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DESIGN AND ANALYSIS OF DIFFERENT SOLAR STILL STRUCTURES

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Abstract: Desalination can be defined as any process that removes salts from water. Desalination processes may be used in municipal, industrial, or commercial applications. With improvements in technology, desalination processes are becoming cost-competitive with other methods of producing usable water for our growing needs.

The conventional distillation process, though simple and effective, uses conventional sources of energy such as fossil fuels. Seeing the rapid depletion of conventional sources of energy and its impact on climate change over the decades, in this project, we have decided to use non – conventional SOLAR ENERGY source for the distillation of water. The project involves designing and analysis of solar stills which can produce enough distilled water. The analysis was done using meteorological data of Bengaluru i.e., temperature on hourly basis were our inputs. Theoretical analysis was done using heat equations of conduction, convection & radiation.

Ansys analysis includes thermal analysis of both top and bottom surface of the solar still this was done to address the heat loss due to reflection, convection, and conduction. The Ansys results shows the temperature of the solar stills and from which we can infer that there is a change in the same for different solar stills.

Index Terms – Solar Still, Solar Energy, Analysis, Temperature.

I. Introduction

Clean Water is a fundamental human need. Each person on Earth requires at least 20 to 50L of clean, safe water a day for drinking, cooking, and simply keeping themselves clean. Polluted water is not just dirty—it is deadly. Some 1.8 million people die every year of diarrheal diseases like cholera. Tens of millions of others are seriously sickened by a host of water-related ailments. And earth contains 97.5% as saline water and remaining as fresh water which is seldom fulfills the need of the humongous population. There are methods for desalination of sea water multi-stage flash distillation (MSF), multi-effect distillation (MES) and vapor compression distillation (VSD) but most of them uses conventional energy source to produce fresh water which again boils down to the fact that it contributes to climate change and global warming due to its high carbon emission and which indirectly affect freshwater availability.

This leads to question of renewable energy source for production of fresh water, this has been addressed using solar energy using solar still. But it has its own limitations, one of the most pronounced challenge is efficiency of the solar still. There is solution to increase the efficiency by modifying the solar still to optimize the output i.e., to increase volume of water produced by solar still. Modification ranges from design, amplification of sunlight to inclusion of other mechanical components like air compressor, air blower, thermal module etc. which increases the inlet temperature and in turn induce evaporation rate, hence increase the freshwater production.

In this project research on design aspect in the modification technique has been done, for which the three shapes viz. Pentagonal, Hexagonal & House shaped were analyzed and have come out with an optimum design shape. Though it is a small step in solar desalination field, but it will have dynamic effect on research having integrated modification of solar still as its study base.

Maximum yield was achieved using the least water depth [1]. The highest yield stills are the stepped with reflectors [2]. As the tilt angle increased the area of glass surface increases and this may increase the yield of fresh water [3]. Pyramid shape solar still has appropriate geometric shape of all among shape, also pyramid shape solar still is more efficient than single slope solar still.
Best inclination angle for ceiling was found to be 15deg & 25deg with base [7].

MODELING AND DESIGN MODULATION

DESIGN CREATION THROUGH SOLID EDGE

1.1 Software Used.

Three types of solar still models have been selected, House Shaped Solar Still, Pentagonal Pyramid Top Solar Still, Hexagonal Pyramid Top Solar still. House Shaped Solar still is mostly used model and easy to fabricate. We wanted to explore other designs too and we chose other two models as mentioned above.

The complete modeling of all the solar stills was designed in SOLID EDGE V19. We divided stills into top and bottom parts for making designing simple in the software and then we assembled those structures in the same software itself.

1.2 Design Parameters

The inclination angle for top inclined surfaces for all the three solar still is same and the angle is 15degrees. As per our literature survey we have found 15degrees would be a better inclination angle for our solar still design with respect to altitude of Bangalore. We kept same angles for all stills to know which is efficient at that inclination angle.

Base area of the stills is also fixed for all stills so that it would be easy for us to compare them and to know which is efficient at that inclination.

1. Base area fixed= 0.05 m^2
2. Height of base that we decided= 0.01 m
3. Volume of base (for all shapes) V= 0.05x0.01

   V= 5x10^-4 m^3

Inlet and Outlet sections are given to the design for pouring and collecting water. Separate sections are created inside base and are connected to outlet section to collect the condensed water.

