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By: GANA Ben Yagoub

KELOUCHE Abd El Kader

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OPTIMIZATION OF THE PHYSICAL PARAMETERES OF A SOLAR WATER COLLECTOR

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Mr BACHIR.KHAROUBI	M.C.B	University of Tiaret	President
Mr ABD EL KADER.SAFA	M.A.A	University of Tiaret	Examiner
Mr BEN AISSA.TRARI	M.A.A	University of Tiaret	Framer

PROMOTION 2020

dedication

I dedicate this work

To our dear parents.

To those who have enlightened our paths and who have encouraged and supported us throughout our studies;

To our friends khaled and mokhtar.

To my binomial abdelkader kelouche and all friends in the physical and energetic promotion and the renewable energies.

To our teachers, to all those who have assisted and supported us

in our studies.

To all the members of our Gana and Kelouche families

Thanks

First of all, we thank God for giving us the strength, courage and patience to carry out this modest work.

Our deep gratitude and our warmest thanks go particularly to our supervisor **Mr. BEN AISSA TRARI**, assistant professor "A" at the University of Tiaret , for having followed and guided us throughout the realization of this work. Also, we thank him for his permanent availability, for his effective orientation and for his original ideas which served to enrich this memory.

We warmly thank our teacher **Mr, BACHIR.KHAROUBI**, Lecturer "B" at Tiaret University, for the honor he did us for agreeing to review our work and chair the jury.

We would also like to thank **Mr, ABD EL KADER.SAFA**, assistant professor "A" at the University of Tiaret, for their participation in the evaluation of this work.

Finally, we sincerely thank all those who, from near or far, have contributed to the achievement of this work.

Gana Ben Yagoub

Kelouche Abd El Kader

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NOMENCLATURE

NOMENCLATURE

SYMBOL	UNIT	DESIGNATION
L	Degree	longitude of the place
h_s	Degree , rad	height of the sun
a	Degree	azimuth of the sun
L	*m*	Length of solar collector
h	degree	height of sun
e abs	*m*	thickness of the absorber
e iso	*m*	Thickness of the insulation
X	*m*	Space variable in the direction of flow
h	*m*	height of the baffles
l	*m*	space between baffles
H	*m*	distance between the absorber and the isolator
S	m^2	Area of the heat flow passage section
V	*m/s*	velocity of the fluid
cp	*J/kg.K*	Specific heat
T	*K*	Temperature
J	*days*	Number of days of the year
d	*hours*	Number of hours of the day
TSV	*hours*	True solar time
TC		Time Correction Factor
LST	*hours*	Local Solar Time

NOMENCLATURE

GREEK LETTERS

LETTER	UNIT	DESIGNATION
φ	Degree	latitude of the place
$\boldsymbol{\omega}$	Degree	time angle
δ	Degree	Solar declination
$\boldsymbol{\alpha}$	Degree	azimuth of the plane (azimuth deviation)
μ	*kg/m.s*	Dynamic viscosity of fluid
υ	m^2/s	cinematic viscosity of fluid
σ		Evaluated Stefan-Boltzmann constant
ρ	kg/m^3	Volumic mass
ϕ	W/m^2	Heat flux
λ	$W / m^2.K$	Thermal conductivity

GENERAL INTRODUCTION

GENERAL INTRODUCTION

The origin and continuation of humankind is based on solar energy, the most basic processes supporting life on earth, such as photosynthesis and the rain cycle, are driven by the solar energy. From the very beginning of its history, the humankind realized that a good use of solar energy is in humankind's benefit. Despite this, only recently, during the last 40 years, has the solar energy been harnessed with specialized equipment and used as an alternative source of energy, mainly because it is free and does not harm the environment.

The greatest advantage of solar energy compared with other forms of energy is that it is clean and can be supplied without environmental pollution. Over the past century, fossil fuels provided most of our energy, because these were much cheaper and more convenient than energy from alternative energy sources, and until recently, environmental pollution has been of little concern. The rapid increase in oil demand occurred mainly because increasing quantities of oil, produced at very low cost, became available during the 1950s and 1960s from the Middle East and North Africa. For the consuming countries, imported oil was cheap compared with indigenously produced energy from solid fuels.

The sun's energy has been used by both nature and humankind throughout time in thousands of ways, from growing food to drying clothes; it has also been deliberately harnessed to perform a number of other jobs. Solar energy is used to heat and cool buildings (both actively and passively), heat water for domestic and industrial uses, heat swimming pools, power refrigerators, operate engines and pumps, desalinate water for drinking purposes, generate electricity, for chemistry applications, and many more operations.

Algeria holds a huge solar energy potential to be exploited for the establishment of a clean and productive economy. This will allow, for sure, having investments less costly and reducing the harmful effects of greenhouse gas emissions on the environment. The use of clean energy is the way most effective and fight against global warming phenomenon in accordance with the Kyoto Protocol and Durban Platform on Climate Change. Algeria can become a model for the use of clean energy through the use of solar energy available to it. But we need to have a political plan and a good strategy in this direction.

Optimizing solar devices is one of the recommended solutions to reverse the current trend and see more use of solar energy in the world. The simplest and most direct use of solar energy is production domestic hot water. It's also one of the oldest, like many solar water heaters have been invented since the early twentieth century to the present day, more efficient than each other.

The three operating parts of a solar heating system are:
capture, storage and distribution. Capture is the essential part for conversion of solar energy. It is represented by the solar collector. It's the latter which transforms solar energy into amount of heat which it transmits to the heat transfer fluid circulating in its absorber. Given the important role that the solar collector plays in conversion of solar energy into thermal energy, several researches have been carried out on the study of the solar collector with the aim of improving its instantaneous yield which represents the most characteristic performance.

The instantaneous yield of a collector varies with its geometry, construction parameters and external parameters such as temperature, etc. The objective of this work is optimized of physical parameters in solar water collector by using ansys program and compared with previous studies in this domain.

This work includes five chapters:

- Chapter 1 present a state of the art on solar water heaters, cite in this chapter the main work carried out on their theoretical models and their experiments.
- Chapter 2 description of the sun and its energy, the parameters of solar position and time.
- Chapter 3 General information on solar water heaters, different components, operation.
- Chapter 4 main equations in this work, numerical methods.
- Chapter 5 results and discussions.

CHAPTER I
BIBLIOGRAPHIC RESEARCH ON SOLAR CAPTORS

I.1 INTRODUCTION

Solar water heating device that mimic those used in residences to capture energy in the form of solar radiation and convert it to thermal energy, this thermal energy is next transfer to water (to be used as domestic hot water) in the form of heat.

The advantage of the radiation provided by our sun, converting it to thermal energy to generate electricity, heat water and cook food. Solar water heating is the conversion of sunlight into renewable energy for water heating using a solar thermal collector. Solar water heating system comprise various technologies that are used worldwide increasingly solar water heater system are designed to hot water for most of the year.

Power storage is a very common problem in our country and most of our work gets interrupted due to sudden power cut and voltage function. Solar power is one of the alternatives to the electricity. Solar power is clean green electricity that is created from sun light, or heat from the sun.

Solar energy is sustained and totally in exhaustible, unless fossil fuel that are finite. It is also non-polluting source of energy and it does not emit any green house gases when producing electricity.

The one of the popular devices that harnesses the solar energy is solar hot water system. Water heating typically represents a high percentage of energy consumption in homes and business; in some cases, 30% dramatically reduce energy bills without any environmental impact [**PRAKASH KUMAR SEN ET AL, 2015**].

I.2 HISTORY

In the 1760s, Horace de Saussure observed "It is a known fact, and a fact that has probably been known for a long time, that a room, a carriage, or any other place is hotter when the rays of the sun pass through glass." de Saussure built a rectangular box out of half-inch pine, insulated the inside, and had the top covered with glass, and had two smaller boxes placed inside. Sunshine penetrated the glass covers. The black inner lining absorbed the sunlight and converted it into heat. Though clear glass allows the rays of the sun to easily enter through it, it prevents heat from doing the same. As the glass trapped the solar heat in the box, it heated up.

The earliest solar hot water collectors, dating back to the nineteenth century, were tanks filled with water and painted black. The downside was that even on clear, hot days it usually took from morning to early afternoon for the water to get hot, and as soon as the sun went down, the tanks rapidly lost their heat because they had no protection from the night air.

In 1891, Clarence Kemp patented a way to combine the old practice of exposing metal tanks to the sun with the scientific principle of the hot box, thereby increasing the tanks' capability to collect and retain solar heat. He called his new solar water heater the Climax - the world's first commercial solar water heater.

In 1909, William J. Bailey patented a solar water heater that revolutionized the business. He separated the solar water heater into two parts: a heating element exposed to the sun and an insulated storage unit tucked away in the house so families could have sun heated water day and night. The heating element consisted of pipes attached to a black-painted metal sheet placed in a glass-covered box. Because the water to be heated passed through narrow pipes rather than sat in a large tank, Bailey reduced the volume of water exposed to the sun at any single moment and therefore, the water heated up faster. Providing hotter water for longer periods put Bailey's solar hot water heater, called the Day and Night, at a great advantage over the competition **[1].**

I.3 BIBLIOGRAPHIC REVIEW

The study of the parameters that influence the thermal performance of solar water heaters, it largely depends on the transmission, absorption and conduction of solar energy and the conductivity of the fluid functioning, basically translate by three methods:

- Increasing the amount of solar energy received by the absorber.
- Reduction of heat losses from the solar collector.
- Influence of artificial roughness on thermal performance.

I.3.1 Influence of artificial roughness on thermal performance

[CARL M ET AL,1987], he was talked about materials science properties of optical materials and coatings for a broad range of solar conversion, architectural glazing and greenhouse energy efficient use and Transparent low emittance coatings for glazing for radiative heat transfer reduction **[CARL M ET AL,1987]**.

[HUCHING ET AL, 2002], they studied the choice of material for optically solar selective coatings on the basis of their optical constants was observed that high refractive index composites have lower reflective properties by choosing suitable metallic volume fraction in dielectric and antireflection coating **[HUCHING ET AL, 2002].**

[ROGÉRIO ANTÔNIO, 2017], he used black chromium coatings on stainless steel AISI 304 substrate using an electrode position technique. that achieved the prerequisites for selective surface with absorptance more than 90.0% **[ROGÉRIO ANTÔNIO, 2017].**

I.3.2 Reduction of heat losses from the solar captor

[A.A.MOHAMAD, 1997], to study blanket towards the atmosphere, he before they pass through the absorber, and use a pore absorber to study the minimization of losses of the passing heat offered to force the air to circulate on the cover heat loss from the on the glass cover passage through the absorber **[A.A.MOHAMAD, 1997].**

[BENKHELIFA, 1998], presented a mathematical model to study the influence of some parameters on the heat loss coefficient towards the front of the sensor, the model used to calculate these heat losses, he found that increasing the coefficient of heat losses depends on the increase in the emissivity of the absorber as well as its temperature and the convective exchange coefficient with ambient air, but the increase in the distance between the absorber and the glass reduces thermal losses **[BENKHELIFA, 1998].**

[A.M.SHARIAH, 1999], they confirmed that the factors characteristics like the sensor efficiency factor and the heat dissipation factor heat are strongly dependent on the thermal conductivity of the absorbent plate **[A.M.SHARIAH, 1999].**

[N.T. AHMAD, 2001], a experimentally studied the minimization of heat losses convective to the environment of a sensor used in the heating of greenhouses **[N.T. AHMAD, 2001].**

[SERGIO COLLE ET AL, 2003], they studied reducing heat loss to non-receiving areas requires good thermal insulation using various materials of varying thickness [**SERGIO COLLE ET AL, 2003**].

I.3.3 Influence of artificial roughness on thermal performance

[**ABDI.H ET AL, 2000**], their work linked of two types of flat captors of different shapes solar panel ,this is mainly to study the impact the geometric shape of the fluid paths on the effectiveness of the captors in the event of contact water absorption plate directly, to improve the efficiency of a flat solar complex, we have sought to promote the exchange of heat between absorbent and heat transfer, the mathematical model was developed and validated against the tests. The results show that the daily efficiency of the captor with a plate convex absorption is better than the concave plate [**ABDI.H ET ALL, 2000**].

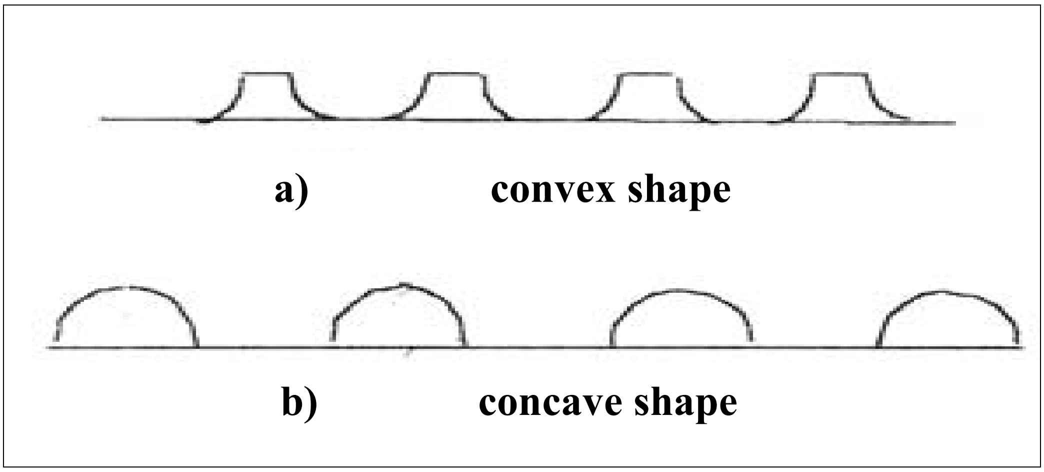

FIGURE I.1: *absorbent sheets* **[ABDI.H ET ALL, 2000].**

[A.A. ZAÏD ET AL, 2001], have experimentally studied the insufficiency of exchange thermal realized in the flat air solar collector between the fluid and the absorber. The user is brought to make improvements for better performance or better thermal efficiency. They introduced baffles (obstacles) to improve the couple Cape temperature yield-deviation **[A.A. ZAÏD ET AL, 2001].**

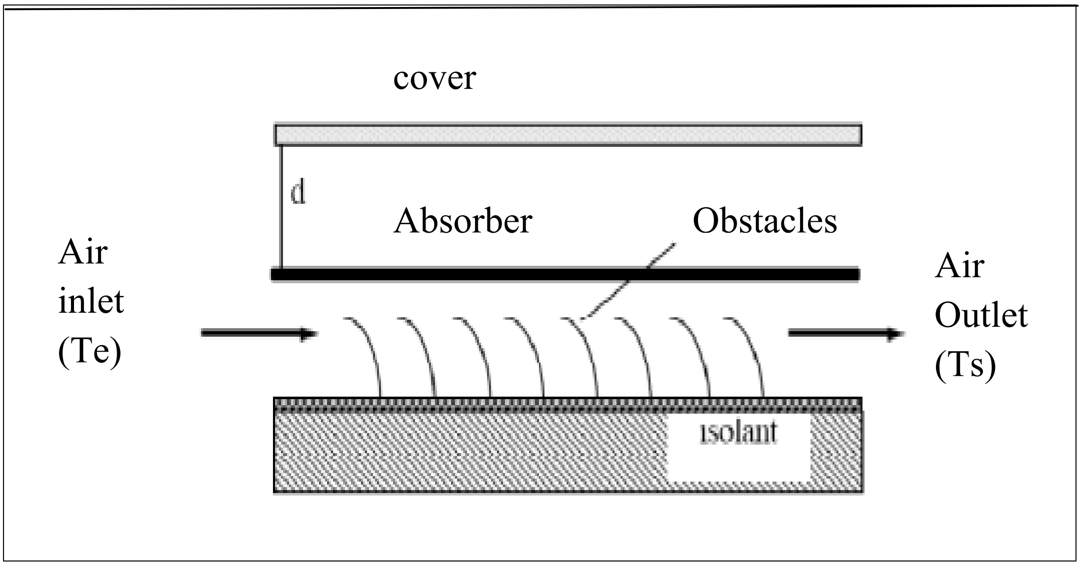

FIGURE I.2: *components of the solar collector* **[A.A. ZAÏD ET AL, 2001].**

[A. ABENE ET AL, 2004], studied a solar collector using different obstacles and application for drying grapes. They found that the introduction of obstacles in the air channel is a very important factor for improving captor performance; they also showed that the dimensions, shape and orientation of these obstacles considerably influence the efficiency of the solar collector **[A. ABENE ET AL, 2004].**

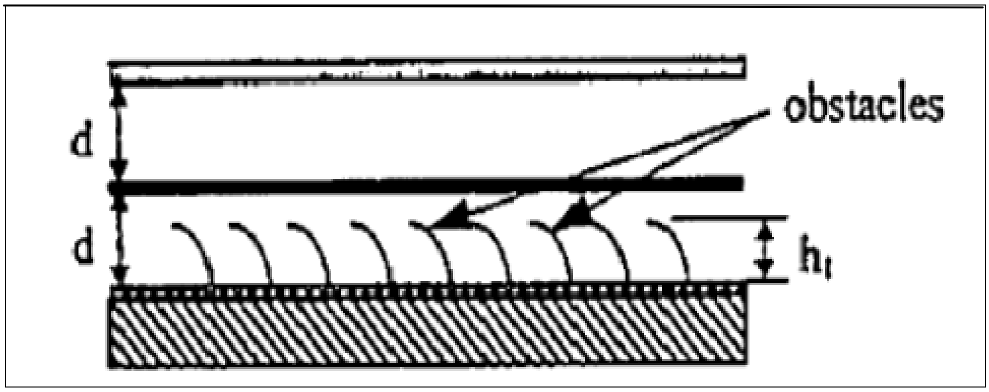

FIGURE I.3: *components of the solar collector with baffles* **[A. ABENE ET AL, 2004].**

[N. MOUMMI ET AL, 2004], at first they shouted a turbulent flow between the absorber and backplate and have reduced dead zones by using obstacles with various rectangular shapes perpendicular to the flow to improve the factor efficiency of these solar collectors. Second and for the same configuration, they carried out a study on the evaluation of the transfer coefficient **[N. MOUMMI ET AL, 2004].**

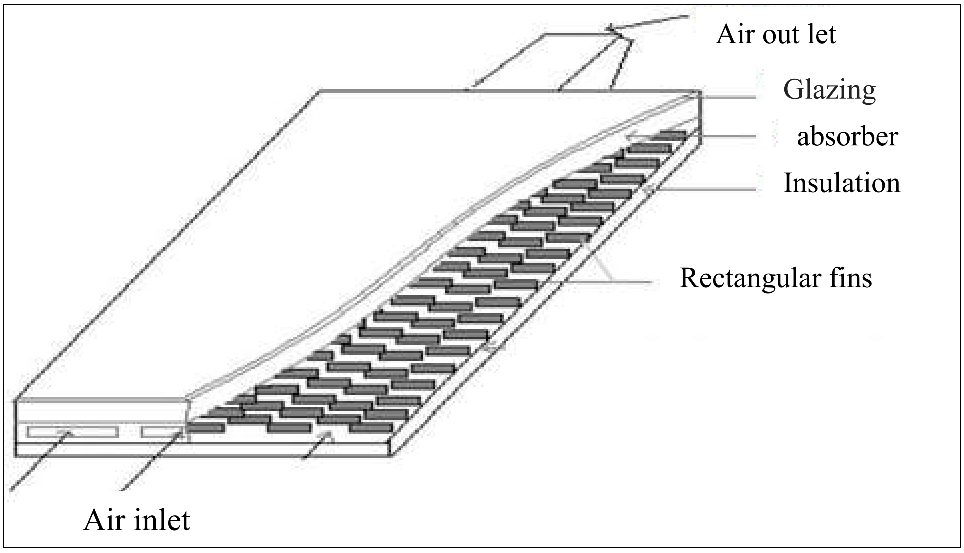

FIGURE I.4: *collector with finned system on the back wooden plate* **[N. MOUMMI ET AL, 2004].**

[S. YOUCEF ALI, 2005], did an experimental study on a solar collector, which he introduces thin rectangular plates oriented parallel to the flow and welded on the underside of the absorber, the study also experimentally compares the case of a double cover captor to that of a triple cover captor **[S. YOUCEF ALI, 2005].**

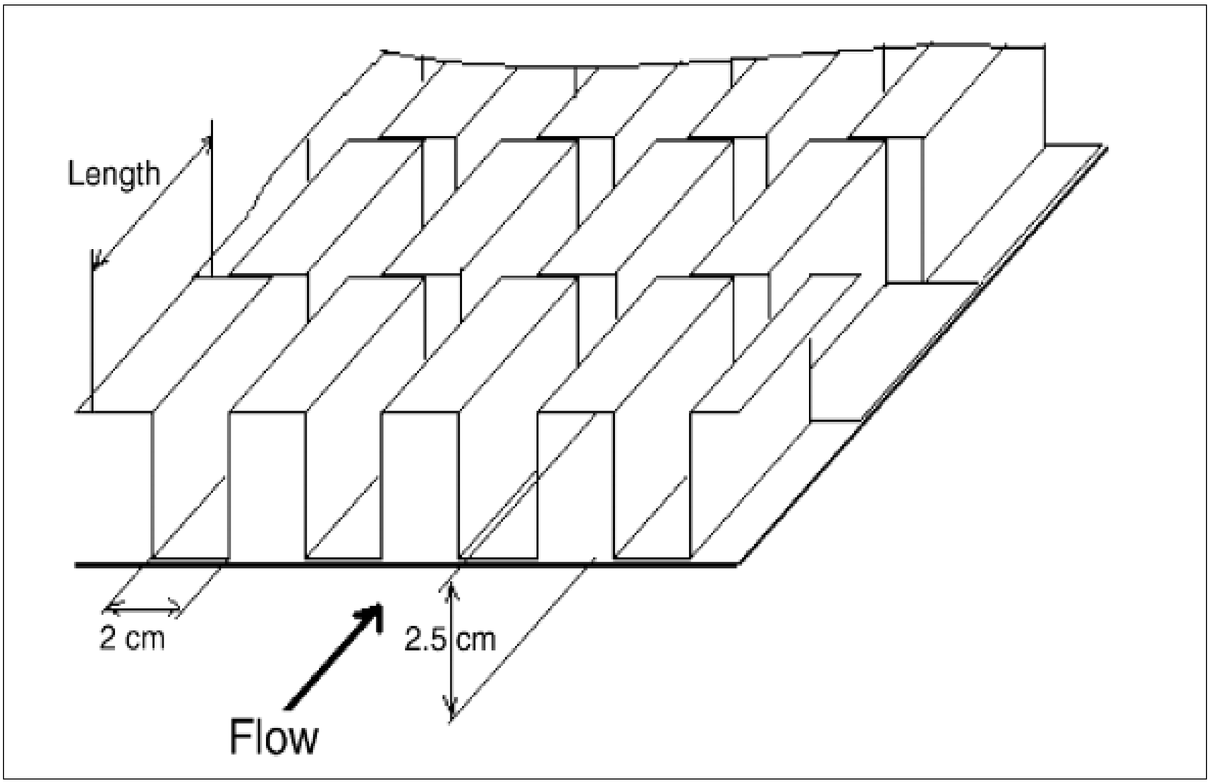

FIGURE I.5: *compensation absorber plate with fins rectangular* **[S. YOUCEF ALI, 2005].**

[ACHOURI ET AL, 2008], they studied the optimization of the convection transfer coefficient in flat solar collector between the heat transfer fluid and the solar radiation absorbing plate, this optimization can be obtained by increasing the exchange surface by introducing obstacles of different geometric shapes (cylindrical shape), they concluded that the yield is much higher for a captor with baffles **[ACHOURI ET AL, 2008].**

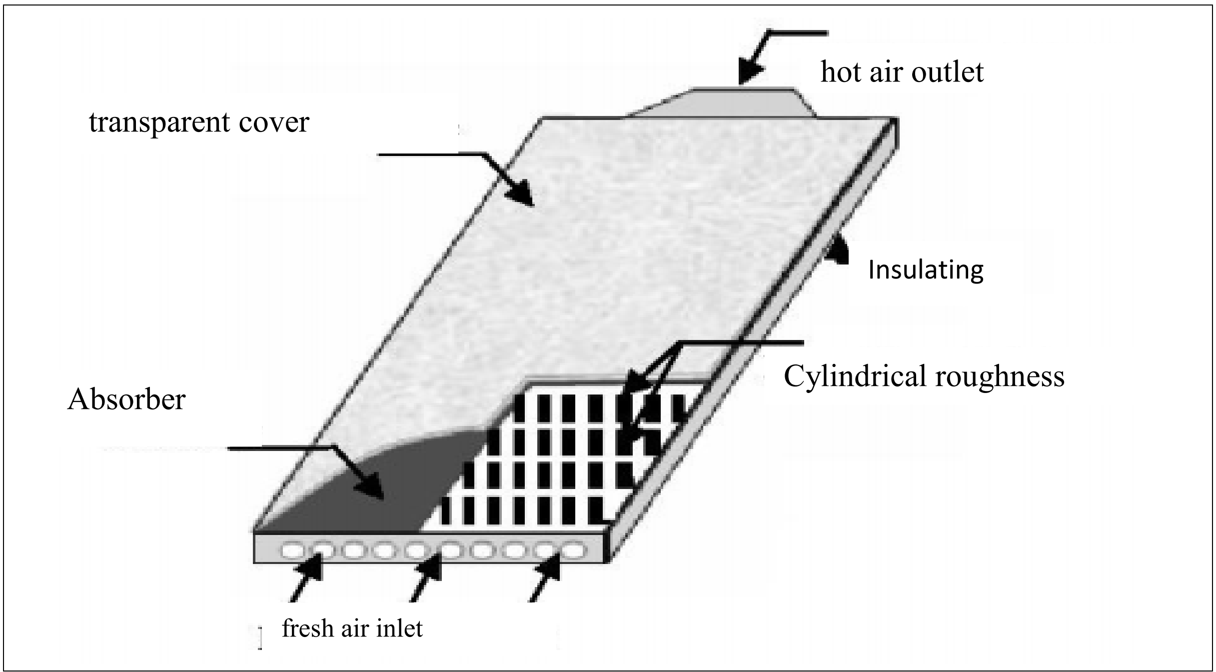

FIGURE I.6: *air plane collector diagram with roughness* **[ACHOURI ET AL, 2008].**

