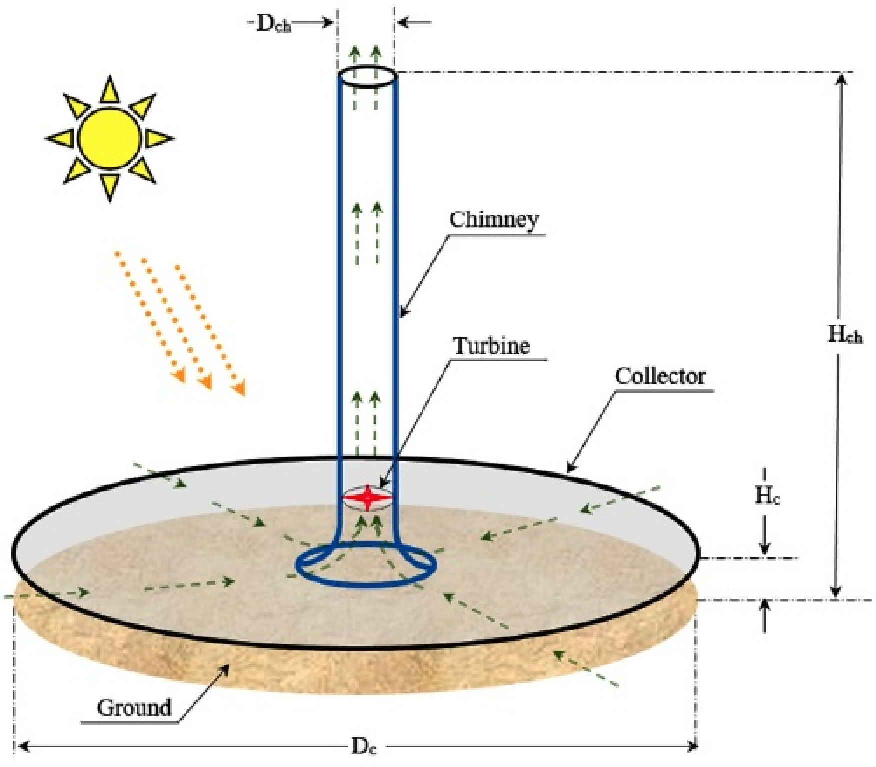
SOLAR CHIMNEY POWER PLANTS: NUMERICAL INVESTIGATIONS AND EXPERIMENTAL VALIDATION



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Solar Chimney Power Plants: Numerical Investigations and Experimental Validation

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Solar Chimney Power Plants: Numerical Investigations and Experimental Validation

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CONTENTS

PREFACE

This book aims to study the effect of the geometrical parameters on the airflow behavior inside a solar chimney power plant.

In the first part, we have developed simulation by using the CFD software ANSYS Fluent to model the airflow. In these conditions, we have adopted the realizable k-ε turbulence model, the DO radiation model, and the convection heat flux transfer model. These models have been validated with anterior experimental results due to the acceptable coherence between results. In the second part, alternate geometric configurations of the solar chimney power plant were numerically studied to expand on the design optimizing of the solar chimney. The goal is the study of the effect of the geometric parameters on the airflow behavior inside the solar chimney to obtain an optimal size available to construct a prototype of a solar chimney power plant. The developed study confirms that the increase in the height and diameter of the chimney, and the diameter of the collector increases the temperature and the air velocity. However, an increase in the collector height decreases these parameters. An experimental study is also presented in the last part of this book. The experimental prototype, constructed at ENIS, is used to study the environmental temperature, distribution of the temperature, air velocity, and the power output generated by the turbine. The main results were found from this prototype are the solar radiation and the gap of temperature in the collector. These parameters are important factors affecting the performance of the solar chimney power plant.

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CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The author(s) confirm that this chapter contents have no conflict of interest.

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Nomenclature

g	Gravitational acceleration ($m.s^2$)
H	Chimney height (m)
d	Chimney diameter (m)
D	Collector diameter (m)
h	Collector diameter (m)
θ	Collector slope (°)
r, z	Cylindrical coordinates
V	Velocity ($m.s^{-1}$)
$\mathbf{V_c}$	Air velocity at collector chimney inlet ($m.s^{-1}$)
p	Static pressure (Pa)
$\mathbf{p_d}$	Dynamic pressure (Pa)
$\mathbf{p_i}$	Pressure inlet (Pa)
$\mathbf{p_o}$	Pressure outlet (Pa)
h	overall heat transfer coefficient ($W.m^{-2}.K^{-1}$)
T	Temperature (K)
$\mathbf{T_0}$	Ambient temperature (K)
ΔT	Air temperature between the collector inflow and outflow (K)
$\mathbf{A_{ch}}$	Chimney cross-section area (m^2)
$\mathbf{A_c}$	Collector area (m^2)
$\mathbf{C_p}$	Specific heat capacity of the air ($J.kg^{-1}$)
$\mathbf{m^{\bullet}}$	Mass flow of air ($kg.s^{-1}$)
ρ	Density of the air ($Kg.m^{-3}$)
$\boldsymbol{\rho_c}$	Specific density of air at the chimney inlet ($kg.m^{-3}$)
$\mathbf{Q_s}$	Total energy input in the collector (W)
Q	Energy produced by the collector (W)
$\boldsymbol{\eta_c}$	Collector efficiency
$\boldsymbol{\eta_{ch}}$	Chimney efficiency
$\boldsymbol{\eta_t}$	Turbine efficiency
$\boldsymbol{\eta_g}$	Generator efficiency
$\boldsymbol{\eta_{tg}}$	Efficiency of the turbine generator
η	Overall efficiency of the solar chimney
G	Global radiation ($W.m^{-2}$)