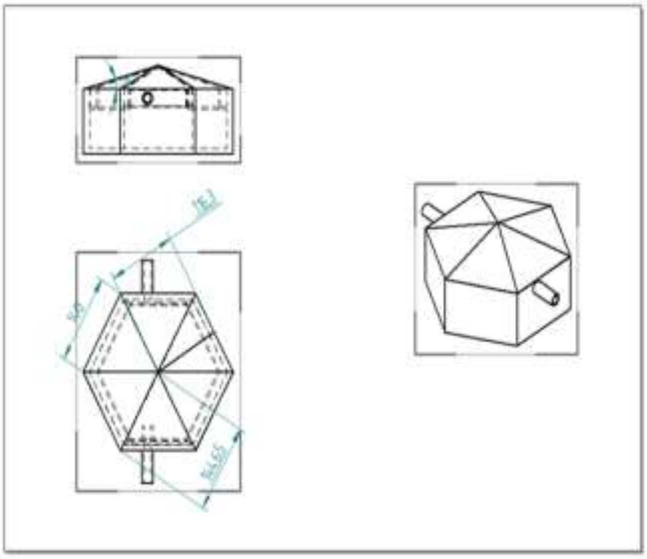

Fig 1 Hexagonal Pyramid Top Still

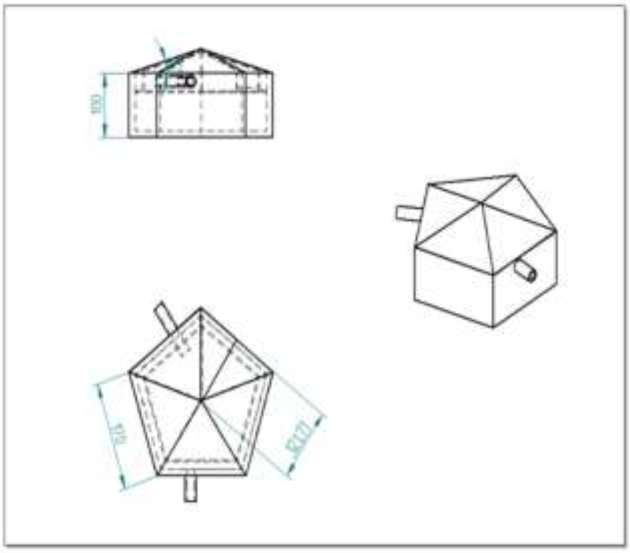

Fig 2 Pentagonal Pyramid Top Still

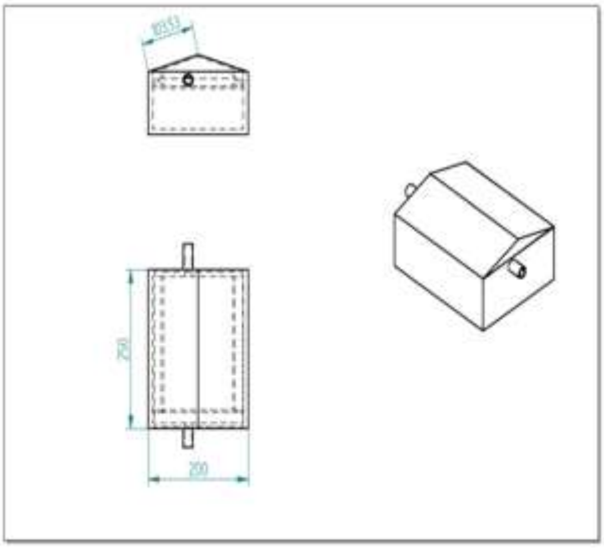

Fig 3 House Shape Still

All Dimensions are in mm.

After modeling them in the software, these models were imported to ANSYS in the form of ***iges*** files for Thermal Analysis.

2. MATHEMATICAL (THEORITICAL) ANALYSIS

For theoretical analysis, we have considered the inclined surfaces of all the three solar stills that are being exposed to the Sun. And for calculations we have taken some constants

2.1 Assumptions: -

Heat transfer is through Conduction from outside to inside of Solar Still.

2.2 Formulae Used: -

- Area of triangle- ½ *b * h - in (m^2)
- Q = q* A - in (W)

Where

- q= Heat flux
- A= Area of the surface exposed
- Q= Heat input on the surface exposed
- b= base of Triangle
- h= height of Triangle

Constants: -

- K= Thermal Conductivity of Glass= 1 W/mK
- L= Thickness of Glass= 5mm
- Energy reaching earth's atmosphere = 1388 W/m2
- Assuming- 50% loss in energy (due to atmosphere, pollution, noise, sound etc)

Hence, energy reaching earth's surface (q) = 694 W/m^2 (Constantly being reached)

1. Base area fixed= 0.05 m²
2. Height of base that we decided= 0.01 m
3. Volume of base (for all shapes) V= 0.05x0.01

V= 5x10^-4 m^3

2.3.1 Analysis of House Structure

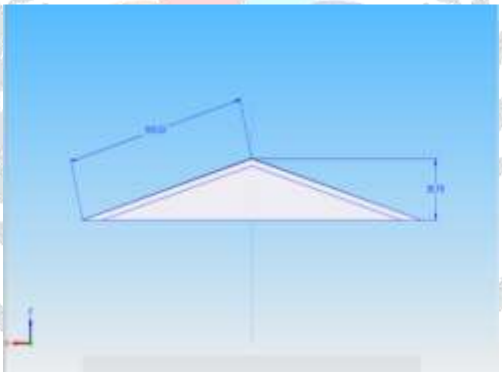

Fig 4 House Shape Still

Exposed Area - (1 side) is a rectangle

$$A= 10.357 * 25 * 10^{-4} = 0.025 \text{ m}^2$$

Heat input on one side is Q= q * A

Q= 694 * 0.025

Q= 17.35 W (on one side)

