DESIGN AND ANALYSIS OF SOLAR HYBRID CHIMNEY

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Abstract :

Solar hybrid chimney, thermo-electric method used for generation of electrical output by the rotation blades of vertical wind turbine placed at bottom center of chimney base. The entire solar hybrid chimney works based on the principles of Chimney effect, the greenhouse effect and the vertical wind turbine. Sun's energy gets absorbed by the flat plate solar collector and transforms energy into heat. This heat energy will be given to air which lies under the solar collector. the air gets heated by the greenhouse effects. The collector being transparent membrane placed at definite height ranging different dimensions from the sea level. The collector is used to improve the air heating process, the chimney promotes the connection between the warm air nearby the surface and the air present in atmosphere and it converts the kinetic energy of heated air into electricity and heated air having low density moves towards chimney due to the low draught pressure developed in the chimney by stack effect. This continuous airflow when collides with turbine-blade at chimney base. The mechanical output drawn from the shaft adjoined to turbine blades will be given to rotor of generation unit for electrical generation. Solar hybrid chimney needed enough land area. A small-scale solar updraft tower may be an attractive option for remote regions in developing countries.

Key words **– greenhouse effect, solar updraft tower, solar collector, continuous air flow.**

1 INTRODUCTION

In many parts of the world, there is a growing awareness that some alternative energy sources could have an important role to play in the production of electricity. However, only the solar energy represents totally nano-polluting inexhaustible energy resources that can be utilized economically to supply human's energy needs for all time.

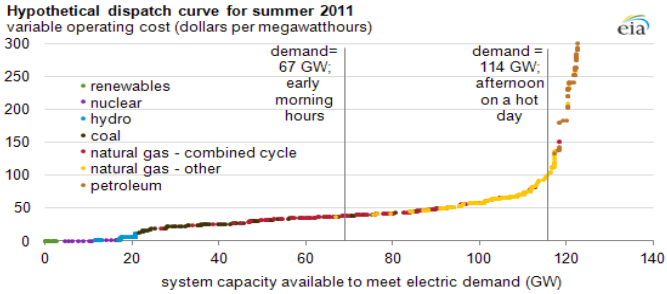
Since 1870's onwards electricity generating system is mainly based on exhaustible fuels such are coal, hydro carbons and uranium, which are damaging the environment and releasing hazardous and harmful gases to the atmosphere. Due to increasing the prices of the limited resources, it being a serious issue even for rich countries.

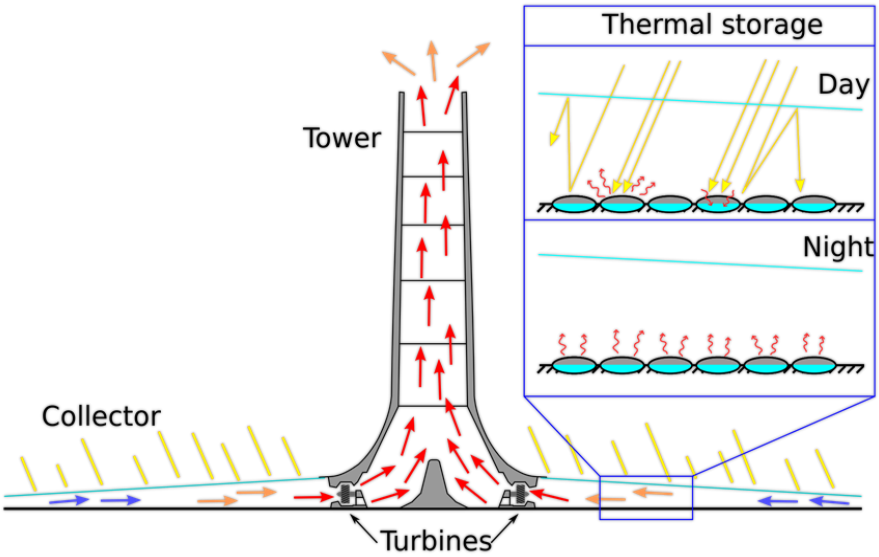
All the people want to and should be use electricity for future. Hence, the demand for electricity is dramatically increasing day by day. But the resources like coal, oil are very less in earth crust and even nuclear power is also very shortsighted.

