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Thème

Analyse numérique des performances thermiques d'un système d'échange de chaleur Terre-Air fonctionnanten climat chaud

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Mémoire préparé au sein du Laboratoire d'**E**xploitation et de **V**alorisation des **R**essources **E**nergétiques **S**ahariennes

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Theme

Numerical Analysis of Thermal Performance of Earth to Air Heat Exchange System Operating in Hot Climate

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Dedication

I am very happy to dedicate this humble act, as a gesture of gratitude:

To my dear mother for her devotion, love, sacrifice and encouragement. my and father, may God have mercy on him, and dwell in his vast paradise.

For our brothers and sisters and all of our family.

For our friends

And to everyone I know from near or far

To all my friends and comrades in the university of El Oued.

Noureddine Adamou

Dedication

I deducate this work for everyone who is waiting for the moment of my graduation with patience my entire family (sister , father, mother , brothers). Also my elder sister who used to help me and motivate me to study during my the studying carrier materially and mentaly too with pleasure also with out forgetting my framer Dr. Abdelmalek Atia And my mentor Mr. Nacer Lebbihiat and my dear colleague Adamou Nour Din. Last but not least , I have fullfiled this. Last but not least , I have fullfiled this Memoir in some exceptional health conditions and I want to say God have mercy on all the martyers that passed away during this pandamic and speed recovery for the patiences .

Abih Ahmed Sidi Mohame

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Nomenclature

T : temperature (°C).

C_ρ : thermal capacity,(J/kg. °C)

Q' : internal source (w)

T_{moy} : Temperature moyenne (°C).

A_s :Heat exchange surface (m2)

Z : Depth (m)

α : Thermal diffusivity

Φ : Thermal flux per unit area through the tube wall, (W/m2).

T_{soil} : Soil temperature, (°C).

T_{air} : Air temperature (°C) .

R : The thermal resistance of a cylindrical wall

R_{cd} : Thermal resistance for the sheath of the duct at the convection, (m2.K/W).

R_{cv} : Thermal resistance for the sheath of the duct at the conduction, (m2.K/W).

r_2 : Outer sheath radius, (m).

r_1 : Inner Sheath Radius, (m).

λ : Thermal conductivity of duct wall, (W/m.K).

L : Duct length, (m).

Q : Quantity of heat exchanged, (J).

S : Lateral surface of the sheath, (m2).

T: Temperature, (m).

ρ : Air density, (kg/m3).

c : Air mass heat, (J/kg.K).

r : Radius (m)

q_v : Flow air volume, (m3/h).

V : Air volume (m).

T_{as} : outlet air temperature , (°C).

T_{ae} : Inlet air temperature, (°C).

T_a : air temperature in exchanger

ε : Efficiency

T_{in} : Temperature inlet (°C).

T_{out} : Temperature outlet (°C).

General Introduction

General Introduction

Since the end of the twentieth century and the beginning of the twenty-first century, the world has witnessed an exacerbation of global environmental challenges, perhaps the most prominent of which is the phenomenon of global warming and climate change. and many reports indicate the role of traditional energy sources (fossil fuels) in these dangerous indicators that predict the worst if no structural measures are taken to change Energy mode especially in developing countries.

Renewable energy sources such as wind, solar and hydrogen power are more beneficial for the future. Among these renewable energy sources is geothermal energy, It is heat extracted from underground and used in various activities such as heating, cooling, bathing, and therapeutic applications. It is also considered one of the few renewable energies capable of continuously producing electricity 24 hours a day, and under the right conditions it can be cost-competitive with coal or Natural gas which means the ability of countries to reduce their dependence on imports of fuels and increase their energy security.deep geothermal resources are largely available across continents and it can be used repeatedly in addition to being environmentally friendly and highly efficient.

In some nations, such as Iceland (27 percent of power) and El Salvador (26 percent of electricity), geothermal energy is already playing an important role. However, the geothermal sector's overall contribution to worldwide power generation is still relatively minor (0.3 percent). The International Energy Agency has suggested that plans be developed to handle technology-specific issues. achieve faster growth and improve policies addressing geothermal energy's pre-development concerns Exploiting deep geothermal resources necessitates great depths, yet experience acquired from the implementation of complicated, engineered deep geothermal projects has revealed technical and economic hurdles, lower-than-expected results and a negative public image As a result, alternative, more sustainable well designs are urgently needed [1].

Algeria is considered one of the countries rich in renewable energy resources, as its desert area is estimated at about 2 km^2. The demand for energy can be easily met due to the large reserves of solar energy (more than 3000 hours of sunshine per year [4]), and energy of origin geothermal, in the most recent survey by the National Water Resources Agency, more than 240 thermal springs were inventoried [2]. It is mainly located in the northeast, northwest, and south regions of the country. The measured temperatures range from 31 ° C in the Ain Mantilla bath to 94 ° C in the Maskotin bath. The El oued region, the site of our study project, is located in the northern part of the Algerian Sahara.

Residential buildings primarily use energy to provide thermal comfort, and reducing energy consumption, particularly in desert regions, is a significant challenge. To this end, a ground-to-air heat exchanger technology was used, which is a system of tubes buried in the ground through which heat is transferred from the surrounding soil to the surrounding air. Convectional airing. It is a passive technology that uses little or no energy and produces nearly no emissions when compared to traditional HVAC systems, which is why it is referred to as a green building technology [3]. Because it employs air as a working fluid, it reduces greenhouse gas emissions.

The ground temperature tends toremain constant along the year. This means that ground temperature is lower than air temperature in summer and is higher inwinter, That is why the exchanger can be used for heating / cooling, Over the past century, there has been a dramatic increase in global direct use of geothermal energy for heating jumped from 8664 MWt in 1995 to 70,329 MWt the in 2015. A large Part of this capacity comes fromthe ground source heat pump, where the deep coaxial borehole heat exchangersconsidered as one of the important ground source heat pump types A deep coaxial borehole heat exchanger consists of two concentric pipes installed in the wellbore that allow the circulation of a working fluid that exchanges heat with the ground [5]. The heat exchanger installation can be placed in horizontal or vertical configurations.

The objective of our work is to study spiral heat exchanger between air and ground in three essential chapters:

- In the first chapter there will be a review of the literature basis of geothermal and the technique of underground heat exchanger cooling and studies that have been carried out in the past on this technique.
- The second chapter will cover the Simulation Model ANSYS FLUENT will be used in this study that used the finite volume method to convert the governing equations in to numerically solvable algebraic equations. The proposed configuration is spiral shape as illustrated.
- The third chapter will present the obtained Results and analysis.

Chapter I:

Literature Review on The Spiral Geothermal Heat Exchanger

I.1 Introduction

One of the most significant current discussions is reducing energy consumption in desert areas is a great challenge due to the high temperature in summer and low in winter. Researchers have found in the last yeara large part of the energy is used in heating, ventilation and air conditioning systems, which leads to huge electrical power ,consumption Moreover he use of these appliances contributes significantly to global warming and especially emissions of CO2.

The transition from conventional to renewable energy is imperative for the creation of a more comfortable life for humanity. Geothermal energy has been studied by many researchers considered among renewable energy resources which allow easy access to low thermal supply energy without environmental impact . It was considered as a promising space-cooling and heating solution. Geothermal energy is very interesting energy source, which considered as one of the few renewable energies could be available for all the a day, and under the right conditions it can be cost-competitive with coal or natural gas.

There are a lot of heat exchanger Type that haves been studied by many researchers, which is a system of tubes (metallic, plastic or concrete) buried in the ground. The air pumped through the pipes, exchanges heat with the ground and gets heat/cool depending on the temperature difference between the air and the ground. The resulting warm/cold air is used to regulate the indoor temperature in order to satisfy the human comfort. This system requires low energy and for that reason it is known as a green building technology.

I.2 Literature review

Asgar Minaei. [6] created a hybrid model for transient heat transport in Earth-Air Heat Exchangers, there are a great number of published works on geothermal heat exchangers. The impacts of air flow rate, installation depth, and soil thermal characteristics on greenhouse air temperatures are investigated, and the results suggest that the provided model outperforms experimental results. configuration spiral earth to air Heat exchanger (SEAHE) intended for the summer cooling inhot and arid regions of Algeria. The authors focused on the effect of diameter, depth, pipe length and of air flow rate on the outlet air in theexchanger. Results demonstrate that in an arid zone, specific heat exchange is used to cool (south-east of Algeria). When the ambient temperature is between 40 and 45 degrees Celsius, the cooling 2 temperature is between 25 and 29 degrees Celsius. The temperature differential between the inlet and outlet air exchangers is 18°C, which is acceptable for cooling a building.

Naghmeh Jamshidi and Nasibeh Sadafi [7] provided additional analysis and discussion on the topic. For the simulation of earthto-air heat exchangers, a new analytical model was created in commercial software. the impact of many parameters on the exhaust air temperature, such as the depth level of buried heat exchanger in soil, the velocity and temperature of incoming air, as well as the Mahendra Kumar Verma [8] conducted a comprehensive study on geothermal heat exchangers. In addition to air velocity, pipe depth, and pipe length, the influence of thermo-physical qualities of soil on the thermal performance of EAHE was discovered. The investigation concluded that the performance of the EAPHE degraded owing to thermal saturation of the soil, rendering it unusable.

A numerical parametric investigation of the thermal performance of a spiral shaped arrangement of EAHE is presented by Naoufel Benrachi et al.[9]. They used a CFD model to investigate the impact of pitch, depth, pipe length, and flow velocity on output air temperature, as well as the EAHE's mean efficiency and coefficient of performance (COP), When the pitch space vs.When the air velocity is increased from 2 to 5 m/s, the mean efficiency falls from 60% to 33%, and the COP of the EAHE falls from 2.84 to 0.46. AHMED, S et al., S AHMED et al., S AHMED Through a parametric analysis, [10] investigated the usefulness cooling performance of a vertical EAHE for a subtropical climatic zone. To assess the parametric investigation, ANSYS Fluent was used to create a thermal transient model for the vertical EAHE. The results reveal that pipe diameter, air velocity, and temperature have a significant impact on cooling performance. and pipe length, while pipe material has no discernible effect. The best performance resulted in an 8.21°C reduction in outlet air temperature.

The susceptibility of open earth air heat exchanger systems to temperature fluctuations was investigated by Zajch and W A Gaugh [11]. The findings imply that boosting ground surface temperatures outside of the summer season can boost Canada's heating potential while having little effect on the cooling potential Lukasz Amanowicz and Janusz Wojtkowiak. [12] explains the deficiency. The numerical validation of the EAHE flow performance was prepared using the CFD software Ansys Fluent and the application of the experimentally determined flow characteristics of multi-pipe earth-to-air heat exchangers (EAHEs). Both experimentally and numerically, the total pressure losses and airflow in each pipe of multi-pipe exchangers were examined. For optimizing the geometrical structure of multi-pipe EAHEs in low-energy buildings to conserve energy and lower operational expenses.

Anuj Mathur et al. [13] emphasize the necessity of space constraints when installing a straight EATHE system by introducing a new spiral-shaped EATHE system. to determine each person's cooling and heating potential, Summer COP was 5.94 and 6.24; winter COP was 1.92 and 2.11 for straight lines. and, correspondingly, spiral. Naghmeh Jamshidi and Nasibeh Sadafi [14] offer a model for the simulation of earth to air heat exchangers that was implemented in commercial software. the effects of many parameters on the exhaust air temperature, such as the depth level of buried heat exchanger in soil, the velocity and temperature of incoming air, and the thermal load absorbed by the heat exchanger, are all being looked into. The results reveal that a spiral geothermal heat exchanger can provide a portion of the thermal energy required for a normal building as well as a portion of the cooling load in the summer. Mohammed Cherif Lekhal [15] conducted a study.. During moments when the EAHE switches from heating to cooling mode, the pipe material can have a major impact on the EAHE performance.

A M AKBAR POOR et al.[16] provided a prospective study designed to evaluate the utilization of an integrated cooling system consisting of an earth-to-air heat exchanger (EAHE) and a domed roof to meet thermal comfort requirements and provide the cooling demand for a building is explored numerically. Air flow simulation in the EAHE and in a test The three-dimensional modeling of the room with the domed ceiling is done with ANSYS FLUENT software, and the thermal behavior of the system is modeled with MATLAB code. The results reveal that the system is capable of providing thermal comfort for a two-story building with a maximum cooling requirement of around 300 W. Two pipes with a length of 35 m and a diameter of 0.4 m are used for each floor. [17] Increased soil moisture content has an effect on heat exchanger performance, according to Kamal et al. The author's system incorporates two EAPHE system configurations buried at a depth of 3.7 m, one for dry soil and the other for wet soil. The knee point for the dry EAPHE system is 40 meters from the input section, whereas the knee point for the wet EAPHE system is 28 meters, 27 meters, and 26 meters with soil moisture levels of 5%, 10%, and 15%, respectively. The average heat transfer rate and coefficient of performance improve until they reach 26.0 percent and 26.1 percent, respectively, after 12 hours of continuous operation. relative to the dry system, and a moisture content of 15% at 30 m of EAPHE pipe length.

