4 m, and the lengths between the pipes are all precisely the same and measure 0.15 m. Also, the heat exchanger features insulation with a thickness (e)of 0.05

The temperature outside is stated as 32 °C The average temperature at the surface of the soil is 25 °C, while the Reynolds number is claimed to be in 1000 and 1500.

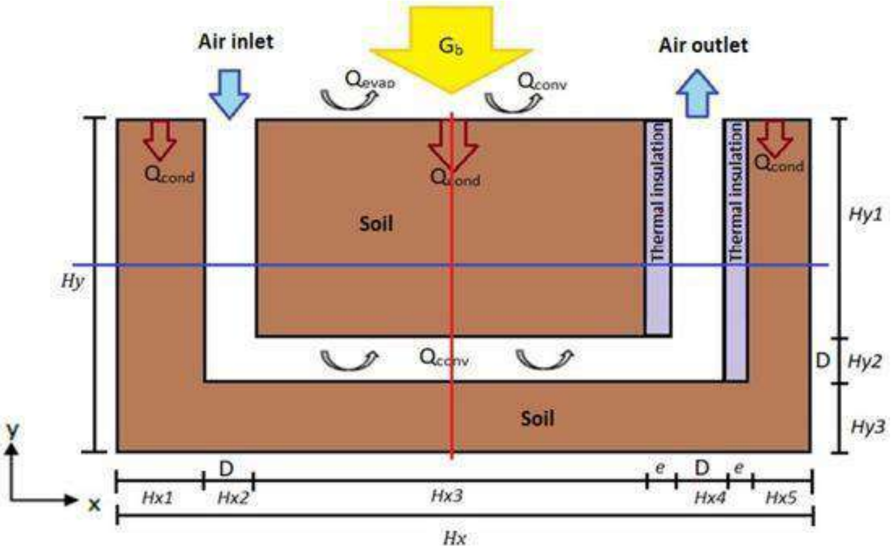


Figure II-8 : Physical model of the GAHE.

II.6.1 Mathematical Model:

The following are the mathematical model's presumptions [18]:

- Laminar regime flow that is incompressible.
- The soil is regarded as a stable, isotropic medium.
- Boussinesq approximation: Density is taken to be constant, with the exception of the gravity factor in the momentum equations, where it is linearly changed.
- Fluid that doesn't participate in radiation.
- The blocking approach is used for the whole non-fluid domain (soil and thermal insulator), which entails permanently setting all flow variables at all nodes of the solid domain to 0 (u = v = P = 0) such that for the solid domain only conduction heat transfer is assessed.

The mass, momentum, and energy equations for natural convection are the steady state governing equations inside the physical model of the GAHE (Figure 8):

$$\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho u)}{\partial y}=0 \ldots\ldots\ldots\ldots (2.7)$$

$$\frac{\partial(\rho u\, u)}{\partial x}+\frac{\partial(\rho v\, v)}{\partial y}=\frac{\partial}{\partial x}(\mu\frac{\partial(u)}{\partial x})+\frac{\partial}{\partial y}(\mu\frac{\partial(u)}{\partial y})-\frac{\partial P}{\partial x}\ldots\ldots\ldots\ldots (2.8)$$

$$\frac{\partial(\rho u\, u)}{\partial x}+\frac{\partial(\rho v\, v)}{\partial y}=\frac{\partial}{\partial x}(\mu\frac{\partial(v)}{\partial x})+\frac{\partial}{\partial y}(\mu\frac{\partial(v)}{\partial y})-\frac{\partial P}{\partial y}\ldots\ldots\ldots\ldots (2.9)$$

$$\frac{\partial(\rho u\, T)}{\partial x}+\frac{\partial(\rho v\, T)}{\partial y}=\frac{\partial}{\partial x}(\mu\frac{\lambda}{C_p}\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(\mu\frac{\lambda}{C_p}\frac{\partial T}{\partial y})\ldots\ldots\ldots\ldots (2.10)$$

2.3. Boundary Conditions

For the temperature, the East, West, and South boundaries are considered adiabatic:

$$\left.\frac{\partial T}{\partial x}\right|_{x=0}=0 \quad \text{for} \quad 0\le y\le H_y \ldots\ldots\ldots\ldots (2.11)$$

$$\left.\frac{\partial T}{\partial x}\right|_{x=H_x}=0 \quad \text{for} \quad 0\le y\le H_y \ldots\ldots\ldots\ldots (2.12)$$

$$\left.\frac{\partial T}{\partial y}\right|_{y=0}=0 \quad \text{for} \quad 0\le x\le H_x \ldots\ldots\ldots\ldots (2.13)$$

On the other hand, the Northern border adopted the energy balance suggested by G. Mihalakakou et al [19].

$$-\lambda \frac{\partial T}{\partial x}\Big|_{y=H_y} = \mathrm{CE} + -(\mathrm{LR}) + (\mathrm{SR}) - \mathrm{LE} \quad \text{for} \quad \mathbf{0} \leq x \leq H_x \ldots\ldots\ldots\ldots (2.14)$$

The convective energy, or CE, that the air exchanges with the soil surface is computed as follows:

$$\mathrm{CE} = h_S(T_{amb}) \ldots\ldots\ldots\ldots (2.15)$$

SR stands for the solar radiation that the ground's surface has absorbed.

LR stands for the solar radiation that the soil emits. Convective heat transfer coefficient (h_S) at the ground surface is a function of wind speed, according to Badescu et al. (2007) [20].:

$$h_S = 5.678\,[0.775 + 0.35(\frac{V_{wind}}{0.304})] \quad \text{for } V_{wind} < 4.88 \ldots\ldots\ldots\ldots (2.16)$$

$$h_S = 5.678\,[0.775 + 0.35\,(\frac{V_{venito}}{0.304})^{0.78}] \quad \text{for } V_{wind} \geq 4.88 \ldots\ldots\ldots\ldots (2.17)$$

$$-(\mathrm{LR}) + (\mathrm{SR}) = -\varepsilon\Delta R + \alpha G b \ldots\ldots\ldots\ldots (2.18)$$

$$SR = \alpha G b \ldots\ldots\ldots\ldots (2.19)$$

ΔR stands for the term in Equation (2.18) that is affected by the soil's relative characteristics, effective atmospheric temperature, and relative humidity of the soil surface. [21]

LE stands for the evaporative latent heat flow from the ground surface:

$$\mathrm{LE} = 0.0168\, f\, h_{sup}((a\, T_{sup} + b) - HR(a\, T_{amb} + b) \ldots\ldots\ldots\ldots (2.20)$$

In Equation (2.20), HR stands for the air's relative humidity, and f is a percentage that mostly relies on the soil's surface.

For a mean soil moisture of: the components a, b, and f have a constant value of [19].:

$$a = 103\ (Pa/K)$$

$$b = 609\ (Pa)$$

$$f = 0.7$$

The boundary condition for the air inlet flow velocity (y = Hy) is calculated as a function of the Reynolds number:

$$v = (Re), u = 0 \, for \, Hx1 \le x \le Hx3 \ldots \ldots \ldots \ldots (2.21)$$

The boundary condition for the outlet air flow (y = Hy) and the pressure are:

$$\frac{\partial u}{\partial y}\Big|_{y=H_y} = 0, \frac{\partial v}{\partial y}\Big|_{y=H_y} = 0 \quad , \frac{\partial P}{\partial y}\Big|_{y=H_y} = 0 \text{ for } \mathrm{Hx3} \le \mathrm{x} \le \mathrm{Hx5} \ldots\ldots\ldots\ldots\ldots\ldots (2.22)$$

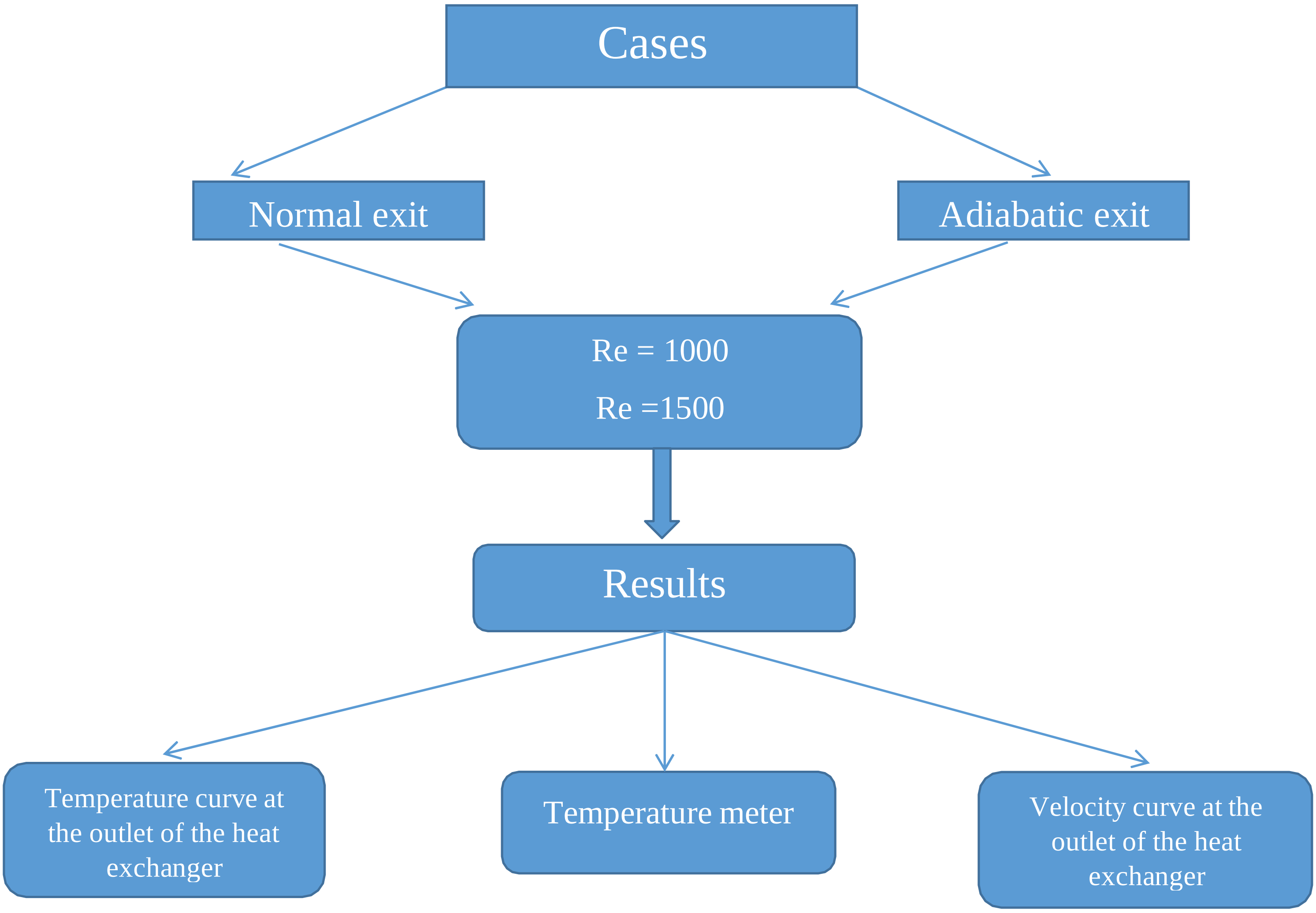
Chapter III:

Numerical Simulation

III.1 Introduction:

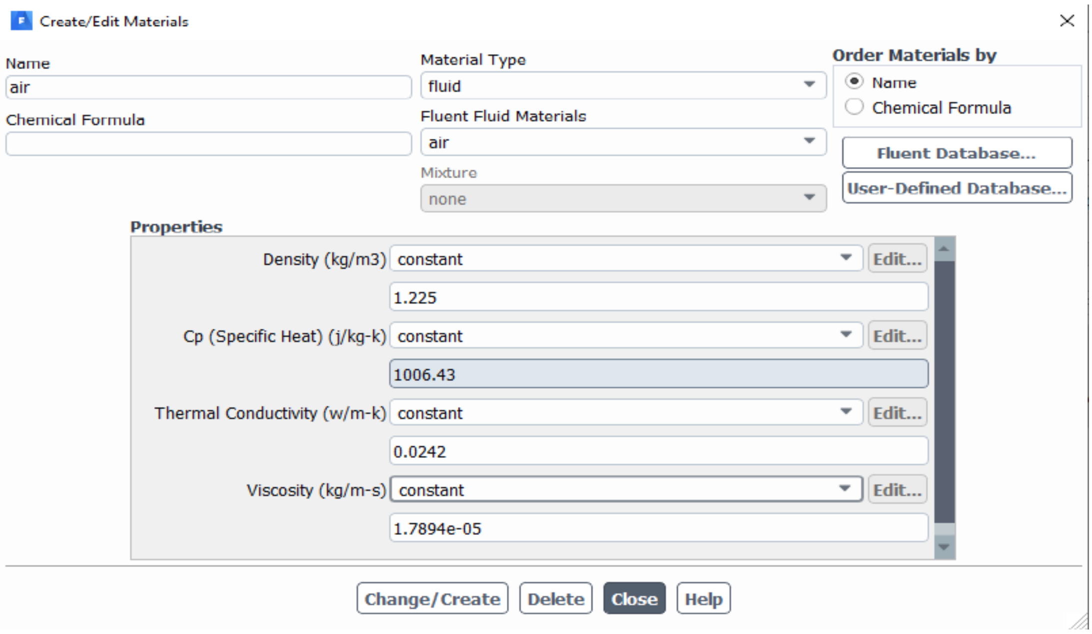
In the world of engineering and innovation, the quest to create groundbreaking designs and solve complex problems requires powerful tools that can simulate and analyze real-world scenarios. One such tool that has consistently pushed the boundaries of engineering simulation is ANSYS 2020. a leading provider of engineering simulation software, ANSYS 2020 has become a go-to solution for engineers and researchers seeking to unlock new possibilities in their respective fields. It empowers engineers to explore designs virtually before committing to costly physical prototypes. By creating a virtual representation of the product or system, engineers can simulate its behavior under different operating conditions .In this chapter, we will examine this heat exchanger under two conditions: one with an adiabatic outlet and another with a normal outlet. Additionally, we will vary the Raynaud's number, specifically in the case of laminar flow, once at 1000 and then at 1500 for both outlet conditions. Finally, we will analyze and evaluate the results obtained from these variations using the ANSYS program.

III.2 Work plan:



III.3 Results and analysis :

In this study, we will construct a heat exchanger with a length of 20 meters, a diameter of 15 cm, and a depth of 3 meters underground, and by choosing a temperature of 32 degrees Celsius (which corresponds to Sunday, May 28, 2023 in Ouargla). And we will study this exchanger in two cases, in the case of an adiabatic outlet and a normal outlet, and change the Raynaud's number in the case of laminar flow once at 1000 and again at 1500 in both cases and study the results obtained.



Name: air

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: air

Mixture: none

Order Materials by: ● Name ○ Chemical Formula

Properties

Density (kg/m3): constant — 1.225

Cp (Specific Heat) (j/kg-k): constant — 1006.43

Thermal Conductivity (w/m-k): constant — 0.0242

Viscosity (kg/m-s): constant — 1.7894e-05

Figure III-1: Image from ANSYS software - create/edit materials

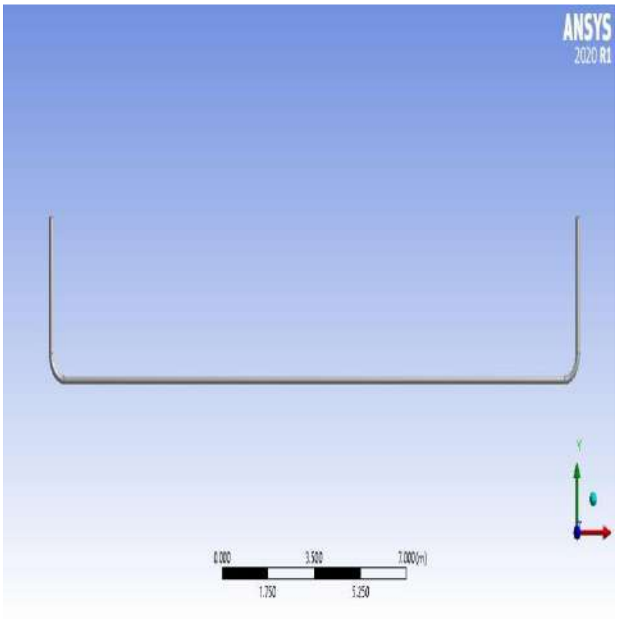


Figure III-2: Image from ANSYS software The mesh

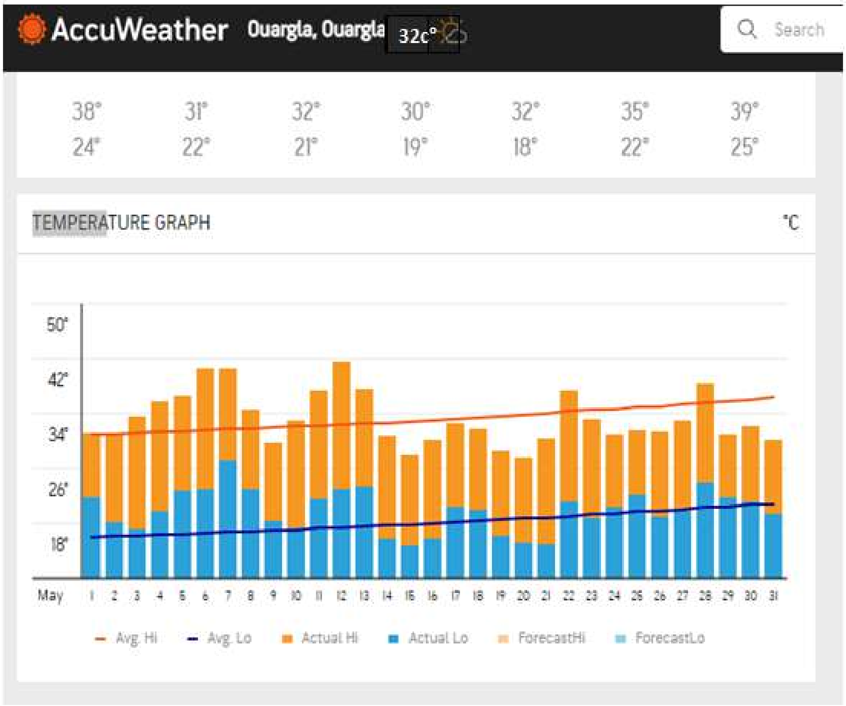


Figure III-3: weather day 28 may 2023 in ouargla (AccuWeather)

III.4 Network Type :

Meshing is the process of breaking down a complex shape into smaller, manageable parts, known as "mesh," for numerical analysis. This step is critical in Ansys 2020r1 simulations as it directly influences the accuracy and reliability of the results.

- Sweep

is a meshing method that involves creating a mesh by moving along specified lines or edges in the geometry. This technique is particularly useful for generating structured meshes with consistent elemental shapes.