2.3.2 Analysis of Pentagonal Structure

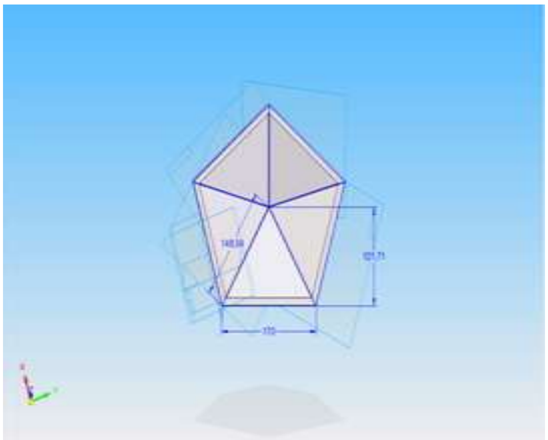

Fig 5 Pentagonal Shape Still

Area exposed – Triangles.

(The triangle in figure is divided into two right angled triangles for easy calculation purpose. That is why the area is being multiplied by 2)

A= $(1/2 * 8.5 * 12.17 * 10^{-4}) * 2 = 0.0103\ m^2$

Heat input on one side is Q = q * A

Q= 694 * 0.0103

Q=7.14 W (on one side)

2.3.3 Analysis of Hexagonal Structure

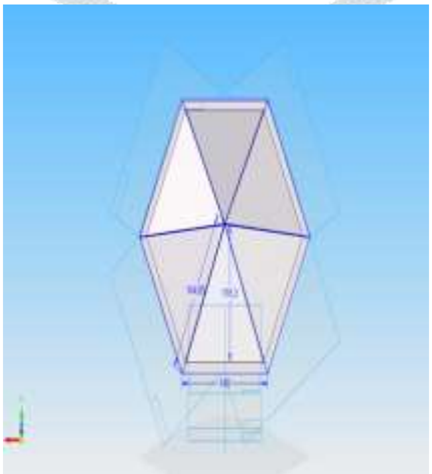

Fig 6 Hexagonal Shape Still

Area of Triangle exposed

Area of Triangle (The triangle in figure is divided into two right angled triangles for easy calculation purpose. That is why the area is being multiplied by 2)

$A= 2 * (1/2 * 7 * 11.63 * 10^{-4})= 0.0162m^2$

Heat input on one side - Q = q * A

Q= 694 * 0.0162

Q= 11.24 W (on one side).

On one inclined surface of **the house structure, the heat input is 17.35 W**. During peak hours, both the surfaces will be exposed to the sun. So, total heat input will be two times the value (since two surfaces are present).

Total value of heat input during peak hours on **House Solar Still Structure** is= **34.7 W.**

On one inclined surface of **the Pentagonal structure**, **the heat input is 7.14 W**. During peak hours, all the surfaces will be exposed to the sun. So, total heat input will be five times the value (since five surfaces are present).

Total value of heat input during peak hours on **Pentagonal Pyramid Top Solar Still Structure** is= **35.7 W.**

On one inclined surface of **the Hexagonal Structure, the heat input is 11.24 W**. During peak hours, all the surfaces will be exposed to the sun. So, total heat input will be six times the value (since six surfaces are present).

Total value of heat input during peak hours on the **Hexagonal Pyramid Top Solar Still Structure** is= **67.44 W.**

3. NUMERICAL ANALYSIS (THERMAL)

3.1 Geometric Modeling of Hexagonal, Pentagonal and House Shaped Solar Still

A three-dimensional CAD model of hexagonal prism, pentagonal prism, and House Shape Solar Stills were designed using Solid Edge, also the models were divided into top and base part for better Analysis. Figure… shows the CAD model of Top and Base part of the Hexagonal Prism shaped solar still geometry. Then in Ansys Transient Thermal Analysis system was selected. Under Engineering Data materials taken are: -

Normal Glass, and Acrylic and their properties Density, Thermal conductivity, Specific Heat, Melting Temperature are being provided.

Acrylic properties-

- Thermal conductivity = 0.18 W/mk
- Density = 1180 kg/m^3
- Specific heat Cp = 1.36e3 - 1.43e3 J/kg °C
- Melting Temp = 160 degrees

Glass Properties-

- Thermal conductivity = 0.8 W/mk
- Density = 2500 kg/m^3
- Specific heat Cp = 792 J/kg k
- Melting temp = 1600 °C

3.2 Meshing of the Model

After geometry creation and importing to ANSYS, the next step is to generate the mesh of the CAD models. Here, the problem domain was divided into many small elements. The governing equations were solved for each of this element to simulate the physical phenomena. Mesh independent study was carried out for the top part and found that the total number of elements in the meshed model is 3,466 and number of nodes is 7,157. Here, tetrahedral type of mesh was generated. The scientific reason behind automatic generation of tetrahedral mesh is because of the shape of the Geometry, which is Irregular and complex**. Fig 3.1, 3.2** shows the meshing of the Thermal Analysis Models which were imported from Solid Edge as .iges files.