A clean inexhaustible source of energy is needed. i.e., The Sun. The solar energy can be used in various direct and indirect forms. It should not need cooling water and is based on environment totally. So, we think about the huge problem that facing by the entire world and decided to design a new and conventional method for generating electric power by using hybrid chimney.

1.1 PRICIPLE OF SOLAR HYBIRD CHIMNEY:

The basic components of the solar hybrid chimney are the collectors, turbine and a chimney. The solar energy radiation is converted into electric power. At the bottom center of chimney, a turbine is placed to convert kinetic energy of air into mechanical energy. The turbine shaft is connected to rotor of the generator, which takes the mechanical energy from the turbine as input and produces electrical power as output. This electrical power generated will be further utilized to meet the demand vs production graph and its urgency such as domestic purposes for lightening the households devices and industrial needs.





1.2 NECESSITY OF SOLAR THERMAL POWER:

In this era energy is consider as main factor for the generation of wealth and relative factor for economic development. Thus, the necessity of solar thermal power became huge as the carbon related fuels causing environmental pollution and hazards came into extinct. According to present scenario, many inventions and discoveries are going on green energy fuel that cause no harm and no pollution, solar thermal power being first of its kind.

Solar thermal power generation systems are also known as solar thermal electricity systems utilizing emerging renewable energy technologies and place a crucial vital role in future electric power generation.

1.3 CHARACTERISTICS OF SOLAR CHIMNEY:

Solar chimney have a number of special characteristics:

1. Compared to other type of power generated units , this solar chimney doesn't require any cooling technology but it requires high maintenance to prevent the damage of collectors.
2. Initial capital cost is high compared to other power generated units, but the output efficiency is better than other.
3. The collector can use all types of solar radiation, both direct and diffuse which place major option in tropical countries.
4. The output comes continuously without altering in working condition and the soil present below the solar collectors acts as natural agent for heat recovery and storage system for 24 hours a day.
5. The temperature difference in and out of the chimney helps to drive the heated air through chimney.
6. The reliable factor for solar chimney is high as it don't require any combustion fuel.
7. It provides huge employment opportunity for educated and un educated people.
8. Chimney is made up of stainless steel because of it high strength and low thermal conductivity.

   Collectors are made up of water glass with low iron content as transparent cover, the absorber plate usually made up of Nickel, copper and chromium. Insulation made up of mineral wool, rock wool, Styrofoam,etc

2. LITERATURE REVIEW:

1. Omer Khalil Ahmed, Abdullah Sabah Hussein from Northern Technical University, IRAQ presented a case study paper publication titled " NEW DESIGN OF SOLAR CHIMNEY" in the year 2018 in ELSEVIER .
2. Amit Sharma, Sachin Kumar from Amity University, Rajasthan, INDIA presented a paper publication titled "PAPER ON SOLAR HYBRID CHIMNEY" in the year of feb-2018 in IJET.
3. Mohammed A. Aurybi, from dept. of mechanical engineering, university of Baghdad,Baghdad,IRAQ Hussain H. Al-Kayiem, Syed I. U. Gilani And Ali A. Ismaeel from solar thermal advanced research centre[starc], university teknologi PETRONAS, Malaysia together presented a analysis paper titled "CFD ANALYSIS OF HYBRID SOLAR CHIMNEY POWER PLANT"IN UTP-UMP-VITSES 2018.

3. COMPONENTS OF SOLAR HYBRID CHIMNEY:

Solar hybrid chimney consists of majorly three parts, that are

1. Solar chimney
2. Solar collectors
3. Vertical wind turbine

3.1 Solar Chimney:

Solar chimney can replace a large nuclear power station. Solar chimney can build now, even in less industrial developed countries. No investments in high tech manufacturing plant is needed. Even in poor countries it is possible to

build a large plant without high foreign currency expenditure by using their own resources and work force. This creates large number of jobs and dramatically reduces the capital investment requirement and the cost of generating electricity.

3.2 solar collectors:

In this project we used flat plate solar collectors as it is having high heat transfer capacity and here, we placed the solar collectors in 4 layers one beside the other, occupying sufficient area to get necessary output. Solar collectors are manufactured with different components made with various materials, like for absorber (black chrome over nickel), transparent cover(glazing water glass with low iron content),insulator.