α Absorptivity of the collector roof

τ Transmissivity of the collector roof

ΔT_a The average difference of temperature under the collector and the ambiant (K)

U Voltage (V)

I Current (A)

P_e Electrical power (W)

k Turbulent kinetic energy ($m^2.s^{-2}$)

ε Dissipation rate of turbulent kinetic energy ($m2.s^{-3}$)

μ_t Turbulent viscosity ($Pa.s^{-1}$)

μ Dynamic viscosity ($m^2.s^{-1}$)

$C\mu$ Function of mean flow and turbulence properties

$\tilde{\Omega}_{ij}$ The mean rate-of-rotation tensor viewed in a rotation reference frame

τ_{ij} Molecular stress tensor for Newtonian fluids

Γ_ϕ Diffusion coefficient for the scalar quantity ϕ

S_ϕ Source term for the ϕ equation

Introduction

Nowadays several energy sources are utilized on a large scale around the world such as oil, gas, and nuclear. Since the oil crisis, depletion of fossil fuel reserves, global warming, and other environmental concerns and continuing fuel price rise. For these reasons, the existing sources of conventional energy may not be adequate to meet the ever-increasing energy demands. Moreover, the demands for energy will tend to grow and it draws attention to the need to save energy, including through the use of soft power. Consequently, Engineering was responsible for finding new and different energy sources to fossil fuels to move them from the production of industrial energy and one day replace. The features that are mainly looking for a source of energy are to produce the least environmental impact possible and less pollution of any kind, which has a potential of energy efficiency and acceptable, that is safe, simple, reliable, cost-effective and cheap, that is renewable energy.

There are many forms of renewable energy resources that are currently available for integration into the power grid; the top four energy sources are wind, sun, water, and geothermal. For thousands of years, civilizations have been harnessing the Sun's energy, so there are several ways of solar systems. One of these ways for humans to harness the sun's light for energy production is called solar chimney technology, also called solar towers, to avoid confusion with polluting industrial chimneys. In this context, we are interested in developing this technology.

This book is structured into five major chapters. In the first, a review of past literature was conducted to have a look at the developments made in solar energy and its different systems. Particularly, we have interest in the solar chimney that is the subject of our study.

The second chapter contains the numerical approach that we used to model the solar chimney. It presents the detailed mathematical model upon which mathematical equations are derived to analyses the design and performance of the solar chimney.

The third chapter presents the choice of the different numerical models responsible for modeling the airflow in the solar chimney. The validations of the numerical results are done with anterior results. In the fourth chapter, we develop a numerical simulation to design our prototype of solar chimney. Particularly, we focus on the study of the effect of the geometrical parameters of the chimney. The numerical results consist of five main parts. It consist also on the study of the solar chimney structure. The validation of the numerical results is done with our experimental results.

In the last chapter, we develop an experimental study for testing the performance of our prototype with different climate conditions in our country.

Finally, we present a general conclusion of this work and the outlook suggested by this study.

CHAPTER 1

Bibliographic Study

1. INTRODUCTION

Renewable energy sources are those that do not rely on stored energy resources. Various forms of renewable energy are currently used for the generation of electricity. As with most industries, the relative cost of a product becomes less expensive as technologies improve and product knowledge increases, with the renewable energy industry being no exception. Using renewable resources, such as the sun, would provide almost unconditional access to energy without depleting the world's natural resources. In this chapter, we are interested in the study of solar energy and its different technologies, particularly to the solar chimney system.

2. SOLAR ENERGY

The sun is the most plentiful energy source for the earth. It is an average star, is a fusion reactor that has been burning over 4 billion years (Askari *et al.*, 2015). The sun emits as much energy to the earth as it is used by the entire population of the planet. In light of the increasing scarcity of fossil fuels, the future of energy supply lies with renewable energy sources and a modern approach to using them. Solar radiation is a free energy source, abundant and renewable. Clean and inexhaustible solar energy helps protect the environment and preserve energy resources, without producing waste or emissions. A global change in energy sources is coming, especially about achieving a healthy balance between economic growth and ecological responsibility for us all, and planet Earth. The future lies in renewable energy sources and modern methods of obtaining them. Innovative and user-friendly solutions are needed to ensure our quality of life (Fig. **1.1**).