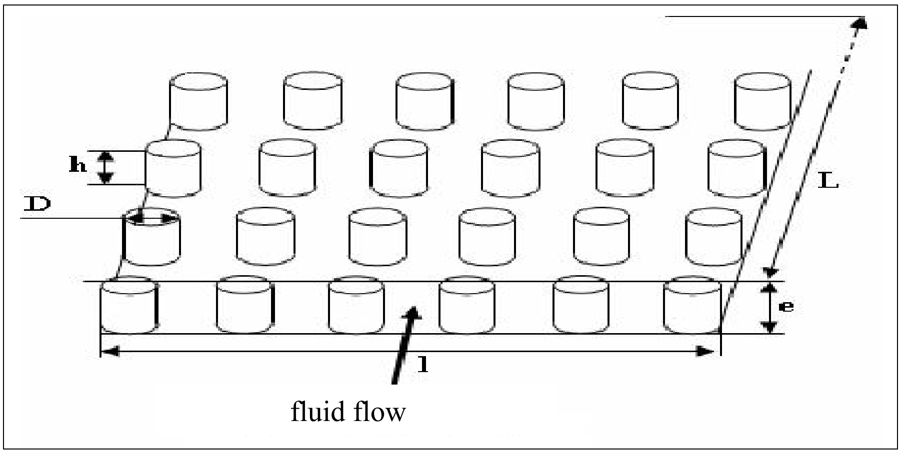

FIGURE I.7: *artificial roughness of cylindrical shape* **[ACHOURI ET AL, 2008].**

[K. AOUES ET AL, 2009], they did a theoretical and experimental study on performance of a menu plan air solar collector of a new form of artificial roughness, they have proposed a model of artificial roughness placed in the moving air stream to create a turbulent flow between the absorber and the bottom plate **[K. AOUES ET AL, 2009].**

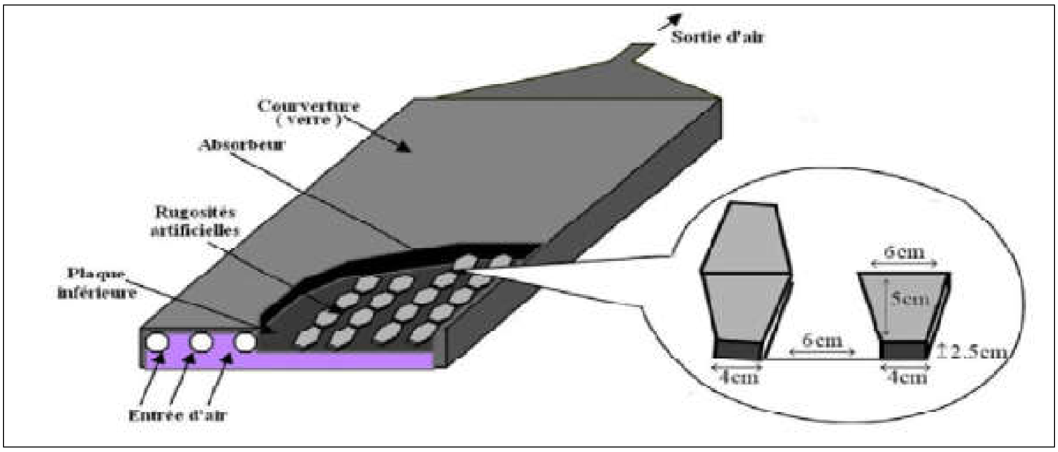

FIGURE I.8: *air plane sensor diagram with roughness* **[K. AOUES ET AL, 2009].**

[H.M. YEH ET AL, 2009], they presented an experimental and theoretical study of a device in which have introduced an absorbent plate to divide the channel into two parts with fins attached by baffles, they compared the experimental and theoretical results with data from a single pass air collector without recycling, an upgrade considerable heat transfer is obtained with the addition of baffles and fins, the influences of the recycling rate and the location of the absorber on the efficiency of heat transfer are also discussed **[H.M. YEH ET AL, 2009].**

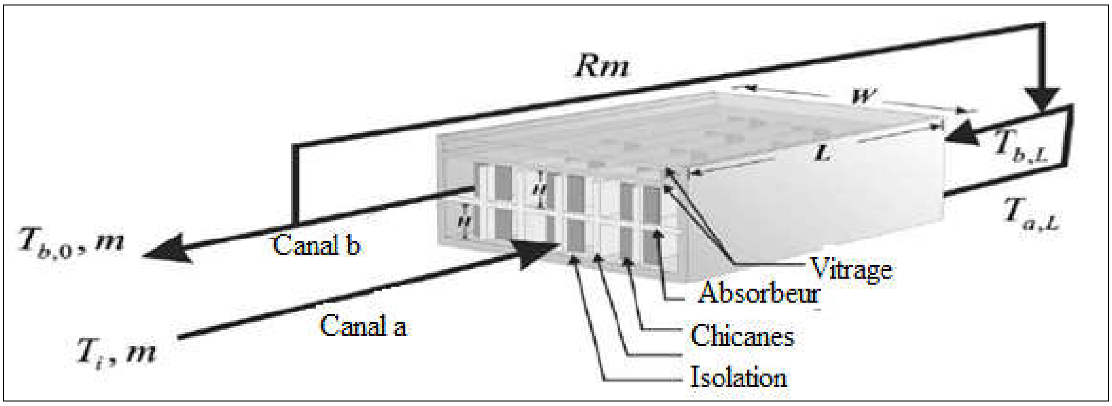

FIGURE I.9: *baffled double-pass flat-plate solar air heaters with internal fins attached* **[H.M. YEH ET AL, 2009].**

[A. FUDHOLI ET AL, 2011], The heat transfer of double-pass solar air collector with longitudinal fins is presented. It is composed of a theoretical study to investigate the effect of mass flow rate, number and height of fins on efficiency, which involves steady-state energy balance equations on the longitudinal fins of solar air collector. The theoretical solution procedure of the energy equations uses a matrix inversion method. The results show that the collector efficiency increases as the number and height of fins increases [**A. FUDHOLI, ET AL, 2011**].

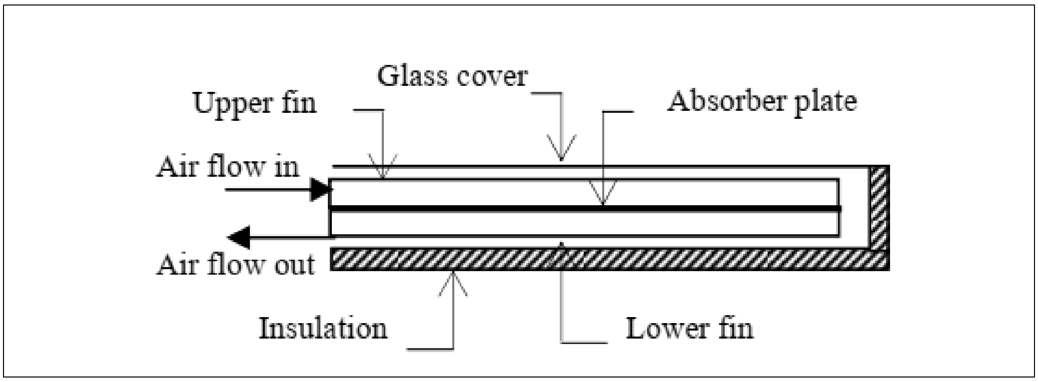

FIGURE I.10: *schematic of the double pass solar collector with longitudinal fins* **[FUDHOLI, ET AL, 2011].**

[R. KUMAR ET AL, 2011], studied the performance of a solar collector PV / T double pass air with and without fins placed in the lower channel. The fins are arranged perpendicular to the direction of air flow to increase efficiency and the rate of heat transfer. The effects of operating parameters and climatic parameters are evaluated on the air outlet temperature, the temperature of the cell, thermal efficiency, and electrical efficiency. The effects of the presence of fins in the lower channel, the depths of the channels, the mass flow and the temperature of the air inlets are evaluated in thermal and electrical efficiency **[R. KUMAR ET AL, 2011].**

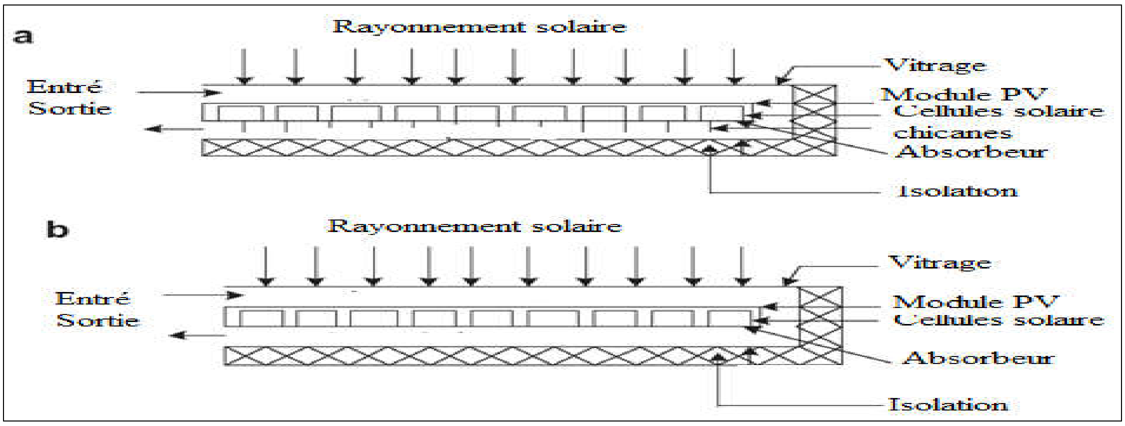

FIGURE I.11: *(a).cross-sectional view of double-pass pv/t solar air heater with fins. (b). cross-sectional view of double-pass pv/t solar air heater without fins* **[R. KUMAR ET AL, 2011].**

[D. HO ET AL, 2012], the performance of a solar air heater featured with double-pass as well as fins and baffles design was investigated for the effect of recycling operation via both experimental and theoretical approaches. The experimental results deviate by 1.5–23% from the theoretical predictions. The performance of solar air heaters with different designs are compared, including the single-pass, double-pass with recycle, fined double-pass with recycle, and fined plus baffled double-pass with recycle. The double-pass device introduced in this study was proposed for aiming to strengthen the convective heat transfer coefficient and enlarge the heat transfer area. Based on both theoretical and experimental results, the collector efficiency of the fined plus baffled double-pass with recycle design is much higher than the other designs under different reflux ratios and mass flow rates. The optimal reflux ratio for the fined plus baffled double-pass design is about 0.5 while considering both the collector efficiency and the pumping power requirement. An economic consideration in terms of the heat transfer efficiency and power consumption increment for double-pass operation is delineated **[D. HO ET AL, 2012].**

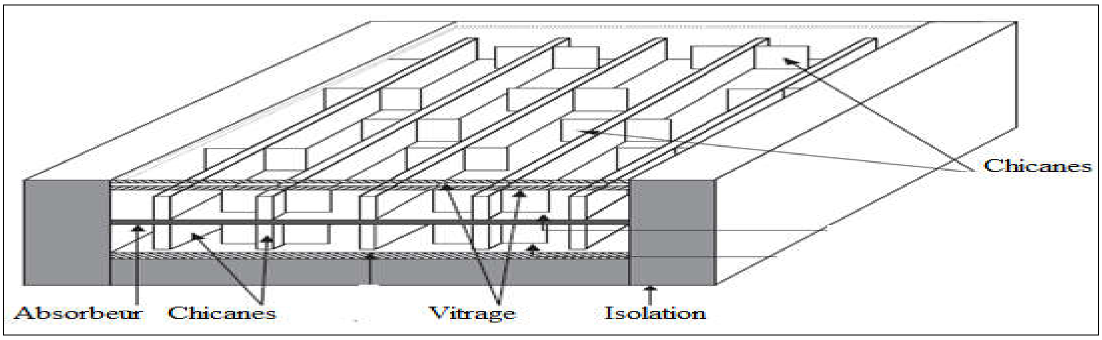

FIGURE I.12: *flat solar collector with rectangular baffles* **[D. HO ET AL, 2012].**

I.4 CONCLUSION

In this chapter we concluded that performance of a solar collector largely depends on the quality of absorption and heat transmission of the absorbent plate thus; several researches have been launched to propose new plate arrangements absorbent to increase the performance of solar collectors.

CHAPTER II
SOLAR DEPOSIT

II.1 INTRODUCTION

The reason for the rapid increase in oil demand occurred mainly because increasing quantities of oil, produced at very low cost, became available during the 50s and 60s from the Middle East and North Africa. For the consuming countries imported oil was cheap compared with produced energy from solid fuels.

But the main problem is that proved reserves of oil and gas, at current rates of consumption, would be adequate to meet demand for another 40 and 60 years, respectively. The reserves for coal are in better situation as they would be adequate for at least the next 250 years.

If we try to see the implications of these limited reserves we will be faced with a situation in which the price of fuels will be accelerating as the reserves are decreased. Considering that the price of oil has become firmly established as the price leader for all fuel prices then the conclusion is that energy prices will increase over the next decades at greater than the rate of inflation or even more. In addition to this is also the concern about the environmental pollution caused by the burning of the fossil fuels.

Basically, all the forms of energy in the world as we know it are solar in origin. Oil, coal, natural gas and woods were originally produced by photosynthetic processes, followed by complex chemical reactions in which decaying vegetation was subjected to very high temperatures and pressures over a long period of time. Even the wind and tide energy have a solar origin since they are caused by differences in temperature in various regions of the earth **[SOTERIS A.KALOGIROU, 2004].**

II.2 SUN DESCRIPTION

The sun is a sphere of intensely hot gaseous matter with a diameter of $1,39.10^{9}\,m$. The solar energy strikes our planet a mere 8 min and 20 s after leaving the giant furnace, the sun which is $1,5.10^{11}\,m$ away. The sun has an effective blackbody temperature of 5762 K. The temperature in the central region is much higher and it is estimated at 8.10^{6} to 40.10^{6} K. In effect the sun is a continuous fusion reactor in which hydrogen is turned into helium.

The sun's total energy output is $3,8.10^{20}$ MW which is equal to 63 MW/m^2 of the sun surface. This energy radiates outwards in all directions. Only a tiny fraction, $1,7.10^{14}$ kW, of the total radiation emitted is intercepted by the earth .However, even with this small fraction it is estimated that 30 min of solar radiation falling on earth is equal to the world energy demand for one year **[KREITH.F ET AL, 1978].**

Basic facts about the sun at the follow table:

Mean distance from earth	149,6 Million km
Length of solar radius	696,000 km
Mass	$1,989.\ 10^{30}$ kg
Volume	$1,412.\ 10^{27}\ m^3$
Density in core	151300 kg/ m^{-3}
Mean density	1409 kg/ m^{-3}
Pressure in core	$2,334.10^{11}$ bar
Surface pressure (photosphere)	0,0001 bar
Surface temperature	5780 K
Luminosity	$3,854.\ 10^{26}$ J/s
Solar “constant“	1367 W/ m^2
Chemical composition	92.1% Hydrogen 7.8% Helium 0.1% other elements
Escape velocity	618 km/s
Energy output	$3,9.10^{23}$ kW

TABLE II.1: *basic facts about the sun* **[KREITH.F ET AL, 1978].**

Structure of the sun was presented in FIGURE II.1 the sun is a seething ball of energy with several distinct layers.

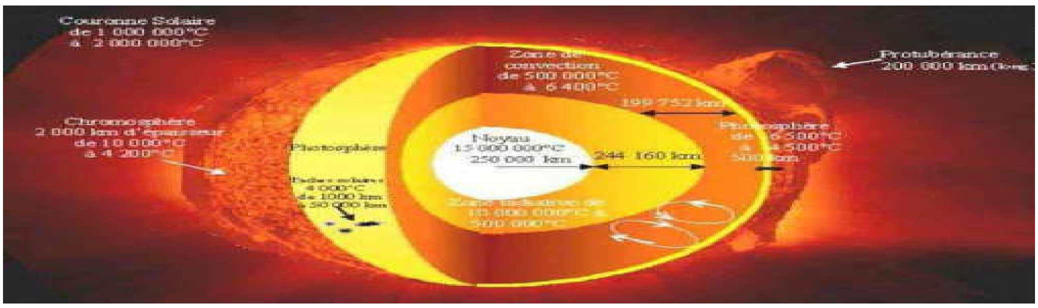

FIGURE II.1: *structure of the sun* **[KREITH.F ET AL, 1978].**

- **Core**: The core produces colossal amounts of energy, including all of the Sun's light and heat , here the temperature and pressure are so great that hydrogen atoms are squeezed together to form helium. This reaction is called nuclear fusion.
- **Radiation zone**: In the radiative zone, energy from the core slowly travels outward. This region is so dense that the Sun's energy takes about 150,000 years to work its way through.
- **Convection zone**: In the convection zone, rising and falling currents carry heat from the radiative zone to the surface. This nonstop churning is similar to what happens when you boil water on a stove.
- **Photosphere**: The photosphere is what our eyes perceive as the visible surface of the Sun. Here, energy escapes from the interior and streams into the Sun's atmosphere and beyond. The photosphere is home to dark sunspots.
- **Sunspots**: Dark blemishes on the Sun's surface. Sunspots are cooler than the area around them.
- **Chromosphere**: The chromosphere is a turbulent layer of the Sun's atmosphere just above the photosphere. It is home to magnificent arcs of gas called prominences and tremendous explosions of energy called solar flares. It gives off most of the ultraviolet (UV) light of the Sun.
- **Flare**: Intense explosions on the Sun that spew enormous amounts of energy into space.
- **Prominence**: Great looping arcs of hot gas that erupt from the Sun.
- **Corona**: The corona is the Sun's extended outer atmosphere. It is the luminous white halo visible in a photo of a total solar eclipse*. Mysteriously, the corona is much hotter than the surface of the Sun, so hot that it also produces a type of light called X-rays [**2**].

II.3 SUN-EARTH GEOMETRIC RELATIONSHIPS

Two major motions of the earth affect the solar radiation received on a surface at any location:

- The rotation of the earth about its polar axis defines a day.
- The orbit of the earth around the sun defines a year (365.25 days).
- The amount of solar radiation received at any location on earth depends on the time of day and year, the local latitude, and the orientation of the surface.
- Also significantly affected by weather conditions.

II.4 EARTH'S ORBIT

- The ecliptic plane is the earth's orbital plane around the sun.

- The equatorial plane is the plane containing the earth's equator and extending outward into space.
- The earth's annual orbit around the sun is slightly elliptical.
- Perihelion is the earth's closest approach to the sun in its orbit, which is about 90 million miles and occurs around January 3.
- Aphelion is the earth's furthest distance to the sun in its orbit, which is about 96 million miles and occurs around July 4.
- One Astronomical Unit (AU) is the average sun-earth distance, which is approximately 93 million miles **[JIM DUNLOP, 2012].**

II.5 EARTH'S POLAR AXIS TILT

The earth's polar rotational axis is tilted at a constant 23.5° angle with respect to the ecliptic plane.

During its annual orbit around the sun, the earth's polar axis is never perpendicular to the ecliptic plane, but it is always inclined to it at the same angle, 23.5°.

This results in a constantly varying angle between the earth's equatorial plane and the ecliptic plane as the earth orbits the sun over a year.

Except at the equinoxes, the earth's axis is tilted either toward or away from the sun, causing the change in seasons **[JIM DUNLOP, 2012].**

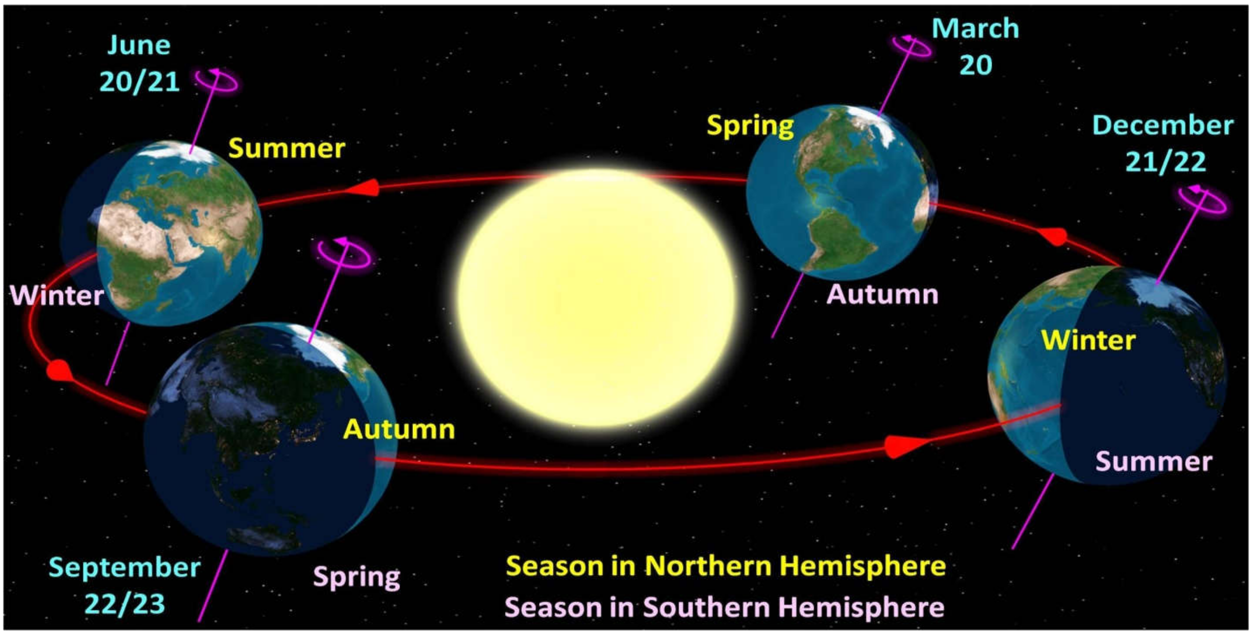

FIGURE II.2: *earth's orbit around the sun* **[JIM DUNLOP, 2012].**

II.6 COORDINATES OF THE SUN RELATIVE TO AN OBSERVER

To determine the coordinates of the sun relative to an observer located on the surface of the earth two coordinates are defined, the equatorial coordinate and the horizontal coordinate.

II.6.1 Equatorial coordinate

The equatorial coordinate system is a coordinate system which originates from the center of the earth and as a reference plane the plane of the equator. In this coordinate system, the position of the sun in the sky is determined by two coordinates, declination (δ) and hour angle (w) **[J. BERNARD, 2004].**

II.7 SOLAR DECLINATION

Solar declination (δ) is the angle between the earth's equatorial plane and the sun's rays varies continuously in a sinusoidal fashion over the year due the earth's nearly circular orbit around the sun.

It varies from –23.5° to +23.5°, and defines the limits of sun position in the sky relative to any point on earth.

$$\delta = 23.45\sin((284 + dn)(\frac{360}{365})j) \qquad \textbf{(II.1)}$$

dn :the number of the day of the year (1st January = 1)

It varies from -23.45 ° at the winter solstice to + 23.45 ° at the summer solstice, and it is zero at equinoxes **[JIM DUNLOP, 2012].**

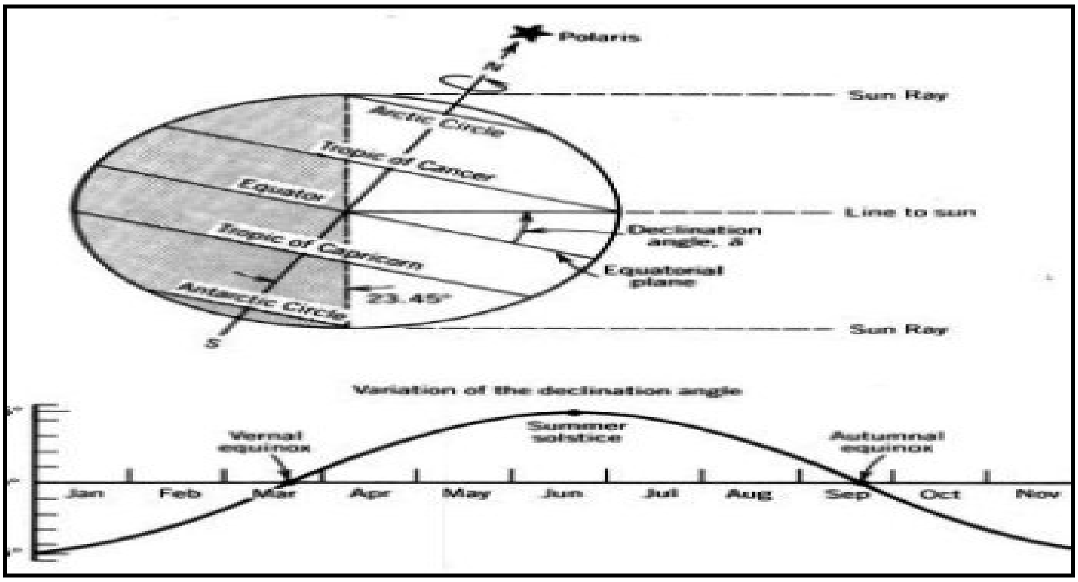

FIGURE II.3: *solar declination angle* **[JIM DUNLOP, 2012].**

II.7.1 Time angle (ω)

Corresponded the angle between projection of the sun on the equatorial plane and the meridian origin of the place considered passing through the south. It is given by the following relation:

$$\omega = 15\,(TSV - 12) \qquad \textbf{(II.2)}$$

II.8 HORIZONTAL COORDINATE

Horizontal coordinate system is a coordinate system which originates from the location of the observer and as a reference plane the plane of the astronomical horizon. In this coordinate system, the position of a star in space can be identified by its coordinates horizontal defined on the celestial sphere FIGURE II .4

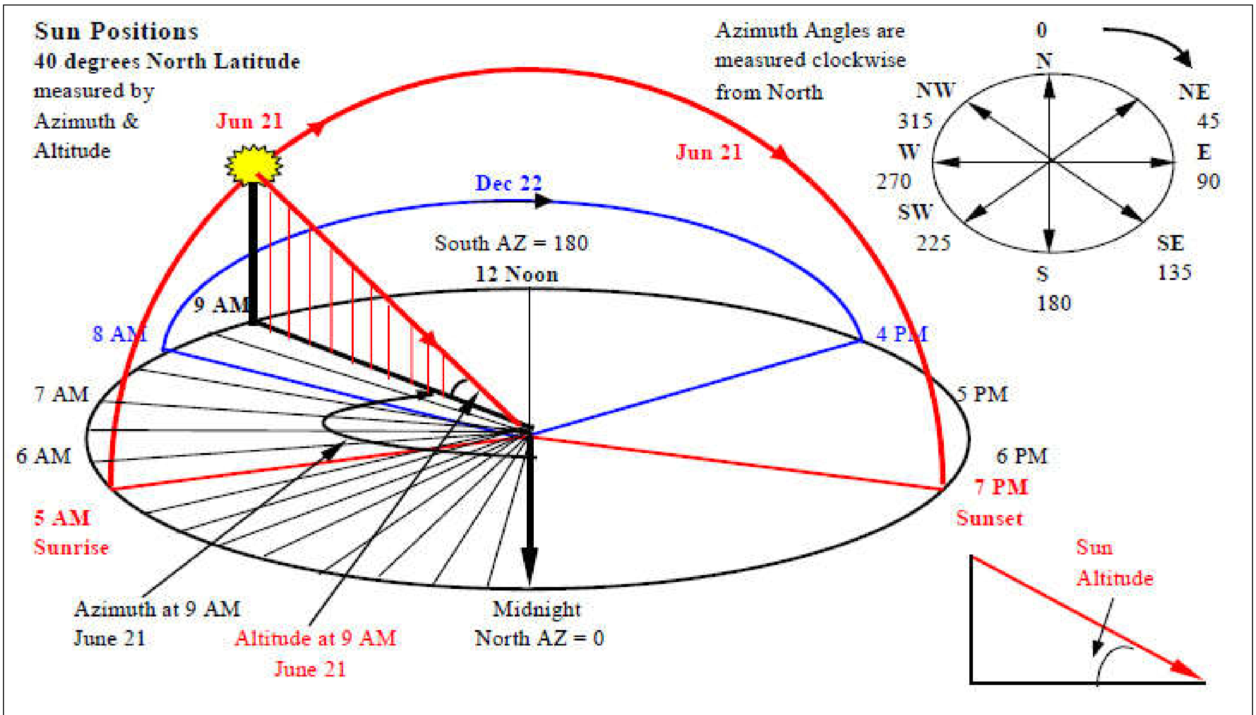

FIGURE II.4: *sun local coordinates*

II .8.1 Height of the sun (h)

It corresponds to the angle formed by the directional vector of the sun and its projection on the horizontal plane, it is 0 ° at sunrise and sunset and it takes its maximum value (90 °) at solar noon. It is evaluated by the following relation **(II.3)**:

$$\sin(h_s) = \cos\delta \cos\omega + \sin\delta \sin\varphi \qquad \textbf{(II.3)}$$

The maximum height of the sun corresponds to ($w = 0$), obtained at noon in solar time true it is evaluated by the following relation

$$h_{s\max} = 90 - (\varphi - \delta) \quad \textbf{(II.4)}$$

It varies according to the latitude of a place and the declination of the sun (the day of the year).