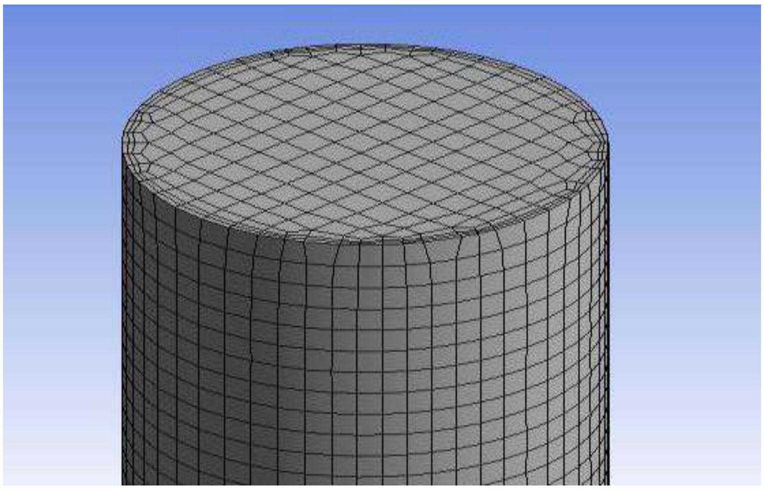


Figure III-4 : mesh in a sweep

- Cartesian

we create a mesh without the need for optimization, which speeds up the simulation process. However, the irregularly sized cut cells at the boundary limit the simulation's stable time step Overcoming this challenge, known as the "small cell problem," involves finding ways to evolve the cut cells while maintaining stability and conservation.

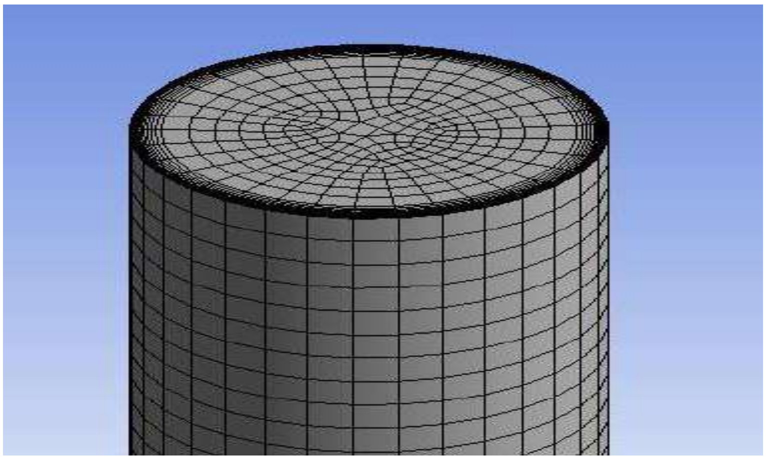


Figure III-5:: mesh in Cartesian

- Multi-Zone Meshing

allows for the creation of a mesh with different types and sizes of elements in different parts of the geometry. This is particularly useful for complex geometries with varying material properties or boundary conditions.

After choosing the meshing method, you can further refine it by specifying the element size and quality controls to guarantee accuracy and reliability. You can also visually inspect the mesh and conduct quality checks to ensure it meets the required criteria.

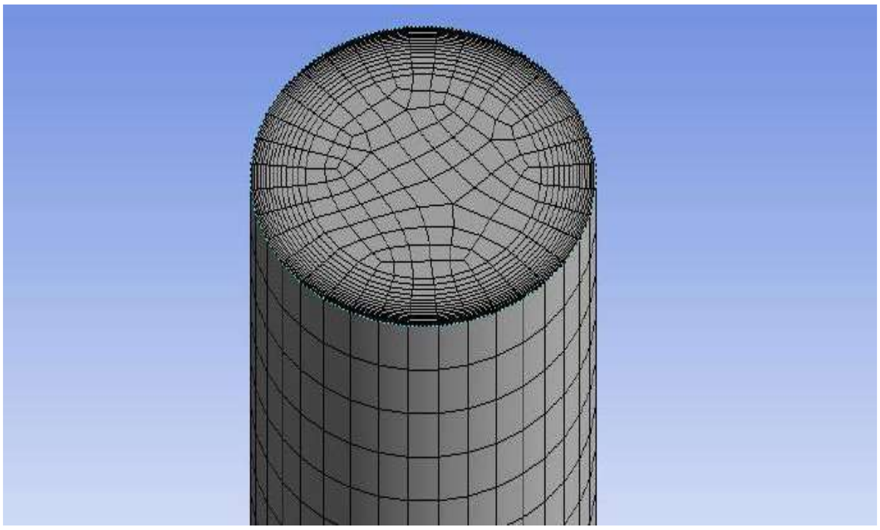


Figure III-6 : 3D Image from ANSYS software - The mesh Multi-Zone

In selecting the network, we conducted a comprehensive pilot phase encompassing three different types: "Scan," "Cartesian," and "Multi-Zone." After a thorough evaluation, we ultimately opted for the "Multi-Zone" network configuration due to its exceptional performance characteristics. It's worth noting that this particular network exhibited the lowest error rate in results generated by the "ANSYS" software. Additionally, it stood out with a significantly higher average number of superior cells, a crucial factor in achieving high-quality results and reducing error rates. The intrinsic relationship between the higher average cell count and enhanced outcomes underscores the suitability of the "Multi-Zone" network type for our specific study.

Mesh Size :

Cells	Faces	Nodes
1210504	3664514	1245321

III.5 Convergence rate:

Convergence rate in the context of the ANSYS program refers to the speed at which a numerical solution achieved through simulation converges to a stable and accurate solution. In engineering simulations, convergence is essential to obtain reliable results that reflect the real-world behavior of the analyzed system. In this numerical simulation we will converge at Re=1000 and Re=1500 in the case of an adiabatic output and in the case of a normal output.

- **Re=1000 :**

Adiabatic output

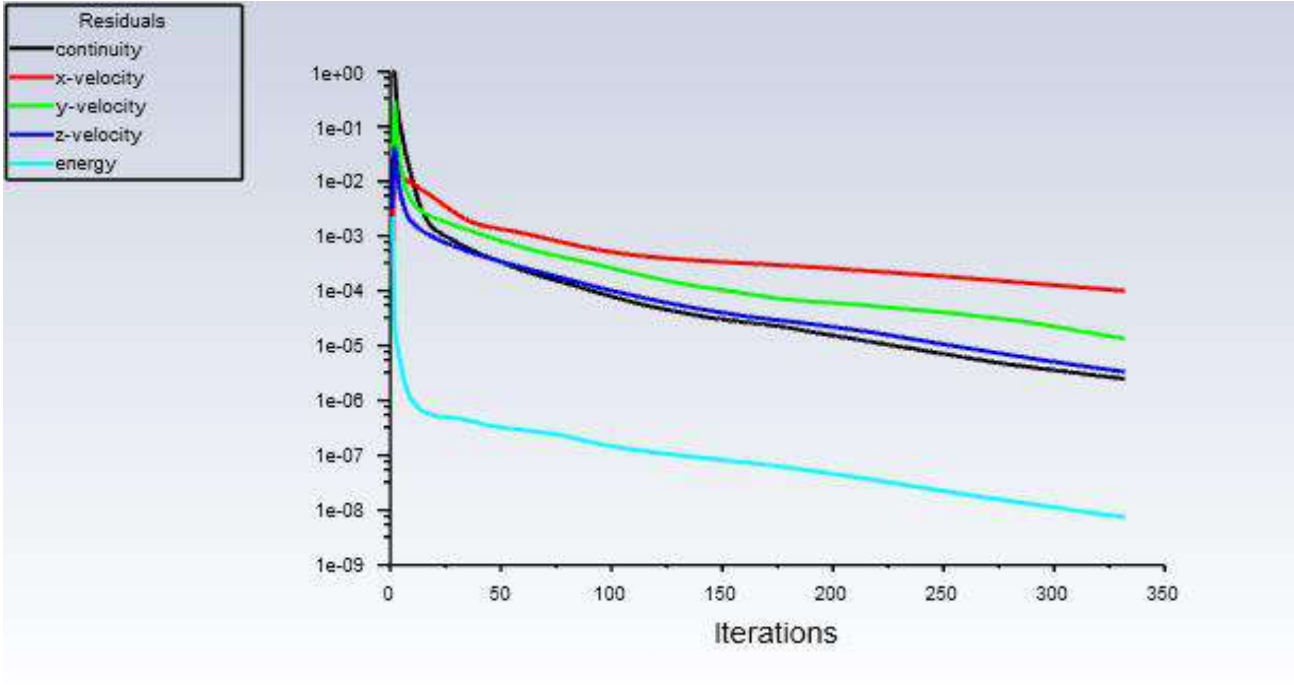


Figure III-7: Residuals evolution by number of iterations Re= 1000 with an adiabatic sort

This curve represents the convergence of the analysis of the fluid flow rates and the transfer of heat and energy, as the curve shows that the curves converge at a value of 66.