The IEA Solar PACES programmer, the European Solar Thermal Electricity Association and Greenpeace estimated global CSP capacity by 2050 at 1 500 GW, with a yearly output of 7 800 TWh, or 21% of the estimated electricity consumption in ETP2010 BLUE Hi-Ren Scenario. In regions with favorable solar resource, the proportion would be much larger. For example, the German

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Aerospace Center (DLR), in a detailed study of the renewable energy potential of the MENA (the Middle East and North Africa region) region plus South European countries, estimated that concentrator solar power plants could provide half the electricity consumption around the Mediterranean Sea by 2050 (Fig. **1.1**). We, based on a study by Price Water House Coopers, Europe, and North Africa together could, by 2050 produce all their electricity from renewables if their respective grids are sufficiently interconnected. While North Africa would consume one-quarter of the total, it would produce 40% of it, mostly from onshore wind and solar power (DLR, 2005).

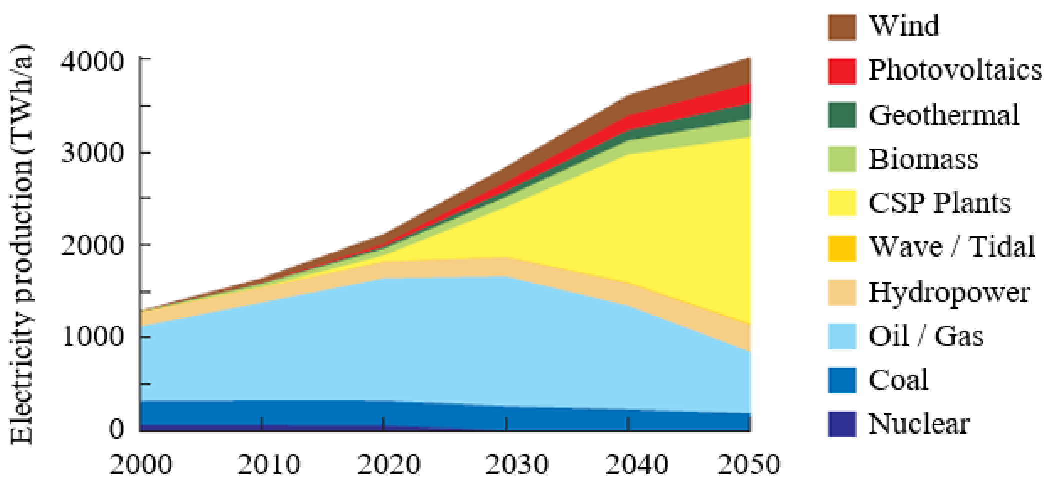

Fig. (1.1). Electricity generation from 2000 to 2050 in 2050 in all MENA region and South-European countries (DLR, 2005).

2.1. Solar Spectrum

The major part of the electromagnetic radiations emitted by the sun is not visible with the naked eye. Fig. (**1.2**) presents a spectrum of the electromagnetic radiations emitted by the sun by including the visible light waves. The naked eye perceives only the rays of which the wavelength lies between 400 and 700 nanometers, which correspond to the cosmic rays. Radiations lower wavelength are called waves decametric, or more usually ultraviolet, and radiations higher wavelength are called infra-red raises. These are the latter, which are responsible for the greenhouse effect that we will be defining later.

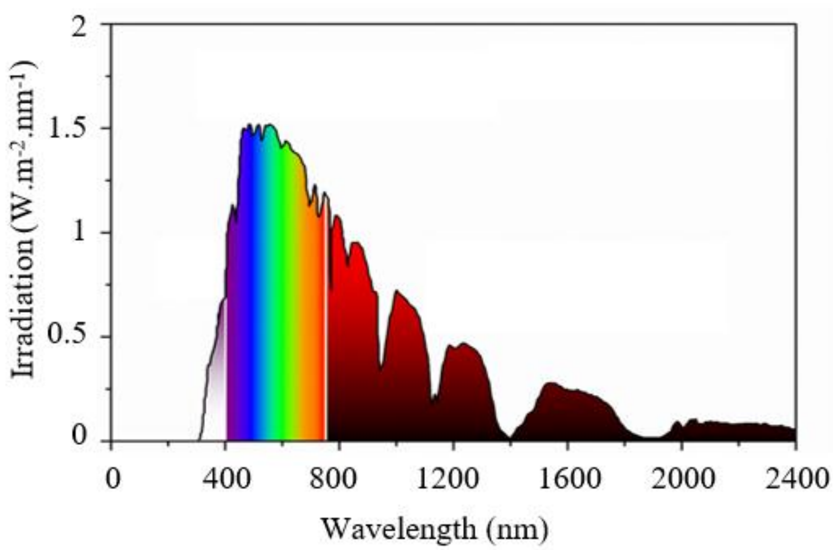

Fig. (1.2). Solar spectrum.