II .8.2 Azimuth of the sun (a)

It corresponds to the angle formed by the projection of the direction of the sun on the plane horizontal and the meridian of the place. It is counted positively towards the east and negatively towards the west. It is given by the following relation **(II.5)**

$$\sin(a) = \frac{\cos(\delta)\sin(\omega)}{\cos(\mathrm{h})} \quad \textbf{(II.5)}$$

II.9 SOLAR TIME

Until the late 19th century most people used local solar time so that noon was when the sun was directly overhead, and each town had its own definition. Transport was slow, so it did not matter that the time in a town miles away varied by a few minutes.

The advent of railways necessitated more accurate time keeping and time zones were introduced to keep an entire region on the same time. Time zones follow political boundaries so that local time may be up to 2 hours different from solar time.

II.9.1 Equation of Time (EoT)

The equation of time (EoT) (in minutes) is an empirical equation that corrects for the eccentricity of the Earth's orbit and the Earth's axial tilt. An approximation 2 accurate to within ½ minute is:

$$\text{EoT}=9.87\sin 2B-7.53\cos B-1.5\sin B \quad \textbf{(II.6)}$$

Where:

$$B = \left(\frac{360}{365}\right)(d - 81) \quad \textbf{(II.7)}$$

II.9.2 Time Correction Factor (TC)

The net Time Correction Factor (in minutes) accounts for the variation of the Local Solar Time (LST) within a given time zone due to the longitude variations within the time zone and also incorporates the EoT above.

TC=4 (longitude ¬ LSTM) + EoT **(II.8)**

The factor of 4 minutes comes from the fact that the Earth rotates 1° every 4 minutes.

II.9.3 Local Solar Time (LST)

The Local Solar Time (LST) can be found by using the previous two corrections to adjust the local time (LT) **[3].**

LST = LT + TC/60 **(II.9)**

II.9.4 Duration of the day

The duration of the day is given by the following relation **(II.10):**

$$d = (TSV)c - (TSV)l = 2 \times \frac{\omega l}{15} \quad \textbf{(II.10)}$$

II.10 CAPTOR ORIENTATION

- The orientation of PV arrays and other solar collectors is defined by two angles with respect to the earth's surface.
- The collector azimuth angle represents the angle between due geographic south and direction the collector faces.
- The collector tilt angle represents the angle the array surface makes with the horizontal plane.
- The solar incidence angle represents the angle between the sun's rays and the normal (perpendicular) to a collector surface **[JIM DUNLOP, 2012].**

II.10.1 Azimuth of the plane (azimuth deviation)(a)

It is defined by the angle made by the projection of the plane normal on the plane horizontal and direction south.

Ideally, the solar devices are oriented due south (a = 0) to be exposed maximum in sunlight.

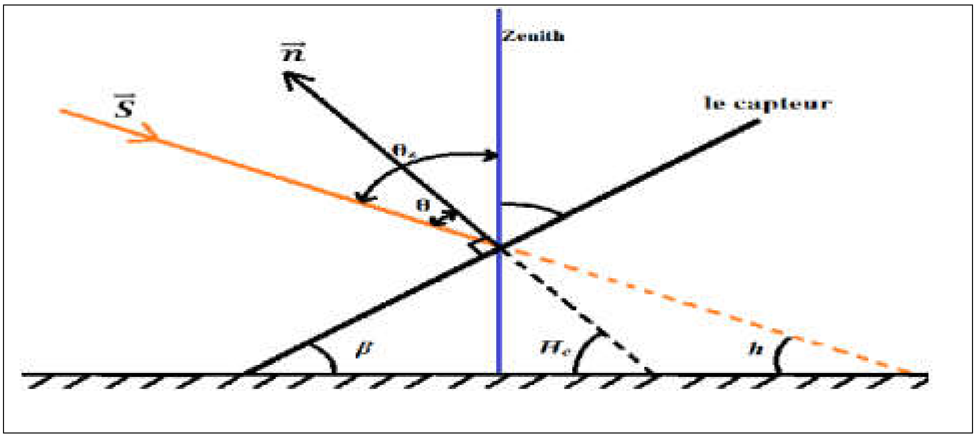

FIGURE II .5: *the angles characterizing an inclined plane captor* **[J. A. Duffie ET AL, 1980].**

II.11 ENERGY ASPECTS OF SOLAR RADIATION

The thermonuclear reactions generated in the heart of the sun producing corpuscular and electromagnetic radiation spreading in all directions of the interstellar vacuum with a speed of 3.108 m /s and encompassing all wavelengths from X-rays and gamma rays to distant IR. Although, 99.9% of the energy is between 0,2 and 8 µm **[J. A. Duffie ET AL, 1980].**

We can admit with an acceptable estimate that the sun shines like a black body with a temperature of 5762 k called the apparent temperature of the sun, which does not correspond to physical reality **[Y. JANNOT, 2011].**

II.11.1 Solar radiation outside the atmosphere

Solar radiation outside the atmosphere is characterized by the solar constant. This last is the power received per unit area perpendicular to the sun's rays in out of the Earth's atmosphere. Its approximate value is equal to 1367 w/m^2 (the value adopted for our study).
Depending on the variations in the distance from the sun (±3.4%), it however, varies slightly over the year. It goes through a maximum in January (around 1423 w/m^2) and a minimum in June (around 1321 w/m^2) **[J. A. Duffie ET AL, 1980].**

Thus, the calculation of the flux of solar radiation I received by a perpendicular surface to the solar rays is ensured by the following relation (II.14):

$$I = I_0.(j) = I_0.[1 + 0.033.COS(\frac{360}{365}.j)] \quad \textbf{(II.14)}$$

were $(j) = 1 + 0.033.COS(\frac{360}{365}.j)$ corresponds to the correction of the solar constant

I_0: The average value of the solar constant currently used (1367 w / m^2)

j: The number of the day of the year (j = 1 for January 1)

II.11.2 Attenuation of solar radiation by the atmosphere

Solar energy is attenuated by different atmospheric components such as air molecules, aerosols, gases, cloudy water droplets or crystals ice suspended in the atmosphere.

Air molecules diffuse radiation (Rayleigh diffusion), and absorb a bet of this radiation, while aerosol particles mainly diffuse the solar radiation through the atmosphere.

The diffusion and absorption properties depend on the chemical compositions of the atmosphere, physical properties of solid particles suspended in the atmosphere and the amount of water vapor in the atmosphere. Steam water, ozone, carbon dioxide and oxygen are the important absorbent gases of solar radiation.

Ozone absorption occurs in the visible and the ultraviolet of the solar spectrum, while most of the absorption band of the water vapor and carbon dioxide occurs in the spectral ranges of the near infrared and red. In addition, oxygen is characterized by small absorption bands in the visible spectrum.

II.11.3 Solar radiation received at ground level

The solar energy represented by the mean solar constant at the input of the atmosphere undergoes an alteration as it passes through the atmosphere, only part of this energy reaches the ground in different forms.

II.11.3.1 Direct component

Direct radiation or the direct component of solar radiation is that incident on any plane from a solid angle around the solar disk. He arrives online straight and on a clear day.

II.11.3.2 Diffuse component

It is the component of the incident solar radiation on a receiving plane after have been released by clouds, dust, aerosols and soil and undergoing multi-reflection phenomenon. It thus comes from all celestial vaults.

II.11.3.3 Global influence

The global radiation corresponds to the sum of the two components of the solar radiation previously defined, namely the direct and diffuse component **[R. BERNARD ET AL, 1983].**

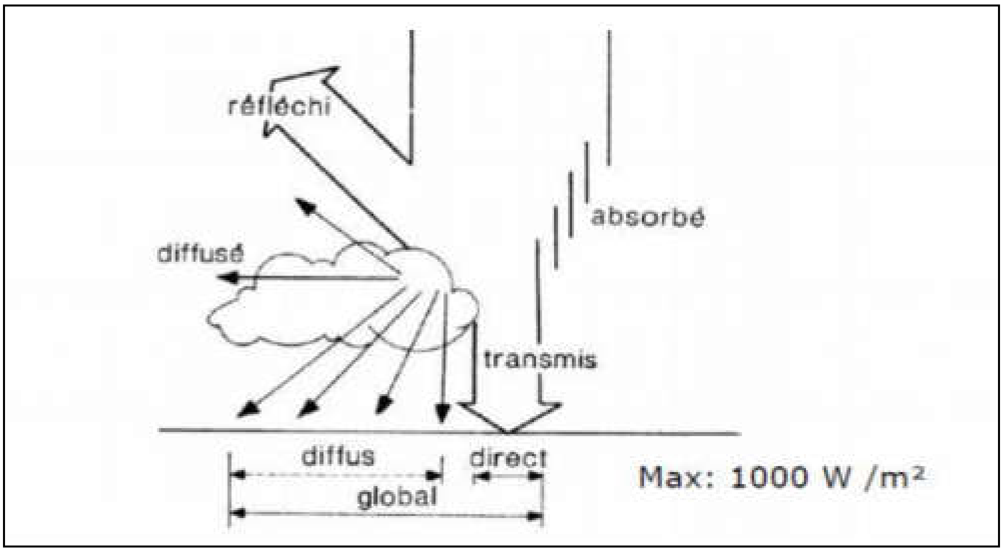

FIGURE II.6: *direct, diffuse and global radiation* **[R. BERNARD ET AL, 1983].**

II.12 CONCLUSION

In this chapter, we have provided a brief description of the sun and its energy, some data necessary for our study in particular the parameters of solar position ,time and description of solar radiation.

CHAPTER III
GENERAL INFORMATION ON SOLAR WATER COLLECTOR

III.1 INTRODUCTION

There are different techniques for capturing part of the solar energy:

- **Photovoltaic solar energy**
  It makes it possible to produce electricity by transforming part of the radiation solar with a photovoltaic cell.

- **Thermodynamic solar energy**
  Thermodynamic solar uses thermal solar to generate electricity on the same principle as a conventional power plant but using power plants thermoelectric helios.

- **Solar thermal energy**
  Solar thermal is a process for transforming solar energy into a form thermal that can be used for indirect use or the heat is used for another use as in thermodynamic solar power plants and solar cooling, or in use direct as in solar water heaters which is our case **[TALAMALI DONIA, 2016].**

III.2 DEFINITION OF SOLAR WATER HEATER

Solar water heater, device that uses solar heat energy to produce hot water, a typical solar water heater consists of a solar collector mounted on the roof of a building and connected to a water-storage tank. Depending on the system, unheated water either can be circulated from the tank through the collector to be heated directly or can be heated by a high-capacity heat-exchange fluid that was warmed in the collector and transfers its heat through tubes in the water in the tank.

While heat transfer from the solar collector to the unheated water can be facilitated passively without mechanical means, “active” solar hot water systems use electricity to circulate the heat-exchange fluid and to operate mechanical pumps and controllers **[SWATI OGALE, 2014].**

III.3 THE DIFFERENT TYPES OF SOLAR WATER HEATERS

There are many models of solar water heaters offered by manufacturers. The type of water heater, the capacity of the tank and the surface of the solar panels, are the three characteristics which vary so much, that the individual who wishes to carry out an installation, can quickly find himself lost, among the diversified offer and the many denominations commercial. To simplify, let's say that there are four main families of solar water heaters:

- ✓ Monoblock water heaters.
- ✓ Thermosyphon water heaters.
- ✓ Forced circulation water heaters.
- ✓ Self-draining water heaters.

III.3.1 Monoblock water heaters

These are water heaters:

- the tank and the solar panel form a single compact unit.
- In general, the balloon is attached to the top of the solar panel.
- In a monobloc system, domestic hot water flows directly through the panels.
- Heated by solar radiation, the water becomes less dense and rises in the balloon.
- There is therefore no need for a pump.
- The disadvantage is that the proximity of the balloon to the panel makes an unattractive whole on the roof.
- In addition it is a water heater reserved for the hot country, as in the overseas countries, or Greece in Europe the simplest.

FIGURE III.1: *Monoblock water heaters* **[4].**

III.3.2 Thermosyphon water heaters

To avoid the drawbacks of the monobloc system, while retaining the advantage of a simple system, the panels can be separated from the hot water tank, as long as the panels remain lower than the storage tank, the water will be able to circulate naturally by the "thermosiphon" effect. The principle of the "thermosiphon" works on the characteristic of heated water, which becomes lighter than cold water, therefore rises to the balloon, replaces the cold water, which, heavier, descends down and passes into the solar panel, the circle is thus closed Here again, the drawback comes from the fact that the liquid is direct sanitary water, therefore sensitive to frost, we cannot therefore use this type of solar water heater in all countries, it is to be reserved for hot countries which do not know the frost.

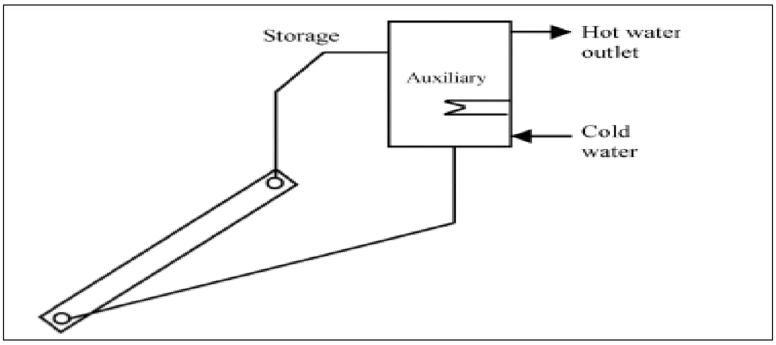

FIGURE III.2: *schematic diagram of a thermosyphon solar water heater* **[4].**

III.3.3 Forced circulation water heaters

The liquid which circulates in the solar panels is a fluid which does not fear freezing (in general glycol water).

It is the same principle as the cooling system of cars, we mix Glycol (an alcohol) antifreeze to lower the point of solidification by cold.

As this liquid, called heat transfer fluid (which transports heat), is unfit for consumption and must not be mixed with domestic hot water, the heat is recovered in the tank through an exchanger.

An exchanger is a coil, inside the tank which isolates the heat transfer fluid from the domestic water.

We are therefore in the presence of two circuits:

- A circuit that heats the fluid in the panels.
- A circuit that transports sanitary water to taps.

The exchange of calories takes place in the balloon, the central tank.

A pump transfers the fluid between the panels and the exchanger. In this system, the position of the balloon relative to the panels does not matter.

FIGURE III.3: *south-roof partially covered by solar collectors* **[4].**

III.3.4 Water heaters Self-draining

This is another alternative to avoid the risk of freezing; it consists of emptying the solar panels during periods of non-use. In this case, the balloon is always located lower than the solar panels, as soon as the sun no longer heats up, the circulation between the panels and the balloon stops and the circuit empties automatically, as soon as the sunshine resumes, traffic starts up again. In this case, domestic water is used directly in the circuit **[4].**

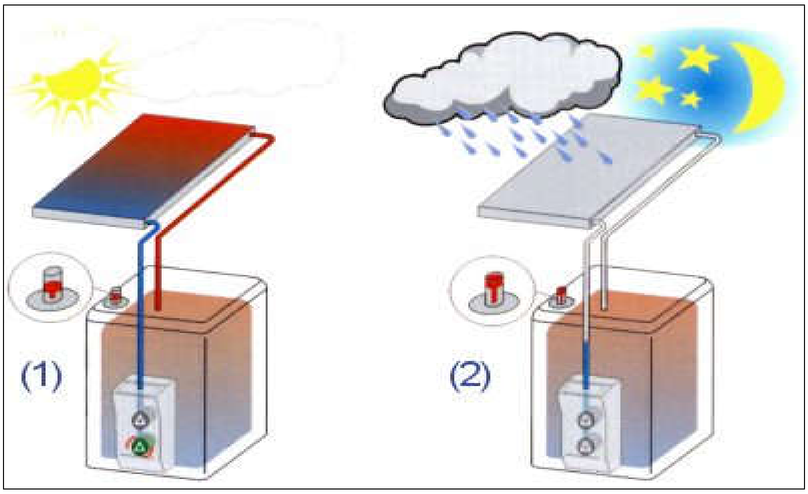

FIGURE III.4: *installation to avoid the risk of freezing* **[4].**

III.4 MAIN COMPONENTS OF A SOLAR HOT WATER SYSTEM

Solar collector panel,mounted on your roof, the collector captures the heat from the sun and transfers it to the liquid circulating through the panel. Sometimes this liquid is water, but it can also be a special type of fluid that eventually transfers the heat to your home's storage tank through a heat exchanger.

- **Storage Tank**. The heater storage tank is your home's current boiler/ hot water heater. The heated water captured by the solar collector panel is stored in the tank for later use.
- **Heat exchanger.** The heat exchanger transfers the heat energy captured by the solar collector panel to the potable water that is stored in the heater tank. In our system, the heat exchanger is external to the solar storage tank.
- **Expansion Tank**. The expansion tank ensures that the system's pressure does not exceed the pressure limits set by the system designer.
- **Control system.** The control system consists of a controller and the circulating pump. The controller compares the temperature difference between the heat exchanger exit point and the solar collector's exit point. When the collector panel's temperature is higher than the heat exchanger's temperature, the controller turns on the pump and circulates the liquid through the system until the temperature equalized, and then turns the pump off **[SOLAR FRED, 2010].**

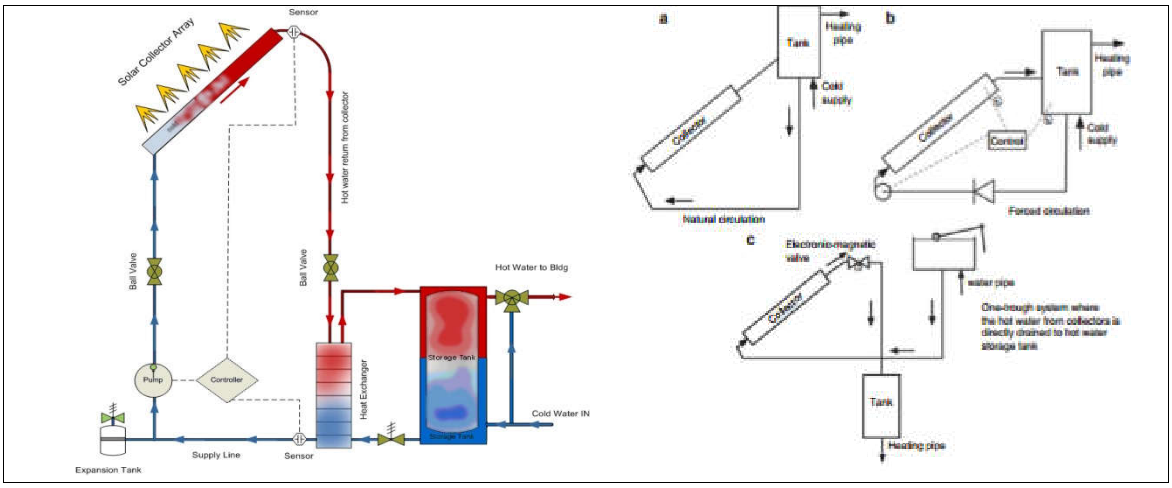

FIGURE III.5: *main components of a solar hot water system* **[SOLAR FRED, 2010].**

III.5 DIFFERENT TYPES OF CAPTORS

The role of the solar collector, also known as the solar panel , is to convert sunlight into heat to power the solar water heater ,for this we use panels crossed by a fluid: either the water directly to be heated (in the case of hot countries without frost), or water added with an antifreeze which will serve as heat transfer liquid to a storage tank, there are three types of solar thermal collectors:

III.5.1 Flat, glazed captor

It is the most widespread model; it consists of an insulated box covered by glazing. Inside is placed the absorber, a coil containing the fluid to be heated, to make the coil better absorb the heat, it is bordered by black fins, the black color transforming the absorbed heat better.
In this type of model, the absorber is protected against heat loss by an insulating material (most of the time, rock wool). The glass is made of very resistant tempered glass (weathering, hail), very transparent (low iron content) and specially designed to present a low level of reflection in order to store maximum heat, if these sensors are the most chosen models, it is because they are:

- Robust and simple in structure.
- Technically sophisticated (glass quality, insulation).
- Easy to integrate thanks to their flat surface.
- Discret on the roof.

The details that will make the difference are to be found in the manufacturing quality of the box (aluminum, stainless steel), the quality and thickness of the insulation around the absorber, the glazing and its anti-reflection treatment, the joints and assembly

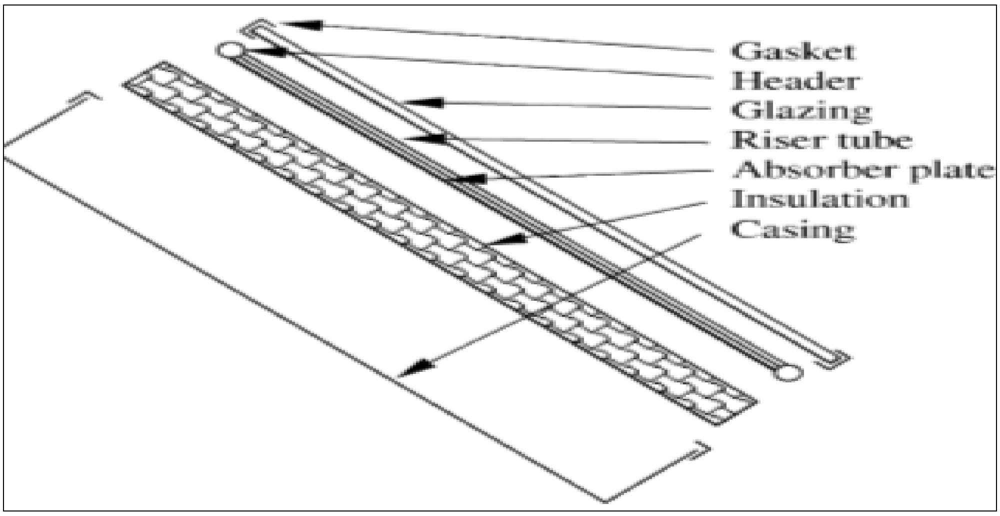

FIGURE III.6: *exploded view of a flat-plate collector* **[5].**

III.5.2 Flat, unglazed captor

Significantly less widespread than the glass sensor, it consists of an absorber without box or glazing, which simplifies manufacturing and manufacturing cost, it is a sensor which on the other hand, is very dependent on the air temperature, efficient in summer, it has a high sensitivity to cold wind in winter due to its lack of glazing. In general, one and a half times more collector area is required to equal the production of flat glass collectors. We finally arrive at a unit price of the equivalent installation with the glass captor.

FIGURE III.7: *a flat-plate solar collector (unglazed)* **[5].**

III.5.3 Vacuum tube collector

It consists of a series of transparent vacuum tubes which isolate the absorber. a vacuum is created in these tubes, as in insulated bottles to reduce heat loss by convection and thermal conduction.

The intensity of the vacuum is of decisive importance for the interruption of the heat transfer mechanism. It can be filled with inert gas, and some with xenon, in order to achieve a significant reduction in the loss coefficient.

This type of sensor reacts with less inertia than conventional sensors.

They heat up more quickly, they make better use of small periods of sunshine, they allow you to better take advantage of the morning and evening sunshine.

As vacuum tube collectors can reach extreme temperatures of over 150 ° C, the heat transfer fluid is specially developed for this type of installation.