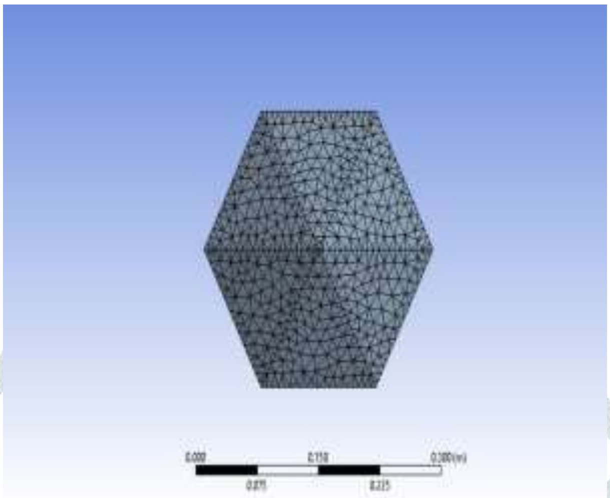

Fig 7 Meshing of the Top part of Hexagonal Domain

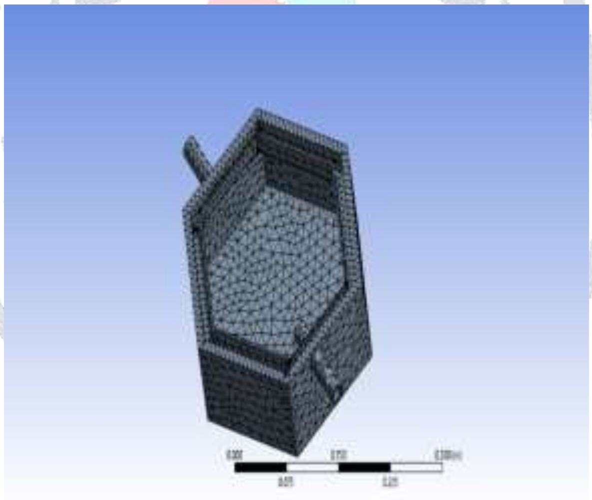

Fig 8 Meshing of the base part of Hexagonal Domain

3.3 Boundary Conditions and Initial Conditions

Solar radiations fall on the upper glass, which then passes through it due to its transmissivity. Material of the Geometry were specified and Physical and thermal properties of materials such as density, specific heat capacity and thermal conductivity.

used for the analysis were also specified, most of the boundary conditions are determined by the physical phenomena. Here, radiation is applied on the outer glass surface. The emissivity of glass is 0.89 and ambient temperature considered as 32 ℃.

3.4 Transient Thermal Analysis Results

ANSYS FLUENT 2020 R2 version is used to find the Transient Thermal Analysis result. Analysis of the hexagonal pyramid (glass surface) of hexagonal solar still was carried out and it was assumed to face the maximum temperature during day which is from 11:00 to 15:00 h according to the longitude, latitude and GMT of the working area which was Bangalore. In case of a solar still, temperatures attained by glass covers and interior plays a vital role for the distillation of water. The temperature and the heat flux on the inner surface of the hexagonal pyramid were found. **Fig. 4.1.1, 4.1.2, 4.2.1, 4.2.2, 4.3.1, 4.3.2** shows the Transient Thermal Analysis Results.

Table 1. Transient Thermal Analysis Results of Solar Stills

SOLAR STILLS	TEMPERATURE (°C) (maximum)	HEAT FLUX (W/m²) (maximum)
Hexagonal Prism	22.142	61.247
Pentagonal Prism	22.197	85.033
House shape	22.214	168.32