3.3 Wind turbine:

In this project, we used vertical axis wind turbine as it gives more output when compared to horizontal axis wind turbine when placed in horizontal air flow direction, as material used for turbine blades will be having desired properties low thermal conductivity, high strength to weight ratio. This when rotated makes rotor of generator to be rotated and the magnetic field gets cuts by moving coil and power is generated.

4. CALCULATION:

1) The height of chimney can be calculated as,

$$H_1 = H[\left(\frac{m_{a+1}}{m_a}\right)[\frac{m_{a+1}}{m_a} * \frac{Tg}{Ta} - 1]$$

Where as, m_a = mass of atmospheric air
m_{a+1} = mass of chimney air
T_a = Absolute temperature of atmosphere and
T_g = Average absolute temperature of chimney air.

2) The diameter of chimney can be calculated as,

$$D^2 = \frac{mg}{\rho_g * C} * \frac{4}{\pi}$$

$$D = 1.128 \sqrt{\left(\frac{mg}{\rho_g * C}\right)}$$

Where as, mg = mass of gases= ρ_g*A*C (kg/sec)
C = velocity of air at inlet=$\sqrt{2gH}$
A = Area of chimney
ρ_g = density of gases

3) Condition for maximum flow discharge through chimney can be calculated as,

$$(H_1)max = H$$

4) The efficiency of the solar chimney can be calculated by,

$$\eta_{ch} = \frac{H[(\frac{m_a}{m_{a+1}}) * \frac{Tg}{Ta} - 1] * g * 10^{-3}}{Cp\,(T' - T'')}$$ in this T' =Tg.

Where as, T' = Absolute temperature of flue gases leaving the chimney to create the draught.
T''= Absolute temperature of flue gases leaving the chimney in case of artificial draught.

5) The efficiency of the solar collector can be calculate as,

$$\text{EFFICIENCY} = \frac{useful\ heat}{incidebt\ solar\ energy\ flux} = \frac{Qu}{A * I_C}$$

$(Q_U) = (Ac)(Fr)[G_T(\tau\alpha) - U_L(T_i - T_a)]$

Also,$(Q_U) = m'c_p(T_O - T_i)$ for collector efficiency in steady conditions.

$$\eta_i = \frac{m' * C_p * (T_a - T_i)}{A_C * G_T}$$

Where as, Ac = collector area (m^2)
F_r = Heat removal factor
G_T = S = Absorbed solar radiation (J/m^2)
U_L = Heat transfer loss co-efficient (J/m^2)
T_i = Mean absorber plate temperature (°C)
T_a = Ambient temperature (°C)

Power generated by the wind turbine:

The power is generated by the wind turbine is,

Power = ½ C*ρ*A*V^3

Where as, C = coefficient off performance

A = frontal area

V = velocity of wind

ρ = air density

Blade radius = 38m

Tip speed ratio = 6

Air density = 1.225 kg/m^3

K.E = ½ mv^2

= ½ $\rho * A * V^3$

= ½*(1.225)*38*(13.5)* $(33.34)^3$

K.E = 11648324.5 watt

=11648.3245 k watt

By using omni wind turbine calculator as turbine efficiency is generally for savonious wind turbine = 40%