In a comparative assessment of the effectiveness of earth to air heat exchanger (EAHE) systems in hot-arid (Yazd) and cold (Hamadan) climates in Iran, Faezeh Fazlikhani et al. [18] created a steady state model to examine the effects of various parameters including inlet air temperatures. The technology lowers the air temperature in the aforementioned cities by 1.3–11.4 °C and 5.7–11.1 °C, respectively, according to the findings. In Yazd's hot, arid climate, the method proves to be more efficient. On 294 days of the year, it can be used. Salsuwanda Selamat et al.[19] investigated certain strategies for optimizing horizontal floor-mounted heat exchanger systems utilizing varied layouts and pipeline materials in a large longitudinal study. Pipe materials with excellent thermal conductivity also enhance longer, more efficient operation, according to the findings. When copper pipes are utilized instead of typical HDPE pipes, a 16 percent improvement is found. When floor heat exchangers are positioned in a vertical configuration, the effective duration can be increased by 14%. Ahmed A. Serageldin et al [20] conducted a number of studiesto look into the effects of various variables (diameter, material, space, pipe length and fluid velocity) The findings revealed that certain parameters had a direct impact on the exchanger's exit temperature. When the pipe diameter is increased by 2 to 3, the outlet temperature drops from 20.4 C to 18.7 C. On the other hand, when the length of the pipe is increased, the temperature of the air at the exchanger's exit rises. When the length of the pipe is increased from 5.45 m to 7 m, and the spacing is increased from 0.2 to 0.5 m, the temperature rises slightly from 19.7 to 19.9 C. 19.8. In addition, the authors have The chosen three materials for the exchanger are (copper, PVC, steel) 19.7 C in PVC pipes, 19.8, 19.8 C for steel, and 19.8, 19.8 C for copper. It is assumed that the variation in outlet air temperature for various pipe materials is taken into account while determining their pricing. and the temperature will drop from 20.4 C to 19.2 C at the completion of the speed increase from 1 to 3 m / s.In order to optimize the performance of the heat exchanger, the air speed must be reduced. Marwa Dabaieh and colleagues [21]. suggested a study provides a design concept for a premium passive refugee house that is appropriate to the Swedish environment and uses three key passive heating and cooling systems (Earth Air Heat Exchanger, Trombe wall, and green wall).The goal of combining the three passive systems is to minimize cooling and heating loads in order to save a considerable amount of primary energy and, as a result, minimize the house's energy use's environmental effect through reduced emissions. The house is planned to meet its energy needs entirely from renewable sources, resulting in an annual surplus of 180 kWh/m2 per year. TRNSYS and ANSYS software were used to implement a dynamic system modeling and simulation strategy. The simulation revealed a heating load of 7.9 kWh/m2/year and a cooling load of 2.8 kWh/m2/year, respectively. with an annual total energy use of 18.4 kWh/m2. Using the three passive solutions, preliminary feasibility costing revealed a payback time of 7.4 years out of the 25-years recommended lifetime of the structure. With a primary energy demand of 0.032 GJ/m2/annum, the amount of CO2emissions is 231.1 kg CO2e/annum. Kamal Kumar Agrawal and his colleagues The goal of this study is to investigate the economic feasibility of using backfilling materials in the area of GAHE pipe using the numerical model given in [22]. For this, a three-dimensional CFD simulation model of the GAHE system with backfilling material was created using FLUENT 15.0, as well as the length of GAHE pipe required to produce a particular drop in air pressure. The temperature has been determined using backfilling materials. The GAHE system's initial installation cost (i.e. pipe cost, trench excavation cost, backfilling material cost) has been calculated based on this. The study found that employing dry sand-bentonite, the initial installation cost of a GAHE system may be decreased by 25.7 percent, 32 percent, and 38 percent, respectively. In place of dry native soil, moist sand-bentonite and wet native soil were used as backfilling materials. Seama Koohi-Fayegh et al.[23] found that the ground temperature remains nearly constant year after year below a particular depth. By connecting a ground heat exchanger to a heat pump, this phenomenon can be taken advantage ofDuring the summer, heat is stored in the earth to be used in the winter. Because it is cooler in the summer and warmer in the winter, the earth is a superior source/sink for heat than outside air for heat pump efficiency. Such devices also aid in the prevention of accidents due to their greater Environmental impact and efficiency The utilization of ground heat pumps for heating and cooling buildings, as well as water heating, refrigeration, and other thermal duties, is receiving a lot of attention these days. Understanding, creating, and optimizing the performance and characteristics of such systems necessitates modeling. For ground heat exchangers, there are several heat transfer models available. which is usually made up of a collection of subterranean pipes that run vertically or horizontally. In this paper, an introduction to several types of ground heat exchangers is given, as well as a discussion and comparison of analytical and numerical models for heat transfer in vertical heat exchangers. Recent developments in the field are covered, as well as design software for vertical ground heat exchangers. A system of a coupled geothermal cooling system with an earth-to-air heat exchanger and a solar collector enhanced solar chimney was presented by Yuebin Yu et al.[30]. In the summer, experiments were carried out utilizing an existing test facility to assess the system's performance. in terms of soil thermal capability, active cooling capability, and passive cooling capability Three distinct tests were conducted in a sequential order over the course of 43 days. The findings reveal that the coupled geothermal system can supply cooling to the facility in a natural operation mode without the use of power. The solar collector improved the efficiency of the solar chimney. With a higher solar intensity, the system can receive more airflow during the day. The indoor air condition under the natural airflow stage was more acceptable in terms of thermal comfort than that under the forced airflow stage, according to the thermal sensation analysis based on expected mean vote and expected percent of unsatisfied people. Due to the increase in subterranean soil temperature, the cooling capacity of the linked system declines quickly after the one-week forced airflow test. J. Xamán [24] carried out study to estimate the thermal and ventilation possibilities of a geothermal Earth-to-Air Heat Exchanger (EAHE) for six different weather conditions in Mexico. Due to the increase in subterranean soil temperature, the cooling capacity of the linked system declines quickly after the one-week forced airflow test. J. Xamán [25] carried out study to estimate the thermal and ventilation possibilities of a geothermal Earth-to-Air Heat Exchanger (EAHE) for six different weather conditions in Mexico. The thermal behavior of the EAHE was numerically modelled for the corresponding warmest and coldest days of the year for each city and three values of Reynolds number (hot humid, hot-sub humid, dry, extremely dry, warm-humid, warm-sub humid). The simulations lasted 24 hours and were run with an in-house code that updated every 10 minutes. The EAHE is suitable for dry climates but not for humid regions, according to the findings. This study was carried out by M C LEKHAL et al. [26] to conduct a survey on the heating performance and feasibility of In Algeria, Oran, two EAHEs are operating in three separate geoclimatic regions. El-Bayadh and Béchar. The results demonstrate that EAHE's thermal performance is mostly influenced by geo-climatic conditions and pipe material. SAKHRI N et al.[27] published a study that looked into the effect of local climatic variables on the efficiency of earth-to-space communications. Experiments with air heat exchangers (EAHEs). EAHEs were examined in four cases: (1) a simple EAHE, (2) an EAHE with sun protection at the top portions, (3) an EAHE with a chimney effect at the outlet, and (4) an EAHE with a fan at the intake, the results showed that Case 4 produced a drying tendency and a stable drop in RH of 30% for virtually the whole day. The addition of a fan improved the effectiveness of the system and minimized the effects of external weather conditions. Mohammed Benhammou and colleagues[28] have created The thermal performance of earth-to-air heat exchangers (EAHE) for summer cooling beneath the Algerian Sahara was studied using a transient one-dimensional model. The impact of extremities was also considered. Validation of the model using both theoretical and experimental evidence from other people. The air outlet temperature reduces as pipe length grows, but it increases when pipe diameter rises, according to the findings air velocity and cross section The daily mean efficiency, on the other hand, increases when pipe length grows, but falls as pipe cross section area or air velocity increases.

It's also worth noting that as air velocity rises, the coefficient of performance falls rapidly. The analysis of Derating Factor demonstrates that the thermal performance of EAHE in transient situations is more influenced by variations in operation time, pipe diameter, and air velocity, taking as a reference the thermal performance of EAHE in steady state settings.

The findings of a 12-month monitoring program of an earth-to-air horizontal heat exchanger (EAHX) system in an Imola school complex were published by Giacomo Chiesa et al.[29]. It is one of the largest Italian applications of this technology, with almost 2 kilometers of subterranean pipes. Inlet and outlet air have significant variations Both in the winter and summer, the temperature has been noted. The energy performance of the system was assessed using data from sensible heat exchange, while air temperature and relative humidity were depicted on a psychrometric chart. In order to verify the parameter values of the monitored findings, they were compared to three comparable cases given in the literature Various EAHX in a variety of climates and design conditions Michel Kepes Rodrigues et al.[30] used the Constructal Design to do a numerical research on several geometrical configurations of an EAHE to determine the highest thermal potential. The findings revealed that, for The number of ducts (complexity of geometry) increased the EAHE thermal performance by roughly 73 percent for cooling and 115 percent for heating for the same area occupied by the ducts and fixed mass flow rate of air.

In a hot and humid subtropical climatic zone in Queensland, Australia, S.F. Ahmed et al.[31] conducted a comparison of earth pipe cooling performance between two different piping systems. In order to test cooling performance, two separate vertical and horizontal piping systems were placed in the ground. ANSYS Fluent is used to create a thermal model for the ground pipe cooling system. Two simulated rooms with two different plumbing layouts and systems were used to collect data. The effect of air temperature and velocity on room cooling efficiency is also investigated. Both piping systems have experienced a temperature drop. In compared to the horizontal piping system, the results reveal that the vertical piping system performs better.

T. Sivasakthivel et al.[32] conducted an optimization research on eight key factors (i.e., U tube radius, borehole radius, heating load, grout conductivity, entering water temperature, distance between U tubes, etc.) , The ideal parameters and levels for GHX length, COP, and GHX thermal resistances, as determined by Taguchi optimization, are A2B1C1D1E3F3G1I3, A2B2C1D3E3F3G1I2, and A1B2C1D2E1F1G3I1, respectively. Results obtained with the above-mentioned optimal set of variables The length of GHX is reduced by 15.17 percent, the COP is increased by 2.5 percent, and the thermal resistance of GHX is reduced by 17.1 percent. The utility idea was used to generate a single set of optimal parameters and levels, which resulted in a 3.2 percent increase in GHX length, a 1.2 percent decrease in COP, and a 13.23 percent reduction in thermal resistance. Rosa et al. [33] used Ansys CFX to construct a thermal model to assess EAHE cooling performance in the Mediterranean environment throughout the summer. The EAHE was made up of PVC pipes that were buried parallel under the clayey sandy soil at a depth of 1.9 meters. The PVC pipes were kept at a constant distance of one meter apart.The study found that when the air velocity increases, EAHE cooling efficacy decreases for a given distance between adjacent pipes and a given diameter. Ansys Fluent was also used to run EAHE thermal models in order to assess their thermal performance. Various air velocities and pipe materials are used. AHMED et al AHMED et al AHMED et el .[34] This research adds to our understanding of the EAHE system's strategies for identifying shortcomings and strengths based on performance, progress, application, and obstacles. Physical as well as hybrid modeling techniques have been used Because these models are routinely used to quantify EAHE performance, there is enough scientific material to consider in this review. Policymakers, building energy researchers, and energy management groups will benefit from the review's recommendations on the best and most appropriate options The EAHE's efficiency can be improved by using a modeling methodology. Nasibeh Nematiet al. [35] did a prospective study to look into the utilization of a new hybrid system that combines an indirect evaporative cooler with underground air tunnels as an environmentally acceptable option for vapor-compression cooling cycles In arid and semi-arid areas, indirect evaporative cooling is an effective thermal comfort cooling strategy. In these areas, managing and monitoring water usage in evaporative coolers is especially important due to global warming and limited water resources. According to the findings, the proposed method can reduce energy and water use by around 62% and 45 percent, respectively. D Qin et al. [36] established a conceptual framework for a complementary geothermal and solar energy system, and they carried it out, coupled with phase change material for improved performance stability, which is vital for the promotion of green buildings that use geothermal and solar energy efficiently. B ASGARI and colleagues.[37] did a study to see how well alternative GHE pipe layouts for three different types of horizontal GHEs (linear, spiral, and slinky) perform in terms of thermal performance. According to the findings, the linear GHE with quadruple layer design delivers the most equal heat distribution in the study the surface Menhoudj et al. [38] used Trnsys to create an EAHE model to estimate cooling performance in Algeria. The EAHE was made up of a pipe with a diameter of 0.12 m, a length of 20 m, and a depth of 2 m, as well as zinc and PVC materials. The PVC pipe reduced the average temperature by 6 degrees Celsius, while the Zinc pipe only added 0.5 degrees Celsius, indicating that the pipe material had no effect on EAHE performance. However, these studies did not take into account all of the factors that influence EAHE performance. Liu and colleagues.[39] investigated the influence of different pipe materials on EAHE performance, finding that stainlesssteel pipes outperformed PE and PVC pipes. This is because materials with a higher thermal conductivity help to lower the temperature of the output air.