2.2. Irradiation Areas

Geography plays an important role in determining what forms of renewable energy will be the most useful. Solar energy is the primary source of electricity for the third world African countries. These countries use solar energy in isolated regions and cities to harness the sun's energy (Austin *et al.*, 2007). Solar systems are suitable to be applied in arid and semi-arid areas and are an advanced way to generate electricity from solar radiation, average height radiation. Average Horizontal irradiation is another term for the total radiation: the sum of the direct normal irradiance and diffuse horizontal irradiance. Fig. (**1.3**) illustrates the levels of total radiation in Tunisia and the world receives annually. We show that the average solar horizontal irradiation in Tunisia is higher than in most other countries in the world. For this reason, the solar systems represented an important source of energy in our country; thus the company Tunoor would export solar capacities from Tunisia to Europe when it makes a solar power station in the south Tunisia desert.

CHAPTER 2

Numerical Approach

1. INTRODUCTION

Modeling is mainly the basis of engineering and it is a suitable simplification of reality. The displaying expertise is to detect the fitting degree of disentanglement, recognize significant highlights from those that are insignificant in a specific application, and use designing judgment. This chapter presents a complete model specification of the solar chimney power plant on which all simulations and results are based and devoted to the presentation of the physical and numerical models by using in the CFD code ANSYS Fluent 17.0. The following will discuss the equations and models incorporated by ANSYS Fluent to model a solar chimney power plant. The governing equations will be presented, which describe the coupling of temperature fields, velocity, and pressure from the conservation equations. Then, the discretization methods and meshing used will be examined. Finally, the models for turbulence and radiation will be explored.

2. MATHEMATICAL FORMULATION

2.1. Governing Conservation Equations

The equations governing the flow of air in a solar chimney are the Navier Stokes equations. ANSYS Fluent 17.0 employs the fundamental three-dimensional fluid mechanic equations for conservation of mass (The continuity equation), momentum, and energy to calculate fluid properties.

The continuity equation expresses the law of conservation of mass for given volume control:

$$\frac{d\rho}{dt} + \vec{\nabla}.(\rho\vec{V}) = 0 \quad \textbf{(2-1)}$$

Where:

$$\vec{\nabla} = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}\right) \quad \textbf{(2-2)}$$

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$$\text{div}\,\vec{v} = \nabla.\vec{v} \quad \textbf{(2-3)}$$

t presents the time, ρ is the density, and $\vec{V}$ is the velocity vector.

$$\frac{\partial}{\partial x_i}(\rho u_i) = 0 \quad \textbf{(2-4)}$$

The momentum equations are written as follows:

$$\frac{d\rho\vec{V}}{dt} + \left(\rho\vec{V}.\vec{\nabla}\right).\vec{V} = -\vec{\nabla}p + \vec{\nabla}.\bar{\bar{\tau}} + \rho.\vec{g} \quad \textbf{(2-5)}$$

Where p is the static pressure.

The stress tensor $\bar{\bar{\tau}}$ is expressed as:

$$\bar{\bar{\tau}} = 2\mu\bar{\bar{D}} - \vartheta(\vec{\nabla}.\overrightarrow{V}).\bar{\bar{I}} \quad \textbf{(2-6)}$$

Where:

$$\bar{\bar{D}} = \frac{1}{2}(\bar{\bar{\nabla}}.\vec{V} + \bar{\bar{\nabla}}^t.\overrightarrow{V}) \quad \textbf{(2-7)}$$

Thus,

$$\bar{\bar{\tau}} = \mu((\bar{\bar{\nabla}}.\vec{V} + \bar{\bar{\nabla}}^t.\overrightarrow{V}) - \frac{2}{3}(\vec{\nabla}.\overrightarrow{V}).\bar{\bar{I}} \quad \textbf{(2-8)}$$

Where $\bar{\bar{I}}$ the identity matrix and μ is the dynamic viscosity.

The final term in the momentum equation represents the buoyancy force.

$$\frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i \quad \textbf{(2-9)}$$

Basing on the first principle of thermodynamics, we can express the conservation equation of energy. This principle connects the various forms of energy, that is to say:

$$\frac{d\rho E}{dt} + \vec{\nabla}(\rho E\vec{V}) = \vec{\nabla}.(\bar{\bar{\tau}}.\vec{V}) + \rho\vec{f}.\vec{V} - \vec{\nabla}.\vec{q} - \vec{\nabla}.p\vec{V} + r \qquad \textbf{(2-10)}$$

Where:

E is the total of the potential, kinetic, and internal energy in the system.

The internal energy, *h*, is the enthalpy of the fluid and is expressed as:

$$h = \int C_p dT \qquad \textbf{(2-11)}$$

Where:

C_p: is the constant pressure specific heat

r: is an additional energy source term.

$$\frac{\partial}{\partial x_j}\left(\rho C_p u_j T\right) = \frac{\partial}{\partial x_j}\left(k\frac{\partial T}{\partial x_j}\right) + \tau_{ij}\frac{\partial u_i}{\partial x_j} + \beta T\left(u_j\frac{\partial p}{\partial x_j}\right) \qquad \textbf{(2-12)}$$

2.2. Simplifying Assumptions

To build precisely our models, it is necessary to take account of simplifying assumptions. For that, we consider that the fluid is Newtonian and incompressible flow. Thus, the stress tensor is proportional to the symmetrical part of the tensor of the rates of deformation. The stress tensor can be reduced to:

$$\bar{\bar{\tau}} = \mu(\bar{\bar{\vec{\nabla}}}.\vec{V}) \qquad \textbf{(2-13)}$$