When calculated with losses output = 4453.725 kw

All losses assumed = 9.7%

Required power output = 4021.714 kw

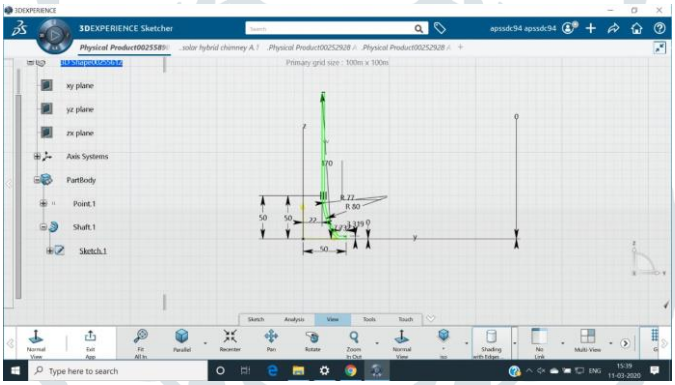
Torque = 423019 Nm

rpm = 100.55rpm

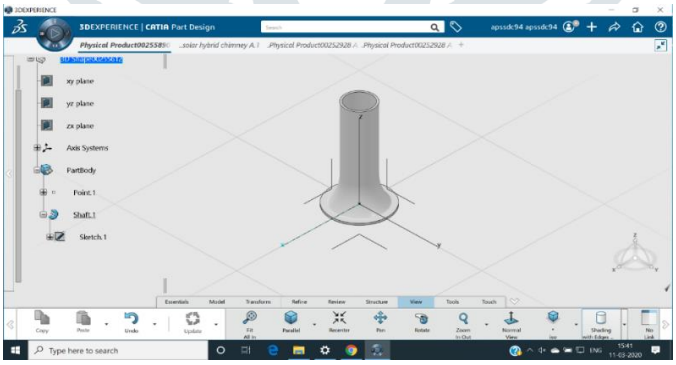
5. DESIGN PROCEDURE:

Solar hybrid chimney is designed by using CATIA software-Dassault Systems with the desired dimensions and specifications:

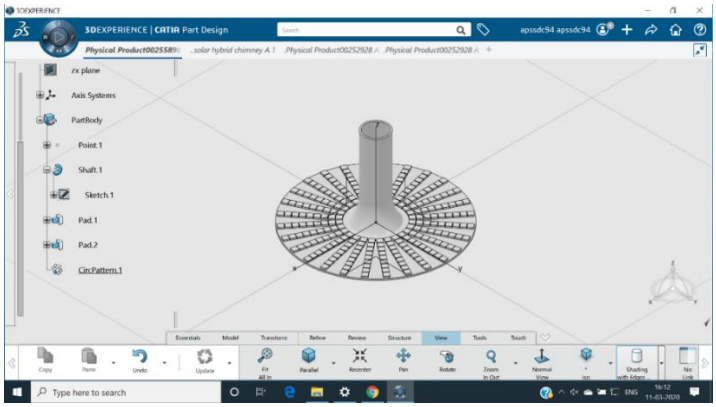
Solar chimney is designed like hyperbolic curved shape at bottom and divergent shape at top by using splines with required diameter by taking axis as reference line. The splines are constrained with correct dimensions and revolve the profile taking axis as reference line.



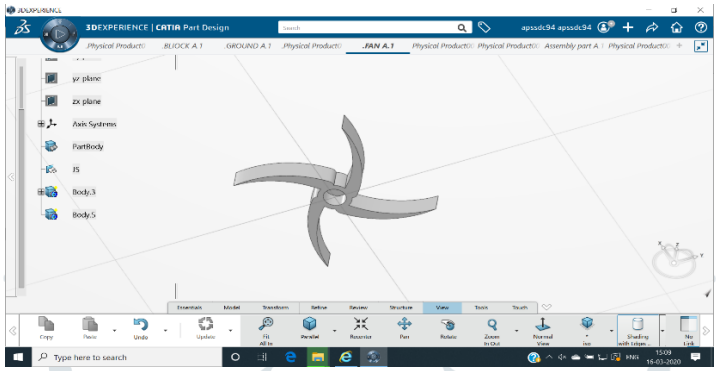
Dimensions of chimney



Solar collector is designed by selecting the plane and draw circular profile with desired dimensions and extrude it with pad tool up to required thickness and draw rectangle profile with desired dimensions and took chimney as reference and used mirror tool. In the same plane, rectangular profile is drawn and extrude it with pad tool.