4. RESULTS AND DISCUSSION

4.1 Thermal Analysis of Hexagonal Pyramid Structure

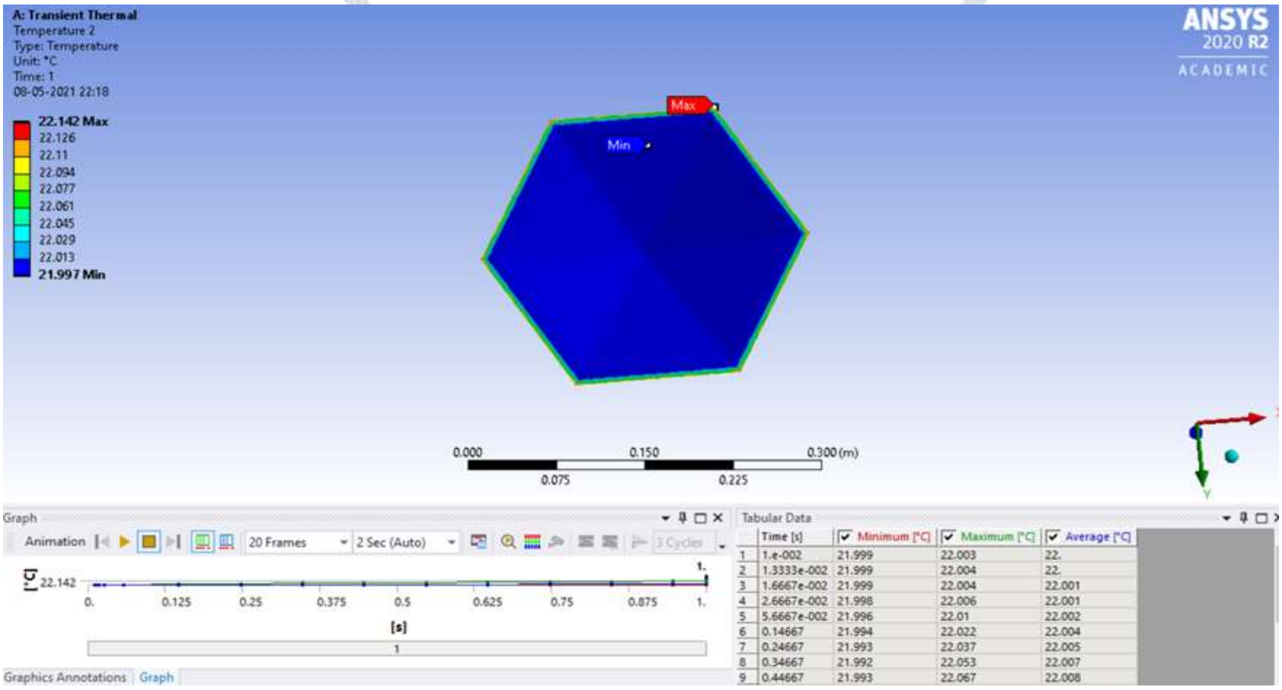

Fig 9 Temperature Analysis of Hexagonal Top

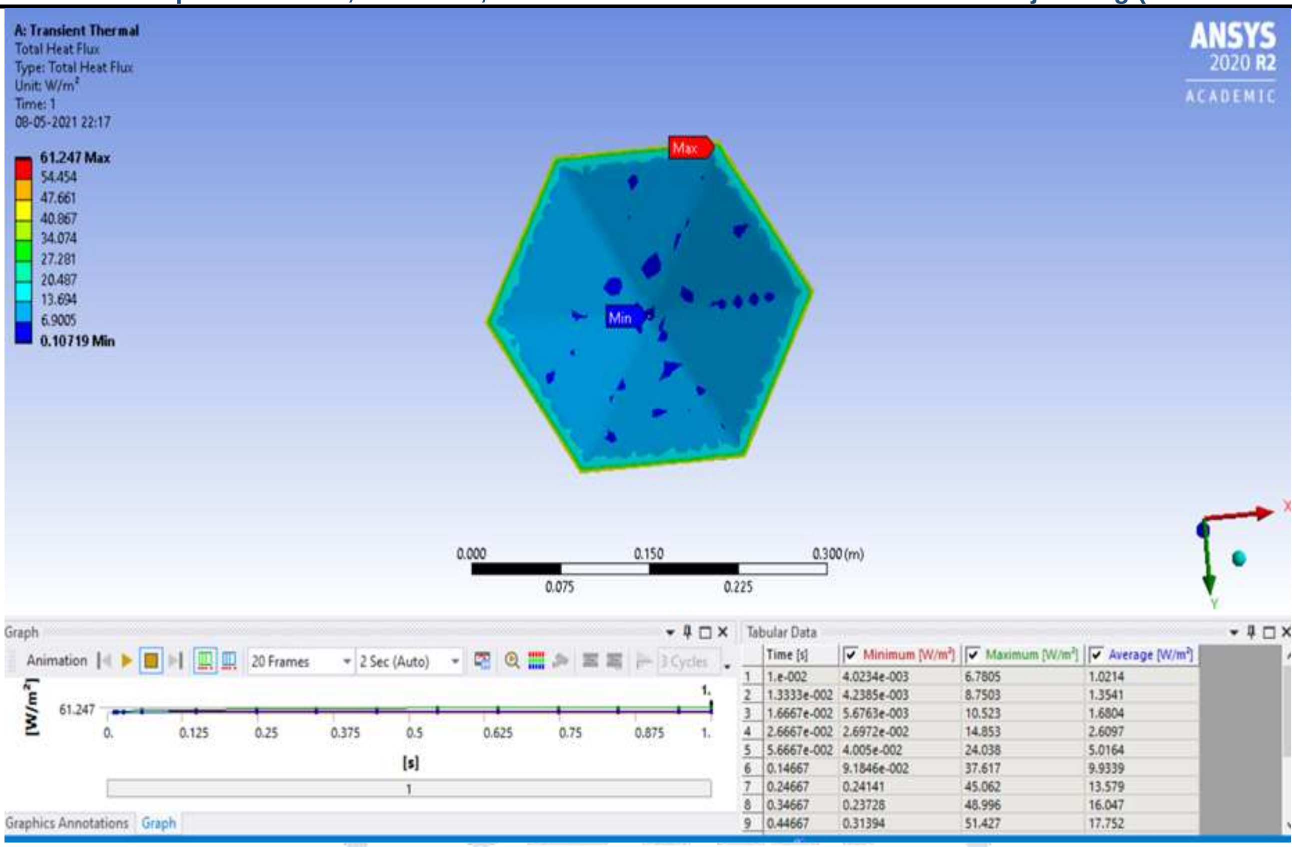

Fig 10 Heat flux Analysis of Hexagonal Bottom

In **Fig. 6** the Maximum temperature of Hexagonal Top was found to be **22.142°C** and the Minimum Temperature found was **21.997°C.** From **Fig. 7** the maximum heat flux on the top of Hexagonal pyramid was found to be **61.247 W/m²**.