Total conductivity is constant, *i.e.* the heat flow is proportional to the gradient of the temperature:

$$\vec{q} = -\lambda\vec{\nabla}T \qquad \textbf{(2-14)}$$

CHAPTER 3

Numerical Models Choice and Validation with Anterior Results

1. INTRODUCTION

This chapter reviews the methodology used to model a solar chimney using ANSYS Fluent 17.0 and the validation study to confirm the different models suitable to simulate the airflow through a solar chimney system. A 2D numerical simulation is carried out to analyze and compare the performance of different numerical models and inner details of the solar chimney by taking Kasaeian *et al.* (2014) as a case validation. We use geometric parameters and metrological data similar to Kasaeian *et al.* (2014). To validate our numerical results with his experimental results. The main objective of this chapter is to choose the numerical parameters using the CFD code to investigate the airflow in the solar chimney.

2. DESCRIPTION OF THE PROBLEM

A solar chimney on a small scale was constructed at the University of Tehran, Iran. Tehran city has a geographical length and width of 51.4° and 35.7°, respectively. The geometry based on designed dimensions similar to Kasaeian *et al.* (2014) is mentioned in Fig. (**3.1**). For the pilot plant, the height and diameter of the chimney are 2 m and 20 cm, respectively. The diameter and angle of the collector are 3 m and zero degrees, respectively. In this application, a polycarbonate (PC) pipe has been used with a thickness of 4 mm for the chimney and the glass for the collector. The absorber consisted of 17 pieces of steel with a thickness of 2 mm and 8 mm chipboard wood which were attached together. In the numerical parameters, we will apply only the steel material because it is the material responsible for the heat flux transfer with air. Table **3.1** shows the characteristics of different materials using in this solar chimney. The experimental data of temperature distribution of Kasaeian *et al.* (2014) were recorded on June 19^{th}, 20^{th}, and 21^{th}, 2013 with the same climatic conditions. The ambient temperature was 306 K and the weather conditions were sunny corresponding to global solar radiation equal to $800 W.m^{-2}$, with no wind at the same hour

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(1:30 pm). The conditions of the numerical analysis, including ambient temperature, solar radiation, and air pressure are almost similar to the experimental conditions.

Fig. (3.1). Solar chimney prototype of Kasaeian *et al.* (2014).

Table 3.1. Characteristics of materials.

Material	Density (kg.m^{-3})	Specific Heat (J.kg^{-1}.K^{-1})	Thermal Conductivity (W.m^{-1}.K^{-1})	Absorption Coefficient (m^{-1})	Refractive Index n
Glass	2700	840	0.77	0.87	1.52
Steel	8030	502.48	16.27	1	0
PC	1200	1200	0.2	0.6	1.59
Air	1.22	1006.43	0.024	0	1

3. NUMERICAL MODEL

3.1. Boundary Conditions

A general interpretation was given based on numerical simulation of the solar chimney. A physical model was simulated using ANSYS Fluent 17.0, based on the geometrical dimensions of the solar chimney. The governing equations were solved, assuming symmetric and steady-state conditions. Also, the turbulent model was applied to describe turbulent flow conditions. Furthermore, wall boundary was applied for the chimney with a heat flux of value equal zero to obtain the adiabatic wall and axis boundary was utilized for the axis of the chimney. Wall boundary was used for the absorber and collector and convective heat transfer option was applied for different parts of the device such as collector and absorber. An inlet pressure boundary condition type was specified at the collector inlet. At the chimney exit, a pressure outlet boundary condition was selected. Furthermore, the pressure inlet is equal to p_i=0 Pa and the pressure outlet is equal to p_o=0 Pa. The boundary conditions are illustrated in Fig. (**3.2**).

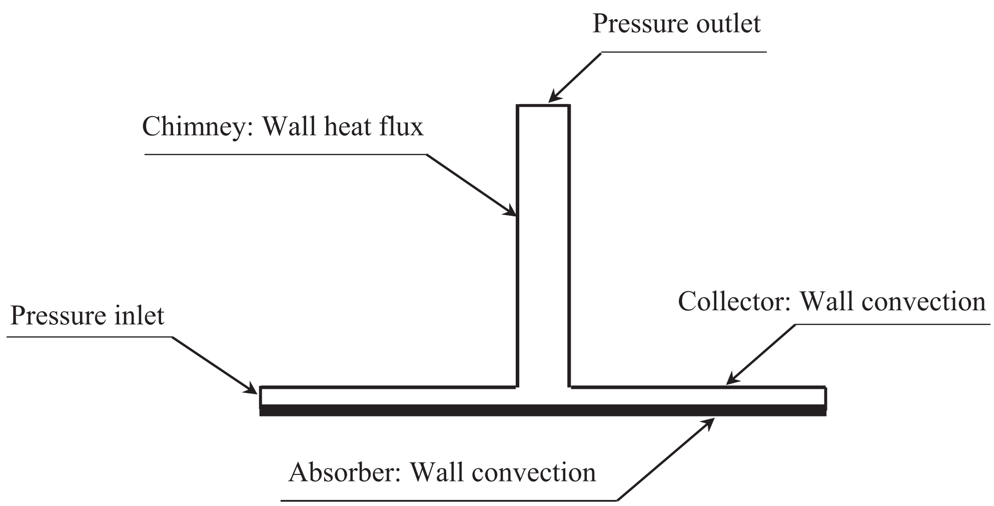

Fig. (3.2). Boundary conditions.