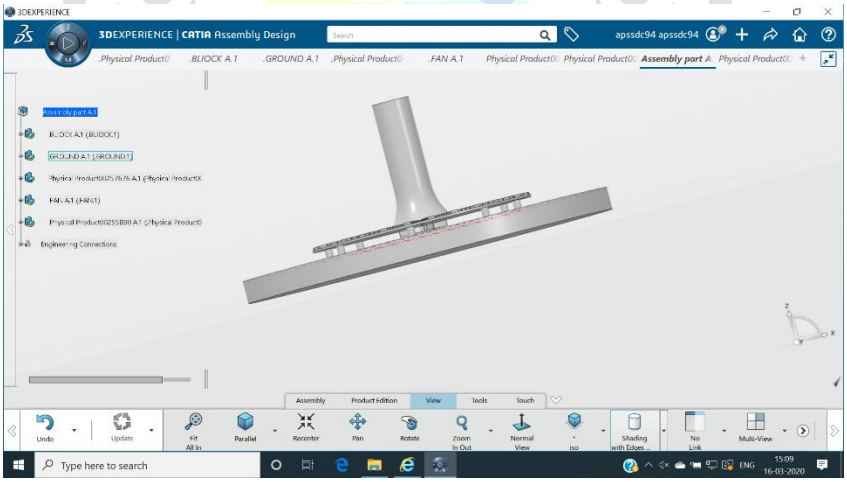


The shaft and generator is designed by using circular and rectangular profiles with required dimension and extrude them. The turbine and blades are designed by using two circular profiles with multisection and extrude them for required thickness.



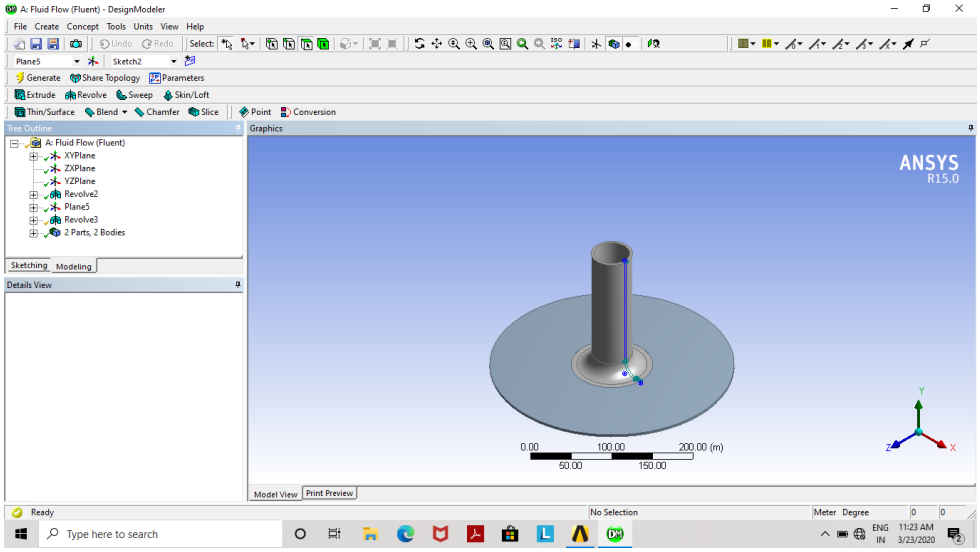
Turbine is designed as tapered section for rotate in conventional way with high speed and can easily flow outside throught chimney within less time. Thus, the efficiency of turbine will increase.

After designed, all the parts are assembled in correct position and applied kinematics to the turbine. Wind turbines can be classified by their mechanical power control, and further divided by their speed control. All turbine blades convert the motion of air across the airfoils to torque, and then regulate that torque in an attempt to capture as much energy as possible, yet prevent damage. At the top-level turbines can be classified as either stall regulated or pitch regulated.