The piping of the circuit seeing the fluid pass over 150 ° C, the copper tubes must not be soldered with tin. The losses being reduced compared to those of a flat glass sensor, the efficiency is much higher **[5].**

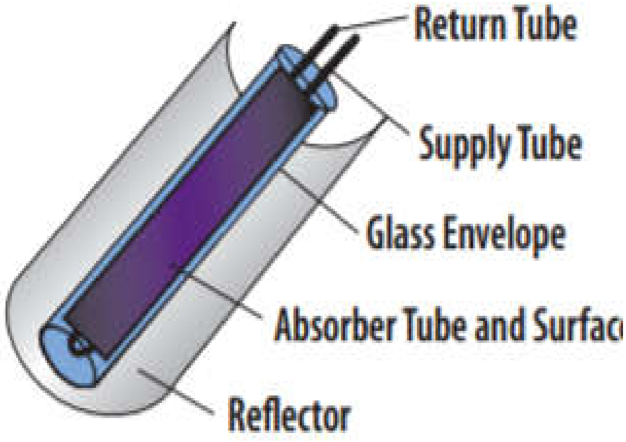

FIGURE III.8: *the components of the vacuum tube collector* **[5].**

III.5.4 Power stations with cylindro-parabolic captors

This type of power plant consists of parallel alignments of long semi-cylindrical mirrors, which rotate around a horizontal axis to follow the course of the sun, the sun's rays are concentrated on a horizontal tube, where a heat transfer fluid circulates which will be used to transport the heat to the power plant itself, the temperature of the fluid can go up to 500 ° C.

This energy is transferred to a water circuit, the vapor then produced activates a turbine which produces electricity.

Some power plants are now able to produce electricity continuously, night and day, thanks to a heat storage system .

III.5.4.1 Benefits

- Inexhaustible and free source of energy
- No polluting emissions
- Can work intermittently

III.5.4.2 Disadvantages

- Requires strong sunlight and a warm area
- Significant floor space **[6].**

FIGURE III.9: *cylindro-parabolic station* **[6].**

III.5.5 CPC captor (Compound Parabolic Concentrator)

It is a flat or vacuum tube captor with a "concentrator reflector parabolic segments. The CPC reflectors have a geometry which allows the direct and diffuse solar radiation reaching the absorber, because the surface of the absorber is cylindrical covering the entire surface of the inner tube. So the part facing the sun can capture direct radiation and the hidden part can capture radiation by reflection.

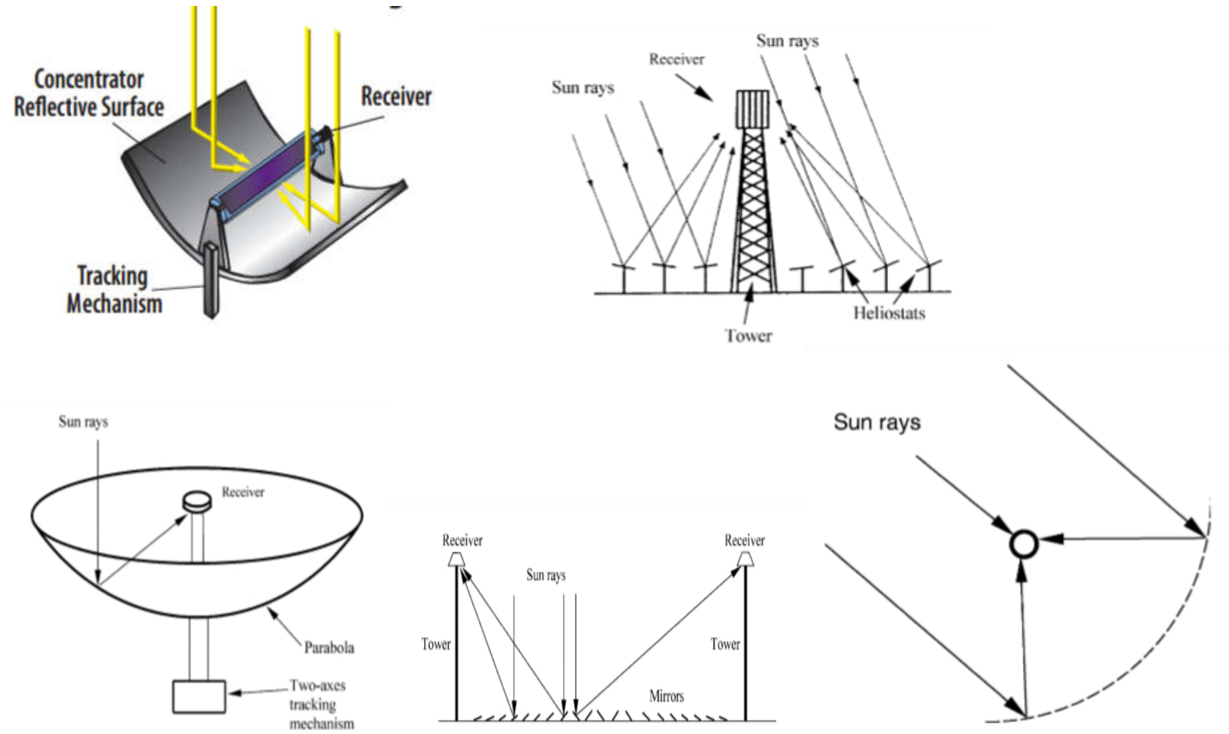

FIGURE III.10: *examples of Compound Parabolic Concentrator types* **[6].**

III.5.6 Carpet captor

It is an unglazed captor consists of a network of black plastic tubes, joined to each other. To heat the water in a swimming pool, the sensors can be inserted into the filtration circuit. They are thus directly traversed by the water returning to the basin .The performance of the carpet captor is very good for producing temperatures close to the ambient air temperature. The few additional degrees brought to the pool water make it possible to extend the comfort and the duration of use by several weeks. The recommended size is 1m2 of collector for 2m2 to 3 m2 of water. Night coverage of the pool also reduces the pool's heat requirements. The carpet sensor does not allow the production of domestic hot water (DHW), except in hot countries. For heating individual or collective summer pools, these sensors represent ideal investments in Rhône Alpes because at low cost, they perfectly meet specific seasonal needs **[7].**

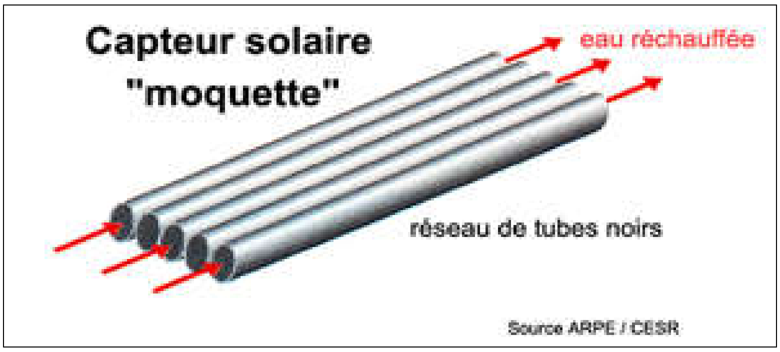

FIGURE III.11: *the carpet captor* **[7].**

III.6 COMPONENTS OF A SOLAR COLLECTOR

Standard solar collectors are made up of the following elements:

III.6.1 Cover

The cover of a solar collector is transparent, may or may not be present. It is usually glass, although plastic is also used because it is cheaper and easier to manage, but it must be a special plastic. Its function is to minimize losses due to convection and radiation and must therefore have the highest possible solar transmittance. The presence of the roof improves the performance of the solar panel. This cover must perform three essential functions:

- Receive the maximum of the incident radiation without reflection or significant diffusion.
- Transmit most of the radiation received.
- Oppose heat loss by convection and radiation.

glass	reflection	absorption	transmission
clear glass	8%	9%	83%
low Fe_2O_3	8%	2%	90%

TABLE III.1: *optical characteristics of some glasses* **[B. AGHILAS, 2016]**

III.6.2 Air channel

It is a space (empty or not) which separates the cover from the absorbent plate. Its thickness will be calculated taking into account the objective of balancing the convection losses and the high temperatures which can occur if it is too narrow.

III.6.3 Absorbent plate

The absorbent plate is the element which absorbs solar energy and transmits it to the liquid which circulates in the pipes. The main characteristic of the plate is that it must have a high solar absorption and a reduced thermal emission. Since common materials do not meet this requirement, combined materials are used to obtain the best absorption / emission.

This absorber must perform three essential functions:

- Absorb most of the incident radiation.
- Transmit the heat produced by this absorption to the heat transfer fluid.
- Accept only the minimum heat exchange to the outside to make this effective part.

matter	Conductivity (w/m °C)	Coefficient of expansion (K^{-1})
aluminum	230	2.38
copper	380	1.65
zinc	112	2.9
steel	52	1.15
Stainless steel	52	1.15
plastic	0.2-0.4	7-20

TABLE III.2: *characteristics of materials used as absorber* **[B. AGHILAS, 2016]**

III.6.4 Heat transfer fluid

is a fluid with the particular capacity to efficiently and durably capture ambient heat . It is therefore used in different systems (motors, solar water heaters, refrigerators, etc.) to transport heat from one point to another, in order to produce a certain effect. For us, its role will be to transport the heat accumulated inside the solar collectors (located on the "panel") to the hot water tank, in order to transmit the heat to the water. Water which will be used for heating by radiators or domestic Hot Water

III.6.4.1 Specifications for heat transfer fluids

- A heat transfer fluid must be stable up to the maximum temperature level during stagnation in the sensor.
- A heat transfer fluid must meet the antifreeze protection conditions if the installation operates under weather conditions including frost.
- A heat transfer fluid must protect the circuit from corrosion.
- The materials of the sensor circuit must be standardized, so that common components and parts can be used with heat transfer fluids meeting standards.
- A heat transfer fluid must meet specific heat and high thermal conductivity standards, allowing efficient transport of heat from the sensor.
- A heat transfer fluid must be non-toxic and have a low impact on the environment.
- A heat transfer fluid must have the lowest viscosity possible to facilitate the task of the circulation pump.
- A heat transfer fluid must be of a reduced price and readily available. **[B. AGHILAS, 2016]**

III.6.5 Tubes or conduits

The tubes touch (sometimes welded) the absorbent plate so that the energy exchange is as great as possible.

For the tubes circulate the liquid which will be heated and will go to the accumulation tank.

III.6.6 Insulating layer

The purpose of the insulating layer is to cover the system in order to avoid and minimize losses. As the insulation is the best possible, the insulating material must have a low thermal conductivity to reduce the thermodynamic transfer of heat to the outside.

The choice of material to be used depends on:

- Its resistance to operating temperatures.
- The permanence of these characteristics over time (thermal conductivity).
- Resistance to impact, humidity, fire, rainwater….etc.**[8]**

insulating	Thermal conductivity at 500(w/m °C)	Temperature (°C)
glass wool	0.041	150
rockwool	0.05	150
polyurethane	0.027	110
polystyrene	0.039	85
Expanded cork	0.042	110

TABLE III.3: *some properties of insulation* **[H. ABDI, 1999]**

III.7 ACTIVE AND PASSIVE SYSTEMS

III.7.1 Active solar hot water systems

Use mechanical pumps and differential controllers to regulate and direct the flow of the heat-transfer fluid or water from the solar collector to the tank. The controllers sense the temperature difference between the water in the tank and the temperature in the solar collector and switch the pump on when the water in the tank cools below the temperature of the collector. Some pumps run on mains electricity and others operate on electricity generated by a solar photovoltaic panel. While some solar-powered systems circulate the fluid only when the sun is shining and store the heated water in well-insulated tanks for nighttime space heating, others use mains electricity as a backup for nighttime and overcast days.

In active solar hot water systems, the water-storage tanks can be located inside the roof space or in any other location that will minimize heat loss to the cold air, as the flow of water does not depend exclusively on gravity. These tanks can therefore be combined with the hot water cylinders in domestic space heating systems, and the solar hot water system can be used to preheat water in the cylinder in winter for space heating **[SWATI OGALE, 2014].**

III.7.2 Passive solar hot water systems

Which rely on gravity rather than electricity, are most efficient in hot climates where night or wintertime freezing is not present, some passive systems use a thermosyphon configuration that uses gravity and convective heat flows .Cold water from a height flows down by gravity to the solar collector and as the water passes through the collector and heats up, it rises through convection to reach the storage tank again, another type of passive system is the integrated collector storage system, in which the collector forms the top of the water-storage tank and heats the water directly in the tank **[SWATI OGALE, 2014].**

III.8 PARAMETERS INFLUENCING THE OPERATION OF A SOLAR COLLECTOR

The thermal efficiency of the solar collector strongly depends on the material, the shape, dimensions, arrangement of the sensor and surrounding conditions. All these factors can be classified into two main categories:

III.8.1 Internal parameters

- **The glass:** Most of the covered solar collectors used are single, double or triple coverage. Many shippers have shown that the triple cover gives greater performance than that with double glass thanks to the minimization of losses to the outside.
- **The absorber:** The increased collector area increases the rate of solar radiation intercepted and the contact surface between the absorber and the heat transfer fluid (increase in the exchange surface), but also it increases the coefficient of heat losses between the cover and outside.
- **Pipes shape and diameters:** Another factor also influences the effectiveness of the sensor, that is, the piping, which is usually welded to the bottom of the absorber and sometimes part of the absorber, its shape differs from one sensor to another.
- **Isolation:** The main heat losses of the sensor are from the roof, since the sides and the back can be isolated, while the front must be exposed to sunlight and room temperature. This is why air is used frequently as insulation against conductive and convective heat losses from the absorber to the glass.

- **The inclination of collector:** Corresponds to the angle made by the plane of collector with the horizontal. The angle calculation of inclination is done by deducting the declination of the sun from the geographical latitude of the place the location of collector. In general, it corresponds to the latitude of the location plus or less 10 to 15°. It is recommended to use a higher tilt angle at the latitude 10 to 15 degrees during the winter months when the suns path is low in the sky (winter position). On the other hand, in summer (summer position), when the trajectory the sun is higher in the sky, use a lower angle of inclination latitude minus 10 degree.
  For an annual capture, the angle of inclination of collector is fixed to the latitude of the place.

III.8.2 External parameters

- **Obstacles:** These are above all buildings and vegetation, their position in the solar trajectory can create shadow harmful to good operation of the installation**.**
- **Solar radiation**: The efficiency of the solar collector is influenced considerably by solar radiation, and the rise in temperature varies almost linearly with incident solar radiation.
- **Temperature:** The temperature of the environment strongly influences the operation of the collector solar, the experimental studies have shown that collector can be damaged by frost overnight**.**
- **Wind speed:** The wind speed appears in the convection coefficient between the glass and the exterior which acts on the value of the losses this is why knowledge of meteorological data is important. When the heat transfer coefficient due to the wind is at its maximum (for a length of 1 m of black absorber installed horizontally) the maximum reduction in efficiency is found at the lowest level **[SANDALI MESSAOUD, 2014].**

III.9 CONCLUSION

We retain from this chapter that to obtain a better production with a best performance of a solar installation it is important to choose the right components (type of sensors types of stratification in the storage tank, quality heat transfer fluid and their dimensions. Their performance depends essentially of the solar energy capture capacity by the collector and the transmit to the heat transfer fluid.

CHAPTER IV

MATHEMATICAL MODELING

IV.1 INTRODUCTION

In this chapter we present the main classical methods of numerical analysis. There are four main methods for formulate a continuous problem in discrete form, the finite difference method, elements finite, finite volumes and the spectral method and we present the equations that govern the phenomenon in laminar regime inside a flat solar collector between the absorber and the insulator.

IV.2 REMINDERS ON HEAT TRANSFER

Thermodynamics can predict the total amount of energy that a system must interact with the outside to move from one state of equilibrium to another. The thermal proposes to describe quantitatively (in space and time) the evolution of the characteristic quantities of the system, in particular the temperature, between the state of initial equilibrium and the final state. The heat flows under the influence of a temperature gradient by conduction of high temperatures to low temperatures. The amount of heat transmitted per unit of time and per unit area of the isothermal surface is called the heat flux density.

IV.2.1 Conduction

It is the transfer of heat within an opaque medium, without displacement of matter, under the influence of a temperature difference. The propagation of heat by conduction inside a body occurs according to two distinct mechanisms **µ** transmission by vibrations of atoms or molecules and transmission by free electrons. The conduction theory is based on the Fourier hypothesis µ the flux density is proportional to the temperature gradient:

$$\overrightarrow{\Phi_{cd}} = -\lambda . S . \overrightarrow{grad\left(T\right)} \qquad \textbf{(IV.1)}$$

$$\Phi_{cd} = -\lambda . S . \frac{\partial T}{\partial X} \qquad \textbf{(IV.2)}$$

were:

Φ_{cd} : The heat flow by conduction (W).

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

λ= Thermal conductivity (W / m. ° C).

X: Space variable in the direction of flow (m).

IV.2.2 Convection

In this case the heat transfer takes place from a liquid or gaseous fluid to a body solid (for example between water and a wall). The particles are found in motion between they. There are two types of convection:

IV.2.2.1 Free or natural convection

The movement of the fluid is caused by variations in density caused by temperature variations within the fluid, such is the case with thermo-circulation.

IV.2.2.2 Forced convection

The movement of the fluid is induced by a cause independent of the differences in temperature (pump, ventilation, etc.).

It is the transfer of heat between a solid and a fluid, the energy being transmitted by fluid displacement.

This transfer mechanism is governed by Newton's law:

$$\Phi_{cv} = h_{cv}.S.\left(T_P - T_f\right) \qquad \textbf{(IV.3)}$$

were:

Φ_{cv} : The heat flow by convection (W).

S: The heat transmitting surface (m^2).

T_P : The solid surface temperature (° C).

T_f : The temperature of the fluid before its contact with the solid (° C).

h_{cv} : The coefficient of thermal transmission by convection (W /° C).

IV.2.3 Radiation

Radiant heat transfer occurs when energy in the form of waves electromagnetic waves are emitted by one surface and absorbed by another. This exchange can take place when bodies are separated by vacuum or any intermediate medium sufficiently transparent to electromagnetic waves.

The fundamental law of radiation is that of Stefan-Boltzmann:

$$\Phi_r = \varepsilon.\sigma.s.\left(T_P^{\,4} - T_\infty\right) \quad \textbf{(IV.4)}$$

Φ_r : Density of heat flow emitted by the body.

ε: Thermal emissivity of the material.

S: Area of the surface (m^2).

σ : Evaluated Stefan-Boltzmann constant $5,6704.10^{-8}\ W.m^{-2}.K^{-4}$

T_P : Surface temperature (K)

T_∞ : Temperature of the environment surrounding the surface **[TALAMALI DONIA, 2016].**

IV.3 DESCRIPTIZATION METHOD

The transition from a continuous partial differential problem to a discrete problem is based on the classical methods of numerical analysis. There are three main methods for formulating a continuous problem in discrete form, the method of finite differences, finite elements and finished volumes.

IV.3.1 Finite difference

The finite difference method presents a technique for solving the equations with partial derivatives, by the approximation of derivatives by finite differences. This method consists of subdividing the study area into a determined number of nodes and representing the function sought in each of the nodes of the domain by a limited development in series of Taylor. Thus, the differential equation is transformed into an algebraic equation for each node. Solving the system of algebraic equations makes it possible to obtain the distribution of the function studied in the field of study. The finite difference method does not take into account the passage conditions from one physical environment to another and nonlinearities, this requires specific treatment. On the other hand, it adapts poorly to objects of complex geometry due to the rigidity of the mesh.

This is the oldest method; the fundamental principle of this method is the field of study a mesh in nodes whose smoothness makes it possible to give an approximation of contours of the domain. Then, by applying the development in each node of the mesh, which makes it possible to obtain a number of algebraic equations equal to the number of values unknowns of the sizes studied.

IV.3.2 Finished elements

The fundamental principle of the finite element method lies in the division of the domain of study in elementary domains of finite dimension. On each of these areas, called elements finite, the unknown function is approached by a polynomial whose degree can vary from application to the other but generally remains weak. These elements, triangles or quadrilaterals, straight or curvilinear, must perform a partition of the field of study (they are disjoint and their union covers the field whole). This partition which is generally called division or discretization of the domain must to respect a certain number of rules which make it possible to ensure a good progress of calculation **[BENELMOUAZ Mohamed Amine, 2018].**

This method consists of transforming the differential equations into integral forms based on the concept of minimizing a quantity (such as energy ...), leading to the exact solution. In other words, it is about finding a global function representing the mathematical model in the field studied.

The fundamental principle of the finite element method consists of:

- Define a partition of the field of study, i.e. subdivided the field of study into elementary regions (Finite Elements).
- Represent the unknown function on each of these elements by an approximation polynomial.
- Construct integral forms.
- Minimize the integral.
- A matrix organization of calculations.
- A resolution of the algebraic system.

FEM is a very powerful method for solving differential equations partial especially in complex geometries. Its implementation, on the other hand, is quite complicated and requires a fairly large memory space**.**

IV.3.3 Finished volumes

The finite volume method consists in discretizing the flow domain into a multitude of control volumes (cells) and then to carry out assessments (of mass, energy, amount of movement ...) on these small volumes. For this reason, the formulation makes appear volume integrations. The advantage of this method is that everything that comes out of a volume, fits into another, this method is therefore conservative, Several methods of discretization of differential partial differential equations are currently used such as: the finite volume method, finite differences and Finished elements. The method used by "Fluent" is that of finished volumes.

IV.3.3.1 Principle of finite volume method

Analytical methods seem to be incapable of solving the equations of the conservation. So the use of numerical methods such as the difference method finished, finished volumes and finite elements is essential. The volume method finite (M.V.F) is the most commonly used for solving conservation equations. It consists in transforming partial differential equations into algebraic equations easy to solve. For this, four steps are required:

Make a mesh of the study area: a mesh is a succession of volume of the control linked together with nodes placed in the center of each volume.2. Integrate the partial differential equations on each control volume.3. Choice of the scheme used: choose the variation profile of 5 between two adjacent nodes for its evaluation at the interface.4. Establish "n" algebraic equations to solve for "n" nodes.5. Use one of the methods for solving nominally linear algebraic equations to solve the equation system.

The two-dimensional formulation consists in subdividing the field of study (Ω) into a number finite elements. Each element contains four nodes. A finished volume surrounds each node **[SLIMANE Sihem, 2019].**

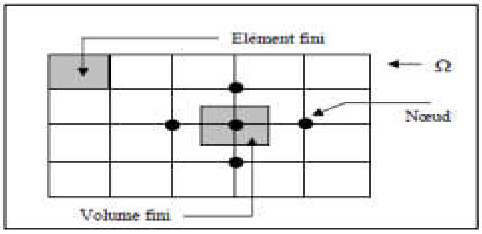

FIGURE IV.1: *Discretization in finite volumes of the field of study in the case two-dimensional* **[SLIMANE Sihem, 2019].**

IV.3.4 Spectral methods

The unknown is approached by truncated Fourier series or by series of polynomials Chebyshev. To compared the finite difference and finite element methods. The approximation is not local but it is valid on all the field of computation. We use also the concept of the weighted residual as in the finite element method where by imposing that the approximation must correspond to the exact solution for the points of the mesh **[BENELMOUAZ Mohamed Amine, 2018].**

IV.3.5 Nodal Method

Modeling is based on the use of the nodal method, the approach consists in cutting the system into a certain number of elementary volumes assumed to be isothermal. The exchanges of flows between the nodes of the discrete systems are carried out through components represented by thermal connections: thermal conductance, heat sources and temperature imposed.

IV.4 REYNOLDS NUMBER

The Reynolds number noted Re, represents the report between the effects of inertia and the effects viscous. It defines the laminar, transient or turbulent nature of a flow.

$$\mathrm{Re} = \frac{VL_c}{\upsilon} = \frac{\rho V L_c}{\mu} \qquad \textbf{(IV.5)}$$

• Laminaire Re< 2000

• Transitoire 2000 <Re< 3000

• Turbulent Re> 3000

Laminar regime

- Flow whose fluid streams do not intersect.
- No mixing but viscous interaction between the fluid threads.
- While hovering, the current lines merge with the trajectory.

Turbulent regime

- The flow becomes unstable.
- There is a mixture of fluid streams even in generally stationary flow.
- The notion of current line no longer has any meaning except "in time average"

Transitional regime

The regime transition depends on the Reynolds number.

Therefore depends on:

- viscosity of the fluid μ.
- velocity of the flow V.
- A characteristic length L.

IV.5 TRANSFER EQUATIONS AND SIMPLIFYING HYPOTHESES

- The fluid is incompressible and Newtonian of constant viscosity
- The flow is two-dimensional (*x* ,*y*), stationnary.
- The input of internal energy due to viscous dissipation is negligible.

IV.6 GOVERNING EQUATIONS FOR FLUID CASE

If we note any general variable measured by the symbol (ϕ), the equation general differential is written:

$$\frac{\partial}{\partial t}(\rho \phi) + div(\rho V \phi) = div\left(\Gamma_{\phi}\, grad\vec{d}\, \phi\right) + S_{\phi} \quad \textbf{(IV.6)}$$

We can consider that the following equations describe the phenomenon inside the flat solar collector

IV.6.1 Continuity Equation

The law of conservation of momentum translated by Navier Stokes equations simply expresses the fundamental law of dynamics to a Newtonian fluid:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad \textbf{(IV.7)}$$

IV.6.1.1 Continuity Equation Of Movement For X

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + v\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) \quad \textbf{(IV.8)}$$

IV.6.1.2 Continuity Equation Of Movement For Y

$$u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + v\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) \quad \textbf{(IV.9)}$$

IV.6.2 Energy Equation

The energy conservation equation is obtained from the first principle of thermodynamics which relates the different forms of energy. The conservation equation of energy is written:

$$\rho C_p\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = \lambda\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) + S_g \quad \textbf{(IV.10)}$$

a: is the thermal diffusivity which is equal to: $\frac{\lambda}{\rho C_p}$

were:

Cp: Mass heat of the fluid.

λ: Thermal conduction.

ρ: The density.

a- Case of a solid

We assume that: u = v = 0

• Energy equation:

$$\lambda_s \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) = 0 \quad \textbf{(IV.11)}$$

λ_s : The thermal conductivity of the solid.