Zhou et al. [40] conducted a series of tests to look at the effects of various pipe materials. The material had no discernible effect on the EAHE performance. However, most parametric studies did not take into account all of the critical EAHE factors, which has an impact on the EAHE system's actual performance. Rainwater harvesting was used by Gao et al. [41] to improve GHE performance, and the GHE was linked with a rain garden to increase soil moisture. Water migration is expected to occur in sandy soils with low moisture levels, as illustrated. The integrated model is shown to be unnecessary for greater moisture content. The difference in moisture dependant conductivity must also be taken into account when predicting GHE performance. F. Al- Ajmi et al.[42] created a theoretical model to forecast the temperature of an EAHE air outlet and the cooling capacity of this device in a hot, arid region.The model was created in the TRNSYS-IISIBAT system for a typical Kuwait City residence. They demonstrated that the EAHE might lower residential cooling energy demand by 30% throughout the summer season. In two separate studies. N. Moummi and colleaguesA theoretical modeling investigation of an EAHE was undertaken by [43]. The exposed analytical model displays variations in air temperature at the EAHE outlet based on key elements such as soil thermophysical characteristics, meteorological circumstances, tube size (inside diameter and length), air flow, and so on. In order to increase EAHEs' energy yield. Mokhtari [44] presented a numerical simulation of an air-ground-water heat exchanger in co-current. They used a coaxial tube with smaller sections to transmit irrigation water that was supposed to be kept at a consistent temperature. The authors did a comparison analysis of the two options. With respect to mechanical ventilation through direct extraction from the outside air, the energy gain that we could have in the event of an EAHE and the case of a ground-waterair heat exchanger. They concluded that if the transferred fluid has interesting thermal properties, the soil-waterair exchanger is far more successful than a basic EAHE. Yang et al.[45] conducted an experimental investigation to assess the EAHE system's performance and cooling/heating capacity for regulating the indoor thermal environment. An EAHE's air temperature, relative humidity, thermal capacity, coefficient of performance (COP), and heat transfer efficiency were all studied, On typical summer and winter days, a scale experiment was done for a continuous 24 hours utilizing two identical buildings (with and without an EAHE) exposed to the same external circumstances. However, The EAHE ventilation system offers a great potential for decreasing building cooling and heating energy consumption in hot-summer and cold-winter climates, according to these findings. C ALIMONI et al. and Smith's comparative study. [46] discovered simple and quick design methods for determining the appropriate energy application for deep borehole heat exchangers that take advantage of geothermal resources. The outcomes When the geothermal source temperature is between 100 and 300 °C, district heating has proved to have a good potential for utilization; fact, DH ensures the highest values of both useable energy and energy efficiency. Because the energy conversion device has low energy efficiency, the absorption chiller alone does not produce good results.

The EAHE's heating and cooling capacity varies depending on a variety of factors such as climate, soil type, and design parameters. This capability has been investigated using both experimental and theoretical methods, or a mix of both.

Several studies[1-19] have shown that the performance of an EAHE is influenced by a number of factors: (1) As the fluid velocity rises, the difference in air temperature between the EAHE output and input diminishes, (2) The bigger the temperature difference between the air at the entrance and the air at the floor, the more heat is transferred. The elements that do not have a substantial impact on performance, on the other hand, are:

(d) lengthen the tube after the optimal distance has a negligible effect on the temperature difference. Many research [20-25] assessed the EAHE's thermal performance under various environmental conditions and design factors.

A detailed analysis of the physical and hybrid modeling methodologies of the EAHE system has been proposed in various research to avoid the phenomenon of performance degradation during continuous operation [26-34].

Yang et al [35-46] highlighted the sensitivity of the geothermal heat exchanger approach, stating that the effect of soil surface temperature variations as well as thermal saturation of soil around the pipe on the heat exchanger's performance should be considered. After a period, due to thermal saturation of the soil around the pipe, The temperature difference between the air moving through pipes and the soil around the pipes decreases, and the EAHE's performance suffers. According to a literature assessment, there is a severe lack of research on a complete examination of a geothermal spiral-shaped heat exchanger configuration of EAHE for cooling in hot and arid locations. A transient three-dimensional model was created to fill this gap. To anticipate the soil and EAHE temperature distribution, a computer model was created. Experimental and numerical data from the literature were used to validate the model. The spiral-shaped model was used to conduct a parametric analysis to evaluate the impacts of pitch, depth, and pipe length, and the effect of flow velocity on output air temperature, EAHE efficiency, and coefficient of performance COP, and an attempt to address the problem of soil saturation, particularly in desert areas, with solutions offered in the context to solve these problems The goal of this research is to increase the efficiency of geothermal heat exchangers and discover a solution to the soil saturation impact during heat exchanger startup, with the study area of El Oued as a case study. (southern Algeria), its meteorological climate characteristics of the soil in this zone, and the cost of installation, which is primarily determined by (the shape of the exchanger and its depth), as well as the reduction of fossil fuel energy consumption and the use of green and sustainable energy sources for air conditioning and heating of buildings.

I.3 Conclusion

We offered a collection of the most important theoretical and empirical study on the exchange in this chapter, where we described the objectives and findings for each work that demonstrate the feasibility of adopting this sort of exchange in our country.

Chapter II:

Modelling & Numerical Simulation

II.1 Introduction

Simulation is defined as the usage or analysis of models relating to a certain system in order to investigate the latter's behavior in a given situation. It is the first method to simulation and is a logical continuation of modeling. As a result, the investigated system becomes more adaptable. Parametric studies are simple to conduct. The study date range can also affect usage.

II.2 The earth–air heat exchanger concept

The principle of EAHE is that one or several tubes are buried in the ground. One end of the piping system (inlet) acts as an inlet for the outside air outside, while the other end of the piping system (outlet) releases air into the building. The surrounding air is drawn into the inlet of the tube, and the air that passes through the tube exchanges heat with the walls of the tubes which come into contact with the surrounding environment underground.

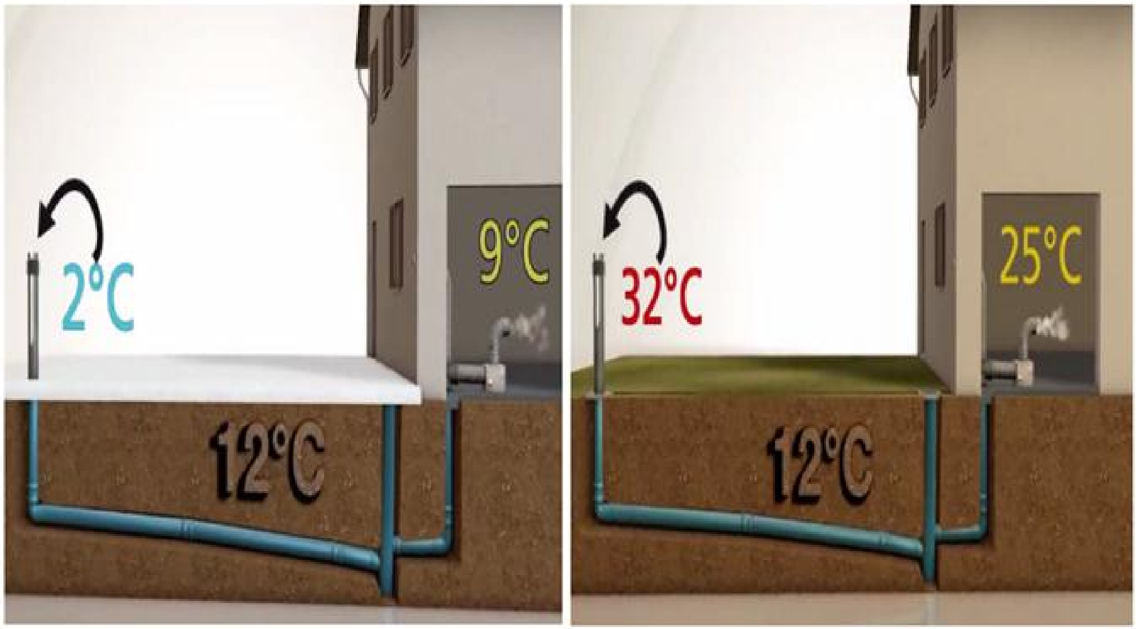


Figure II.1: Diagram of an earth-to-air heat exchanger in simplified form

In this way, heat is transferred to or from the surrounding soil by conduction through the tube wall and convection in the tunnel air, which causes the air to be softened as it flows through the tube. illustrates figure (II.1).

The depth of the burial depends on the geographical location and the climate. In winter, the soil at this depth is warmer than the outside temperature. Then the cold air is heated as it passes through the buried exchanger.

In summer, it is the same way, the air that passes through the buried pipes takes advantage of the freshness of the soil and enters the house, even at + 40 ° C outside, the air can reach comfortable temperatures .

II.3 Presentation of ANSYS simulation software

ANSYS is a program that allows the user to build and divide the arithmetic field geometry into microcontrollers or arithmetic cells. All these elementary volumes form the network. The appropriate boundary conditions, at the level of cells that coincide or touch the boundaries of the arithmetic field, are also defined at this level. It makes it possible to create several types of networks according to the geometry that can be specially used under FLUENT, and to determine the type of material (liquid or solid).

The theoretical study of heat exchanger using CFD software is very important in the research because it enables to know the various aspects of the EAHE system, based on the analysis of the simulation results by making a 3D CFD model. It also allows the study to be repeated by controlling the parameters. And do all the parametric studies before actually going to install the system in an external environment. The numerical study was performed using ANSYSFLUENT 17.2 software package in unstable conditions with an optimized 3D general analysis of the airborne heat flux of tubes in the vertical heat exchanger.

A preliminary simulation of bare soil was performed to determine the stabilization conditions. The second part is devoted to testing the effect of the parameters on the air flow and heat transfer processes inside the exchanger.

The solution of the equations depends on an iterative method by converting them into algebraic equations that can be solved numerically by using the finite volume method.

II.4 Physical model

The heat exchanger under study with a vertical spiral shape as illustrated in Fig II.2. because the horizontal model requires a large area in addition to the high operating and maintenance costs related to the experimental study.The proposed design has diameter of 1 m and height of 3 m, made of PVC material. With a 60 mm diameter and thickness of 3.5 mm and lengthof 44 m, the exchanger consists of 12 tower. The distance between two consecutive towers 25cm.

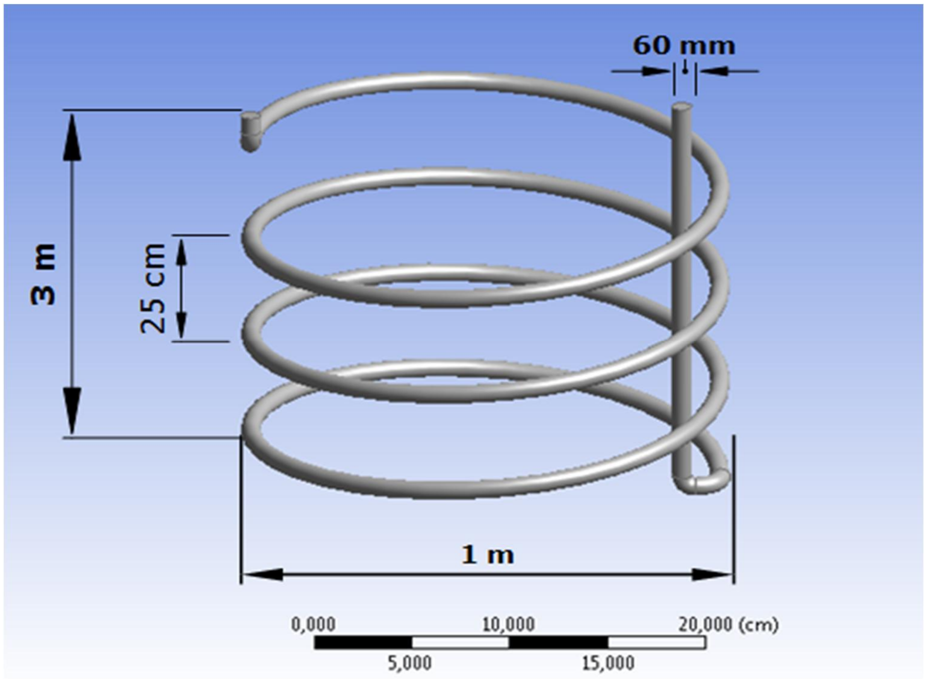


Figure II.2: Ground heat exchanger schematic

Due to poor soil hardness, the exchanger was installed inside a concrete well with a height of 3 m and an inner and outer diameter of 1.2m and 1.3 m respectively, as shown in figure II.3.