Normal output

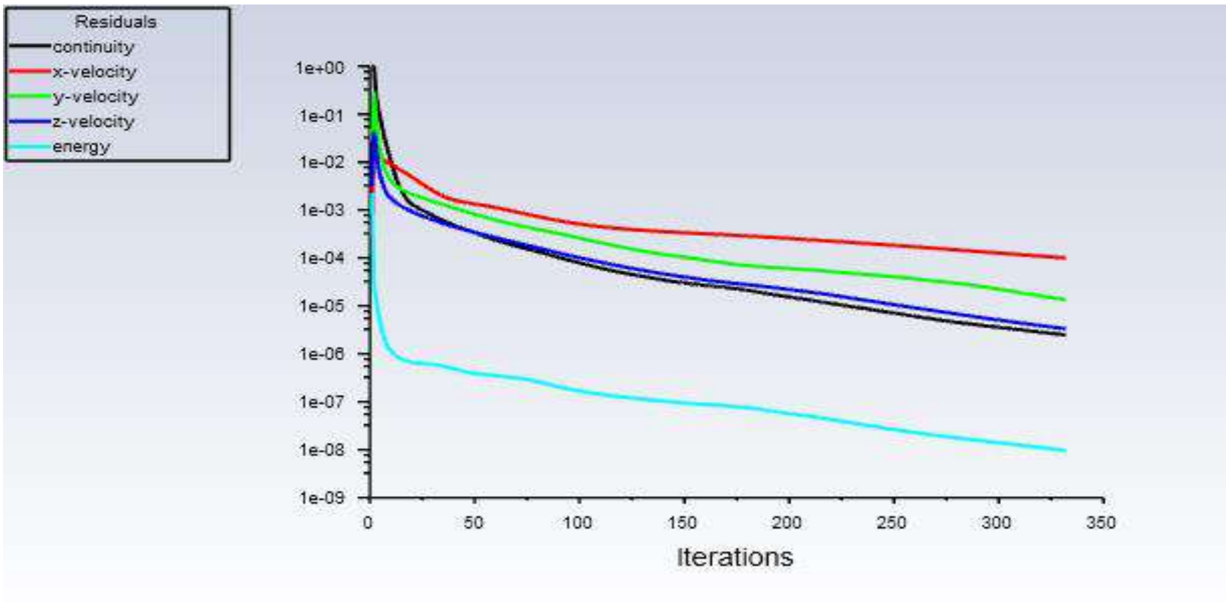


Figure III-8: Residuals evolution by number of iterations Re= 1000 with an normal sort

This curve represents the convergence of the analysis of the fluid flow rates and the transfer of heat and energy, as the curve shows that the curves converge at a value of 57.

- **Re=1500:**

Adiabatic output

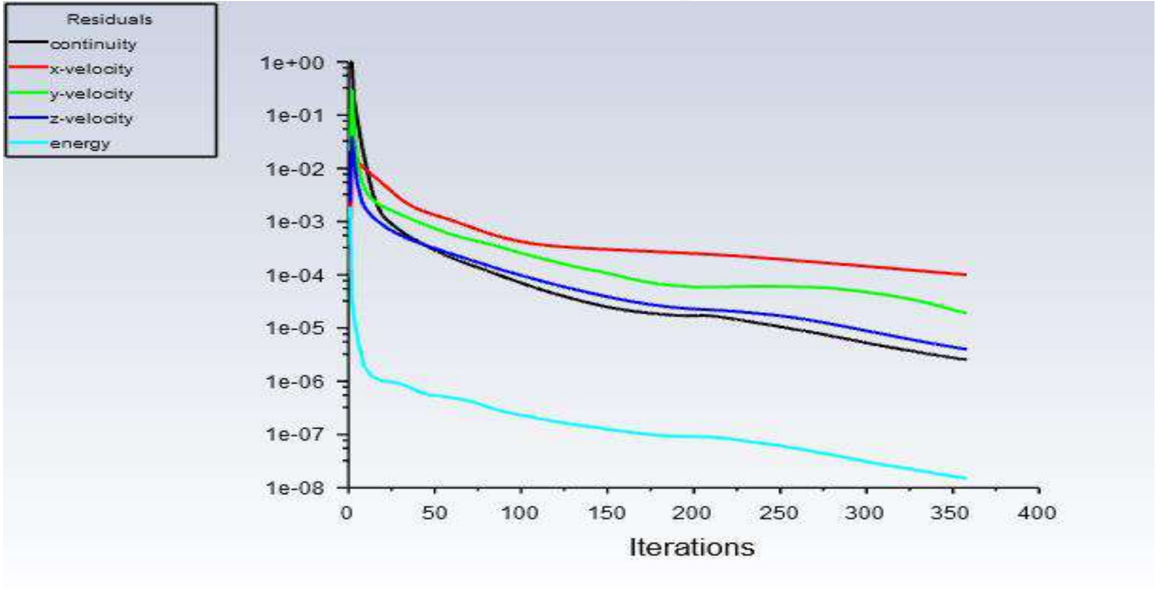


Figure III-9: Residuals evolution by number of iterations Re= 1500 with an adiabatic sort

This curve represents the convergence of the analysis of the fluid flow rates and the transfer of heat and energy, as the curve shows that the curves converge at a value of 62.

Normal output

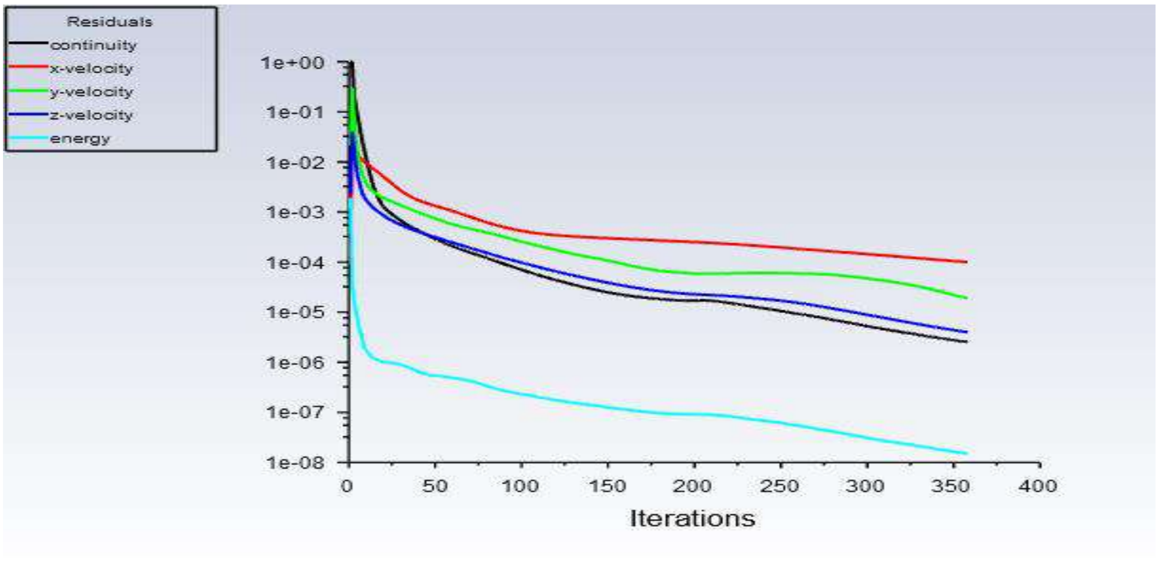


Figure III-10 : Residuals evolution by number of iterations Re= 1500 with an normal sort

This curve represents the convergence of the analysis of the fluid flow rates and the transfer of heat and energy, as the curve shows that the curves converge at a value of 62.

III.6 The Temperature meter:

The Temperature meter represents the temperature changes in the exchanger in different colors defined by a scale, where the color of the ground temperature is graded so that the air acquires the ground temperature, which has a value of 294 along the tube, the temperature exit is shown relative to the outlet with an appropriate cooling degree. In this numerical simulation we will provide pictures to show the temperature change inside the exchanger at Re=1000 and Re=1500 in the case of an adiabatic output and in the case of a normal output.

- **Re=1000 :**

Adiabatic outlet

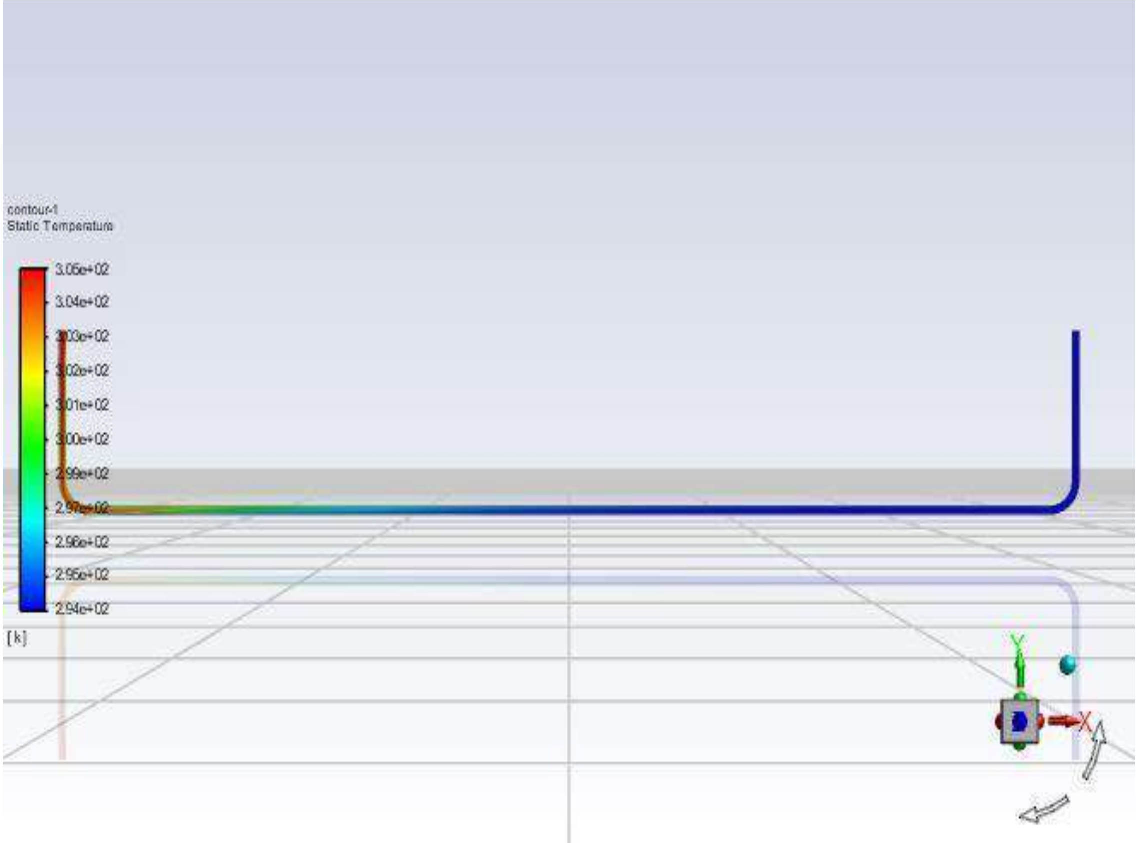


Figure III-11: The evolution of the air temperature in the tube – Re = 1000 with an adiabatic sort

In this exchanger, we notice that the temperature change was fast and constant from the value 305 to the value 294. The temperature outlet appears in dark blue.