IV.7 CONDITIONS TO THE LIMITS

The boundary conditions for the set of governing equations are presented below:

a- Entrance: x = 0

For water as heat transfer fluid {eis< y < H +eis}

$$\begin{cases} Qm = 10kg / h \\ T = T \ entrance = 300K \end{cases}$$

For isolator { y <eis}

$$\begin{cases} u = v = 0 \\ \dfrac{\partial T}{\partial x} = 0 \end{cases} \quad \textbf{(IV.12)}$$

b- Outlet- x = L

For water:

$$\frac{\partial u}{\partial x} = \frac{\partial u}{\partial y} = 0 \quad \textbf{(IV.13)}$$

For the isolator

u=v=0

$$\frac{\partial T}{\partial x} = 0 \tag{IV.14}$$

c- Absorbent wall:

$$\lambda_{abs} \left. \frac{\partial T}{\partial y} \right|_{y=yl} = 714 \, {}^{w}\!/_{m^2} \tag{IV.15}$$

IV.8 CONCLUSION

We have devoted this chapter to the presentation of the heat transfer modes and the equations which govern the phenomenon in laminair regime then we have presented the various methods of descritisation (finite volumes, finite element ...ect).

CHAPTER V

RESULTS AND DISCUSSION

V.1 INTRODUCTION

In this chapter, we present the calculation codes (solidwork, ansys) and the results of numerical simulation of a water flow through a 2D flat solar water collector with transverse baffles with different absorber materials.

V.2 GEOMETRY OF FLAT WATER SOLAR

The geometry of the problem is presented on FIGURE V.1. It is a crossed rectangular conduit by an air flow provided with baffles of rectangular shape. As shown in the following diagram:

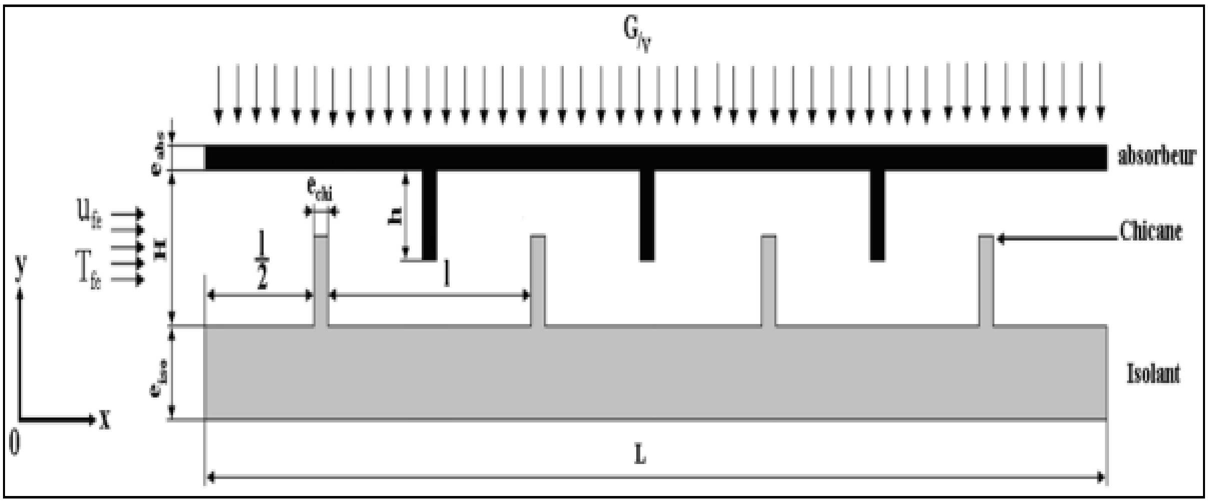

FIGURE V.1: *Problem geometry*

The geometric dimensions of the problem studied are based on the data published by **[YOUCEF ET AL, 2016]**

Length of solar collector	L=0.9 m
The thickness of the absorber	e abs =0.0015m
Thickness of the insulation	e iso =0.055m.
The thickness and height of the baffles	h =0.02m
The spacing between baffles	l =0.24m
The distance between the absorber and the isolator	H=0.055m

TABLE V.1: *Geometric dimensions of the solar collector* **[YOUCEF ET AL, 2016]**

materials	$\rho[kg / m3]$	$Cp[J / kg.K]$	$\lambda[W / m.K]$
Copper(absorber)	8978	381	387.6
aluminum(absorber)	2719	871	202.4
Silver (absorber)	1500	0.24	429
Polysterene(isolator)	12	1300	0.047
Water (fluid)	998.2	4182	0.6

TABLE V.2: *Thermophysical properties of the absorber,fluid and insulator used in simulation*

Reynolds number

We have **Dh = 0.1042 m**

By equation **(IV.5)**

Re = 5.97 <2000 So laminar regime

V.3 PRESENTATION OF CALCULATION CODE

There are a certain number of industrial codes, with efficient mesh workers, allowing the fluid flow prediction (ANSYS, FLUENT, CFX, PHOENICS, STAR-CD, TRIO, FEMLAB, CFD-ACE, FLOTRAN, N3S, CFDS-FLOW3D).

V.3.1 definition of solid works

SolidWorks is computer-aided design (CAD) software owned by Dassault Systèmes. It uses the principle of parametric design and generates three kinds of interconnected files: the part, the assembly, and the drawing. Therefore, any modification to one of these three fileswill be reflected in the other two. **[9].**

V.3.2 Ansys workbench

Is a project-management tool, it can be considered as the top-level interface linking all our software tools.

• Workbench handles the passing of data between ANSYS Geometry / Mesh / Solver / Post processing tools.

• This greatly helps project management. You do not need worry about the individual files on disk (geometry, mesh etc). Graphically, you can see at-a-glance how a project has been built. Because Workbench can manage the individual applications AND pass data between them, it is easy to automatically perform design studies (parametric analyses) for design optimization .

V.3.2.1 Ansys Workbench Overview

- **Analysis Systems:** are ready-made stencils that include all the individual systems (applications) needed for common analyses (for example Geometry + Mesh + Solver + Post-Processor)
- **Component Systems:** are the individual building-blocks for each stage of the analysis
- **Design Exploration**: provides tools for optimizing designs and understanding the parametric response.

V.3.3 Ansys Fluid Flow (Fluent)

This tutorial illustrates using ANSYS Fluent fluid flow systems in ANSYS Workbench to set up and solve a three or tow dimensional (turbulent, laminar) fluid-flow and heat-transfer problem in a mixing elbow. It is designed to introduce you to the ANSYS Workbench tool set using a simple geometry. Guided by the steps that follow, you will create the elbow geometry and the corresponding computational mesh using the geometry and meshing tools within ANSYS Workbench. You will use ANSYS Fluent to set up and solve the CFD problem, then visualize the results in both ANSYS Fluent and in the CFD-Post post processing tool. Some capabilities of ANSYS Workbench (for example, duplicating fluid flow systems, connecting systems, and comparing multiple data sets) are also examined in this tutorial. This tutorial demonstrates how to do the following:

• Launch ANSYS Workbench.

• Create a Fluent fluid flow analysis system in ANSYS Workbench.

• Create the elbow geometry using ANSYS Design Modeler.

• Create the computational mesh for the geometry using ANSYS Meshing.

• Set up the CFD simulation in ANSYS Fluent, which includes:

– Setting material properties and boundary conditions for a turbulent forced-convection problem.

– Initiating the calculation with residual plotting.

– Calculating a solution using the pressure-based solver.

– Examining the flow and temperature fields using ANSYS Fluent and CFD-Post.

• Create a copy of the original Fluent fluid flow analysis system in ANSYS Workbench.

• Change the geometry in ANSYS Design Modeler, using the duplicated system.

• Regenerate the computational mesh.

• Recalculate a solution in ANSYS Fluent **[10].**

V.3.3.1 Mesh geometry

Our geometry is built on solidwork in 2D,we must generate a computational mesh throughout the flow volume. For this section , w'll use the ANSYS Meshing application to create a mesh for CFD analysis, then review the list of files generated by ANSYS Workbench

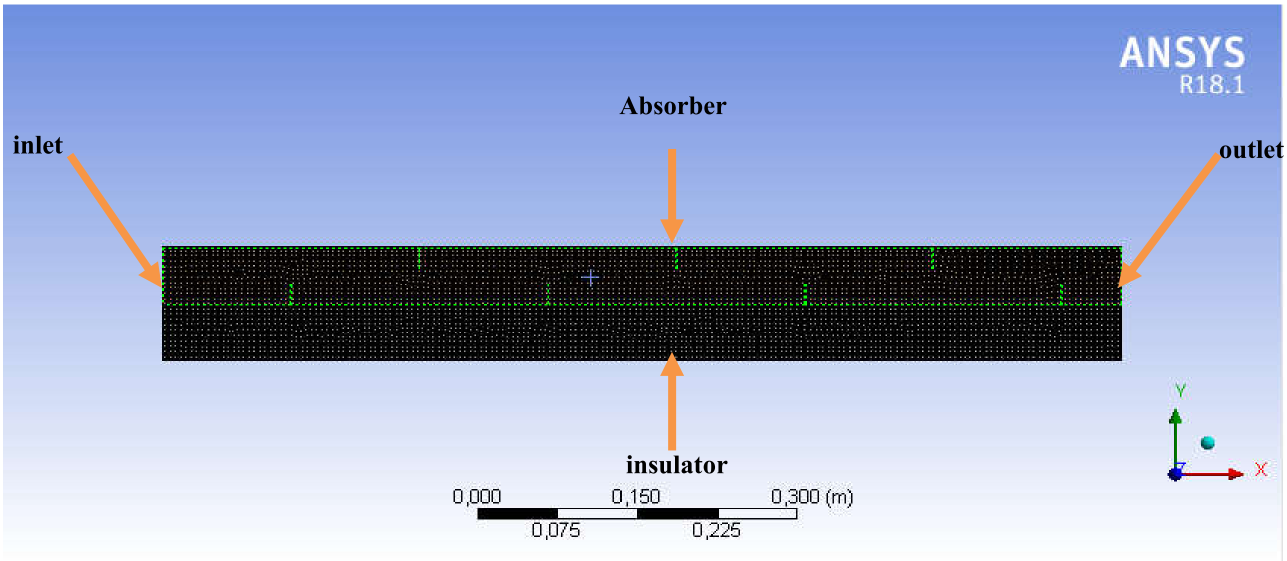

FIGURE V.2: *Meshing the Geometry*

a) Bondary condition

The solar water collector studied as explained in the figureV.2 is composed of three zones according to their materials, for this reason we group them all under three sides:

- Inlet :mass flow
- Absorber : copper,aluminum,silver
- insulator :polysterene
- outlet:pressure outlet

b) Mesh Quality

Mesh quality	Maximal	Minimal	Average	Standard deviation
Orthogonality	1	0.71228	0.99799	1.7241e-02
Aspect ratio	2.0953	1	1.0299	6.9388 e-02
Skweness	0.49563	1.3057 e-10	1.41131e-02	3.9617e-02

TABLE V.3: *Mesh quality*

c) The Convergence

Convergence is reached for 1347 iterations. Fig.V.3 shows the convergence of the solution. The accuracy of the convergence is much better (10e-6).

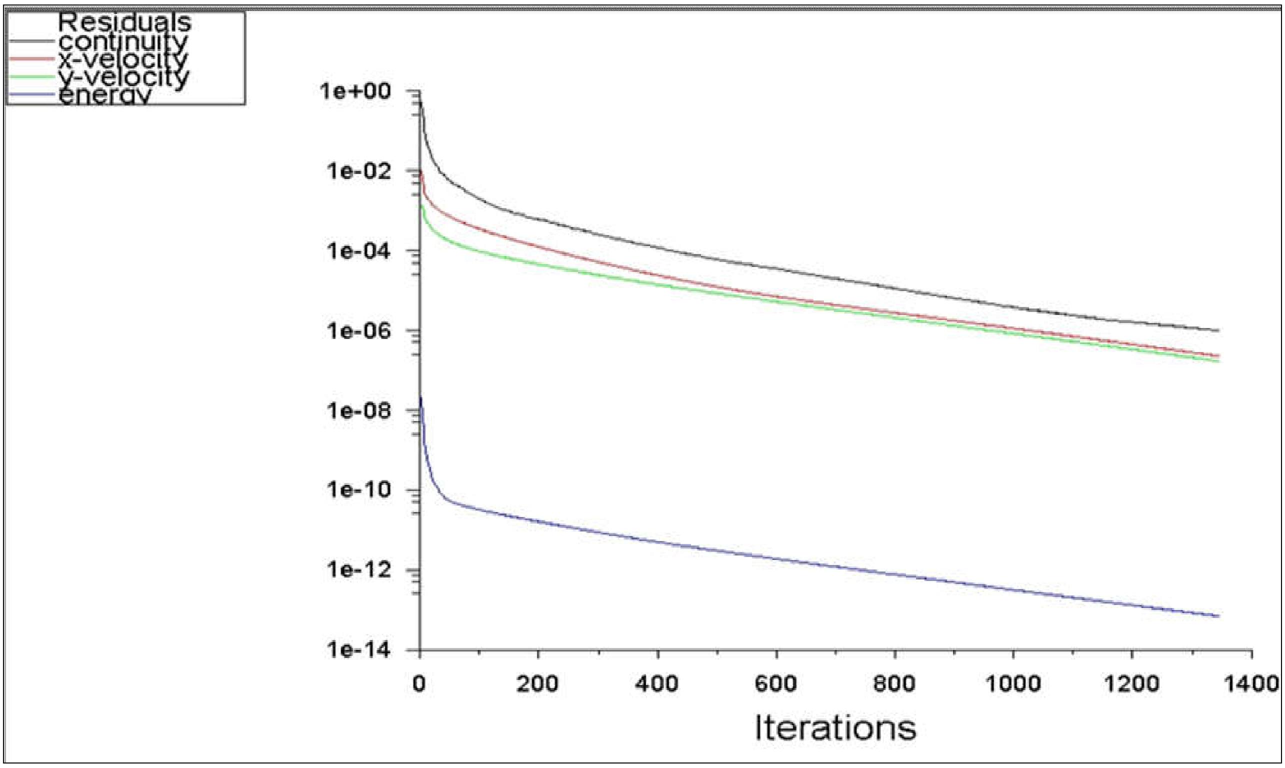

FIGURE V.3: *The convergence of the solution*

V.4 VALIDATION

From this curve (FIGURE V.4), we see that the temperature increase, as we can observe that there is a small divergence between numerical result and those found by **[YOUCEF ET AL, 2016]**, this difference may be due to the hypotheses for calculation.

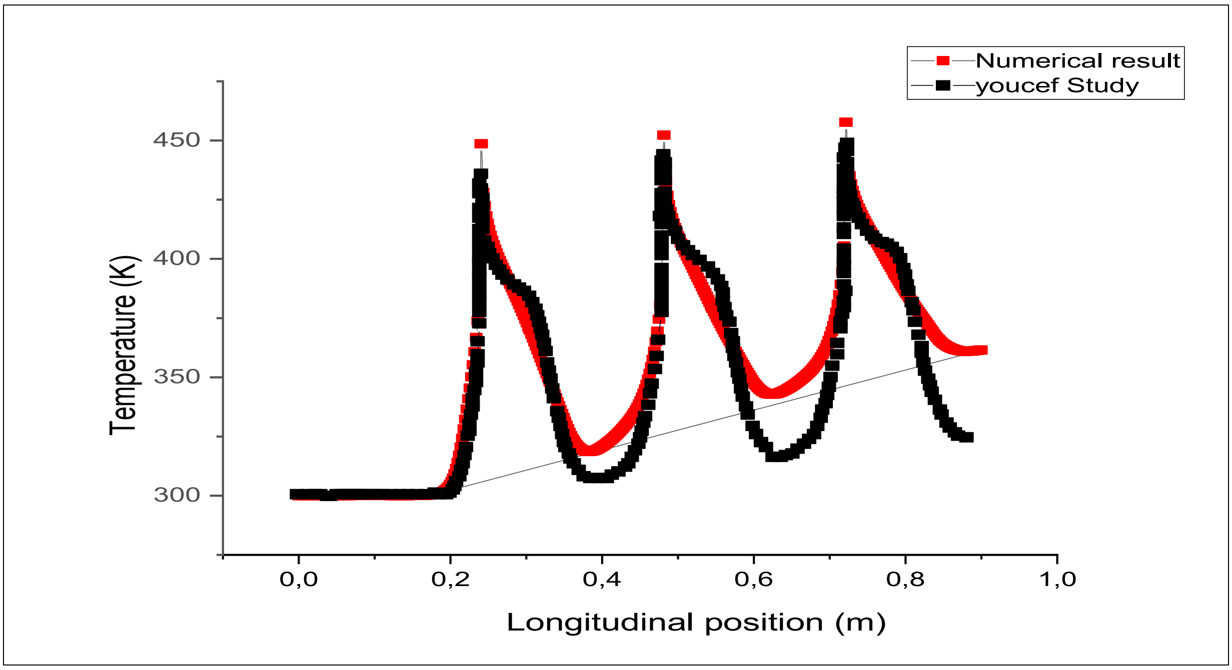

FIGURE V.4: *Comparison of the variation fluid temperature between numerical result and YOUCEF study*

V.5 OBJECT STUDY

The objective of this study is to optimize a solar water collector using different materials to absorb the maximum possible solar radiation at the lowest cost.

V.5.1 Thermal flow study

V.5.1.1 Changing the heat transfer fluid

The first step in this work is to maintain the same working conditions as mentioned in reference while changing the heat transfer fluid from air to water.

The following parameters are choose:

Absorber:copper

Fluid: Water

Mass flow:30 kg/h

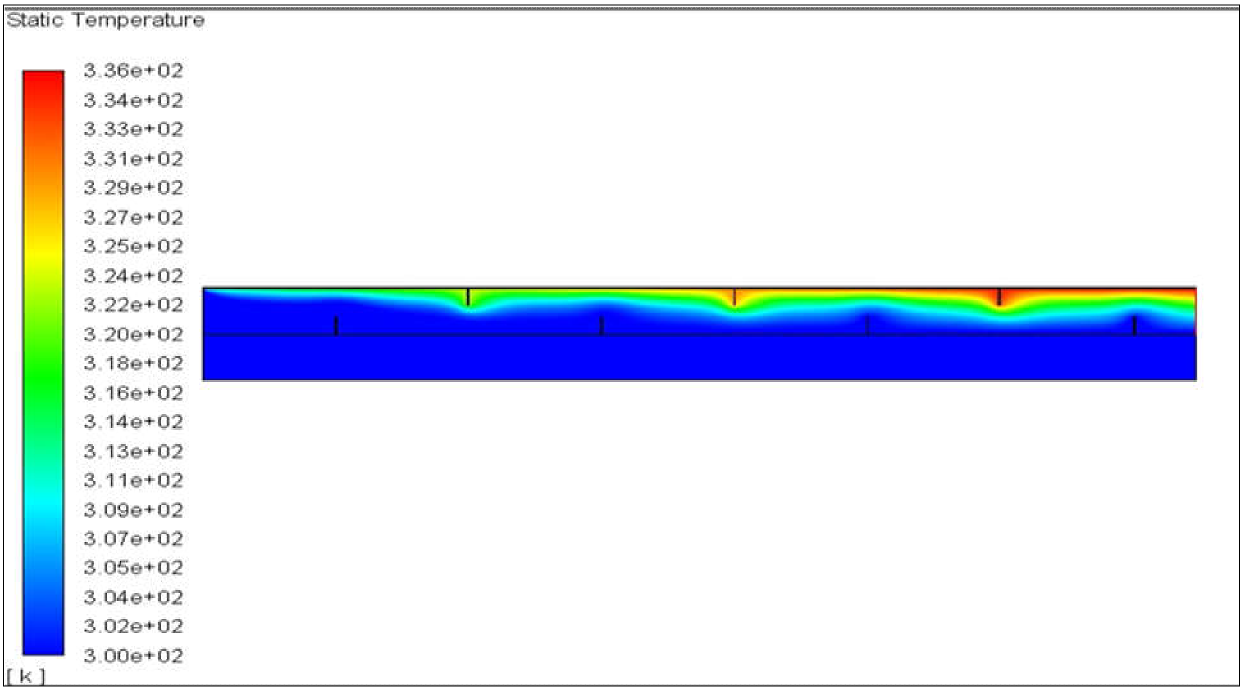

FIGURE V.5: *Contour of static temperature (K), (copper, qm=30kg/h)*

The results of figure V.5 shows the contour of the temperature variation in the solar water collector equipped with transverse baffles and water as heat transfer fluid. We notice the temperature starts at ambient value then increases especially in the region close to the absorber until reaching a maximum value of 336K.

V.5.1.2 Changing in mass flow

In order to maximize the contact time between the fluid and the absorber, the mass flow rate has been reduced to a value which allows a satisfactory exchange.

The value which allowed us to determine a remarkable exchange was at a mass flow rate equal to 10 kg / h.

The following parameters are choose:

Absorber:copper

Fluid: water

Mass flow:10 kg/h

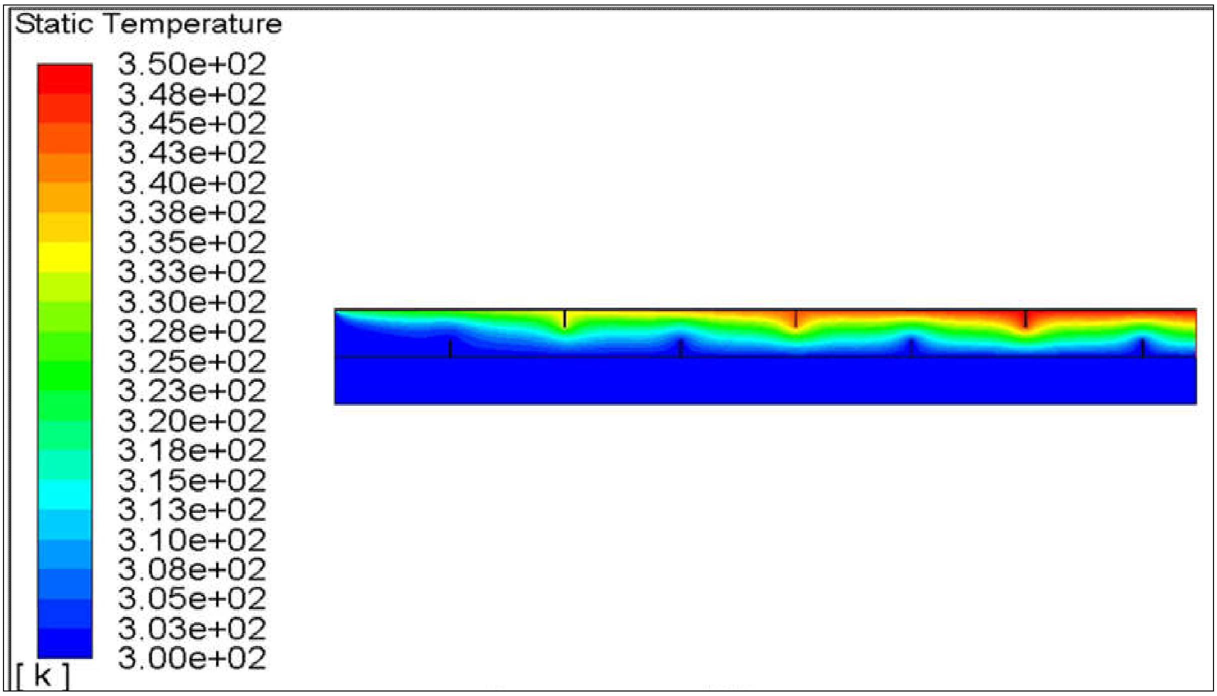

FIGURE V.6: *Presentation of the static temperature contour (K), (copper, qm=10kg/h)*

Figure V.6 show the temperature contour of the temperature change in the solar water collector equipped with transverse baffles and water as a heat transfer fluid. We notice that the temperature starts from the ambient value and then increases, especially in the area close to the absorber, until it reaches a maximum value of 350 K, because we applied less flow to give the heat transfer fluid enough time to absorb more temperature.

V.5.1.3 Changing material of absorber

a) Silver as absorber material at 10 kg/h

According to (reference) silver has better thermo-physical properties compared to copper.

Mater	Density [kg/m^3]	cp [$J/kg.K$]	Thermal conductivity [$W/m.K$]
Copper	8978	381	387.6
Silver	1500	0.24	429

TABLE V.4: *Thermo-physical properties copper and silver*

The following parameters are choose:

Absorber:Silver

Fluid: Water

Mass flow:10 kg/h

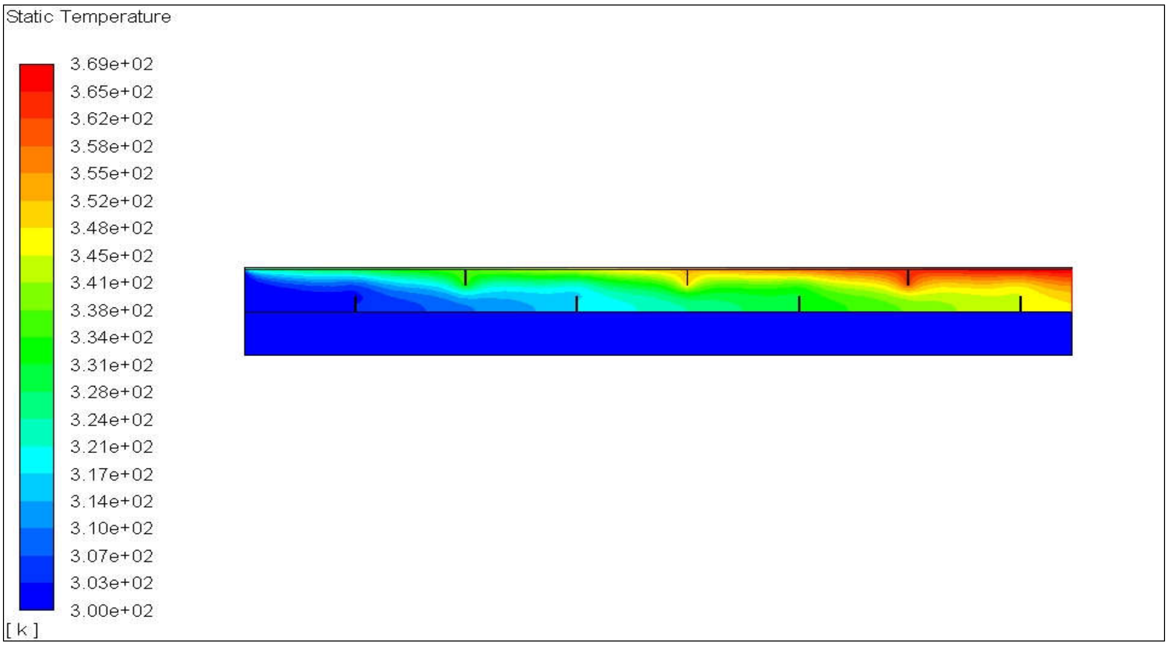

FIGURE V.7: *Presentation of the static temperature contour (K),(silver,qm=10kg/h)*

Through the figure we see that the temperature has increased to a value of 369 K, using silver as an absorbent, where we have found a better result , and this is due to the physical and thermal properties(thermal conductivity).

b) Aluminum as absorber material at 10 kg/h

although the results obtained by the use of silver are clearly superior to copper. but the economic contention of the cost of the panel is not favorable. This prompted us to reflect on the use of another material that will give us superior thermal results at a reduced cost.