The well is fixed in the soil at a depth of 3 m. The thickness of the soil surrounding the well is estimated at 1. m

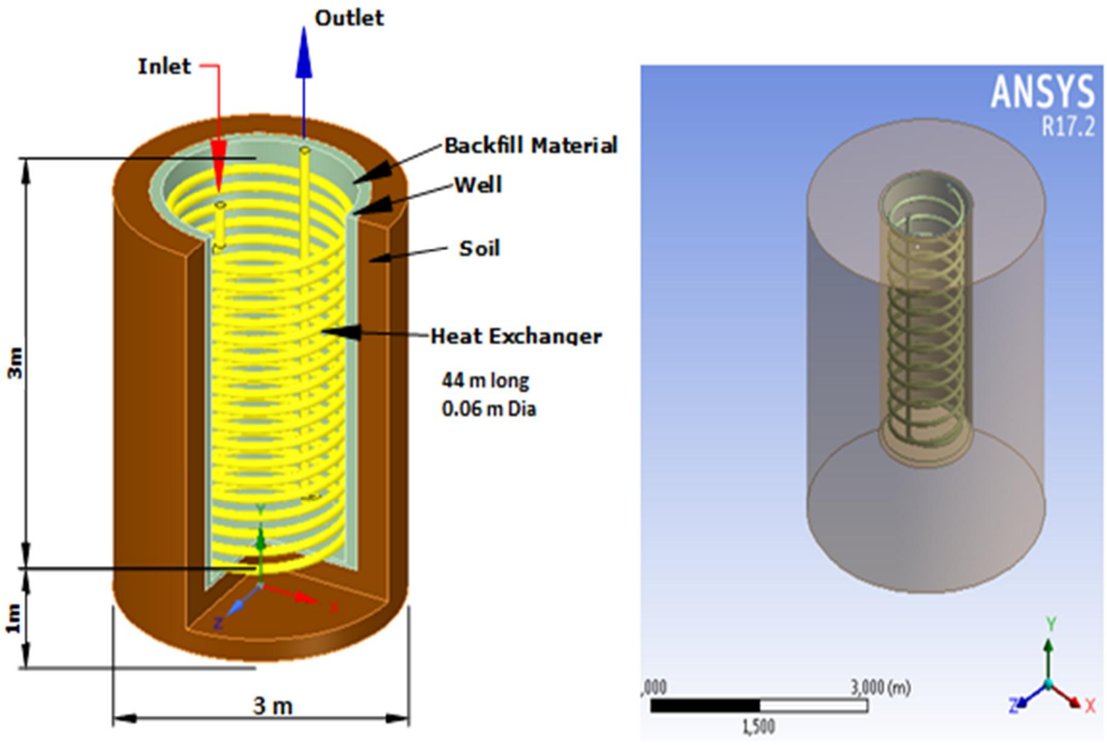


Figure II.3: Schematic diagram of a Canadian well

II.4.1 The physical properties of materials

Table II.1: Displays the thermophysicsproperties of the materials used in the design of the studied model.

Material	**Density** (kg .m^{-3})	**Cp (Specific Heat)** (J .Kg^{-1}.K^{-1})	**Thermal Conductivity** (W .m^{-1}.K^{-1})
PVC	1380	900	0.16
El-Oued Soil	1758	1000	0.58
Air	1.225	1006	0.0262
Concrete	2500	837	1.63

II.4.2 Parameters used in the simulation

Table II.2: Parameters of the materials used in the construction of the ground-air heat exchanger and used in the simulation

Parameter	**Value**
Pipe Diameter	60, 110, 200 mm
air velocity	5, 10, 15 m/s

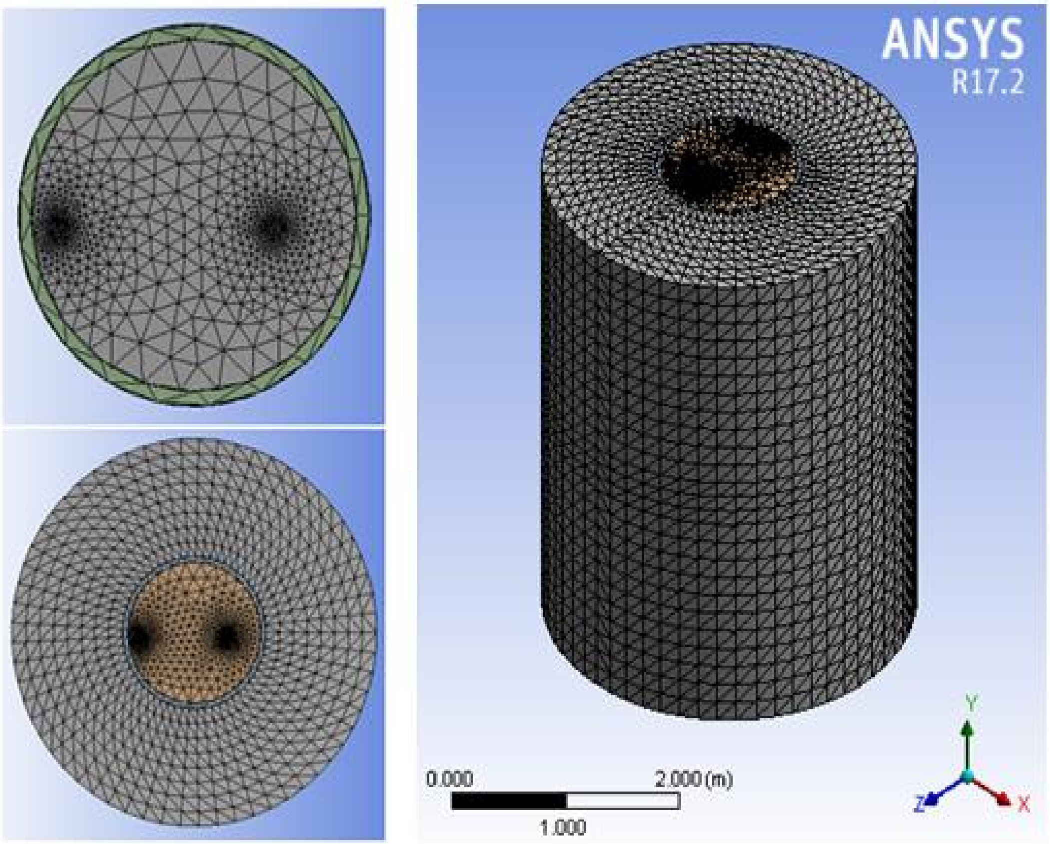


Figure II.4: View of total meshes of EXHE, backfill and soildomain

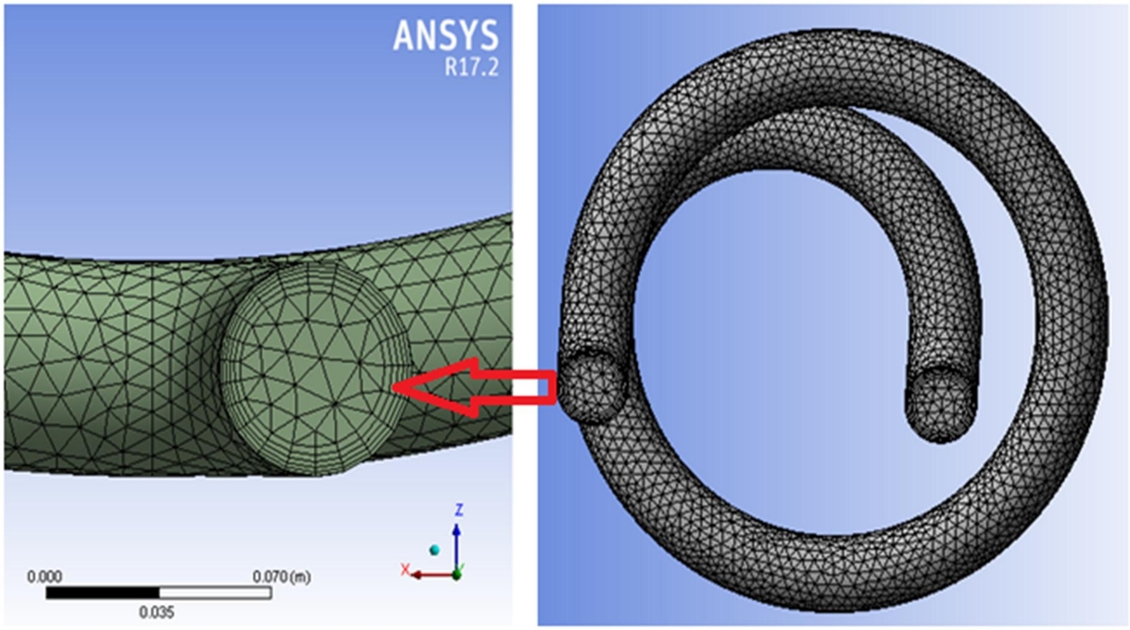


Figure II.5: Finite volume meshschematic of pipe

II.5 Model validation

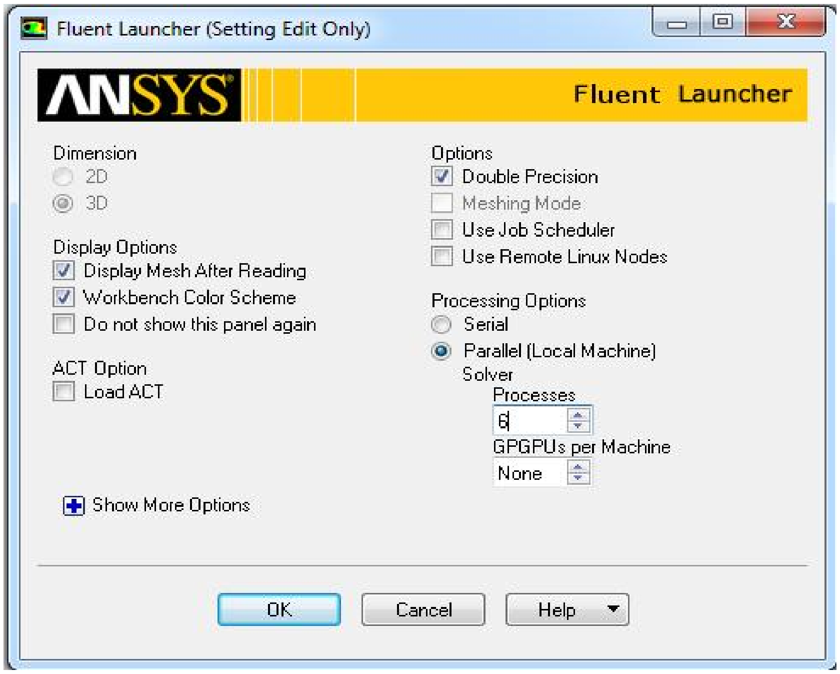
In this simulation, different time steps ranging from 36 to 3600 seconds were used. , It was observed that through the use of large time steps the T-out decreases, in the early stages of time the temperature change is far from recognizable as the temperature change in the range from 600s to 3600s is 0.045 ° C while it is 0.006 °C At 36 to 600 seconds. As a result, 600 seconds of time steps were used in this work.

The effects of relevant parameters (air velocity, pitch spacing, and length) on the outlet air temperature, mean efficiency and the performance coefficient of the EAHE are discussed below.

II.6 Resolutionunder Fluent

In all its versions, "Fluent" offers two calculation modes: the "double precision" mode and the "single precision" mode. The flip side of this precision is that the first mode requires a lot more memory.

In addition, the "double precision" mode is recommended, among others, for flows involving reduced scale lengths: since the geometry is in 3D, and the geometry is of a significant length and the tube has a small thickness. compared to the rest of the computational domain.



Fluent Launcher (Setting Edit Only)

ANSYS Fluent Launcher

Dimension
○ 2D
● 3D

Display Options
☑ Display Mesh After Reading
☑ Workbench Color Scheme
☐ Do not show this panel again

ACT Option
☐ Load ACT

Options
☑ Double Precision
☐ Meshing Mode
☐ Use Job Scheduler
☐ Use Remote Linux Nodes

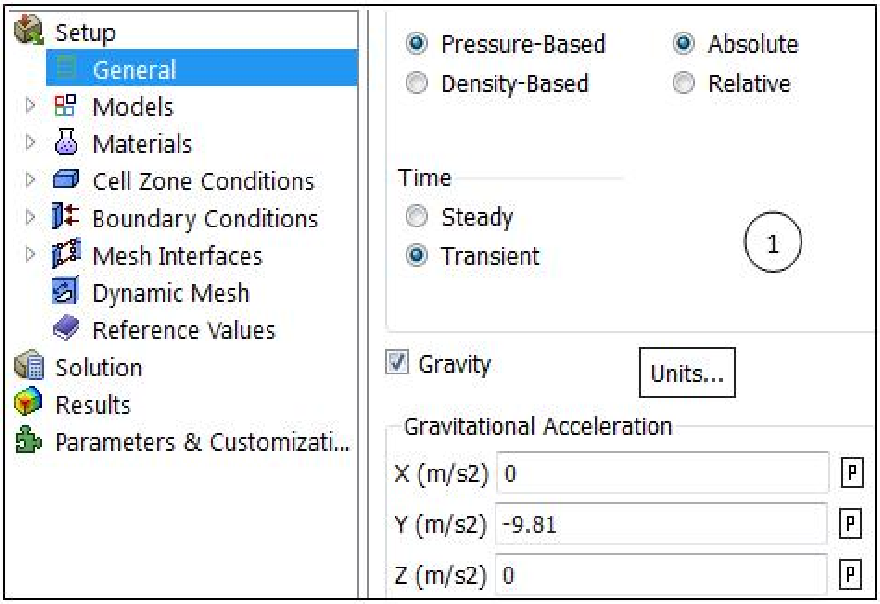
Processing Options
○ Serial
● Parallel (Local Machine)
Solver
Processes: 6
GPGPUs per Machine: None

Show More Options

Figure II.6: Fluent Launcher

the choice of double precision 3D seems the most appropriate for our simulation, it is therefore chosen as follows [47].