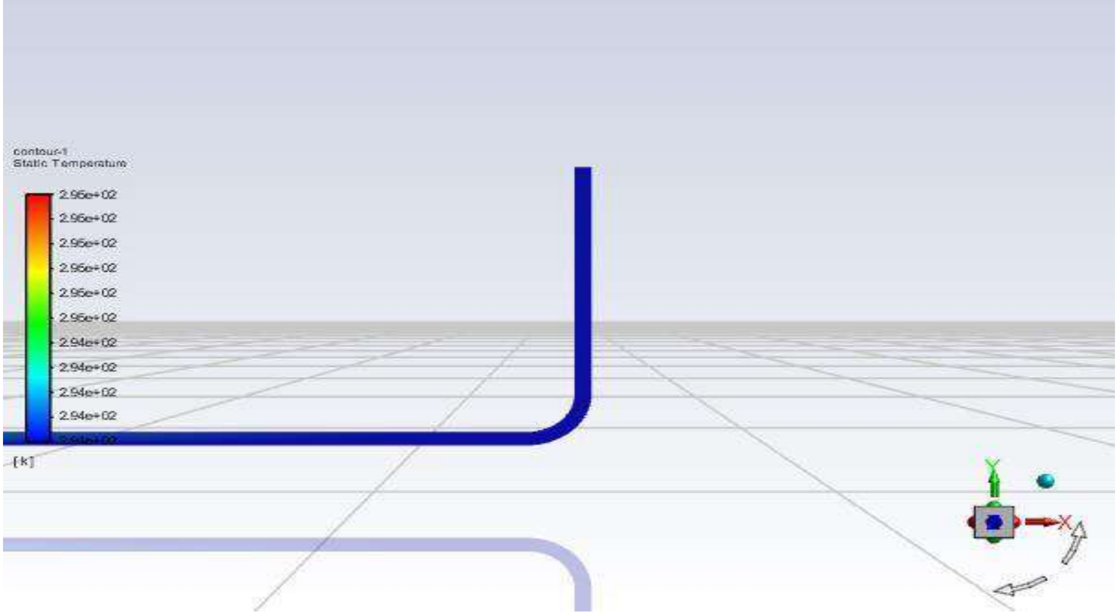


Figure III-12: The evolution of the air temperature in the tube – Re = 1000 with an adiabatic sortby zooming in

Normal outlet:

Figure III-13 The evolution of the air temperature in the tube – Re = 1000 with an normal sort

In this exchanger, we notice that the change in temperature was rapid and not constant, as we see at the end of the tube at the outlet a blue to green color gradient, which indicates energy loss. So that at entry it was at a value of 305, then it decreased to an ideal value of 294, then the temperature increased at exit due to the lack of isolation of the exit and its influence on the surrounding medium to a value of 297.

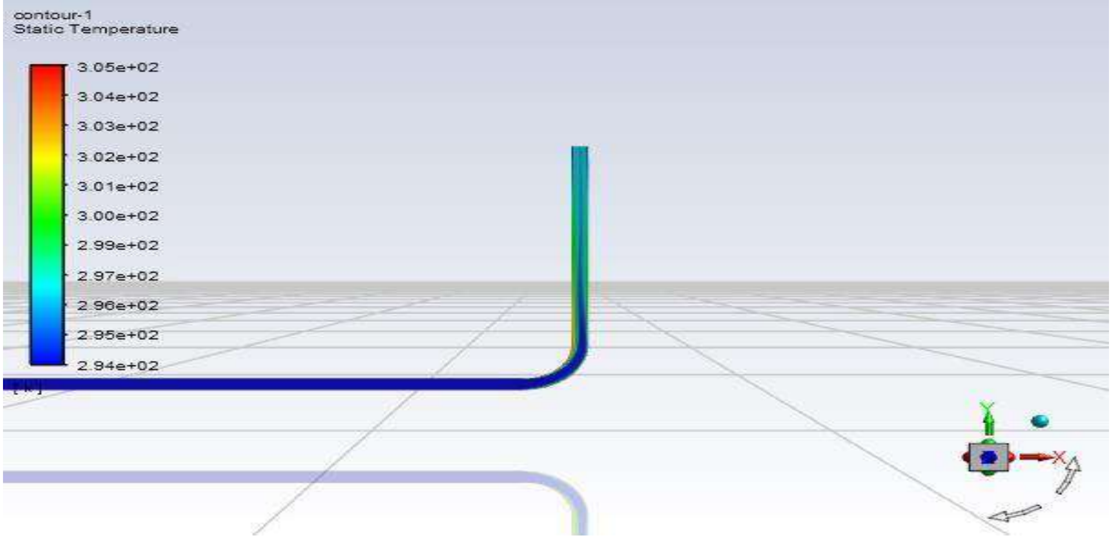


Figure III-14: The evolution of the air temperature in the tube – Re = 1000 with an normal sortby zooming in

- **<u>Re=1500</u>**

Adiabatic outlet:

Figure III-15: The evolution of the air temperature in the tube - Re = 1500 with an adiabatic sort

Here we notice in this heat exchanger that the temperature decreased from 305 to 295 and then increased to 297.

This indicates that in the case of the adiabatic output the higher the Raynaud's number the higher the temperature.

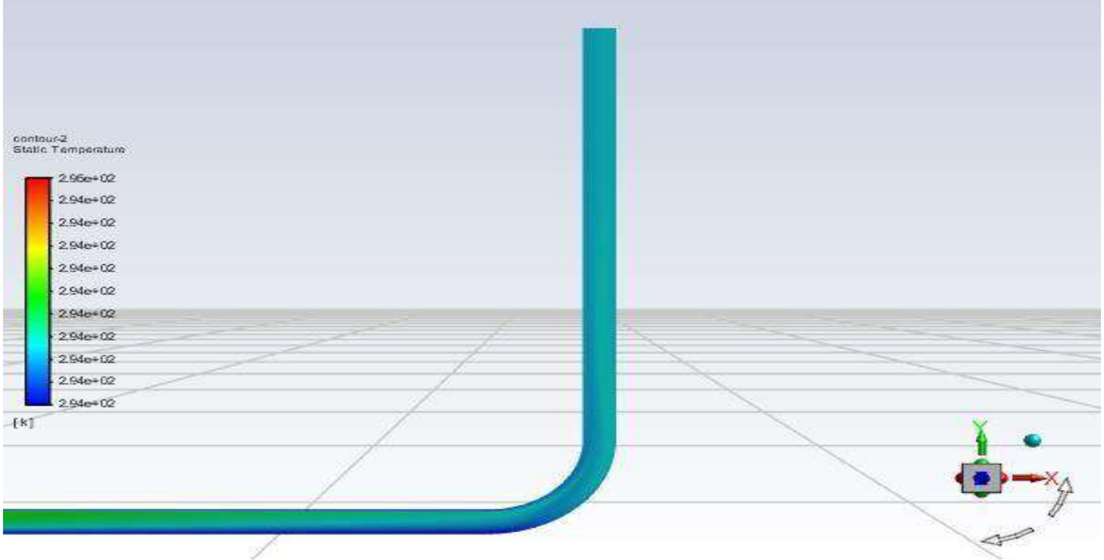


Figure III-16: The evolution of the air temperature in the tube - Re = 1500 with an adiabatic sortby zooming in

Normal outlet

Figure III-17: The evolution of the air temperature in the tube - Re = 1500 with an normal sort

In this exchanger, we notice that the temperature change was slow and not constant, as we seeat the end of the tube at the outlet a blue to green color gradient, indicating the loss of energy.

So that the temperature decreased from 305 to 294 then increased slightly at the exit to 296 andthis proves the result that at the normal exit the higher the Raynaud number the lower the temperature.