3.2. CFD Parameters

Several parameters govern solar performance and accuracy. The default values are usually good enough to ensure a robust path to a converged simulation. However, occasionally it may be necessary to modify these parameters to achieve better convergence for steady-state simulations via relaxation factors and higher accuracy via differencing schemes. Typically, these parameters are the domain of advanced users. Besides, we take so many iterations to have a good value of residuals (6000 iterations). The convergence criteria are 10^{-5} for all residuals, and configuration does not have problems with the convergence. The used diagram is the scheme “upwind”. This scheme takes into account the direction of the flow to determine the size convective on the faces of volumes of controls. The scheme

CHAPTER 4

Design of Prototype

1. INTRODUCTION

Numerous studies about the use of solar chimney for air conditioning, drying, and electrical power production were performed. The present study considered first the heat transfer process and the fluid dynamics in the collector and the chimney tower and extended later by a parametric study on the effects of the geometrical parameters. A validated CFD code was adopted to the solar chimney shape to resolve the governing equations (continuity, momentum, and energy equations). The investigation displays a necessity for a more detailed analysis of such systems, which is essential for an ample definition of the design rules. The available literature is scarce on this type of analysis, as research mostly concentrates on the evaluation of the global performance of such systems. For the design of real systems, more detailed studies of the geometrical and operational aspects are needed, involving meteorological conditions and geometric performances. This work is based on understanding the mechanisms of flow and transfer of natural convection in two-dimensional configurations using the CFD software ANSYS Fluent to find the optimal design that allows adequate thermal control and maximum energy performance. Besides, we have studied numerically the effect of the geometrical parameters, such as the chimney diameter, the chimney height, the collector diameter, the collector slope angle, and the collector height, thus to obtain the optimal parameters.

2. SOLAR CHIMNEY SYSTEM

The solar chimney prototype is composed of three main parts, the chimney, the collector, and the absorber (Fig. **4.1**). The chimney is a PVC pipe, its height and diameter are H and d respectively with a thickness of 3 mm, the absorber is a wooden platform of diameter D with an 8 mm thickness painter with a black layer. The wooden platform was chosen because it is a good thermal insulator and causes to improve the performance of the system. We choose polyethylene low density such a collector roof with a thickness of 1 mm, h indicates the inlet height, and θ indicates the collector slope angle. Different proprieties of our materiel are given in Table **4.1**. The geometrical arrangements are illustrated in Fig. (**4.2**).

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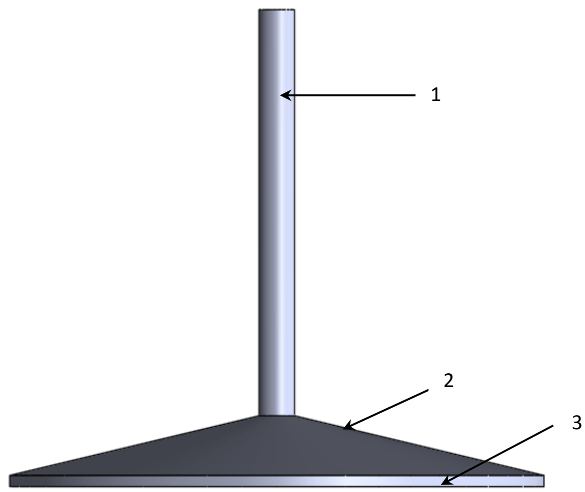

Rep.	Designation
1	Chimney
2	Collector roof
3	Absorber

Fig. (4.1). 3D model of the prototype.