In this step, we will define an analyzer and define the physical models, material properties, simulated area conditions.



● Pressure-Based
○ Density-Based
● Absolute
○ Relative

Time
○ Steady
● Transient

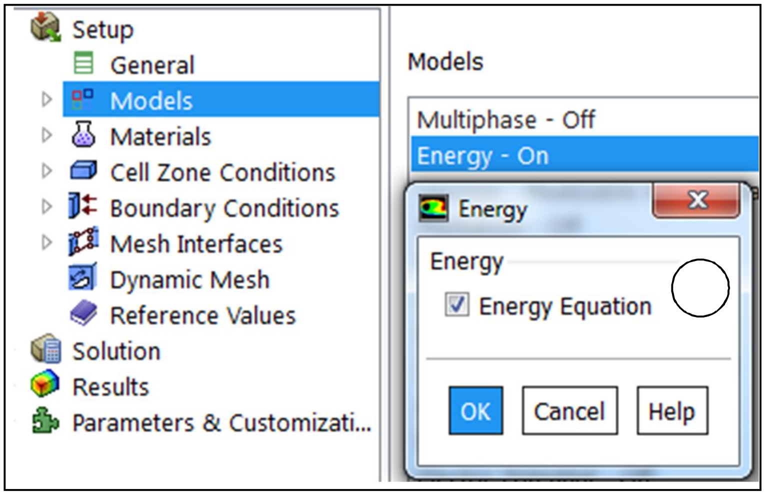
☑ Gravity

Gravitational Acceleration
X (m/s2) 0
Y (m/s2) -9.81
Z (m/s2) 0

Figure II.7: General window

II.6.1 Activation of the energyequation

The energy equation must be activated for the study of thermal fields



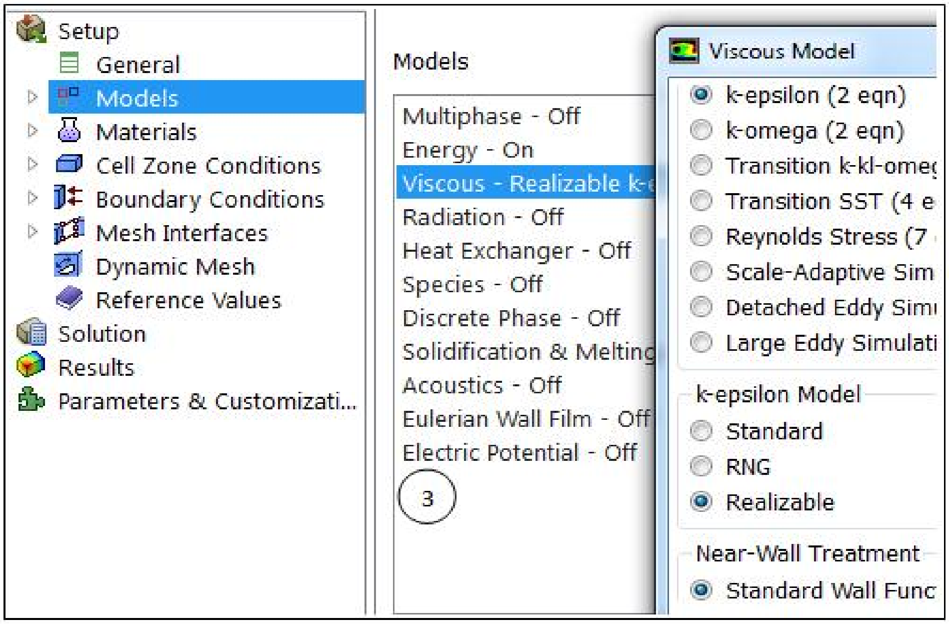
Multiphase - Off
Energy - On

Energy
☑ Energy Equation

Figure II.8: Activation of the energy equation

II.6.2 Viscous Model Dialog Box

The Viscous Model dialog box allows setting parameters for inelastic, laminar, and turbulent flow.



Multiphase - Off
Energy - On
Viscous - Realizable k-e
Radiation - Off
Heat Exchanger - Off
Species - Off
Discrete Phase - Off
Solidification & Melting
Acoustics - Off
Eulerian Wall Film - Off
Electric Potential - Off

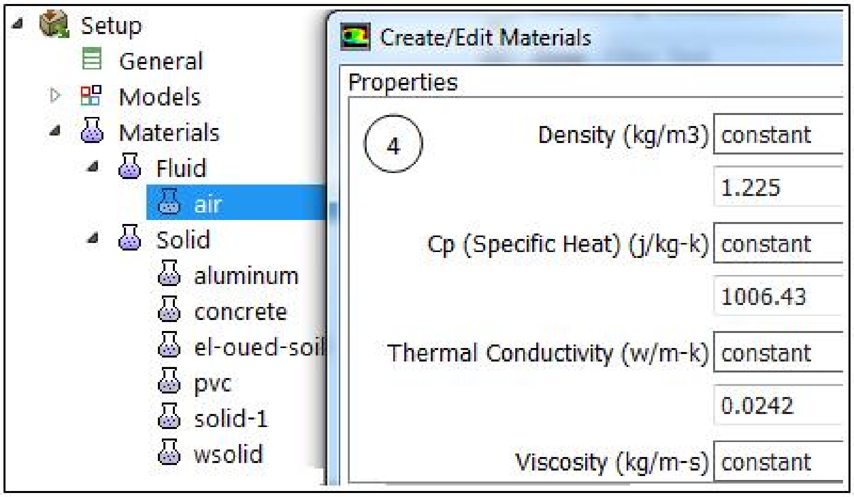
● k-epsilon (2 eqn)
○ k-omega (2 eqn)
○ Transition k-kl-omeg
○ Transition SST (4 e
○ Reynolds Stress (7
○ Scale-Adaptive Sim
○ Detached Eddy Simu
○ Large Eddy Simulati

k-epsilon Model
○ Standard
○ RNG
● Realizable

Near-Wall Treatment
● Standard Wall Func

Figure II.9: Activate the Model Dialog Box

II.6.3 DefineMaterials(fluid, solid)



Density (kg/m3) constant 1.225

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

Thermal Conductivity (w/m-k) constant 0.0242

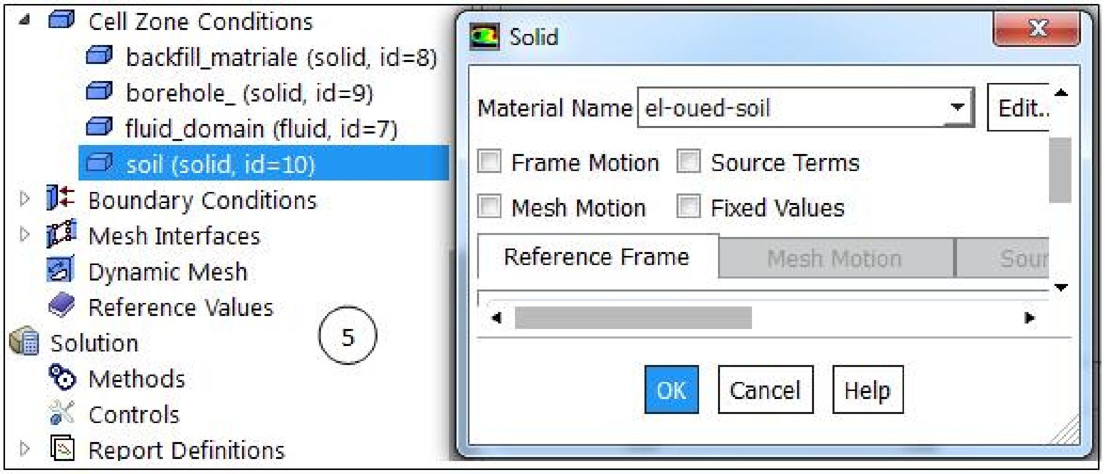
Viscosity (kg/m-s) constant

Figure II.10: DefineMaterials

The properties of the liquid represented in air are downloaded from the data library and the properties of soil, concrete and PVC are entered.

II.6.4 Zone Conditions

Determine the materials to be used in the conditions of the area after entering their physical properties



Material Name el-oued-soil

☐ Frame Motion ☐ Source Terms

☐ Mesh Motion ☐ Fixed Values

Figure II.11: Zone Conditions

II.6.5 Boundary Conditions

The boundary conditions for each boundary will be defined with the Boundary condition window. One then selects, the concerned border one introduces the associated boundary conditions.

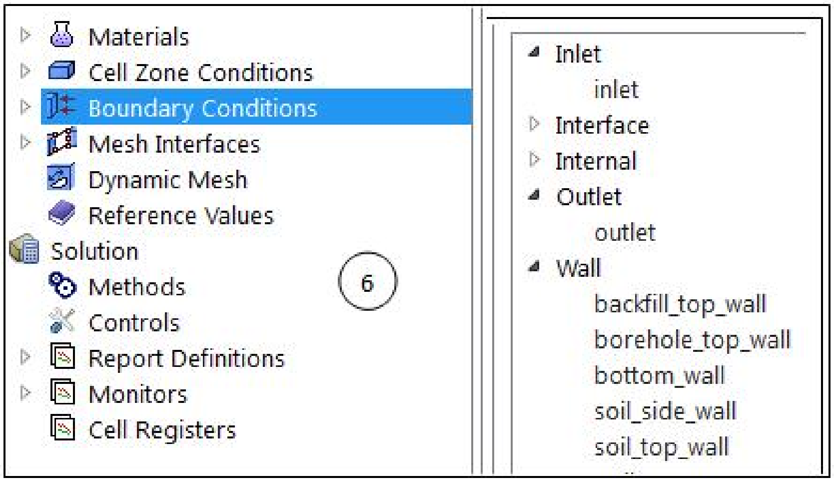
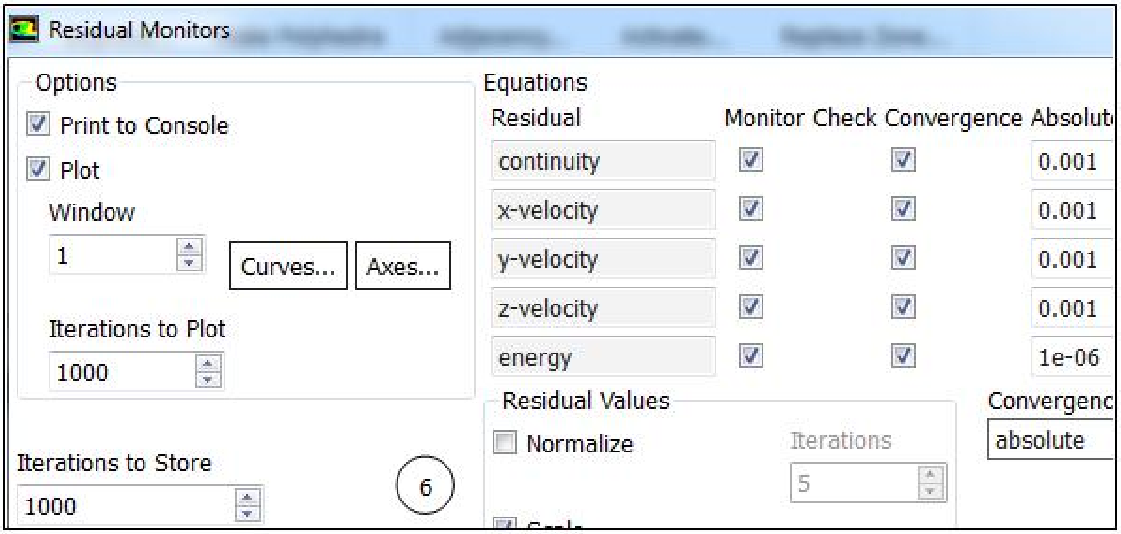


Figure II.12: Boundary Conditions

II.6.6 Residual Monitor

The residual must be specified in order to obtain precise results. Our calculation is made for a precision of 10-4 by following this order.