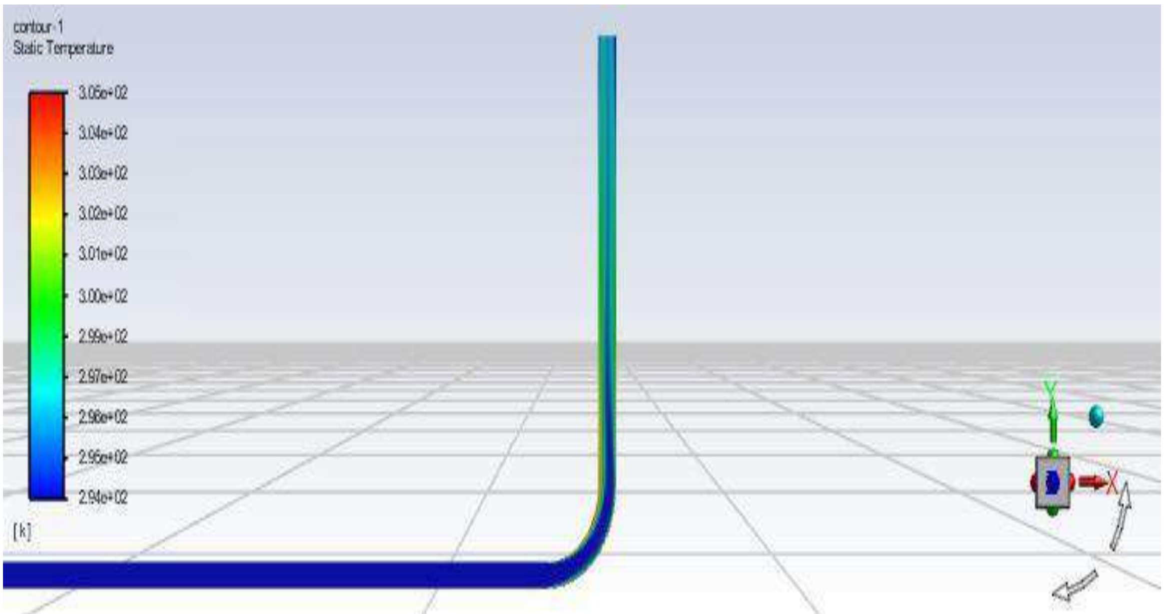


Figure III-18: The evolution of the air temperature in the tube - Re = 1500 with an normal sortby zooming in

III.7 Temperature profiles:

Understanding temperature distribution and behavior is critical in various engineering applications. In this aspect, we will show the distribution and behavior of temperatures at Re=1000 and Re=1500 in the case of an adiabatic output and in the case of a normal output.

- **Re=1000**

Adiabatic outlet

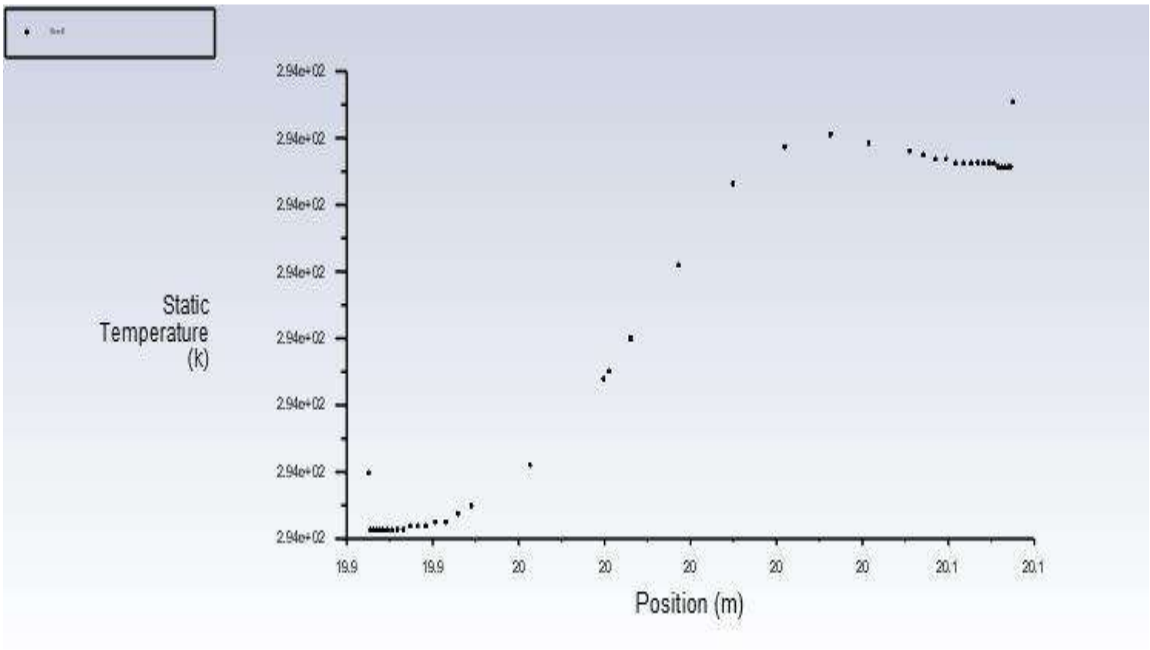


Figure III-19: Temperature profiles - Re=1000 with an adiabatic sort

The temperature profile appears relatively stable at the adiabatic outlet of the flow Re = 1000 with a value of 294 limit, which is due to the role of the insulator that resists the heat flow and regulates the speed.

Normal outlet

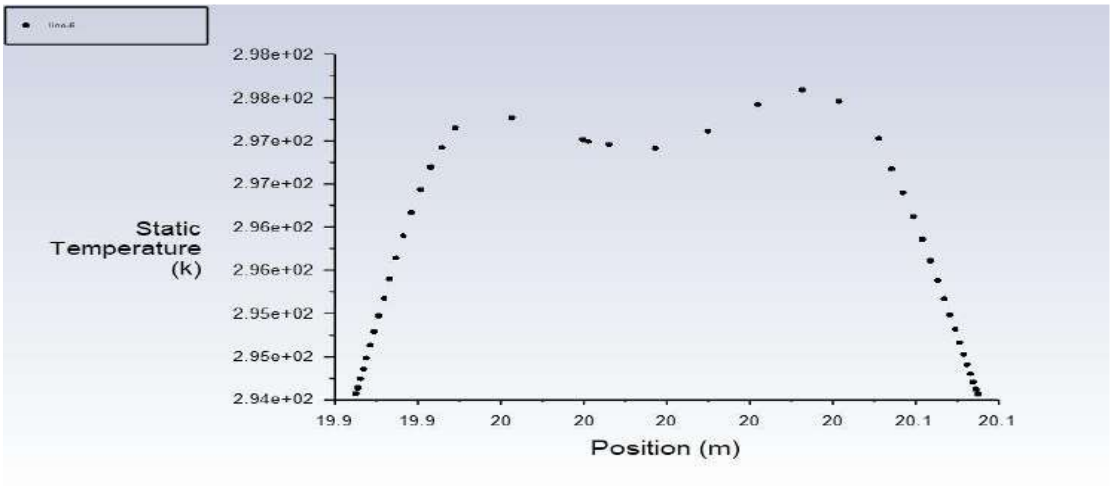


Figure III-20: Temperature profiles - Re=1000 with an normal sort

The temperature file shows a loss in temperature accompanied by a loss of energy at the outlet of the exchanger due to the influence of the outlet by external factors.

- **Re=1500**

Adiabatic outlet

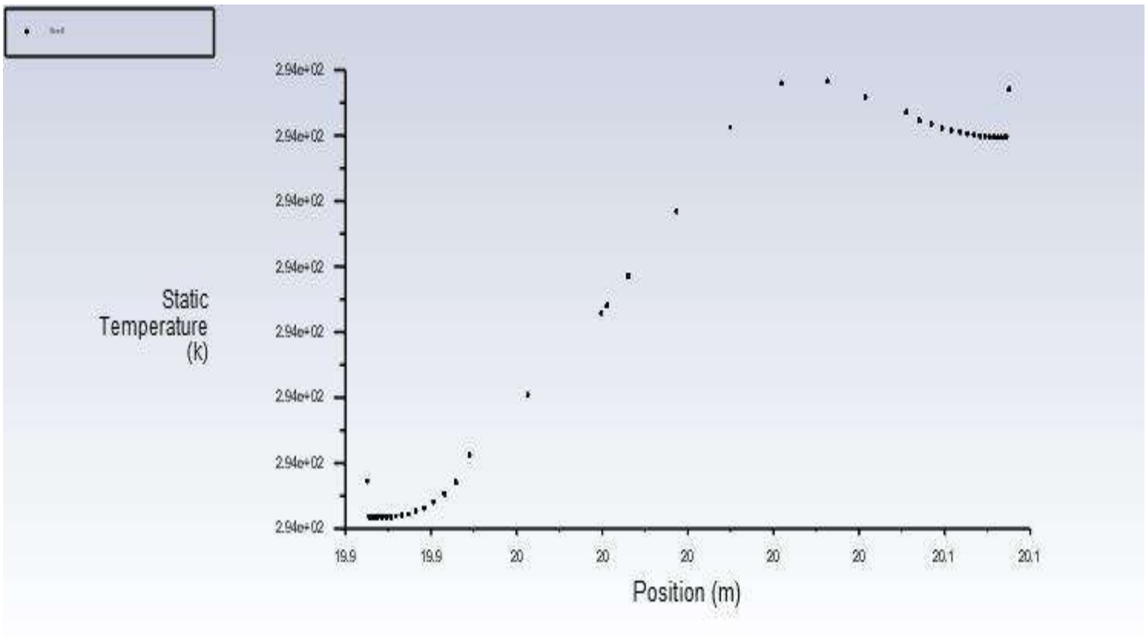


Figure III-21: Temperature profiles - Re=1500 with an adiabatic sort

The temperature profile appears relatively stable at the outlet of the flow heat exchanger Re = 1500 with a value of 294 limit, which is due to the role of the insulator that resists the heat flow and regulates the speed. There is a slight drop in the temperature at the outlet due to the flow number.