Mater	Density $[kg/m^3]$	cp $[J/kg.K]$	Thermal conductivity $[W/m.K]$
Cuivre	8978	381	387.6
Silver	1500	0.24	429
Aluminum	2719	871	202.4

TABLE V.5 *Thermo-physical properties of copper, silver and aluminum*

The following parameters are choose:

absorber:aluminum

Fluid: Water

mass flow:10 kg/h

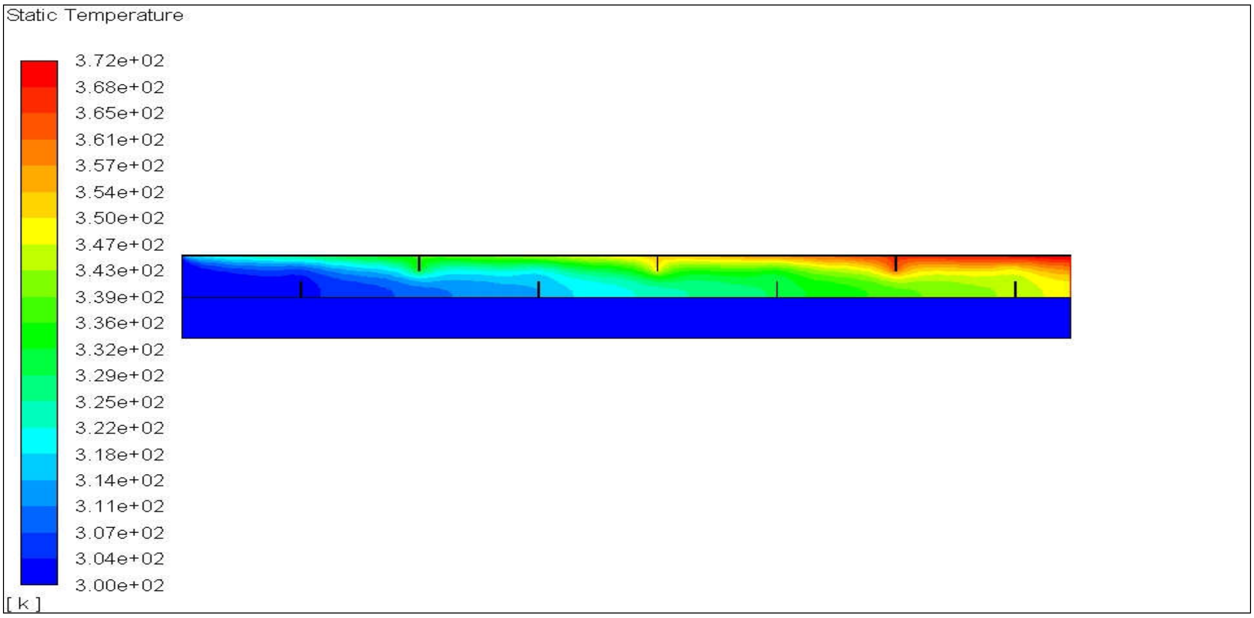

FIGURE V.8: *Presentation of the static temperature contour (K),(aluminum,qm=10kg/h)*

Through the figure V.8 we see that the temperature has increased to a value of 372 K, using aluminum as an absorbent, where we have found a better result , and this is due to the physical and thermal properties(thermal conductivity).

V.5.2 Temperature evolution in transversal sections

In order to study the variation of the physical parameters of the fluid on the height of the collector, we have broken down this height into different cross sections as follows:

y11= 0.11m: section of the lower face of the absorber.

Y55 = 0.055 m: section of the upper face of the insulation.

Y75 = 0.075 m: section of the upper faces of the baffles attached to the insulator.

Y825 = 0.0825 m: average section of the water flow duct.

Y9= 0.09 m: section of the upper faces of the fins attached to the absorber.

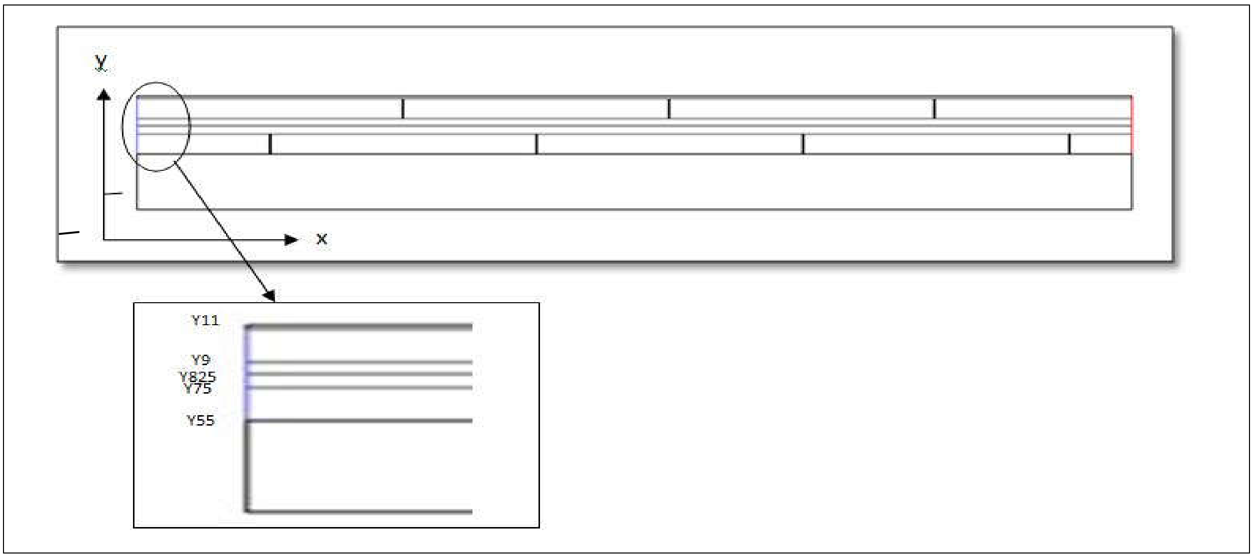

FIGURE V.9: *Presentation of transversal sections*

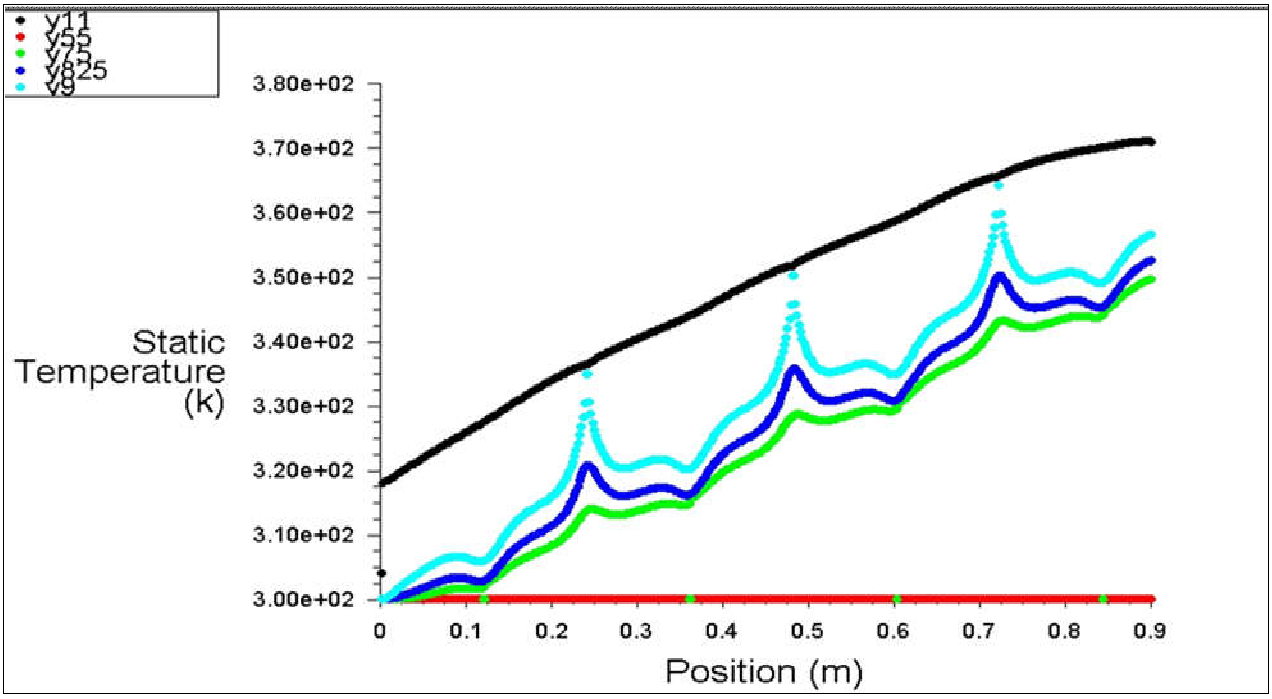

FIGURE V.10: *Temperature evolution in transversal sections in the collector solar water*

The distribution of the temperature presented in figure V.10 shows that the temperature at the level of the insulation remains constant at a value of 300 k and that of the absorber evolves according to the longitudinal displacement until reaching a maximum value of 372k. On the other hand in the sections of the medium the temperature changes gradually but presents a disturbance at the level of baffle.

The maximum temperature reached is approximately 372K.

V.5.2.1 Study of thermal flow around the 1st baffle

En presents here the variation of temperature in the cross sections of the 1st baffle

X11 = 0.11 m: section downstream the baffle.

X1205 = 0.1205 m: section at the baffle level.

X13= 0.13 m: upstream section of the baffle.

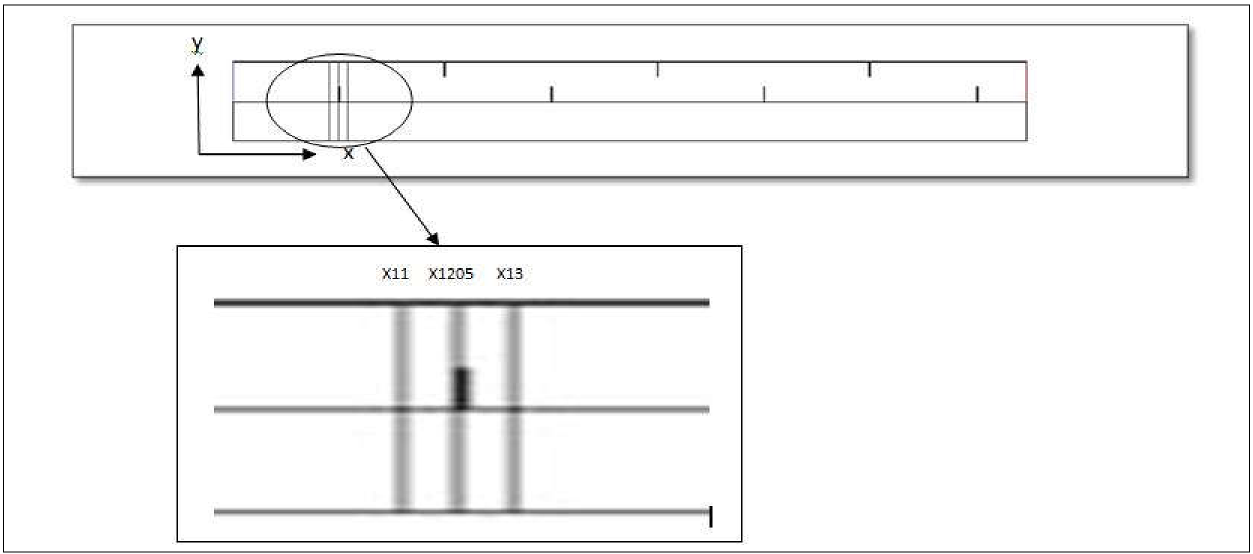

FIGURE V.11: *Presentation of vertical sections around 1st baffle*

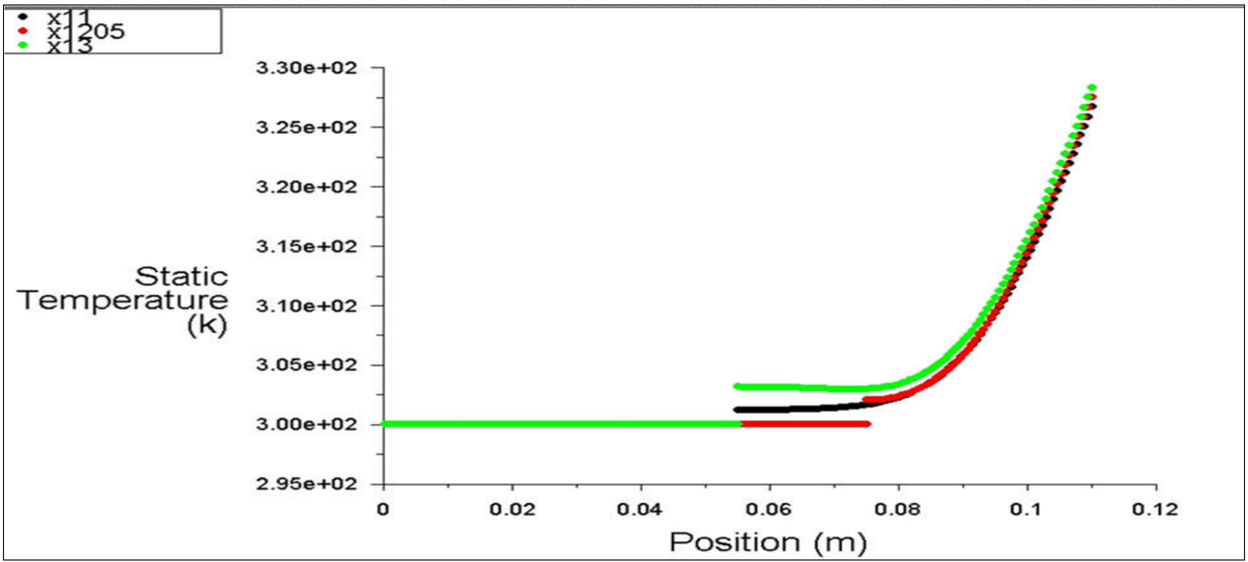

FIGURE V.12: *Temperature curve around the 1st baffle*

Fig 12 indicates that the temperature takes maximum values as it approaches the upper surface close to the absorber because the fluid begins to exchange temperature with the absorber

V.5.2.2 Study of thermal field around the 2nd baffle

In this section presents the evolution of temperature in sections next transverse:

X23= 0.23 m: section before the baffle.

X2405 = 0.2405 m: section at the baffle axis.

X25 = 0.25 m: upstream section of the baffle.

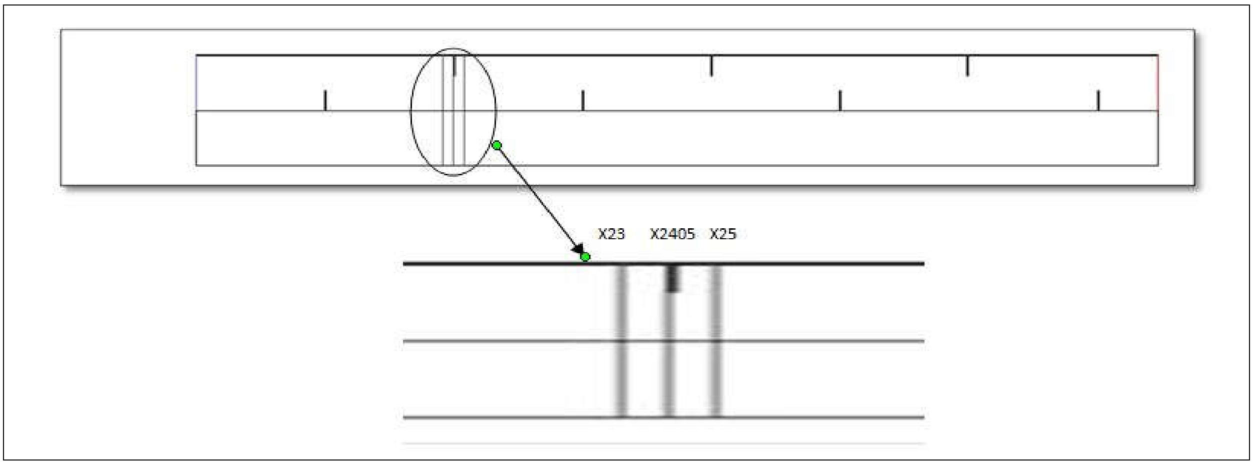

FIGURE V.13: *Presentation of vertical sections around 2nd baffle*

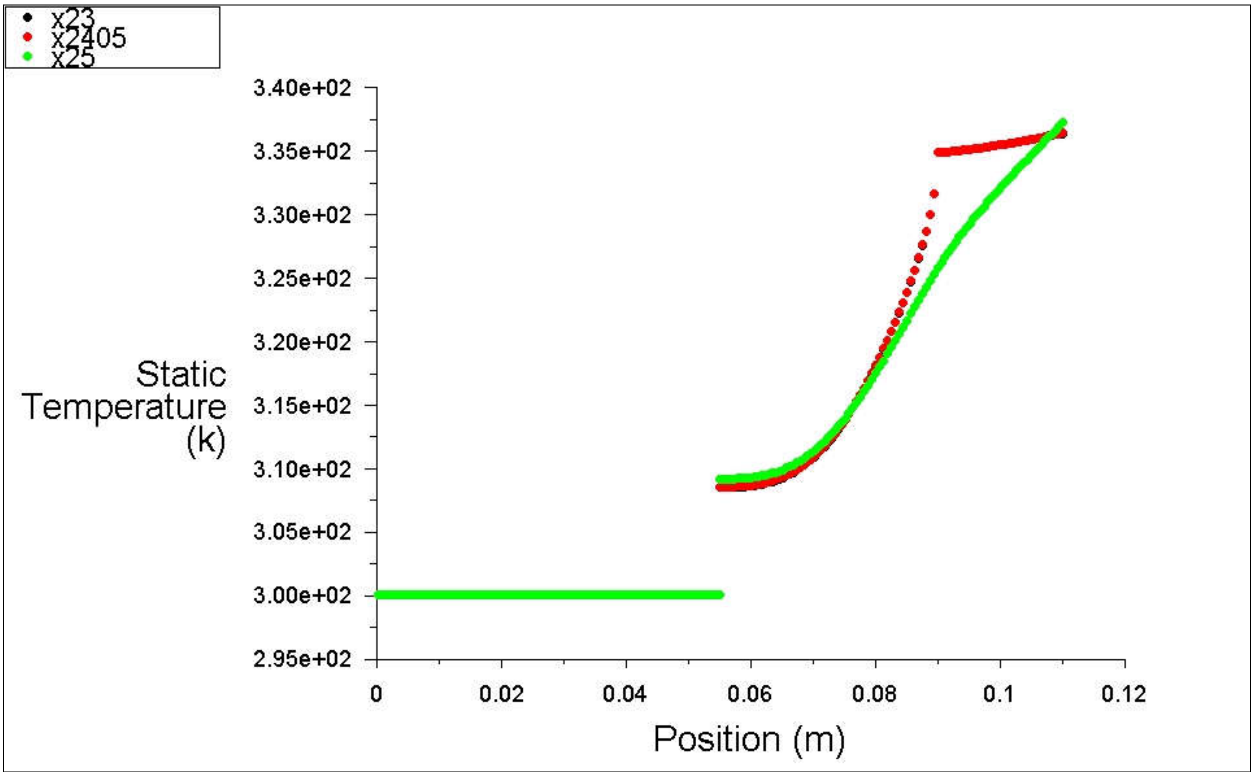

FIGURE V.14: *Static Temperature curve around the 2nd baffle*

We observe that the temperature at the level of the baffle axis (x = 0.2405m and $0.09 \leq y \leq 0.11$) remains almost constant ($T \approx 336K$).

V.6 CONCLUSION

The results presented in this chapter showed that the material of the absorber has a great influence on the heat transfer. Based on the thermo-physical properties of the absorbent material the results of the study showed that the choice of aluminum as absorber material give better results than silver and copper even his cost is low.

Another result consists on the importance of the baffles in increasing the heat transfer. The study indicates that the role of the baffle is to decelerate the heat transfer fluid and as consequence an increase in the heat transfers.

A low mass flow of the heat transfer fluid offers better results than a high mass flow.

GENERAL CONCLUSION

GENERAL CONCLUSION

The use of solar energy is one of the priority areas of research in Algeria which has a significant solar deposit. In this context the study focus on the way to optimize the physical parameters of solar water collector

An introduction of solar deposit has been made in order to illustrate the collector solar environment general notions and the different types of solar captor have been introduced in this study.

The modelization of the flow and the main classical methods of numerical analysis have been detailed.

The aim of this study is to analyze the influence of physical parameters on the performances of a solar water collector, in accordance to this aim, we studied different absorber material and mass flow of solar water collector using a numerical calculation based on Ansys fluent to obtain their influence on the heat transfer.

The results showed that the material of the absorber has a great influence on the heat transfer. Based on the thermo-physical properties of the absorbent material the results of the study showed that the choice of aluminum as absorber material give better results than silver and copper even his cost is low.

In another hand, the importance of the baffles in increasing the heat transfer has been studied. The role of the baffle to decelerate the heat transfer fluid and as consequence an increase in the heat transfers have been illustrated.

The numerical study showed that a low mass flow of the heat transfer fluid offers better results than a high mass flow.

The use of aluminum metal as an absorber for the solar water collector gave better results compared to copper and silver.

REFERENCES

REFERENCEES

[A. ABENE ET AL, 2004], A. ABENE ET AL ,«Study of a solar air flat plate collector use of obstacles and application for the drying of grape», Journal of Food Engineering, 65 ,pp 15–22.

[**A. FUDHOLI, ET AL, 2011],** A. FUDHOLI, M.H ET AL, «Mathematical Model of Double-Pass Solar Air Collector with Longitudinal Fins» ,Solar Energy Research Institute (SERI), Universiti Kebangsaan Malaysia 43600 UKM Bangi, Selangor, MALAYSIA.

[A.A. ZAÏD ET AL, 2001], A.A. ZAÏD ET AL, «Amélioration des Performances des Capteurs Solaires Plans à Air: Application au Séchage de l'Oignon Jaune et du Hareng». Rev. Energ. Ren. Vol.4 ,69-78.

[A.A.MOHAMAD, 1997], A.A.MOHAMAD , «High efficiency solar air heater», Solar Energy Volume 60, Issue 2, ,Pages 7-71.

[A.M.SHARIAH, 1999], A.M.SHARIAH, « Effect of thermal conductivity of absorber plate on the performance of a solar water heater», Applied Thermal Engineering ,Pages 733-741, July.

[**ABDI. H ET ALL, 2000],** ABDI. H ET MESSAOUDENE, N. AIT, «Etude expérimentale et théorique des performances de deux capteurs plans à contact direct eau–plaque d'absorption», Revue des Energies Renouvelables, Chemss, p 53-60.

[ACHOURI ET AL, 2008], ACHOURI ET AL, « Etude de l'influence des rugosités artificielles sur les performances thermiques des capteurs solaires plans à air » Revue des Energies Renouvelables Vol. 11 N°2 219 – 227.

[B. AGHILAS, 2016], AGHILAS BRAHIMI, «Etude de performances d'un capteur solaire plan à eau» Mémoire de Master 2, UNIVERSITE DE LORRAINE.

[BENELMOUAZ Mohamed Amine, 2018], BENELMOUAZ Mohamed Amine, «*Etude numérique du comportement thermique et dynamique d'un capteur solaire plan à eau en vue d'améliorer ses performances*» mémoire de master, Université Ibn khaldoun Tiaret.

[BENKHELIFA, 1998], BENKHELIFA, « Optimisation d'un Capteur Solaire Plan »., Rev. Energ. Ren, Physique Energétique, pp. 13-18.

[CARL M ET AL, 1987], CARL M.LAMPERT «Advanced optical materials for energy efficiency and solar conversion», Solar & Wind Technology Volume 4, Issue 3, Pages 347-379.

[D. HO ET AL, 2012], D. HO ET AL, « Performance improvement of a doublepass solar air heater with fins and baffles under recycling operation»,Applied Energy 100 ,155–163..

[H. ABDI, 1999], H. ABDI *, «Contribution à la détermination des performances de capteurs plans à contact direct eau-plaque d'absorption* **»** Mémoire de Magister, Université de Blida.

[H.M. YEH ET AL, 2009], H.M. YEH ET AL, «The influences of recycle on performance of baffled double-pass flat-plate solar air heaters with internal fins attached», Applied Energy 86 pages 1470–1478.

[HUCHING ET AL, 2002], HUCHING, M. FAROOQ «Optical properties of higher and lower refractive index composites in solar selective coatings», Solar Energy Materials and Solar Cells Pages 73-83.

[J. A. Duffie ET AL, 1980], J. A. Duffie, W. A. Beckman, «*Solar engineering of thermal processes* » John Wiley and Sons.

[J. BERNARD, 2004], J. BERNARD. Energie solaire calculs et optimisation, Ellipse Edition Marketing.

[JIM DUNLOP, 2012], JIM DUNLOP SOLAR,«*terminology and definition geometric and atmospheric effects solar power and energy measurements and data*».

[K. AOUES ET AL, 2009], K. AOUES, N. MOUMMI ET AL,« Amélioration des performances thermiques d'un capteur solaire plan à air: Etude expérimentale dans la région de Biskra » Revue des Energies Renouvelables Vol. 12 N°2 237 – 248.

[KREITH.F ET AL, 1978], KREITH F, KREIDER JF. «Principles of solar », engineering. New York: McGraw-Hill.