Options
☑ Print to Console
☑ Plot
Window: 1
Iterations to Plot: 1000
Iterations to Store: 1000

Equations

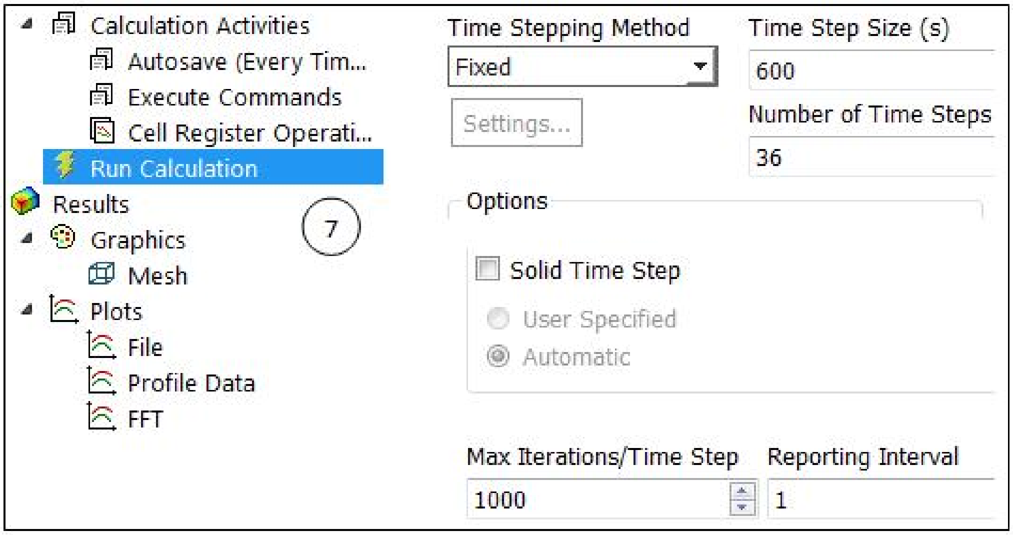
Residual	Monitor	Check Convergence	Absolut
continuity	☑	☑	0.001
x-velocity	☑	☑	0.001
y-velocity	☑	☑	0.001
z-velocity	☑	☑	0.001
energy	☑	☑	1e-06

Residual Values
☐ Normalize
Iterations: 5
Convergenc: absolute

Figure II.13: Displays the windows Residual Monito

II.6.7 Run Calculation

The "Run Calculation" window allows to initiate solution iterations and to perform time-dependent calculations to obtain the results.



Time Stepping Method: Fixed

Time Step Size (s): 600

Number of Time Steps: 36

☐ Solid Time Step

○ User Specified

● Automatic

Max Iterations/Time Step: 1000

Reporting Interval: 1

Figure II.14: Run Calculation window

II.6.8 Residual interface

After converging, the results are extracted and saved

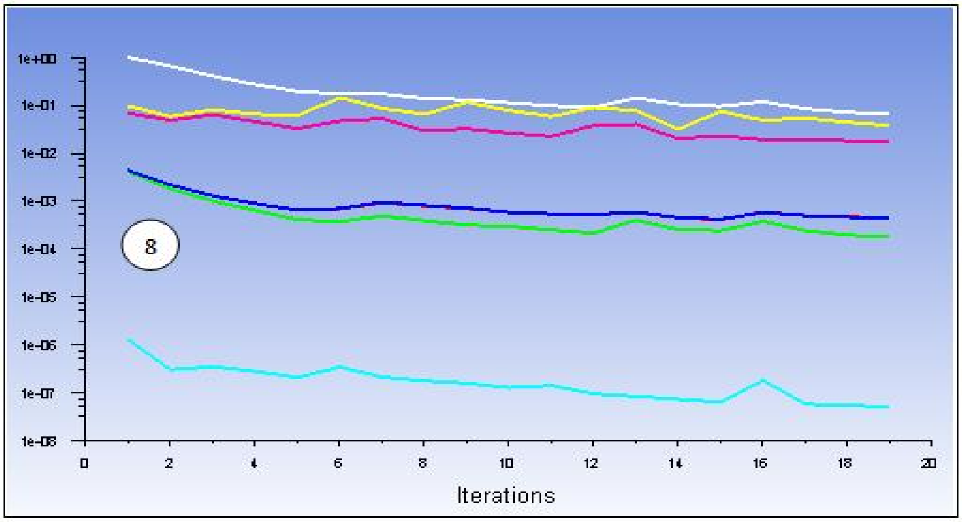


Figure II.15: Residual window[48]

II.7 Configuration in Modeling and Meshin

II.7.1 Soil modeling

In surface geothermal energy, the Earth can be considered a near-infinite medium, and in order to exploit this energy, changes in soil temperature throughout the year must be determined.

These changes are obtained using modeling depending on soil properties and ambient temperatures.

In this study, we considered constant soil temperature with the aim of arriving at energy equilibrium relationships, which express the evolution of air temperature in the exchanger.

$$\frac{\partial T}{\partial t} = \frac{\lambda}{\rho . C_\rho}\left(\frac{\partial T^2}{\partial x^2} + \frac{\partial T^2}{\partial y^2} + \frac{\partial T^2}{\partial z^2}\right) + \frac{Q'}{\rho . C_\rho} \qquad \text{(II.1)}$$

Or for a one-dimensional transfer along the z axis, we will have:

$$\frac{\partial T}{\partial x} = \frac{\partial T}{\partial y} = 0 \qquad \text{(II.2)}$$

On the other hand, if the transfer is without an internal source $Q' = 0$, the equation reduces to:

$$\frac{\partial T}{\partial t} = \frac{\lambda}{\rho . C_\rho}\left(\frac{\partial T^2}{\partial x^2}\right) = \alpha\left(\frac{\partial T^2}{\partial x^2}\right) \qquad \text{(II.3)}$$

$$\alpha = \frac{\lambda}{\rho \times C_\rho} \qquad \text{(II.4)}$$

$$T(Z,T) = T_{moy} - A_s \times (Exp - (z)\sqrt{\pi/8760} \times cos\left\{\frac{2\pi}{8760} \times (t - t_0 - \frac{Z}{2} \times \sqrt{8760/\pi\alpha}\right\} \qquad \text{(II.5)}$$

This equation represents the soil temperature at any depth as a function of the days of the year.

illustrates the fluctuations in bare soil temperature for different depths in the city of ElOued over the course of a typical year. As the depth of the soil increases, the ground temperature amplitude decreases until it reaches a consistent value throughout the year (about 24 °C) at a

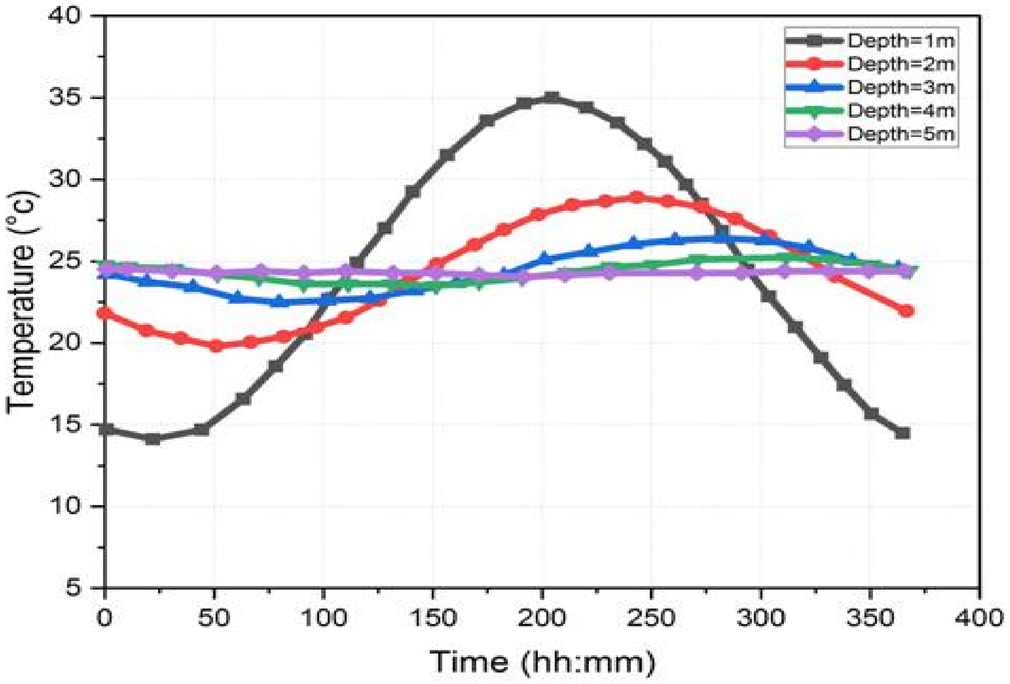


Figure II.16: Temperature of the ground as a function of depth. [49].

depth of 6 m. At this level of detail, The daily and seasonal swings have little effect on the temperature. We conclude that for this sort of shallow geothermal, it is not essential to put the EAHE deeper than 6 m. Furthermore, Figure 7 demonstrates that the temperature difference between 3 and 6 meters is quite minor (less than 1°C) [49].

The heat flux (φ) exchanged per unit area through the duct wall is proportional to the temperature difference between the inner and outer surface of the tube:

$$\varphi = \frac{T_{sol} - T_{air}}{R} \qquad (II.6)$$

$$R = R_{cd} + R_{cv} = \frac{ln(\frac{r_2}{r_1})}{2\pi.\lambda.L} + \frac{1}{5.55 \times V^{0.8}} \qquad (II.7)$$

$$\partial Q = \varphi \times S \times \partial t = \frac{T_{sol} - T_{air}}{R} S \times \partial t = \frac{T_{sol} - T_{air}}{R} \times 2\pi \times r \times L \times \partial t \qquad (II.8)$$

$$\partial Q = \rho \times c \times V \times \partial T_{air} = \rho \times c \times \pi \times r^2 \times L\ \partial T_{air} \qquad (II.9)$$

$$q_v = s \times v = \frac{\pi \times d^2}{4} \times v \qquad (II.10)$$

$$\mathrm{v} = \frac{\partial \mathrm{L}}{\partial \mathrm{t}} \rightarrow \partial t = \frac{\partial L}{\mathrm{v}} \tag{II.11}$$

$$\frac{\partial T_{air}}{T_{sol} - T_{air}} = \frac{2 \times \partial L}{\rho \times c \times r \times v \times R} \tag{II.12}$$

$$\int_{T_{ae}}^{T_{as}} \frac{\partial T_{air}}{T_{sol} - T_{air}} = \int_0^L \frac{2 \times \partial L}{\rho \times c \times r \times v \times R} \tag{II.13}$$

$$T_a = T_{ae} \times \exp\left(\frac{-2L}{\rho \times c \times r \times v \times R}\right) + T_{sol} \times \left(1 - exp\left(\frac{-2L}{\rho \times c \times r \times v \times R}\right)\right) \tag{II.14}$$

II.7.2 Mean efficiency or Specific dissipation Rate

The heat transfer efficiency of the ground heat exchangers can be determined by using a concept of effectiveness coefficient of thermal energy (ε). It is a ratio of actual heat transfer capacity to theoretically maximum heat transfer capacity which is shown in Eq.

$$\varepsilon = \frac{\mathrm{T_{in}} - \mathrm{T_{out}}}{\mathrm{T_{in}} - \mathrm{T_{soil}}} \tag{II.15}$$

II.8 Conclusion

The processes for completing the simulation on the proposed geothermal exchanger model are outlined in this chapter.

We infer from this simulation analysis that climatic circumstances have a major impact on heat exchanger operation.

The presence of a specific depth impacts the heat exchanger's operation or raises the temperature of the outside air, and increasing the depth of the soil allows the exchanger's working condition to be stabilized and its efficiency to be increased.

Chapter III:

Results & Analysis

III.1 Introduction

Ground temperature variations, air-to-ground exchanger outlet temperature, cooling potential, and exchanger efficiency are all examined in this chapter. The major goal of these systems is to reduce electrical energy usage by utilizing a readily available, non-polluting power source.

The findings of numerical modeling are then compared to previous experience, which was used to demonstrate the impact of various operational factors on the performance of the exchanger and the temperature of the exit air.

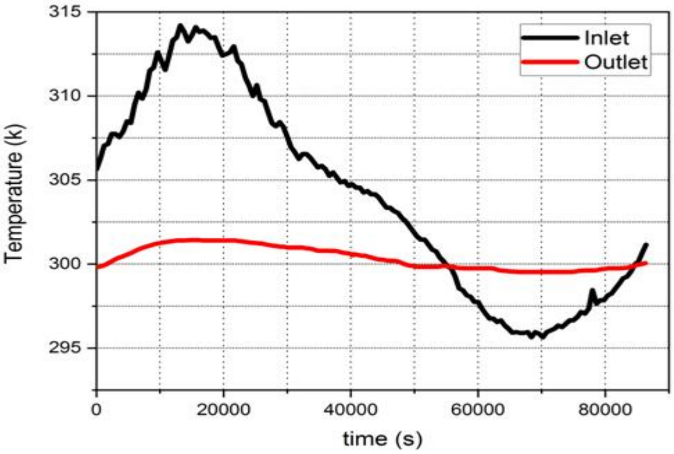
III.2 Influence of the air temperature entering the exchanger on the outside

The graph below shows the evolution of the air temperature at the outlet of the exchanger in terms of the evolution of the temperature at the inlet for 24 hours.