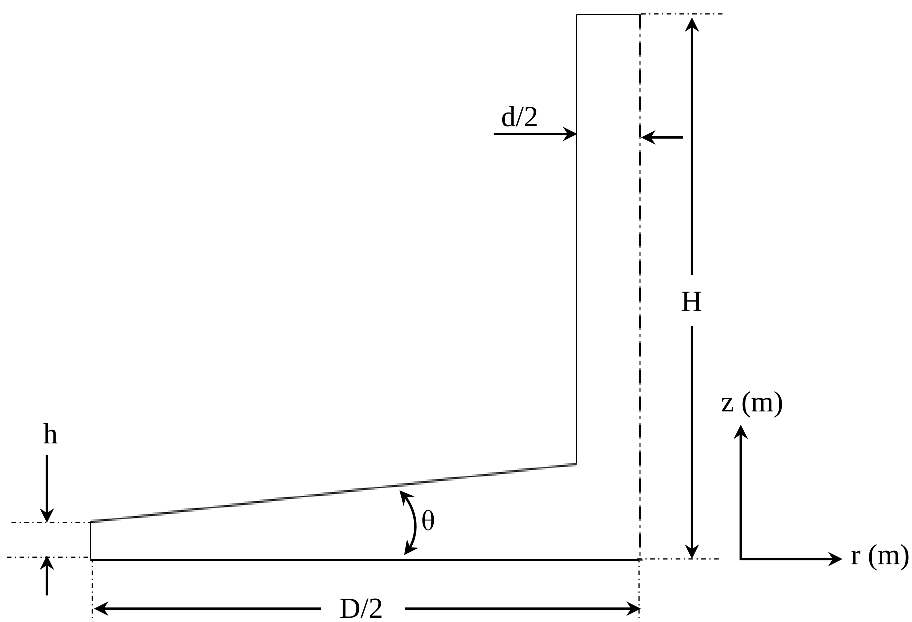

Fig. (4.2). Two-dimensional axisymmetric model of prototype.

Table 4.1. Characteristics of materials.

	Material	Density ρ (kg.m^{-3})	Specific Heat Cp (J.kg^{-1}.k^{-1})	Thermal Conductivity K (W.m^{-1}.k^{-1})	Absorption Coefficient α (m^{-1})
Fluid	Air	1.122	1006.43	0.0242	0
Solid	Wood	700	2310	0.024	0.8
	PVC	1380	1046	0.2	0.6
	Polyethylene	920	2100	0.33	0.4

3. NUMERICAL PARAMETERS

3.1. Meshing

Meshing is one of the most important aspects of any CFD simulation. According to the study of the meshing effect in the last chapter, we use in this chapter, the mesh presenting 356 000 cells. The schematic of the meshing is shown in Fig. (**4.3**).

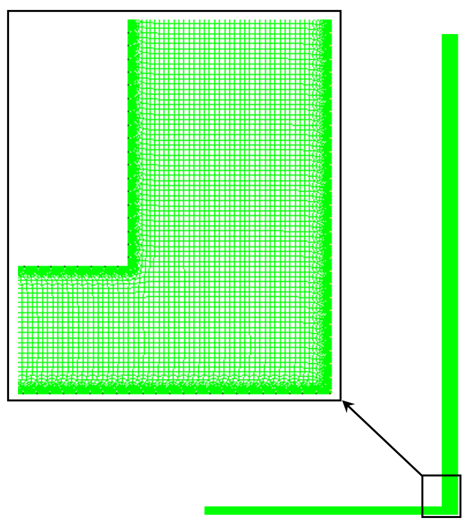

Fig. (4.3). Meshing.

3.2. Boundary Conditions and Numerical Parameters

In this chapter, a general description was given based on the different models that we fixed in chapter 2. A physical model was simulated using ANSYS Fluent 17.0,

CHAPTER 5

Experimental Study

1. INTRODUCTION

There are many configuration sizes of the small-scale solar chimney in the world, because of various meteorological and geographic conditions. The main objective of their works is to test the heat transfer performance of the collector and the power output. However, our work is based on the numerical study and numerical optimization of geometric parameters to testing the performance of the prototype with meteorological data. In the first part, we are interested in the experimental characterization of a solar chimney with specific instrumentation. In particular, we present a detailed description of the realization and the various manipulations made to the study. A discussion of results is then presented at the end of this chapter.

2. PROTOTYPE PRESENTATION

The prototype consists of a solar chimney of a small scale that we have conducted to highlight the physical phenomena studied on the numerical system, including the natural convection phenomena. After we respected the dimensions that we choose in the precedent chapter, we have created a design that is simple, effective, and rigid to construct our prototype of the solar chimney by using simple and available tools. Fig. (**5.1**) shows a schematic view of the experimental solar chimney for power generation situated on the experimental site. It consists of five major components, such as:

· Collector (matrix with roof)

· Chimney

· Support of chimney

· Turbine generator

· Absorber

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The dimensions of our prototype are represented in Fig. (**5.2**), consisting of a collector with a diameter equal to D=2.75 m and a height equal to h=5 cm. The chimney has H=3 m in tall and d=16 cm in diameter. The slope angle of the collector is equal to q=0°. Besides, the stage of the realization of our prototype is given by appendix 2.

Fig. (5.1). Our prototype.

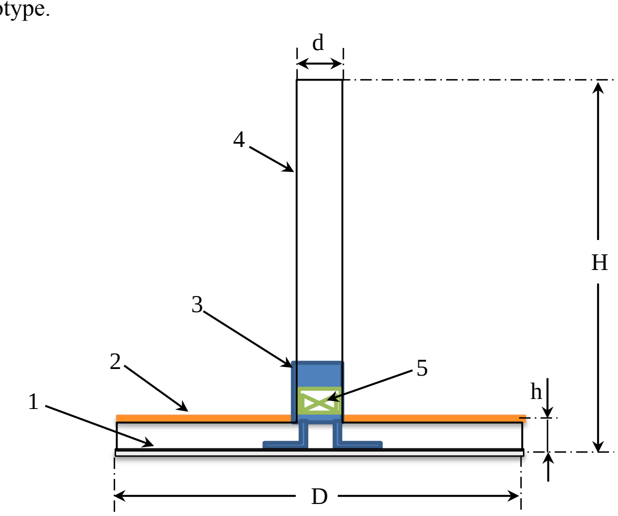

Fig. (5.2). Schematic of our prototype.