4.2 Thermal Analysis of House Shaped Structure

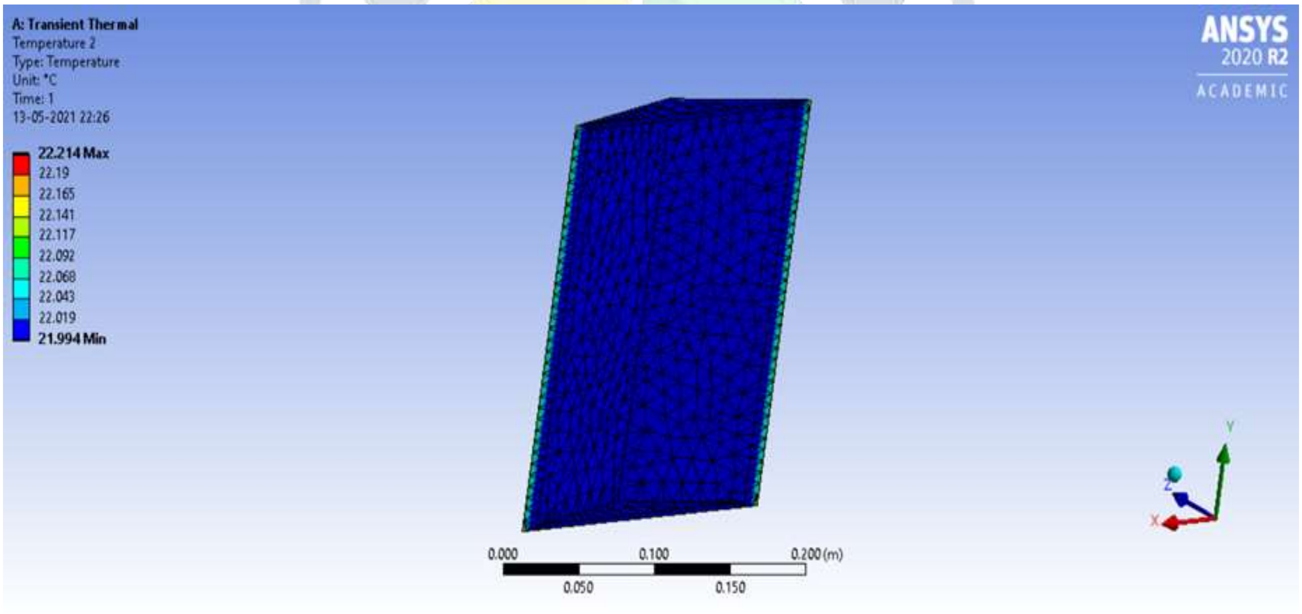

Fig 11 Temperature Analysis of House Top

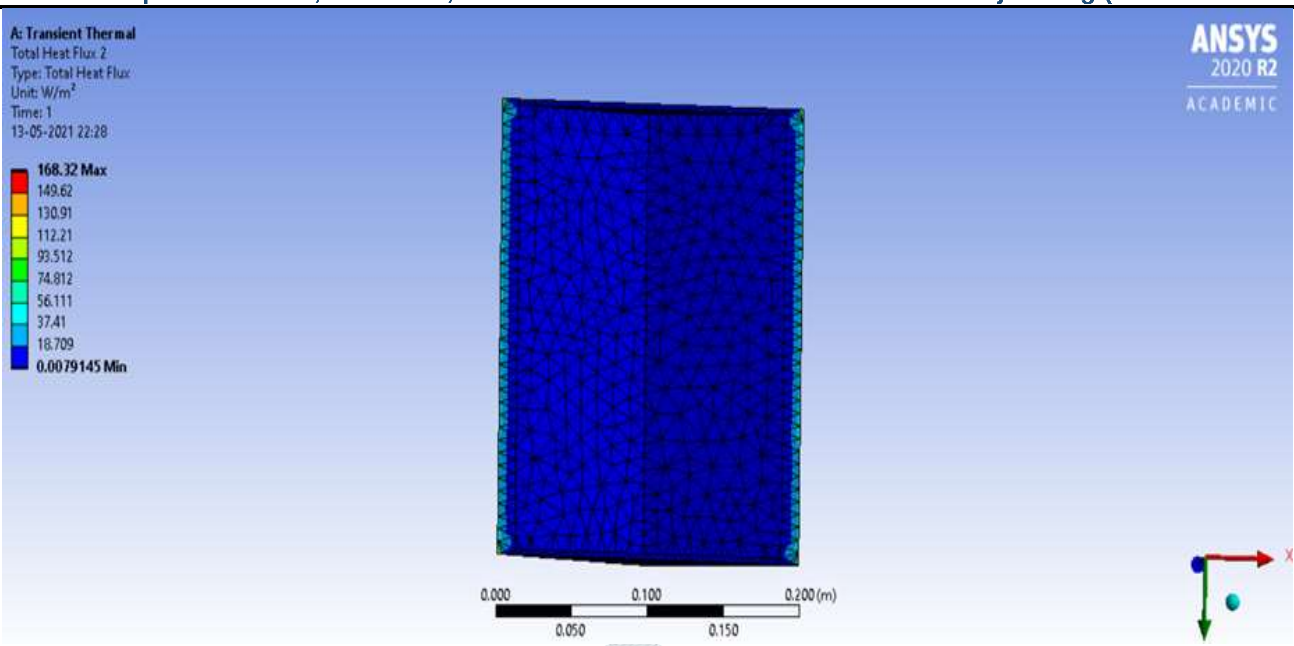

Fig 12 Heat Flux Analysis of House Top

In **Fig. 8** the Maximum temperature of House Top was found to be **22.214°C** and in the Minimum Temperature found was **21.994°C.** From **Fig. 9** the maximum heat flux on the top of House Top was found to be **168.32 W/m²**.