Normal outlet

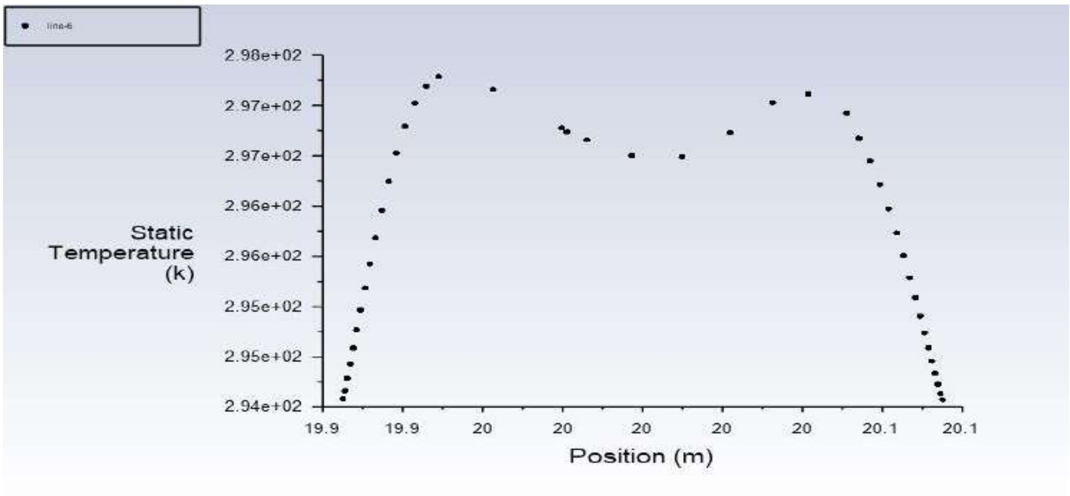


Figure III-22: Temperature profiles - Re=1500 with an normal sort

The temperature profile shows a temperature loss accompanied by a power loss at the outlet of the exchanger due to the influence of the outlet by external factors and the large flow number.

III.8 Comparing the outlet temperature at an adiabatic outlet and a normal outlet at a flow of Re=1000:

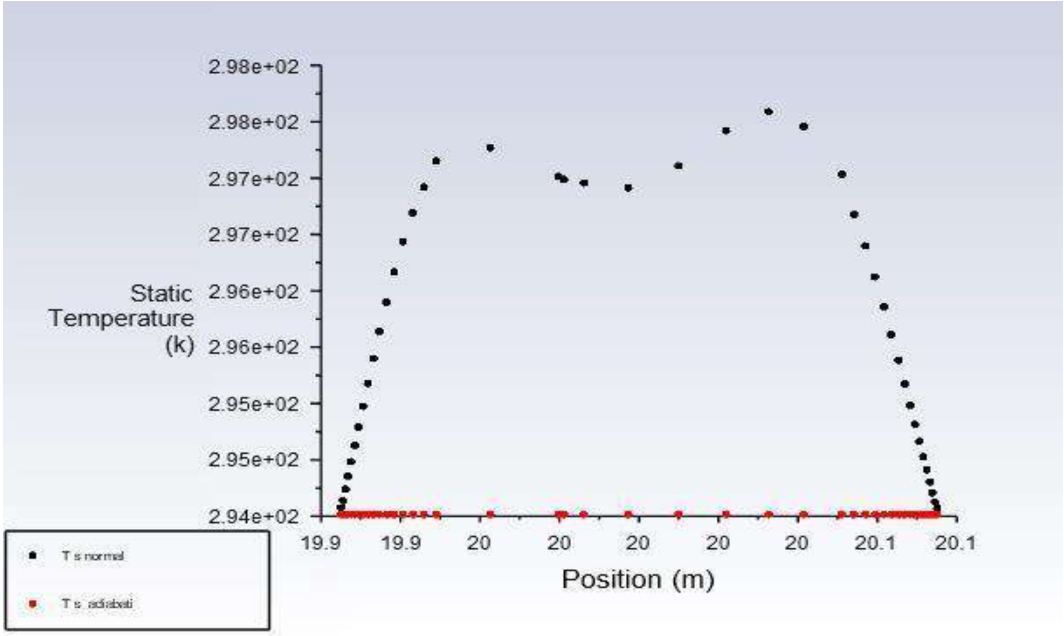


Figure III-23 : Comparing the outlet temperature at an adiabatic outlet and a normal outlet at aflow of Re=1000

From the graph, we observe that the adiabatic curve exhibits stability, indicating no energy loss and maintaining a constant temperature. On the other hand, the normal outlet curve shows temperature variations due to external factors that influence the overall temperature. The reason for the decrease in the normal outlet curve at the ends is convection.

Here we note that Raynaud's number is ideal for temperature stability.

Therefore, we find that the lower the Raynaud's number, the lower the temperature at the adiabatic exit. And This is what we need for cooling.

III.9 Comparing the outlet temperature at an adiabatic outlet and a normal outlet at a flow of Re=1500:

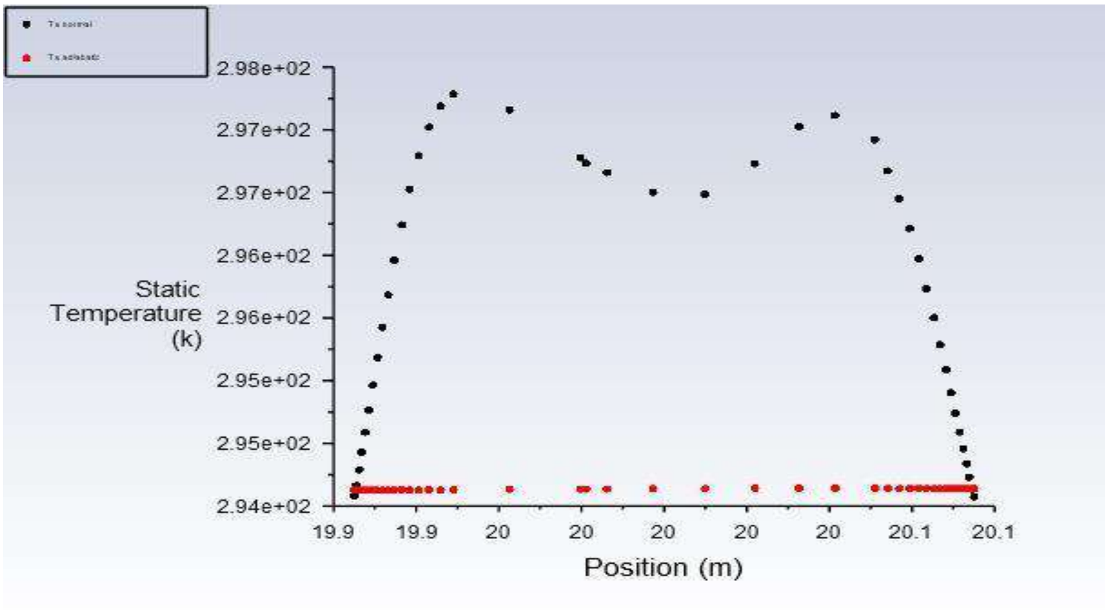


Figure III-24: Comparing the outlet temperature at an adiabatic outlet and a normal outlet at aflow of Re=1500

In this graph, we can observe that the temperature at the adiabatic outlet remains relatively stable, while there is a noticeable temperature change at the normal outlet. This difference is primarily attributed to the impact of surrounding factors, energy loss, and the increase in the number of flows. The reason for the decrease in the normal outlet curve at the ends is convection.

In comparison with the previous curve studied, we find that the higher the Raynaud's number, the higher the temperature at the adiabatic exit.

III.01 Speed comparison at an adiabatic outlet and a normal outlet at a flow of Re=1000:

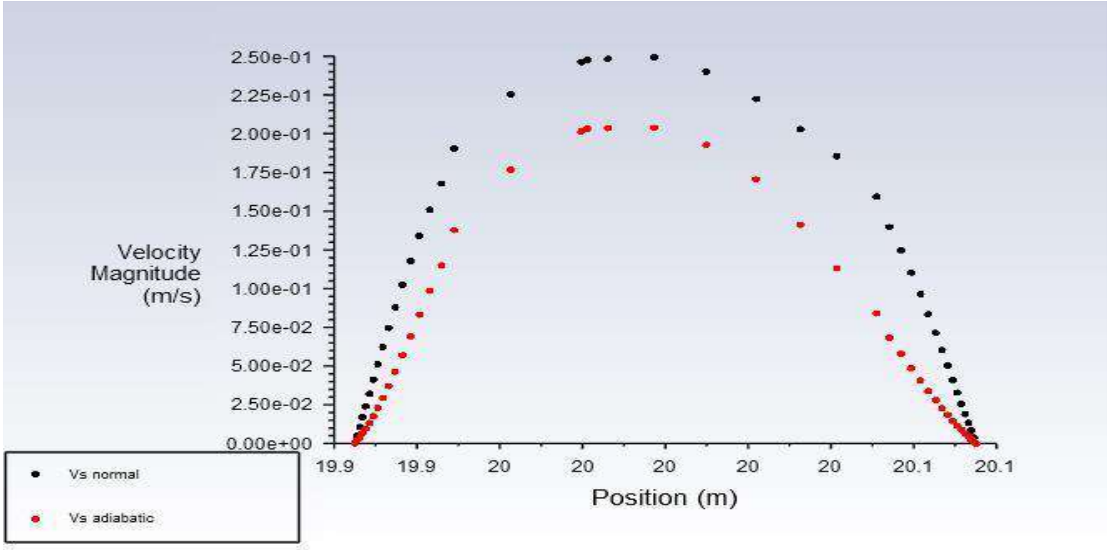


Figure III-25: Speed comparison at an adiabatic outlet and a normal outlet at a flow of Re=1000

In both curves, we can observe that the velocity is higher at the center of the tube and gradually decreases towards its ends. The curve representing the tube with a normal outlet shows the highest velocity value of 0.25 m/s, whereas the curve representing the tube with an adiabatic outlet shows a slightly lower velocity of 0.20 m/s. Additionally, there is a slight variation between the two curves due to the temperature difference.