[N. MOUMMI ET AL, 2004], N. MOUMMI, S.Y. ALI, A. MOUMMI, J.Y. DESMONS, «Energy analysis of a solar air collector with rows of fins». Renewable Energy, 29 ,pp. 2053–2064.

[N.T. AHMAD, 2001], N.T. AHMAD, «Agricultural solar air collector made from low cost plastic packing film». Renewable Energy, 23, pp. 663–671.

[**PRAKASH KUMAR SEN ET AL, 2015**], PRAKASH KUMAR SEN ET AL «study on solar water heater and its system performance» , IJARSE, Vol. No.4, Special Issue (01).

REFERENCEES

[R. BERNARD ET AL, 1983], R. BERNARD, G. MENGUY, M. SCHWARTZ. Le rayonnement solaire conversion thermique et applications ; Technique et documentation, Paris.

[R. KUMAR ET AL, 2011], R. KUMAR, M. A. ROSEN, « Performance evaluation of a double pass PV/T solar air heater with and without fins», Applied Thermal Engineering 31 .

[ROGÉRIO ANTÔNIO, 2017], ROGÉRIO ANTÔNIO, XAVIER NUNES «Selective Surfaces of Black Chromium for Use in Solar Absorbers», Materials Research.

[S. YOUCEF ALI, 2005], S. YOUCEF-ALI, « Study and optimization of the thermal performances of the offset rectangular plate fin absorber plates», with various glazing, Renewable Energy, 30 pp. 271 280.

[SANDALI MESSAOUD, 2014], SANDALI MESSAOUD,«*Etude dynamique et thermique d'un capteur solaire à air à double passe avec milieu poreux*» , mémoire Pour obtenir le diplôme deMagister en génie mécanique, université de aboubekr belkaid,tlemcen.

[SERGIO COLLE ET AL, 2003], SERGIO COLLE ET AL,«Cost optimization of low-cost solar domestic hot water systems» assisted by electric energy.

[SLIMANE Sihem, 2019], SLIMANE Sihem **,** «*Etude du comportement thermique et dynamique d'un capteur solaire plan à air en présence des chicanes transversales*» mémoire de master, Université Ibn khaldoun Tiaret.

[SOLAR FRED, 2010], SOLAR FRED,**«** *Main Components of a Solar Hot Water System***»** , Solar Thermal 101,April 6.

[SOTERIS A.KALOGIROU, 2004], SOTERIS A.KALOGIROU, Solar thermal collectors and applications, Progress in Energy and Combustion Science Volume 30, Issue 3, Pages 231-295.

[SWATI OGALE, 2014], SWATI OGALE,«*Solar water heater*»,ENCYCLOPÆDIA BRITANNICA TECHNOLOGY.

[TALAMALI DONIA, 2016], TALAMALI DONIA«*Simulation des performances d'un chauffe eau solaire*» mémoire de Master, universite m'hamed bougara, boumerdes.

[Y. JANNOT, 2011], Y. JANNOT. Thermique solaire.

[YOUCEF ET AL, 2016], A. YOUCEF ET R. SAIM, «*Etude numérique de l'influence de disposition des chicanes sur le comportement dynamique et thermique d'un écoulement dans un échangeur de chaleur*» Revue des Energies Renouvelables Vol. 19 N°3 ,415 – 427.

THE WEBSITES

[1]https://www.sunnyhotwater.com/history.html

[2] FieldTestVersion–SpaceScienceInstitute©2004, p 8

[3] www.pveducation.org

[4] https://www.lepanneausolaire.net/quels-sont-differents-types-chauffe-eau-solaires.php

[5]https://www.lepanneausolaire.net/les-differents-types-capteurs.php

[6] https://www.ecosources.info/dossiers/Centrale_solaire_thermique_capteurs_cylindro-paraboliques

[7]http://solar.powergreen.fr/capteurs.html

[8]https://lenergie-solaire.net/energie-solaire-thermique/composants/capteurs-solaires-thermiques#capteurs-solaires-a-plaque-plate

[9] https://www.sculpteo.com/en/glossary/solidworks-definition/

[10] http://users.abo.fi/rzevenho/ansys%20fluent%2018%20tutorial%20guide.pdf

ABSTACT

In this work, we have studied numerically using the "ansys fluent 2D" computer code, the thermal behavior of the water flow in forced convection, in a flat solar water collector in the presence of rectangular transverse baffles. The fluid is considered as Newtonian, incompressible with constant properties in laminar regime. The governing equations have been integrated and discretized using the finite volume approach.

The aim of this work is to optimize the physical parameters of the solar water collector to increase absorption, for this purpose we have used different materials of the absorber and the influence of mass flow on thermal transfer.

Keywords: solar collector, Ansys, Absorber, water, optimization

RESUMÉ

Dans ce travail, nous avons étudié numériquement à l'aide du code de calcul "ansys fluent 2D", le comportement thermique de l'écoulement d'eau en régime laminaire en convection forcée, dans un collecteur d'eau solaire plat en présence de chicanes transversales rectangulaires. Le fluide est considéré, newtonien, incompressible avec des propriétés constantes. Les équations gouvernantes ont été intégrées et discrétisées selon l'approche des volumes finis.

Le but de ce travail est d'optimiser les paramètres physiques du capteur solaire d'eau pour augmenter l'absorption, a cet effet nous avons utilisé différents matériaux de l'absorbeur et l'influence du débit massique sur transfert thermique.

Mots clé : capteur solaire, Ansys, Absorbeur, eau, optimisation

الملخص

في هذه الدراسة ، درسنا عدديًا باستخدام كود الكمبيوتر "ansys fluent 2D" السلوك الحراري لتدفق الماء في الحمل الحراري القسري ، في مجمّع المياه الشمسي المسطح في وجود حواجز عرضية مستطيلة. . يعتبر السائل نيوتوني غير قابل للضغط وله خصائص ثابتة في النظام الرقائقي. تم دمج المعادلات المتحكمة وتقديرها باستخدام نهج الحجم المحدود.

الهدف من هذا العمل هو تحسين الخصائص الفيزيائية لمجمع الماء الشمسي لزيادة الامتصاص ، ولهذا الغرض استخدمنا مواد مختلفة للممتص وتأثير تدفق الكتلة على النقل الحراري

الكلمات المفتاحية: جامع الطاقة الشمسية ،ansys ، ممتص ، ماء ، تحسين

ANNEXES

ANNEX

PRESENTATION OF CALCULATION CODE:

SOLID WORKS :

<u>Global view:</u>

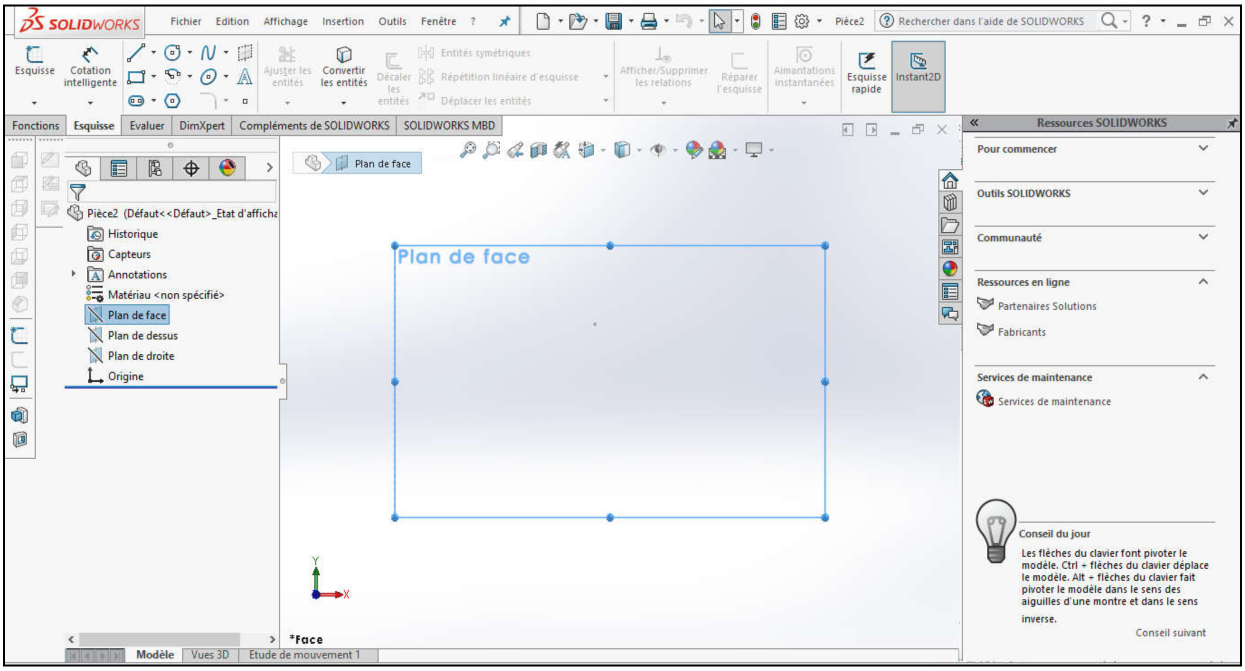

FIGURE A.1. Overview of solidworks

<u>The main steps to obtain a volume:</u>

- ✓ **Choose a plan:**

A plan can be defined in two ways:

One of the three reference plans: O, x, y (front view), O, x, z (top view), O, y, z (right view)

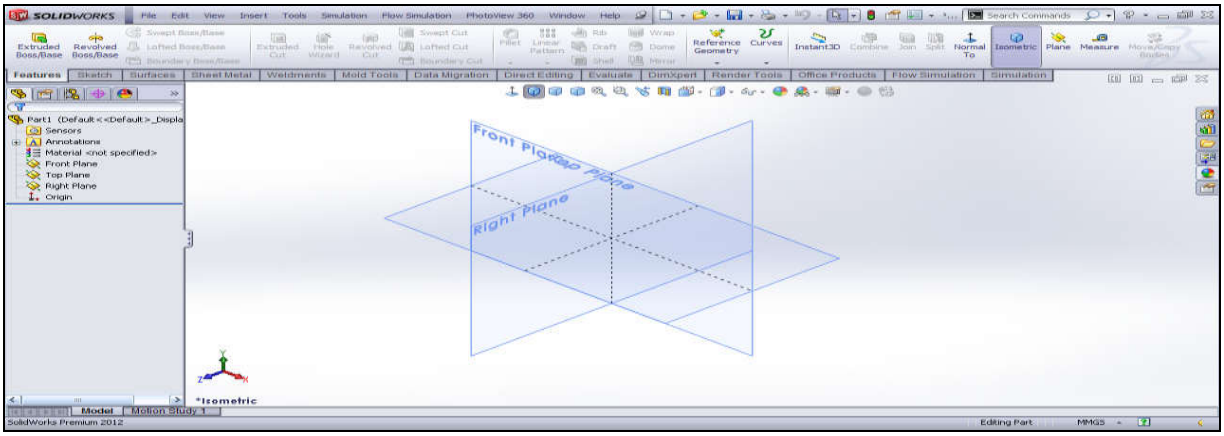

FIGURE A.2. the three plan o,x,y,z

- ✓ **create a surface:**

A flat surface of an existing volume

One side of a prism

A shoulder of a piece of revolution

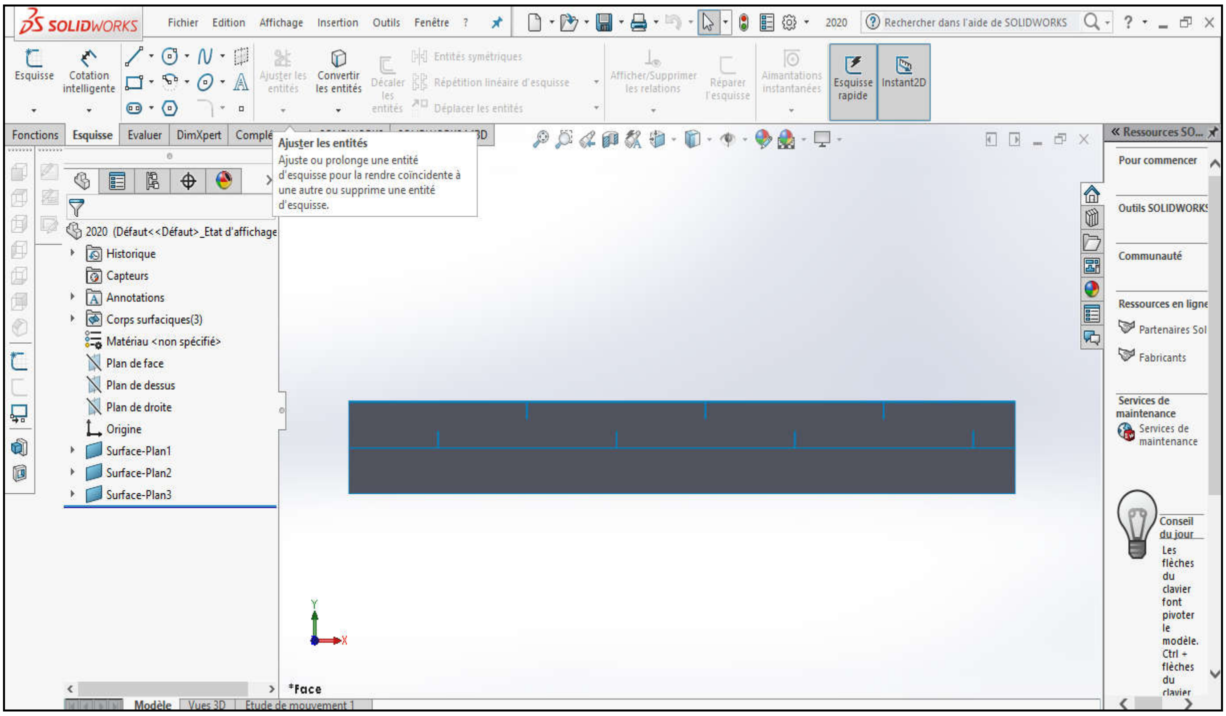

FIGURE A.3. the surface of geometry

- ✓ **Draw a sketch, the constrain :**

A sketch is a plan drawing (in 2 dimensions) defining the external contours of the section or ½ section of a volume (a section represents the part of a room located in a plan cutting this same part).

<u>ANSYSWORKBENCH</u> :

AnsysWorkbench Overview:

- ❖ **Analysis Systems :** are ready-made stencils that include all the individual systems (applications) needed for common analyses (for example Geometry + Mesh + Solver + Post-Processor)

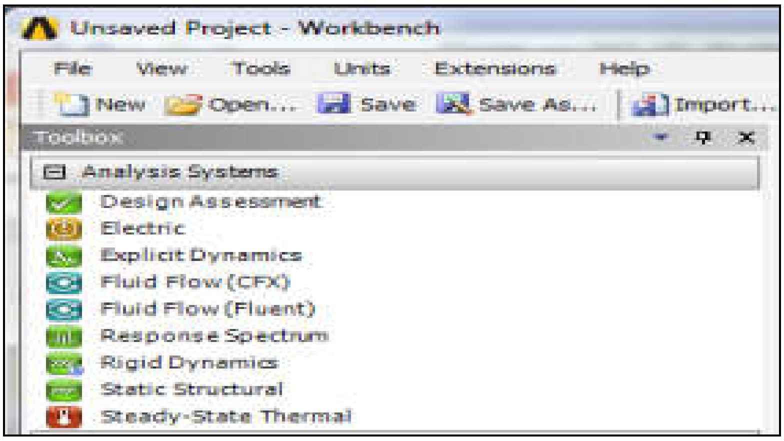

FIGURE A.4. Analysis Systems

- **Component Systems :** are the individual building-blocks for each stage of the analysis

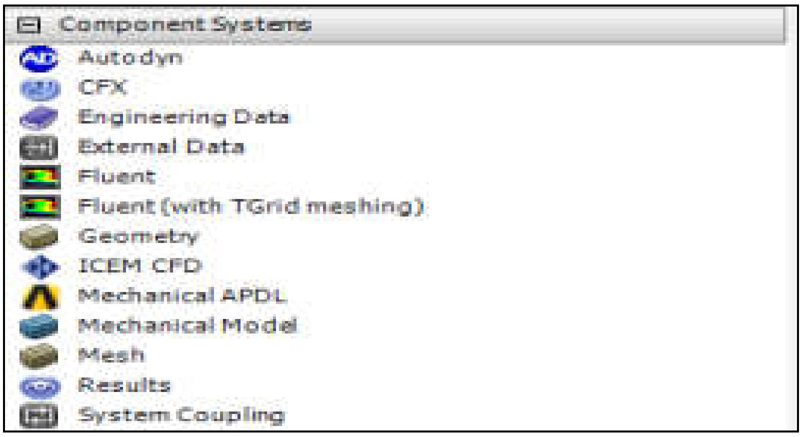

FIGURE A.5. Component Systems

- **Design Exploration**: provides tools for optimising designs and understanding the parametric response.

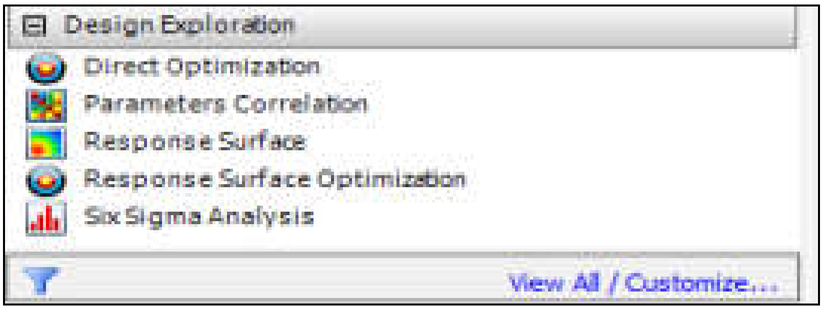

FIGURE A.6. Design Exploration

Ansys Fluid Flow (Fluent):

FIGURE A.7. the steps to analyze fluid

The Steps To Analyze Fluid:

- **geometry:**

After we created the geometry in solidworks, we import it**:**

FIGURE A.8. *Creat geometry*

- **Meshing the Geometry :**

we must generate a computational mesh throughout the flow volume. For this section of the tutorial, you will use the ANSYS Meshing application to create a mesh for your CFD analysis, then review the list of files generated by ANSYS Workbench

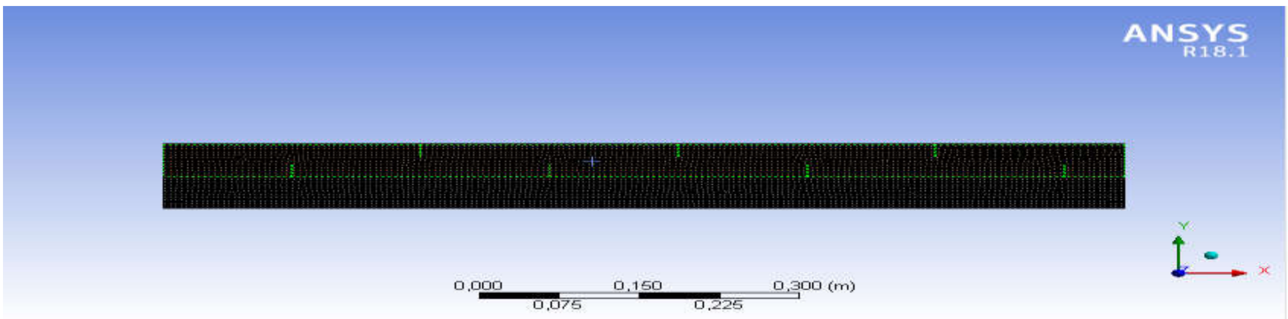

FIGURE A.9. *Meshing the Geometry*

❖ Configuration :

w'll set up a CFD analysis using ANSYS Fluent, then review the list of files generated by ANSYS Workbench.

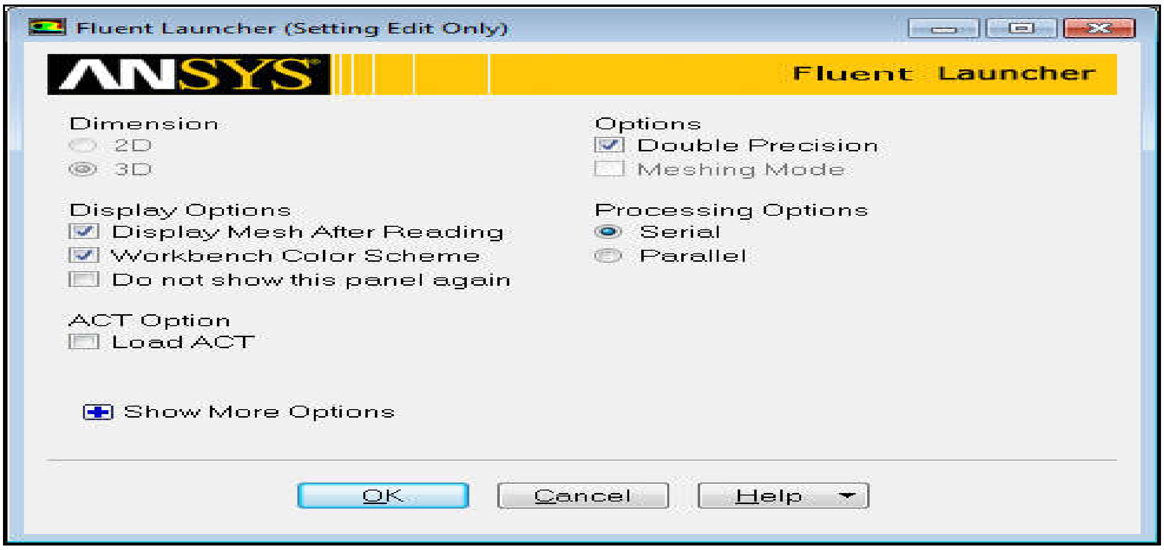

FIGURE A.10. *Fluent Launche*

2d demension → double precision → ok

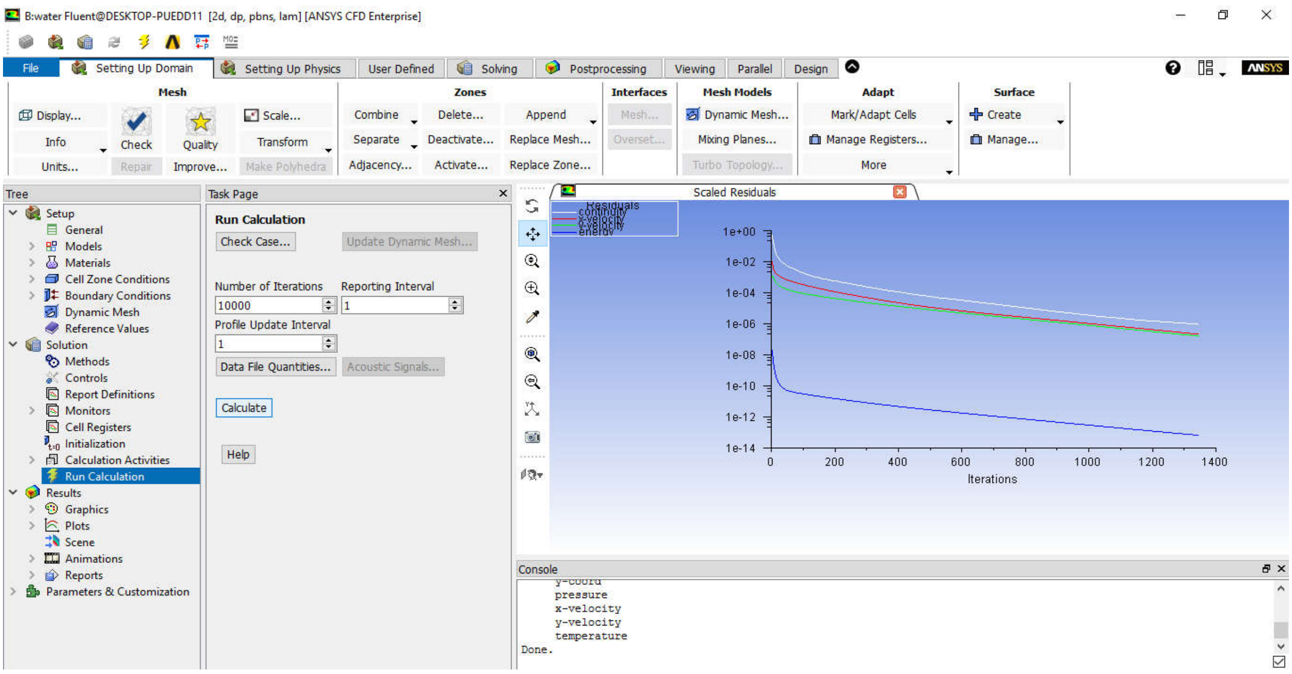

FIGURE A.11. *The ANSYS Fluent Application (configuration)*

❖ Setting Up Domain :

In this step, w'll perform the mesh-related activities using the Setting Up Domain tab (Meshgroup).

FIGURE A.12. Setting Up Domain

- **Change the units for length :**

Setting Up Domain → Mesh → Units

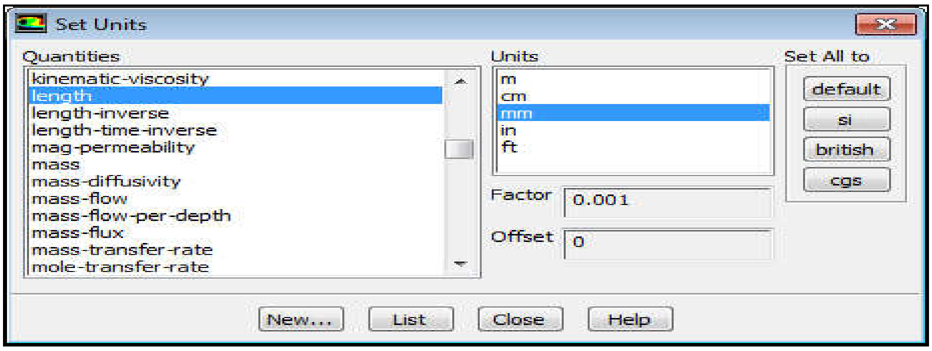

FIGURE A.13. Change the units

- **Setting Up Physics :**

In the steps that follow, we'll select a solver and specify physical models, material properties, and

zone conditions for your simulation using the Setting Up Physicsribbon tab.

1. In the Solver group of the Setting Up Physicsribbon tab, retain the default selection of the steady pressurebased solver.