Rep.	Designation
1.	Absorber
2.	Collector Roof

(Table 5.2) cont.....

Rep.	Designation
3.	Chimney Support
4.	Chimney
5.	Turbine Generator

2.1. Collector

The collector must ensure good insulation of the front face of the sensor exposed to the solar radiation. For that, it must let pass the maximum of the energy of the exterior towards the absorber while being opposed to heat exchange reverse whatever their nature. In the same way, it must be transparent with the solar radiation but opaque with the infrared radiation. The second significant parameter by carrying out this chimney is the distance between the collector and the shock absorber. The larger this distance, the more the convective exchange is significant. For this, we must reduce the thickness as much as possible to reduce to the minimum the loss of heat outside. The most usual material is glass considering the factor of transmissivity for radiation solar is 0.85 without using it as cover, considering which it is very fragile. We replace glass by other materials that transmit less radiations but is easy with cutting and deformation as an adhesive film (tarpaulin) shown in Fig. (**5.3**). The thickness of the tarpaulin is another important parameter because if the thickness is significant than the transmissivity is low. For this reason, we have used a polyethylene with low density.

2.2. Chimney and Support

We take a PVC pipe for the chimney. It has H=3 m in tall, d=16 cm in internal diameter and 3 mm in thickness. We choose PVC because of its strength, maneuverability on change, good thermal resistivity, lightweight, resistivity to climatic factors (rain, wind, sun), and availability. The pipe is fixed on a support. This support should be a cylindrical boring with 16.5 cm in internal diameter, where it supported the PVC pipe of 16.3 cm in external diameter. Because we do not have a cylindrical shape with 16.5 cm in diameter in our workshop, we will use and weld a steel dish to obtain a cylindrical shape. To fix this cylindrical boring on the wooden platform, we weld three square on the external surface of the cylinder. We choose three square only because of decrease friction with air and increase the area in which the air enter the PVC pipe. The distance between the wooden platform and the inlet cylinder is 15.3 cm because we will have moved the pipe to change the slope of the collector. Fig. (**5.4**) shows the system chimney and support.

CONCLUSION AND RECOMMENDATIONS

Solar chimney is an interesting alternative to centralized electricity generation power plants. It is very important for the future because our resources are limited, except sun and the study of this technology has a topicality in the energetic fields. In these objectives, we are interested in this book on the numerical and experimental study of a solar chimney.

At first, a detailed literature survey of this system was performed. Particularly, we have developed the computational fluid dynamics (CFD) simulation that used to model the airflow through a solar chimney. Mathematical derivations were provided to predict the theoretical equations used in CFD software to model the solar chimney.

In this part, we have concluded that the best or realistic models used to model the airflow through a solar chimney are the realizable k-ε turbulence model, and the DO radiation model and convection heat flux transfer model were employed in ANSYS Fluent. This model has been validated with anterior experimental results due to the acceptable coherence between its numerical results and experimental results. This study shows that CFD is a useful tool for investigating the possibilities of a proposed device before prototype and testing. It is helpful in the development of solar chimney retrofit for existing buildings.

In the second part, alternate geometric configurations of solar chimneys were studied numerically to expand the study of optimizing the design of the solar chimney. Simulations were performed using the commercial CFD software ANSYS fluent. The goal of this part is the study of the effect of the geometric parameters on the airflow behavior inside the solar chimney to obtain an optimal size available to construct a prototype of solar chimney. This study shows that the increase in the height, in the diameter of the chimney, and the diameter of the collector increases the temperature and the air velocity however, an increase in the collector height decreases.

An experimental study is presented in the last part of this book. The experimental prototype, constructed at ENIS, is used to study the environmental temperature, distribution of the temperature, air velocity, and the power output generated by the turbine. The main results were found from this prototype are the solar radiation and the gap of temperature in the collector. These parameters are important factors affecting the performance of the solar chimney. It is found that the temperature gap in the collector is approximately equal to 20 °C when the solar radiation is great at noon. It is therefore concluded that the solar chimney stands to achieve good performance in areas that exhibit the highest monthly average daily solar radiation. Indeed, we have concluded that our country, particularly the region of Sfax, presents a good area for installing the solar chimney power plant, where the technology and the material to build such plants are available.

Based on the conclusions, the following suggestions and recommendations might be found useful in future work:

- Increasing the height of the collector and the diameter of the chimney to improve the power output and efficiency.
- Installing a storage heat system, it has been suggested that by placing extra thermal mass under the collector in the form of black containers with water, the plant could generate power at night.
- Studying the effect of different materials on absorber and the collector to determine the best material that give the most performance.

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SUBJECT INDEX

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