In the daytime, a rise in inlet temperature is observed, reaching a peak at 41 °C, and then gradually decreasing with time. On the other hand, there is an increase in the outlet temperature to reach an estimated value of 27,5 °C. Corresponding to the maximum heat value of the inlet.

The temperature difference between the inlet and outlet explains that the inlet temperature is higher than the soil temperature, which is estimated at 26.5°C. This difference causes an increase in the outlet heat, causing the exchanger to carry out the cooling process at high temperatures.

At night, the temperature in the entrance is lower than the floor temperature, its value reaches 22,8 °C. While the temperature in the exchanger is greater and is estimated at 26,5 °c.



FigureIII.1: Variation in air temperatureat the exchanger's input and exit

This means that the exchanger is heating, as the ground temperature is greater than the inlet temperature.

III.3 The effect of air velocity on the behavior of the exchanger

The plot below illustrares the evolution of the air flow temperature in the proposed model from the inlet to the outlet in terms of the change in air flow velocity.

The model was tested at three different speeds (V = 5 m/s, V = 10 m/s, V = 15 m/s). To find out the effect of air flow rate on the behavior of the geothermal heat exchanger while maintaining constant length, diameter and depth.

Note that the lower the flow velocity the lower the outlet temperature. This is because the flow at slow speeds gives enough time for heat exchange between the inlet air and the temperature of the soil. Where a temperature difference of 12.5°C was recorded. Corresponding to the velocity V = 5 m/s.

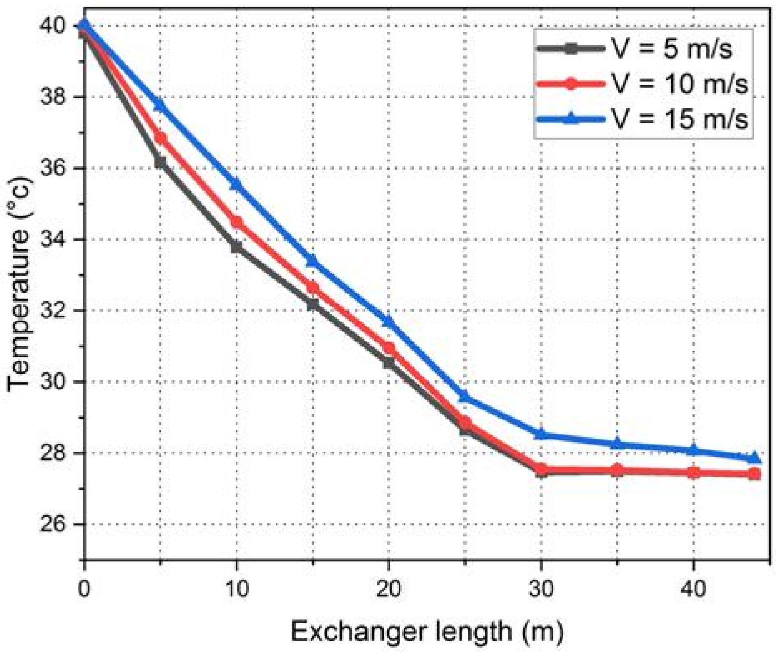


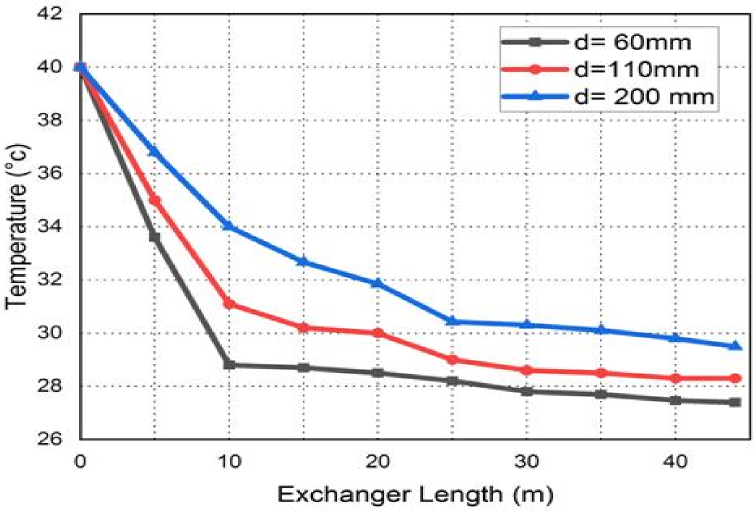
Figure III.2: Air temperature variation as a function of exchanger length

III.4 The Effect of Air Tube Diameter on the Exchanger's Performance

The chart below. shows the evolution of temperature in the geothermal exchanger from the inlet to the outlet in terms of the change in the diameter of the exchanger.

To highlight the effect of the exchanger diameter, the changes of the exchanger were represented according to three diameters (d= 60 mm, d =110 mm, d=200 mm).

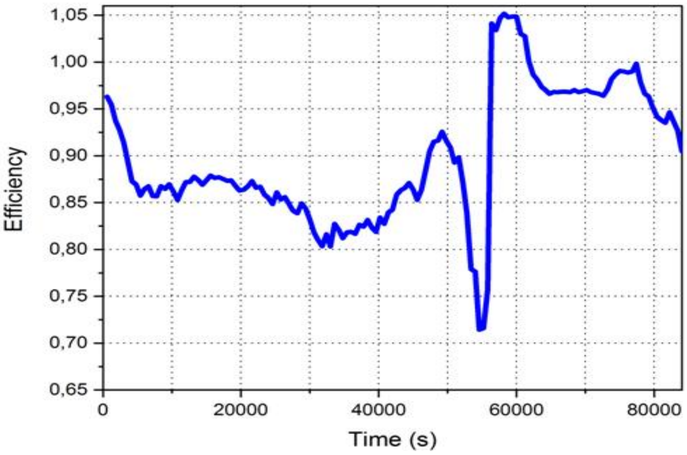
It was also observed that an increase in the diameter of the exchanger leads to a rise in the air temperature due to a decrease in the residence time of the air flowing inside the exchanger.



FigureIII.3: Outside air temperature variation as a function of pipe diameter and exchanger length

III.5 Heat exchanger efficiency

The figure (III.4), below shows the variation of the average thermal efficiency during 24 h. The lowest value of thermal efficiency was recorded as a result of the decrease in the temperature entering the pipe during the night period, which is estimate by 71 %.



FigureIII.4: The variation of the average thermal efficiency during 24 h.

III.6 The effect of air velocity on the efficiency of heat exchangers

Figure III.5, shows the variance of average thermal efficiency over awholeday in terms of air flow velocity change, The air flow velocitywasbetween (V = 5 m/s, V = 10 m/s, V = 15 m/s).

It was observed that when the velocity in creased, the efficiency of the system decreased. Indeed, the residence time influences directly the amount of heat absorbed by the air. Therefore, as the velocityincreases, the heattransfer coefficient increases, but on the other hand the residence time of the air in the heat exchanger decreases, so the temperature of the outlet air increases, which finally results in a decrease in the heat exchange efficiency.

The largest value of efficiency was recorded, estimate dat 93%. Approval of speed V= 5 m/s.

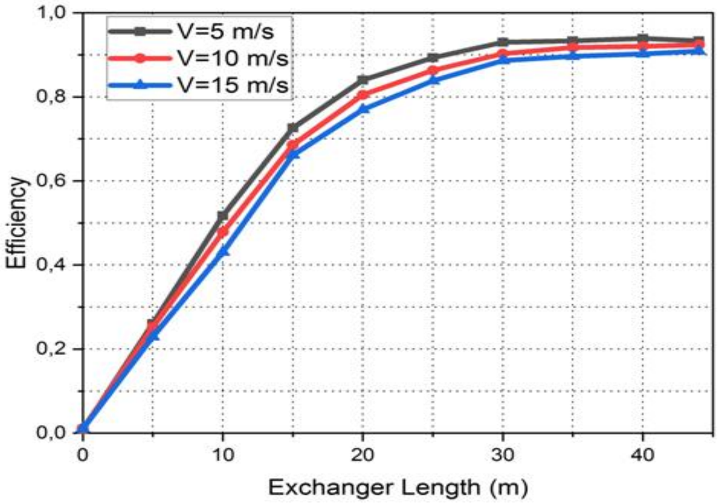
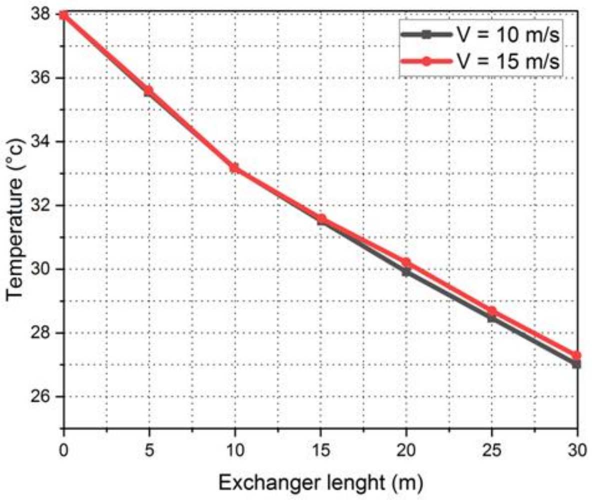


Figure III.5: Heat exchanger efficiency vs. exchanger length at various air speeds

III.7 The effect of air velocity on the behavior of the exchanger

Measurement survey was carried out to know the evolution of air temperature through the exchanger and the effect of velocity on the behavior of the geothermal heat exchanger, the experimental measurement was carried out with two different speeds introduced to the exchanger (V = 10 m/s, V = 15 m/s), showing the evolution of temperature Air through the exchanger per velocity In the diagram below, it is clear that when the velocity increases, the efficiency of the exchanger decreases due to the decrease in the gap between the inlet and the outlet air temperature of the exchanger. An important gap was achieved between the inlet and the outlet air temperature of the exchanger as V = 10 m/s and the temperature gap reached up to 11.2 °C.

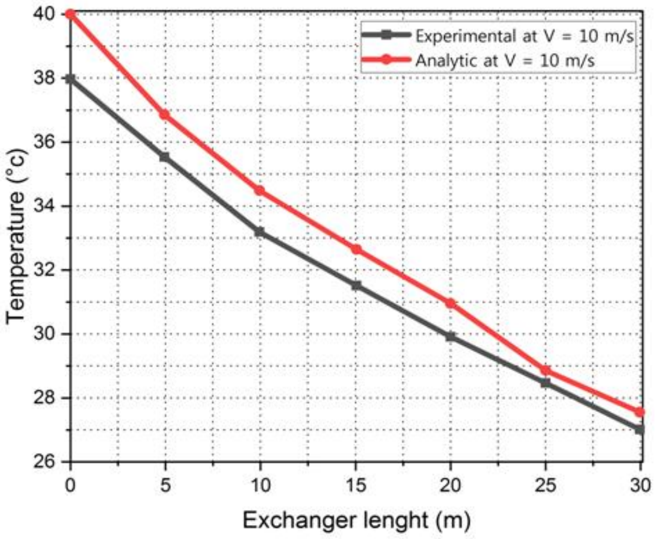


FigureIII.6: Variation in air temperature as a function of exchanger length

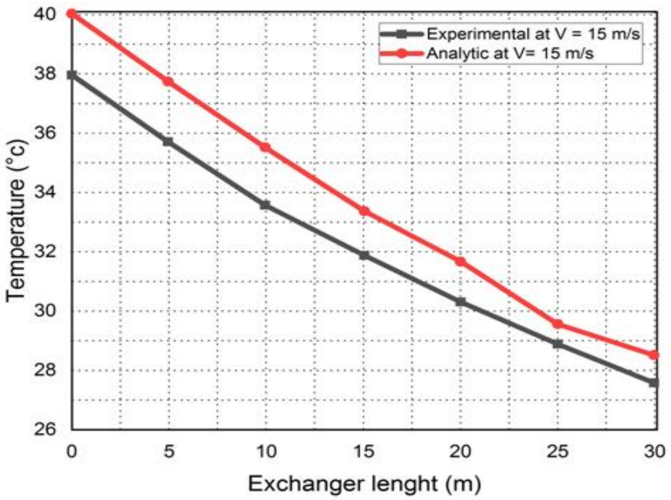
At the end of this study. acomparison was made between the result sobtained in the simulation and the experimental results of aprevious study of velocities (V = 10 m/s, V = 15 m/s).Figure (III.7 and III.8).

Show the differences between the theoretical and experimental models. This is due to the approximate values of the physical properties of the materials used in the simulation.

But any way the curves of the analytic experimental have almost th e same pace and needs just matching to get coincides. Note that the devices & the temperature sensors used may have some measurement errors.



FigureIII.7: Variation in air temperature as a function of exchanger length



FigureIII.8: Variation in air temperature as a function of exchanger length

III.8 Conclusion

The findings and discussions from our research are presented in this chapter. As a result, we set out to test our numerical model using a real-world study conducted by other researchers. The following are the outcomes:

The effect of air flow velocity on outside air temperature was studied. In creasing the velocity from 5 m/s to 10 m/s causes the air temperature to riseup to twice.