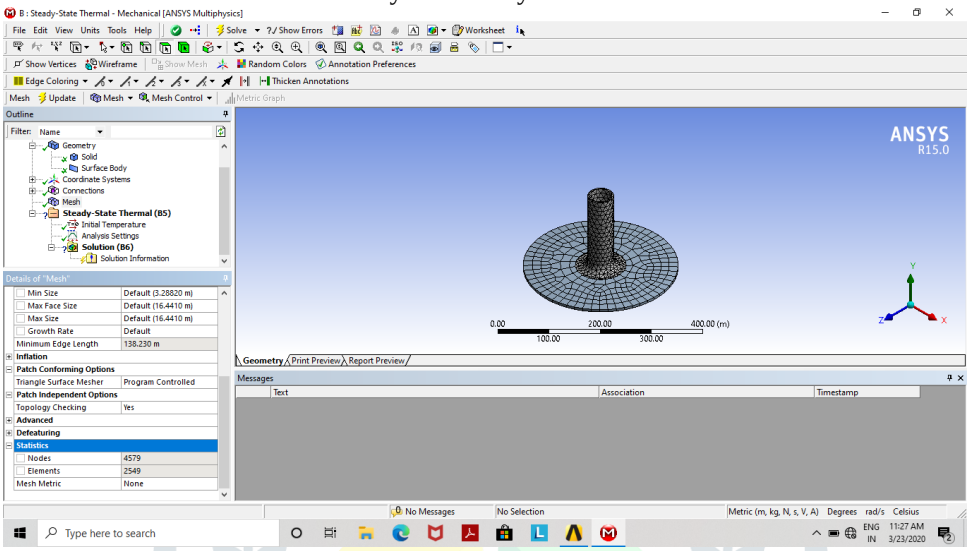


ANYLIZING OF PROJECT IN ANASYS:

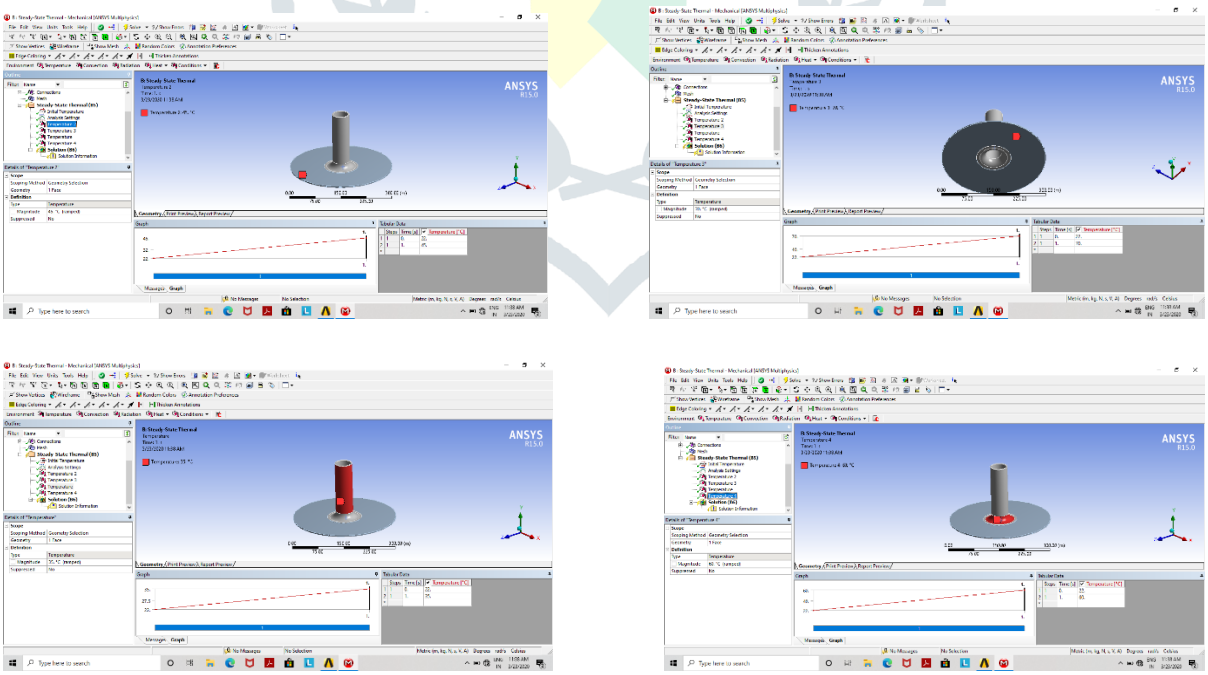
In ANSYS Workbench 15.0, we designed the solar hybrid chimney setup in static thermal with required dimensions. Applied mesh with relevance center as fine and created named selections for each section. The nodes and elements are 4579 and 2549. In the setup window, the materials, nichrome and stainless steel are added to solar collectors and to chimney.