Essentially, when the temperature increases the viscosity of the fluid decreases. This reduced viscosity allows the fluid to flow more easily, resulting in less obstruction and higher velocity. Therefore, the change in temperature affects the fluid's behavior and influences the velocity distribution along the tube.

III.00 Speed comparison at an adiabatic outlet and a normal outlet at a flow of Re=1500:

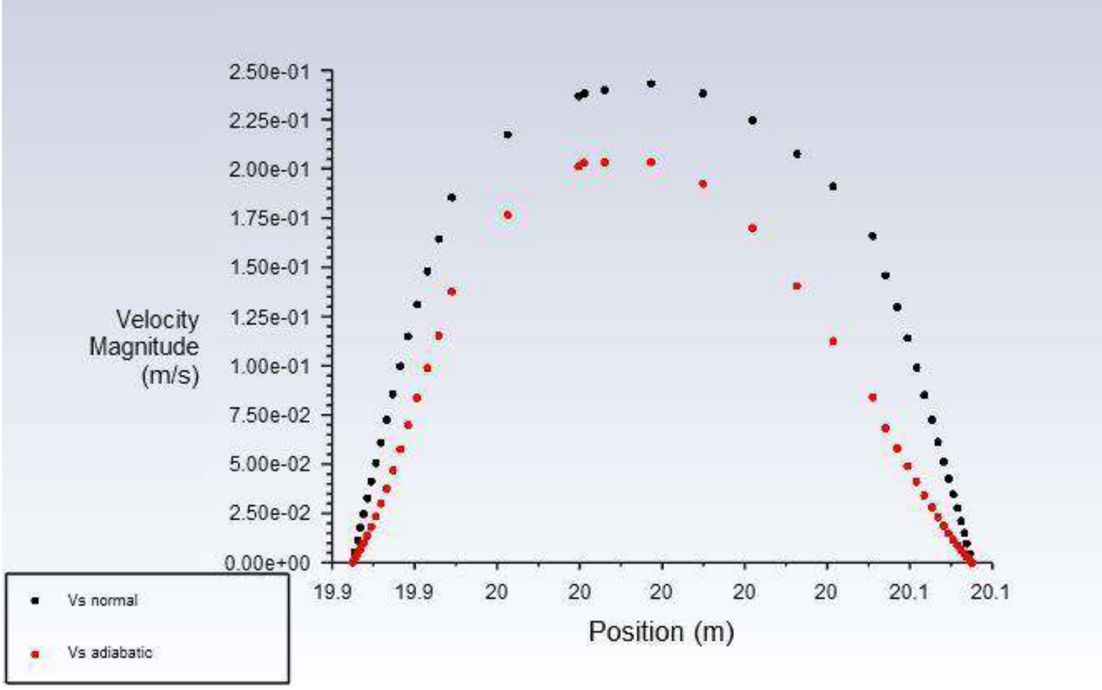


Figure III-26: Speed comparison at an adiabatic outlet and a normal outlet at a flow of Re=1500

Both curves show that the velocity is highest at the center of the tube and decreases gradually as we move towards the ends. The curve representing the tube with a normal outlet has the highest velocity recorded, reaching 0.25 m/s. On the other hand, the curve representing the tube with an adiabatic outlet shows a slightly lower velocity of 0.20 m/s. It is important to note that there is a slight variation between the two curves, which can be attributed to the difference in temperature conditions.

And this is what we noticed when comparing the speed at an adiabatic outlet and a normal outlet at a flow of 1000, and this indicates that the speed in the heat exchanger is not affected by the type of outlet or the number of flow, but is generally affected by the temperature.

Conclusion:

A heat exchanger is a crucial component in cooling systems. It plays a vital role in various applications, including air conditioning, refrigeration, and industrial processes. Cooling by an air-to-air heat exchanger, commonly known as an air sol, is a crucial process that plays a significant role in our daily lives. Air sol heat exchangers are designed to transfer heat from the outgoing stale air to the incoming fresh air, resulting in efficient cooling and improved indoor air quality.

In our work, we used the ANSYS program for numerical simulations, considering that the flow is laminar, Newtonian, constant, and unidirectional.

After the simulations, the different results obtained in this study showed that: At the Adiabatic exit: The lower the Reynolds number, the lower the temperature

At the normal exit: The higher the Reynolds number, the lower the temperature

From our study, the best results were shown at the adiabatic output when the Reynolds number is 1000, so that the temperature changed from 305 to 294.

General Conclusion

General Conclusion:

In conclusion, using air-to-air heat exchangers, particularly those having an adiabatic output, for cooling purposes has several positive effects. The efficiency and efficacy of the cooling process are increased overall by using air sol heat exchangers with adiabatic outputs.

It is crucial to include an adiabatic exit in the heat exchanger since it can further improve cooling efficiency. Water is evaporated during adiabatic cooling, which lowers the temperature of the output air stream and increases cooling capacity. Improved temperature control and more effective heat transmission are made possible by this technique, which also results in greater energy efficiency and cooling efficacy.

Air sol heat exchangers can gain improved cooling efficiency by including an adiabatic output, especially in hot and dry areas. Without the need of extra mechanical cooling equipment, the evaporation of water in the output air stream contributes to a decrease in temperature and an increase in cooling capacity. In addition to saving energy, this lowers the running expenses linked to conventional cooling techniques.

In the aforementioned investigation, we constructed a heat exchanger with the following dimensions: 20 meters in length, 15 cm in diameter, 3 meters deep, and 32 degrees Celsius air temperature. In two different scenarios, one with an adiabatic outflow and the other with a conventional outlet, we performed research and altered the Rayleigh number in each case, specifically at 1000 and 1500.

After examining the simulations, we came to the conclusion that a heat exchanger with a Rayleigh number of 1000 and an adiabatic outlet that is insulated from outside effects produces the best results. This conclusion is drawn from the finding that lower Rayleigh numbers provide superior results, signifying a better performance.

Future studies should combine a computer simulation research that focuses on the heat exchanger's behavior under turbulent flow circumstances with an experimental analysis to assess the heat exchanger's performance.

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Summary:

For energy efficiency, indoor air quality, and general comfort in our living and working environments, cooling through air sol heat exchangers is essential. These heat exchangers contribute to lower energy use, better air quality, and the development of surroundings that are healthier and more sustainable by recovering and transmitting cooling energy.

The performance assessment of a horizontal air-ground geothermal exchanger with an adiabaticoutlet is the main topic of the graduation thesis. The purpose of the study is to evaluate the efficacy and efficiency of this particular design of the geothermal system. Various characteristics and aspects impacting the functioning of the system are investigated andassessed through Numerical Simulation. The horizontal air-ground geothermal exchanger with an adiabatic outlet's thermal behavior, heat transfer properties, and energy efficiency are discussed in the thesis.

Keywords: Ground-to-air heat exchanger, performance evaluation, horizontal configuration, adiabatic outlet, thermal behavior, heat transfer, energy efficiency.

ملخص:

من أجل كفاءة الطاقة وجودة الهواء الداخلي والراحة العامة في بيئات المعيشة والعمل لدينا ، فإن التبريد من خلال مبادلات حرارية الهواء هو أمر ضروري. تساهم المبادلات الحرارية هذه في تقليل استخدام الطاقة وتحسين جودة الهواء وتطوير محيط أكثر صحة واستدامة من خلال استعادة ونقل طاقة التبريد.

يعد تقييم أداء المبادل الحراري الأرضي الجوي الأفقي مع منفذ ثابت الحرارة هو الموضوع الرئيسي لأطروحة التخرج. الغرض من الدراسة هو تقييم فعالية وكفاءة هذا التصميم الخاص لنظام الطاقة الحرارية الأرضية. يتم التحقيق في الخصائص والجوانب المختلفة التي تؤثر على أداء النظام وتقييمها من خلال المحاكاة العددية. تمت مناقشة المبادل الحراري الأرضي الجوي الأفقي مع السلوك الحراري لمخرج ثابت الحرارة ، وخصائص نقل الحرارة ، وكفاءة الطاقة في الأطروحة.

الكلمات المفتاحية :المبادل الحراري الأرضي الجوي ، تقييم الأداء ، التكوين الأفقي ، المنفذ الأديباتيكي ، السلوك الحراري ، نقل الحرارة ، كفاءة الطاقة

Résumé:

Pour l’efficacité énergétique, la qualité de l’air intérieur et le confort général dans nos environnements de vie et de travail, le refroidissement par des échangeurs de chaleur sol air est essentiel. Ces échangeurs de chaleur contribuent à réduire la consommation d’énergie, à améliorer la qualité de l’air et à développer un environnement plus sain et plus durable en récupérant et en transmettant l’énergie de refroidissement.

L’évaluation des performances d’un échangeur géothermique air-sol horizontal avec sortie adiabatique est le thème principal de la thèse de fin d’études. Le but de l’étude est d’évaluer l’efficacité de cette conception particulière du système géothermique. Diverses caractéristiqueset aspects affectant le fonctionnement du système sont étudiés et évalués par simulation numérique. L’échangeur géothermique horizontal air-sol avec le comportement thermique d’une sortie adiabatique, les propriétés de transfert de chaleur et l’efficacité énergétique sont discutés dans la thèse .

Mots-clés : Échangeur de chaleur sol-air, évaluation des performances, configuration horizontale, sortie adiabatique, comportement thermique, transfert de chaleur, efficacité énergétique.