4.3 Thermal Analysis of Pentagonal Pyramid Structure

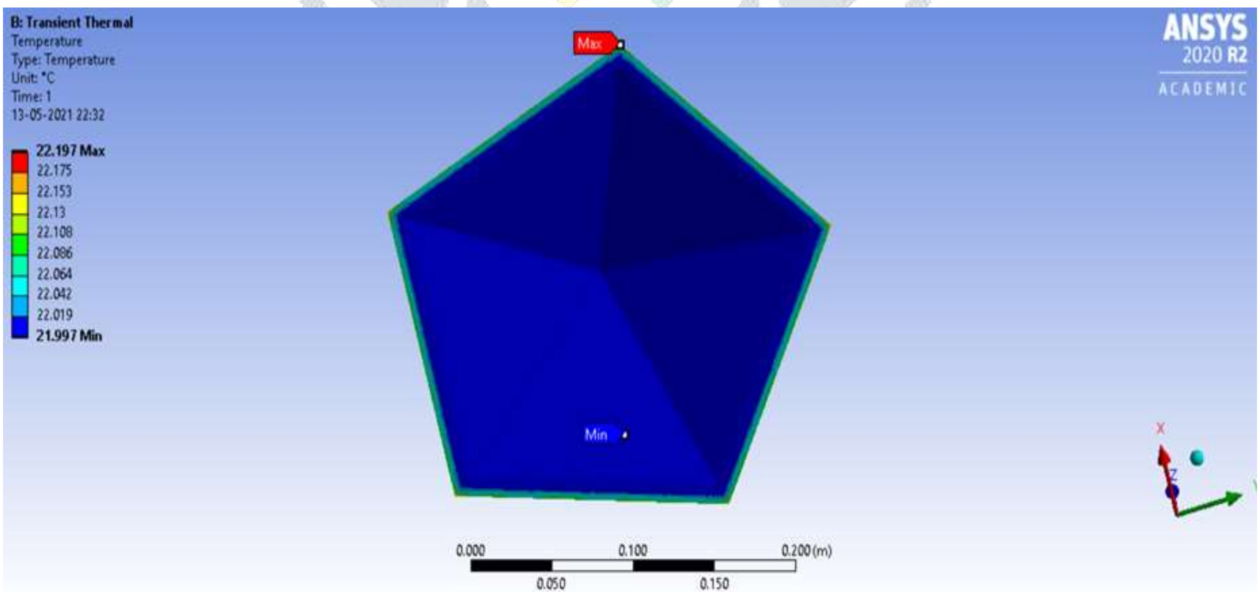

Fig 13 Temperature Analysis of Pentagonal Top

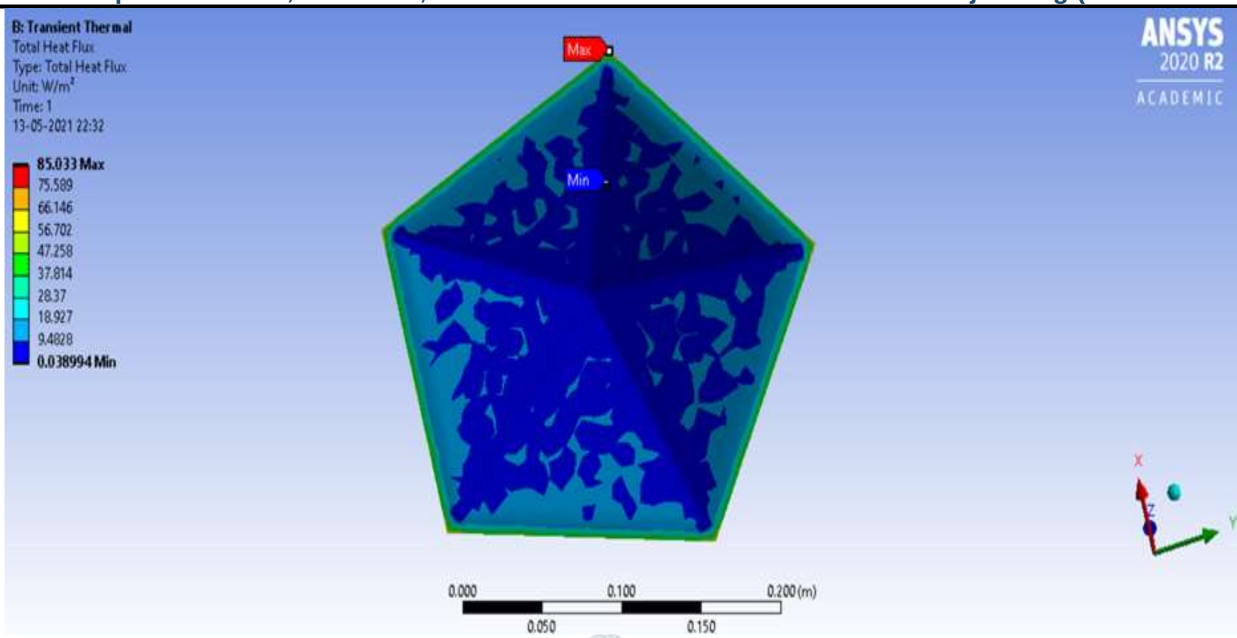

Fig 14 Heat Flux Analysis of Pentagonal Top

In **Fig. 10** the maximum temperature of the Pentagonal Top found to be **22.197℃** and minimum temperature was **21.997℃**. From **Fig.11**, maximum Heat flux of the Pentagonal top found to be **85.033 W/m².**

The main objective of this study was to perform experimental investigations, develop a three-dimensional Geometrical model of House Shape, Pentagonal Shape, Hexagonal Shape solar stills and compare the Theoretical and Numerical results. The setup was made ready as per the required dimensions. Upper and lower glass temperatures, and ambient temperature were taken an average from time range of 10AM to 2PM.

Then, a three-dimensional geometric model of solar still was developed in Solid Edge software through part modelling. The appropriate models were then selected for the physical phenomena occurring in the solar still. Material properties and appropriate boundary conditions were defined in ANSYS for Thermal Analysis of the problem. Thermal Analysis was conducted for unsteady state conditions with the ANSYS 2020 R2.

From the results of theoretical analysis, we can understand that the flux that is being transmitted inside solar still is very high in Hexagonal Pyramid Top Sill when compared to Pentagonal Pyramid Top Still & House Shape Still.

Even though the base area was same to all the stills, and the inclination angle of the inclined surfaces area same the heat flux was varying. This is because the area that is being exposed to the sun is varying.