Geometry of chimney and collector

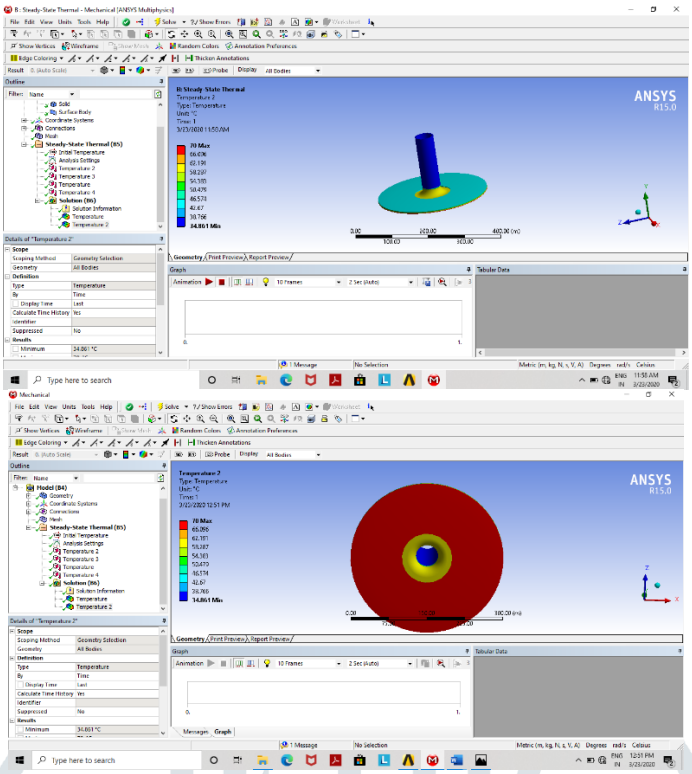


Meshing of chimney and collector



representing the temperatures at every position

In solution window, inserted the temperature and evaluated all the results with the required values.



temperature differences at each position

PARAMETERS:

Ac= Collector area
Ach= Area of the chimney entrance section
Cp= Specific heat capacity of air
H= Convention heat transfer
Hc= Collector height
Hch=Chimney height
K= Turbulence kinetic energy
mg= Mass flow rate
P= Static pressure
$Pp_{0=}$ Potential power output
Pr= Prandtl number
r= Radial number
R= Radius of hyperbolic divergence
Rc= Collector radius
Rch= Radius of chimney section
R_H= Ratio of radius and height of hyperbolic chimney
t= time
T= Temperature
u= Radial velocity

v=Air velocity
Vch= Air velocity at the chimney entrance
V out= Air velocity at the chimney exit
w= Axial velocity
z= Axial co-ordinates
β= Thermal expansion co-efficient
ΔT = Temperature rise in the collector
ΔP= Pressure drop in the chimney
ε= Dissipation rate of turbulence kinetic energy
λ= Thermal conductivity of air
μ= Dynamic viscosity
μ_t= Turbulence viscosity
ρ= Density of air
ρ_0= Reference density
ρ_{ch}= Density at the chimney entrance
η_c= Collector efficiency
η_{ch}= Chimney efficiency
η_T= Turbine efficiency

FUTURE SCOPE:

- This plant can also be used as heat exchanger which is used as to increase the temperature of the water given as input to the boiler in thermal power plants.
- The output of solar hybrid chimney can be used as fuel for electric vehicles in future.
- The electrical power generated from the solar hybrid is used for domestic purposes for the people of remote and deserted areas.

RESULT & CONCLUSION:

Some major numerical results and data that should be found during our project

1. The obtained power output from wind turbine = 4021 KW
2. Wind Speed at the inlet of turbine =33.34m/sec
3. Temperature produced beneath the layers of collectors =353k
4. The materials that are selected for the components based on their respective properties.
5. Efficiencies
   a) Chimney =68%
   b) Collectors=88.8%
   c) Turbine =50% (included losses)

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This paper we finally concluded that the enough power is generated through this solar hybrid chimney during normal day sunlight and we designed this solar chimney in CATIA 3D EXPERIENCE and analysis is also done in ANSYS software and effectives shapes for solar chimney is hyperbolic taper also concluded.

The nodes and elements that are obtained from ANSYS meshing are,

Nodes = 42278
Elements = 143981

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