Setting Up Physics → Solver

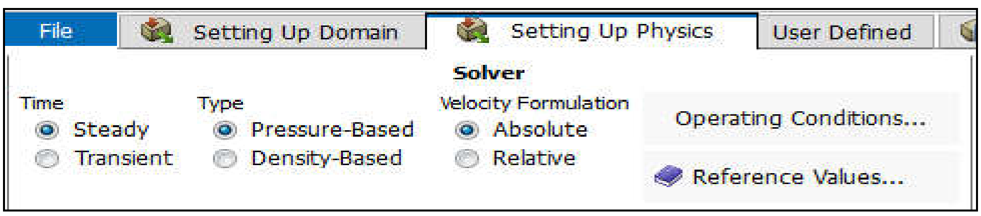

FIGURE A.14. Setting Up Physics

2. Set up your models for the CFD simulation using the Models group of the Setting Up Physicsribbon tab.

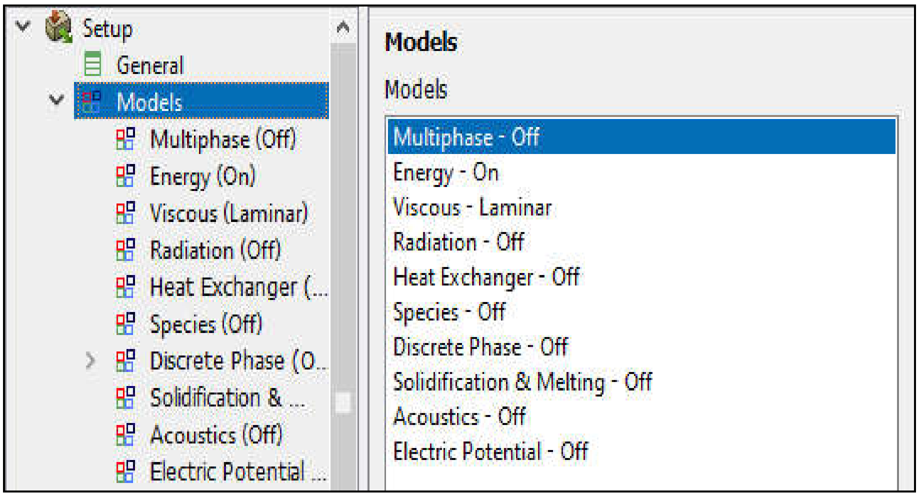

FIGURE A.15. *Setting Up Physics(Models)*

a. Enable heat transfer by activating the energy equation.

In the Setting Up Physics ribbon tab, select Energy (Models group)

Setting Up Physics → Models → Energy

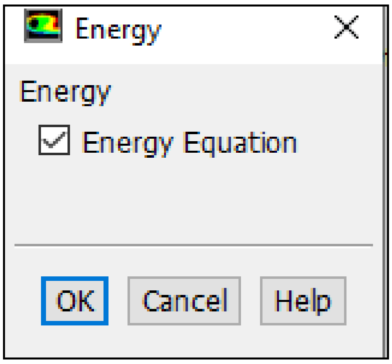

FIGURE A.16. *activating the energy equation*

b. Enable the laminair model

- In the Setting Up Physics ribbon tab, click Viscous... (Models group).
- Setting Up Physics → Models → Viscous

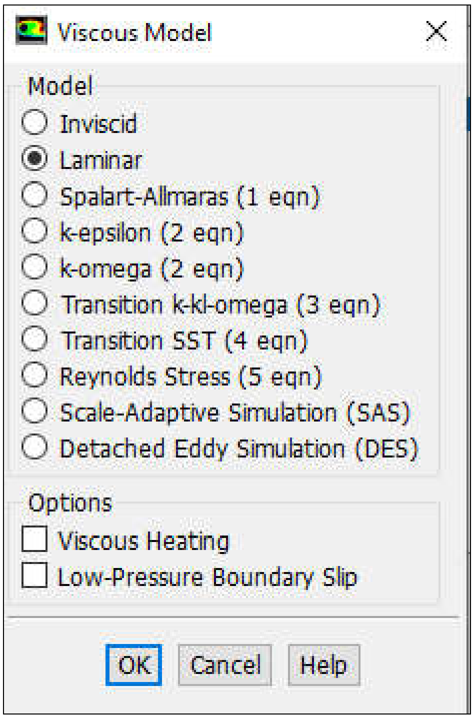

FIGURE A.17. *chose the viscous model*

The Create/Edit Materials (Polystyrene):

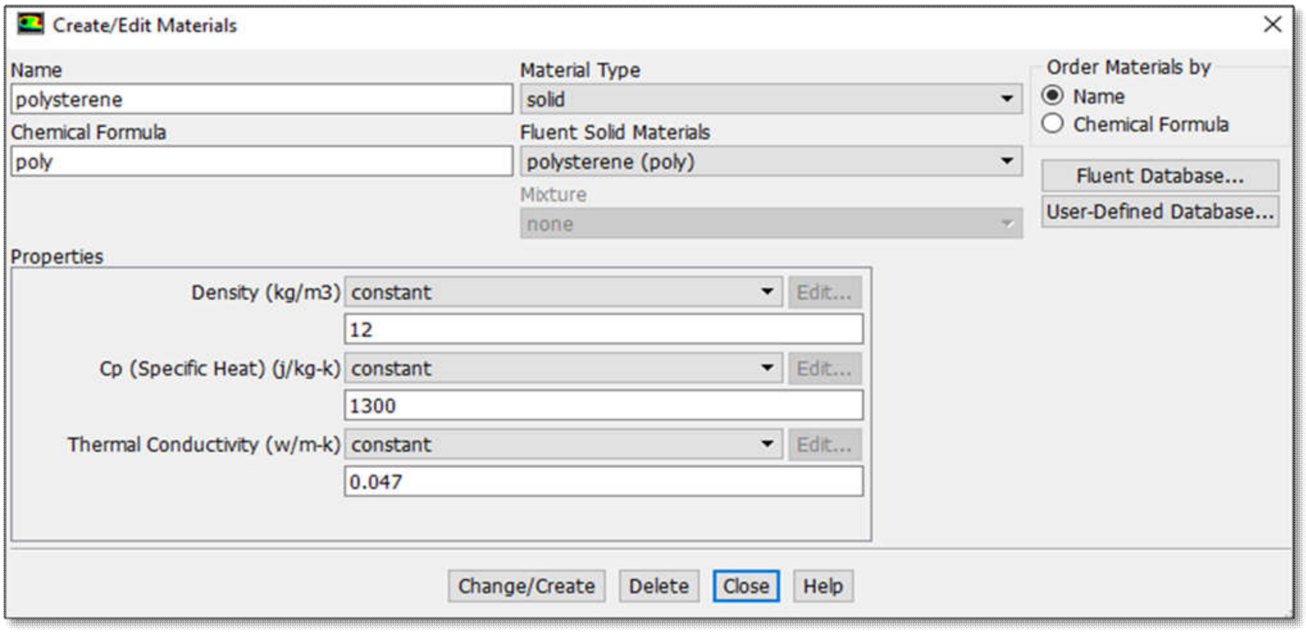

FIGURE A.18. *create or edit the materials*

Cell Zone Conditions :

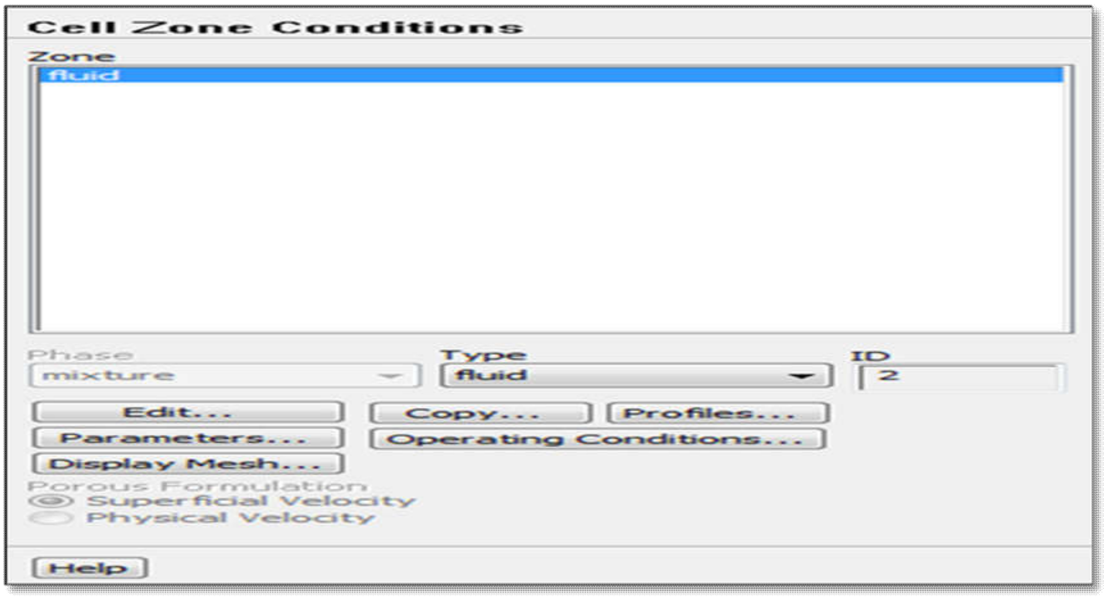

FIGURE A.19. *Cell Zone Conditions*

❖ CellZone Conditions →fluid → Edit

Boundary Conditions :

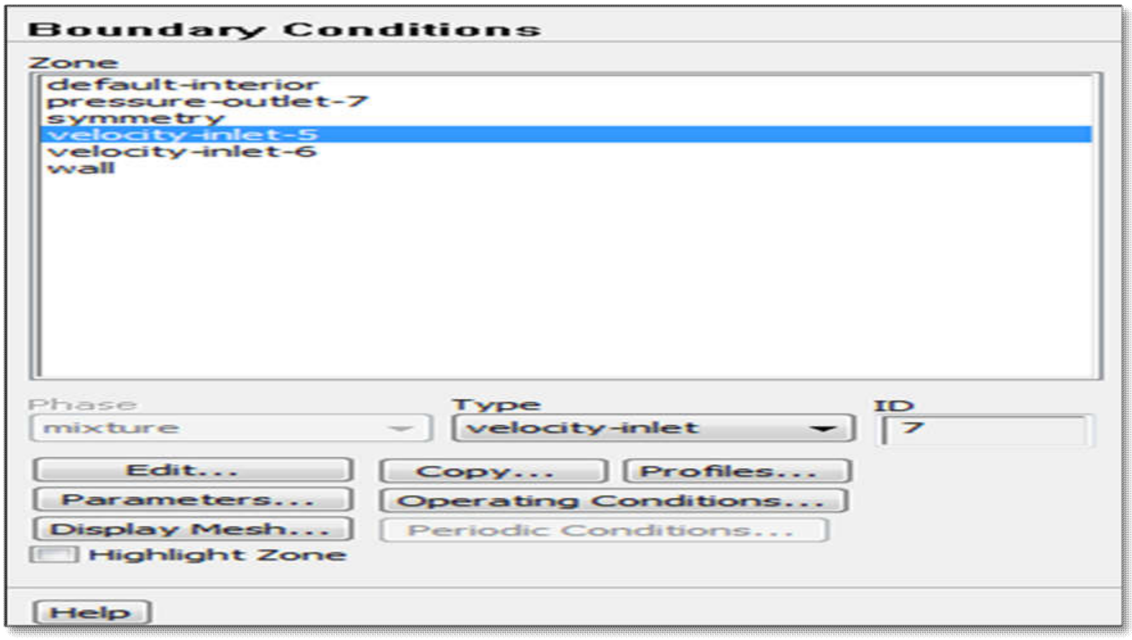

FIGURE A.20. *Boundary Conditions*

❖ Boundary Conditions →velocity-inlet→ Edit

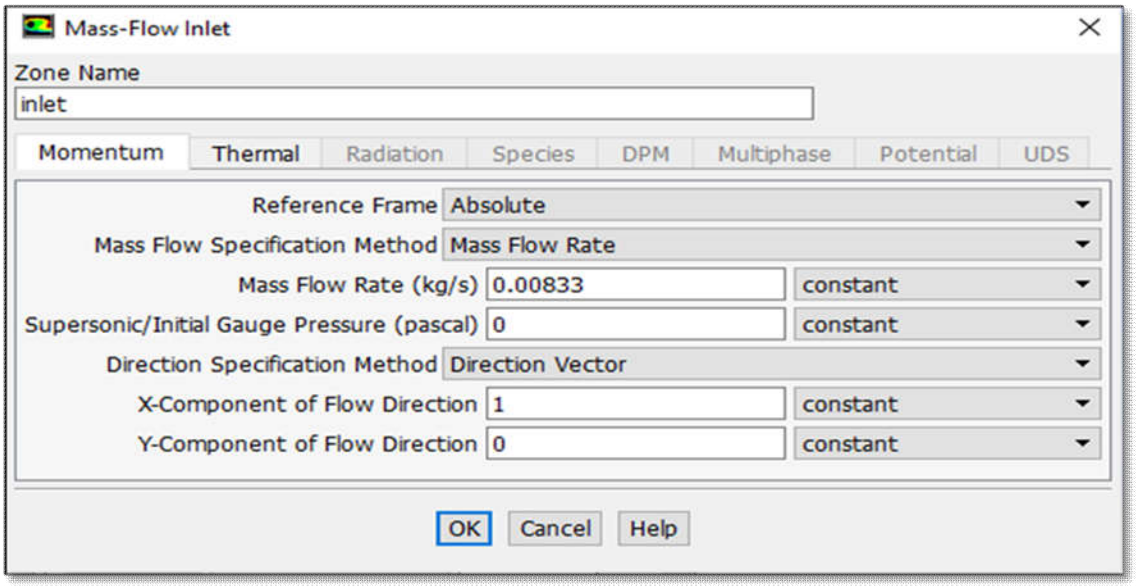

FIGURE A.21. *velocity-inlet*

❖ Boundary Conditions → pressure-outlet → Edit

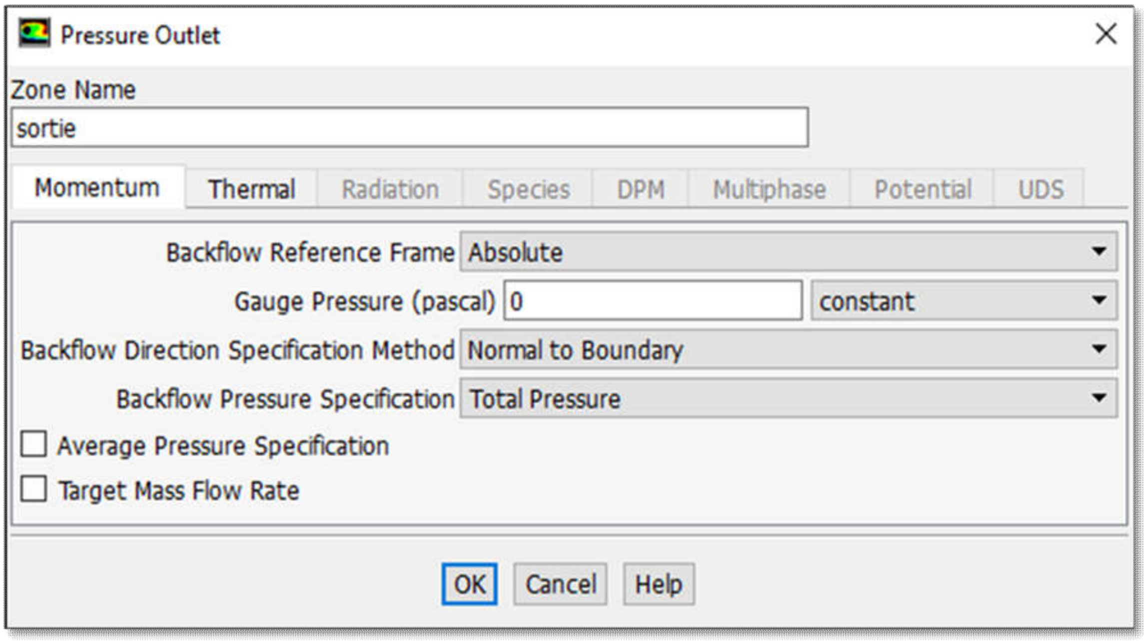

FIGURE A.22. *pressure-outlet*

❖ Boundary Conditions → wall absorber → Edit

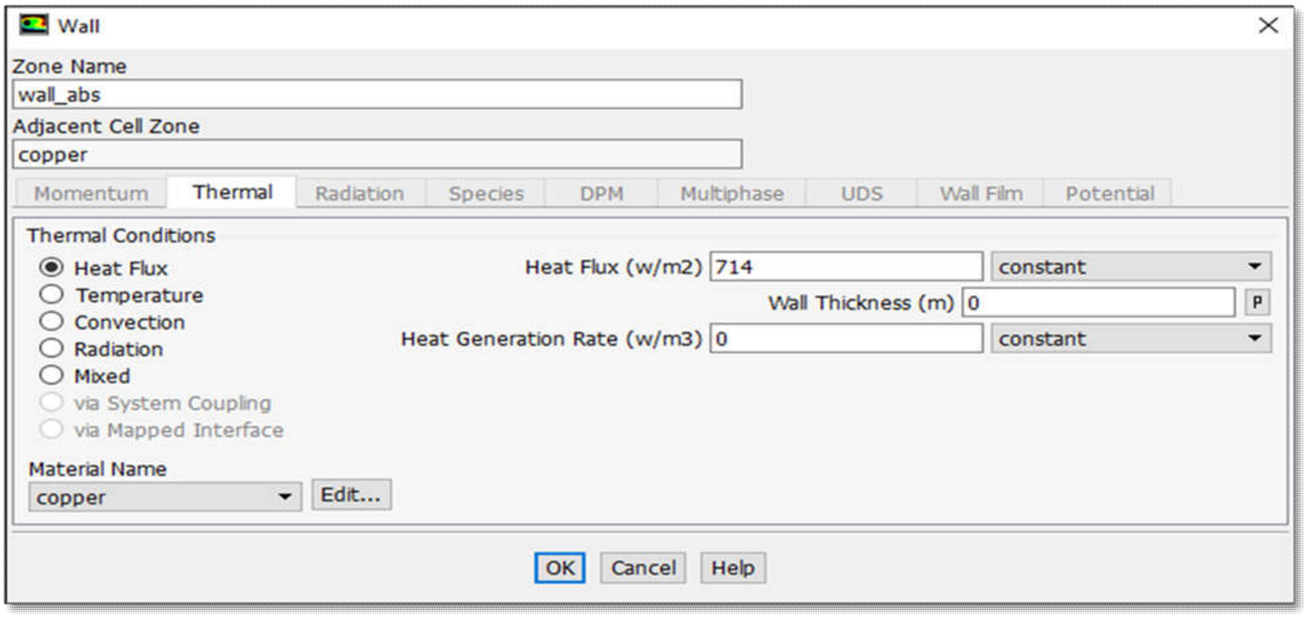

FIGURE A.23. *Boundary Conditions (absorber)*

❖ **Solution :**

Solution Methods :

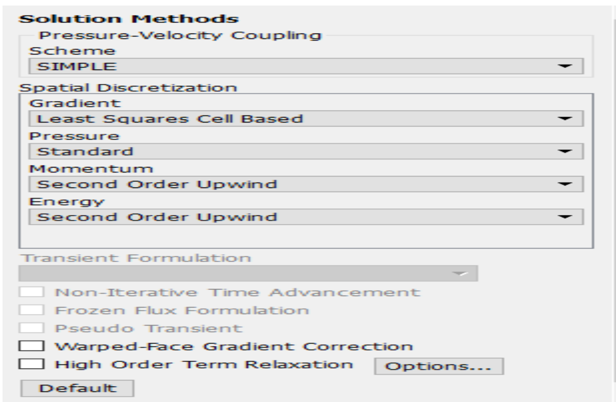

FIGURE A.24. *Solution Methods*

- ❖ Monitors → residual→ Edit

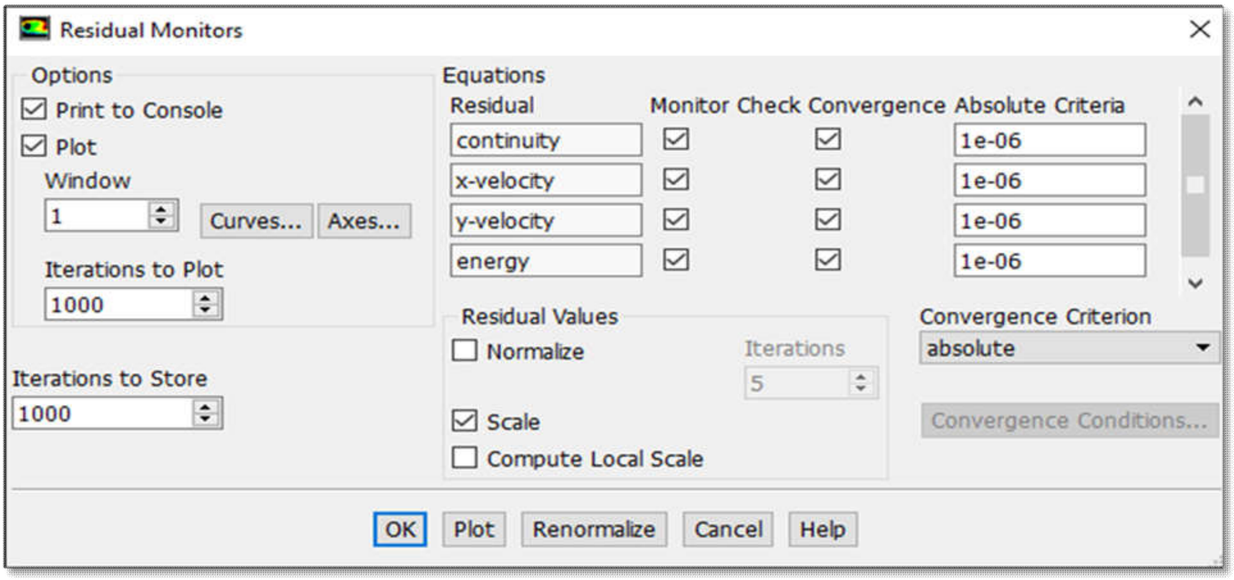

FIGURE A.25. Monitors (residual)

- ❖ Solution Initialization :Initialization Method→Hybrid Initialization

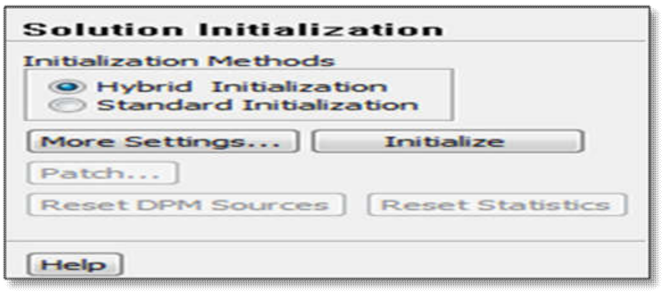

FIGURE A.26. Hybrid Initialization

- ❖ Run Calculation :

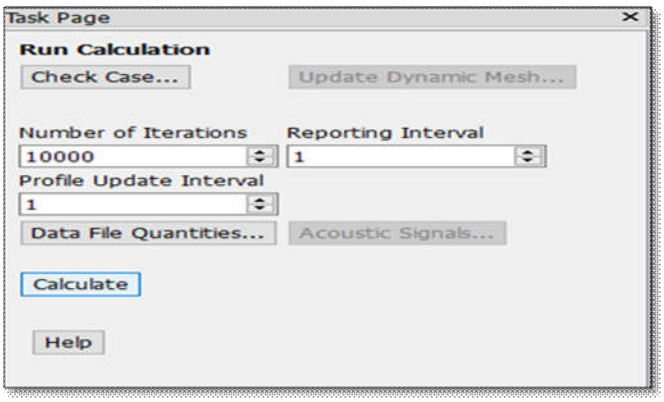

FIGURE A.27. Run Calculation

❖ Convergence :

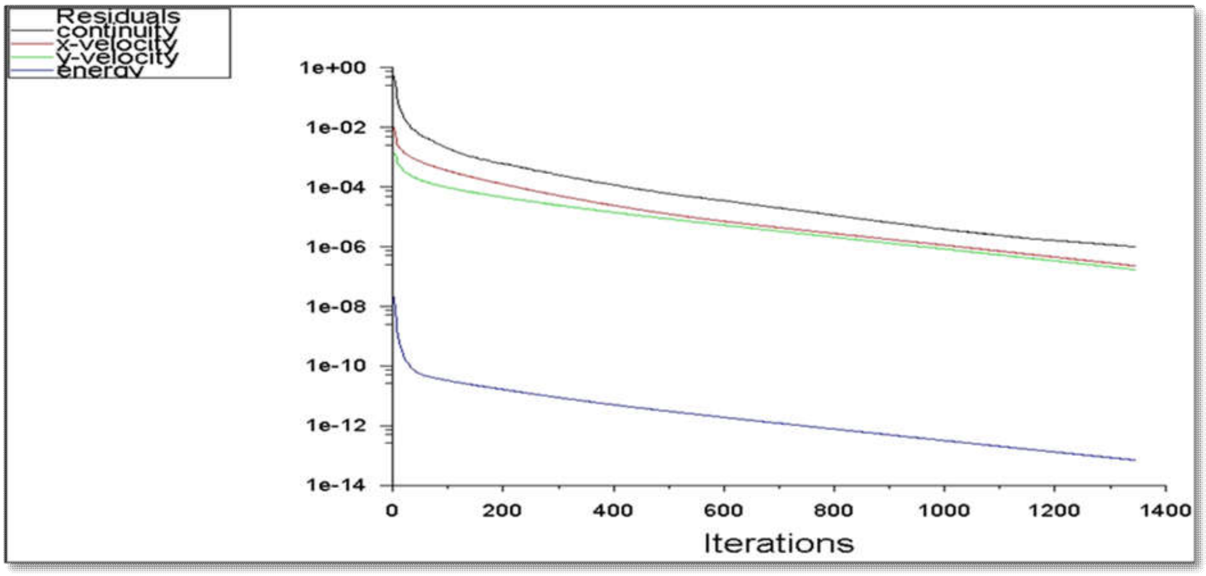

FIGURE A.27. *iterations*