The depth of 3 m isconsidered the appropriate depth for burial where the soil temperatureis constant throug hout the year.

Theoutlet air temperature is decreasing with the diameter of the pipe atthe smaller the diameter usedin this study (60 mm in our case), the loweroutlet air temperatureattained.

Air velocity affects the average efficiencyinversely, thehighest efficiency value of was 93was obtainedat velocity of 5 m / s.

The results obtained are encouraging and showed that cooling using helical air-to-ground exchanger technology is promising and can be used for cooling or pre-cooling homes and buildings.

General Conclusion

The numerical analysis of El-Oued city was conducted on an air-to-ground spiral heat exchanger employing geothermal energy for cooling in this paper. The average ambient temperature of this location during the summer is around 40°C, and air was used to replicate the air temperature over the course of the air/ground heat exchanger, while analyzing the influence of various factors on this temperature.

The primary goal of our research is to conduct a numerical analysis of the geothermal/air heat exchanger. The air distribution and soil temperature as a function of exchanger running time were studied using the unsteady state finite difference approach.

The continuous functioning of the heat exchanger causes heat to accumulate in the soil around the tube, according to a review of the literature, and soil qualities play an important role in the design of these exchangers.

It can be argued that steady heat dissipation caused by the continuous operation of air on the globe results in global warming. As a result, air/ground heat exchangers' thermal performance degrades over time.

These findings demonstrate the validity of using this form of exchange in the Algerian Sahara.

References

[1] La nature des énergies, https:// www.maxicours.com/se/cours/la-nature-des-energies ,30/05/2017.

[2] Hu, X., et al. (2021). "Effects of temperature-dependent property variations on the output capacity prediction of a deep coaxial borehole heat exchanger." Renewable Energy 165: 334-349.

[3] Falcone, G., et al., Assessment of deep geothermal energy exploitation methods: The need for novel single-well solutions. Energy, 2018. 160: p. 54-63..

[4]Bouznit, M., M.d.P. Pablo-Romero, and A. Sánchez-Braza, Measures to promote renewable energy for electricity generation in Algeria. Sustainability, 2020. 12(4): p. 1468.

[5] Salima Ouali, Elements of the Geothermal Atlas of Algeria, CDRE, April 2018.

[6] Soni, S.K. Heating/Cooling Techniques used in Green Buildings: A Review. Int. J. Emerg. Tech. 2019, 10, 1–8.

[7] https://nl.pinterest.com/pin/343962490263754370/

[8] Hu, X., et al. (2021). "Effects of temperature-dependent property variations on the output capacity prediction of a deep coaxial borehole heat exchanger." Renewable Energy 165: 334-349.

[9] Amanowicz, Ł. and J. Wojtkowiak. Experimental investigation and CFD simulation of multi-pipe earth-to-air heat exchangers (EAHEs) flow performance. in E3S Web of Conferences. 2017. EDP Sciences.

[10] Amanowicz, Ł. and J. Wojtkowiak. Experimental investigation and CFD simulation of multi-pipe earth-to-air heat exchangers (EAHEs) flow performance. in E3S Web of Conferences. 2017. EDP Sciences.

[11] Minaei, A., et al., Thermal resistance capacity model for transient simulation of Earth-Air Heat Exchangers. Renewable Energy, 2021. 167: p. 558-567.

[12] Hadjadj, A., et al., Numerical study of a new earth-air heat exchanger configuration designed for Sahara climates.

[13] Jamshidi, N. and N. Sadafi, An evaluation for spiral coil type earth-air heat exchanger at different climate conditions. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2020. 42(24): p. 3045-3062.

[14] Verma, M.K., V. Bansal, and K.B. Rana, DEVELOPMENT OF PASSIVE ENERGY SOURCE AS EARTH AIR PIPE HEAT EXCHANGERS (EAPHE) SYSTEM-A REVIEW. Journal of Thermal Engineering, 2020. 6(5): p. 651-676.

[15] Benrachi, N., et al., Numerical parametric study of a new earth-air heat exchanger configuration designed for hot and arid climates. International Journal of Green Energy, 2020. 17(2): p. 115-126.

[16] Ahmed, S., et al. (2021). "A parametric analysis of the cooling performance of vertical earth-air heat exchanger in a subtropical climate." Renewable Energy.

[17] Zajch, A. and W. A. Gough (2021). "Seasonal sensitivity to atmospheric and ground surface temperature changes of an open earth-air heat exchanger in Canadian climates." Geothermics89: 101914

[18] Amanowicz, Ł. and J. Wojtkowiak. Experimental investigation and CFD simulation of multi-pipe earth-to-air heat exchangers (EAHEs) flow performance. in E3S Web of Conferences. 2017. EDP Sciences.

[19] Mathur, A., et al., Comparative study of straight and spiral earth air tunnel heat exchanger system operated in cooling and heating modes. Renewable Energy, 2017. 108: p. 474-487.

[20] Jamshidi, N. and N. Sadafi, An evaluation for spiral coil type earth-air heat exchanger at different climate conditions. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2020. 42(24): p. 3045-3062.

[21] Lekhal, M.C., A.M. Mokhtari, and R. Belarbi. Evaluation of two earth–air heat exchangers efficiency of different pipe materials within a warm temperate climate. in MATEC Web of Conferences. 2020. EDP Sciences.

[22] Akbarpoor, A. M., et al. (2021). "Performance analysis of domed roof integrated with earth-to-air heat exchanger system to meet thermal comfort conditions in buildings." Renewable Energy168: 1265-1293.

[23] Rodríguez-Vázquez, M., et al., Thermal potential of a geothermal earth-to-air heat exchanger in six climatic conditions of México. Mechanics & Industry, 2020. 21(3): p. 308.

[24] Lekhal, M. C., et al. (2021). "Effect of geo-climatic conditions and pipe material on heating performance of earth-air heat exchangers." Renewable Energy163: 22-40.

[25] Sakhri, N., et al. (2021). "Impact of the environmental conditions on the efficiency of earth-to-air heat exchangers under various configurations." International Journal of Environmental Science and Technology: 1-14.

[26] Ahmed, S., et al. (2021). "Physical and hybrid modelling techniques for earth-air heat exchangers in reducing building energy consumption: Performance, applications, progress, and challenges." Solar Energy216: 274-294.

[27] Nemati, N., et al. (2021). "Performance evaluation of a novel hybrid cooling system combining indirect evaporative cooler and earth-air heat exchanger." Energy215: 119216.

[28] Qin, D., et al. (2021). "A novel solar-geothermal system integrated with earth–to–air heat exchanger and solar air heater with phase change material—numerical modelling, experimental calibration and parametrical analysis." Journal of Building Engineering35: 101971.

[29] Asgari, B., et al. (2020). "Assessment and comparison of different arrangements of horizontal ground heat exchangers for high energy required applications." Applied Thermal Engineering167: 114770.

[30] Wei, H., et al., Field experiments on the effects of an earth-to-air heat exchanger on the indoor thermal environment in summer and winter for a typical hot-summer and cold-winter region. Renewable Energy, 2021. 167: p. 530-541.

[31] Alimonti, C., et al. (2021). "Producing geothermal energy with a deep borehole heat exchanger: Exergy optimization of different applications and preliminary design criteria." Energy220: 119679.

[32] Agrawal, K. K., et al. (2019). "Effect of soil moisture contents on thermal performance of earth-air-pipe heat exchanger for winter heating in arid climate: In situ measurement." Geothermics 77: 12-23.

[33] Fazlikhani, F., et al. (2017). "Numerical analysis of the efficiency of earth to air heat exchange systems in cold and hot-arid climates." Energy conversion and management 148: 78-89

[34] Selamat, S., et al. (2016). "Numerical study of horizontal ground heat exchangers for design optimization." Renewable energy 95: 561-573.

[35] Serageldin, A. A., et al. (2016). "Earth-Air Heat Exchanger thermal performance in Egyptian conditions: Experimental results, mathematical model, and Computational Fluid Dynamics simulation." Energy conversion and management 122: 25-38.

[36] Dabaieh, M. and A. A. Serageldin (2020). "Earth air heat exchanger, Trombe wall and green wall for passive heating and cooling in premium passive refugee house in Sweden." Energy conversion and management 209: 112555.

[37] Agrawal, K. K., et al. (2021). "CFD simulation study to evaluate the economic feasibility of backfilling materials for ground-air heat exchanger system." Geothermics 90: 102002.

[38] Koohi-Fayegh, S. and M. A. Rosen (2021). "Modeling of vertical ground heat exchangers." International Journal of Green Energy 18(7): 755-774.

[39] Yu, Y., et al. (2014). "Investigation of a coupled geothermal cooling system with earth tube and solar chimney." Applied energy 114: 209-217.

[40] Benhammou, M. and B. Draoui (2015). "Parametric study on thermal performance of earth-to-air heat exchanger used for cooling of buildings." Renewable and Sustainable Energy Reviews 44: 348-355.

[41] Chiesa, G., et al. (2014). "A 3-field earth-heat-exchange system for a school building in Imola, Italy: Monitoring results." Renewable energy 62: 563-570.

[42] Rodrigues, M. K., et al. (2015). "Numerical investigation about the improvement of the thermal potential of an Earth-Air Heat Exchanger (EAHE) employing the Constructal Design method." Renewable energy 80: 538-551.

[43] Ahmed, S. F., et al. (2014). "Comparison of earth pipe cooling performance between two different piping systems." Energy Procedia 61: 1897-1901

[44] Sivasakthivel, T., et al. (2014). "Optimization of ground heat exchanger parameters of ground source heat pump system for space heating applications." Energy 78: 573-586.

[45] Rosa, N., et al. (2020). "Assessment of an earth-air heat exchanger (EAHE) system for residential buildings in warm-summer Mediterranean climate." Sustainable Energy Technologies and Assessments 38: 100649.

[46] Menhoudj, S., et al. (2018). "Study of the energy performance of an earth—Air heat exchanger for refreshing buildings in Algeria." Energy and buildings 158: 1602-1612.

[47] Liu, Z., et al. (2019). "Numerical modeling and parametric study of a vertical earth-to-air heat exchanger system." Energy 172: 220-231

[48] Ansys fluent 19.7

[49] Gao, Y., et al. (2016). "Thermal performance improvement of a horizontal ground-coupled heat exchanger by rainwater harvest." Energy and buildings 110: 302-313.

Thesis Title: Numerical Analysis of Thermal Performance of Earth to Air Heat Exchange System Operating in Hot Climate.

Keywords: geothermal energy, ground-air heat exchanger, Numerical simulation, heating, cooling

Abstract:

Geothermal heat exchangers provide a new and clean way of heating and cooling buildings in the world. They make use of renewable energy stored in the ground, providing one of the most energy-efficient ways of heating and cooling buildings.

In this study, numerical model will be employed to investigate the heat transfer performance of earth to air heat exchanger with spiral configuration and analysing the effects of both design and operating parameters, such as diameter of the pipe, properties of the employed materials and flow velocity

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Titre de la Thèse: Analyse numérique des performances thermiques d'un système d'échange de chaleur Terre-Air fonctionnant en climat chaud.

Mots Clés: géothermie, échangeur de chaleur sol-air, Simulation numérique, chauffage, refroidissement

Abstrait:

Les échangeurs de chaleur géothermiques offrent une nouvelle façon propre de chauffer et de refroidir les bâtiments dans le monde. Ils utilisent l'énergie renouvelable stockée dans le sol, offrant l'un des moyens les plus écoénergétiques de chauffer et de refroidir les bâtiments.

Dans cette étude, un modèle numérique sera utilisé pour étudier les performances de transfert de chaleur de l'échangeur de chaleur terre-air avec une configuration en spirale et analyser les effets des paramètres de conception et de fonctionnement, tels que le diamètre du tuyau, les propriétés des matériaux utilisés et la vitesse d'écoulement.

عنوان المذكرة : التحليل العددي للأداء الحراري لنظام التبادل الحراري الأرضي إلى الهواء الذي يعمل في المناخ الحار.

الكلمات المفتاحية : الطاقة الحرارية الأرضية ، المبادل الحراري الأرضي-الهواء ، المحاكاة العددية ، التسخين ، التبريد

الملخص : تعتبر المبادلات الحرارية الجوفية طريقة جديدة ونظيفة لتدفئة وتبريد المباني في العالم. لكونها تستخدم الطاقة المتجددة المخزنة في الأرض ، مما يجعلها واحدة من أكثر الطرق كفاءة في استخدام الطاقة لتدفئة المباني وتبريدها.

في هذه الدراسة ، سيتم استخدام النموذج العددي للتحقيق في أداء نقل الحرارة للمبادل الحراري أرض / هواء. بتكوين حلزوني وتحليل تأثير كل من معلمات التصميم والتشغيل ، مثل قطر الأنبوب وخصائص المواد المستخدمة وسرعة التدفق.