In Hexagonal Pyramid Top Still, the total area of the triangles combined is higher than the total areas of the other two solar stills exposed areas that we considered for analysis. And hence, more heat flux was also able to get inside solar still.

This indicates that more heat will be absorbed by the water inside Hexagonal Pyramid Solar Still and more water gets evaporated and as output we get purer water when compared to other solar still structures.

From our analysis we can conclude that, when more area is being exposed to the sun more heat flux is being transferred into the still. And if there is more heat flux transfer into to the still, we get more pure water as output.

And when compared to all the structures that we considered for analysis, Hexagonal Pyramid Top Solar Still Structure can bring us best result if tested experimentally.

5. CONCLUSIONS

The following conclusions were made from Theoretical and Numerical Analysis:

- Solar stills have distillate output as it utilizes latent heat of condensation to raise the temperature.
- Glass temperatures increase with time from 10:00 a.m. up to 02:00 p.m. as solar radiation intensity increases and further decreases as time proceeds. Hence, it can be said that they follow a similar trend to that of solar radiations.
- The contours of glass temperatures also show that temperatures on the lower end of condensing glass are relatively less than the temperatures at the upper part of the glass. This is because freshwater slides down on the inner wall surface from upper part to the lower side of the glass covers.

- From theoretical analysis, we can conclude that more area exposed to sun, more the heat flux can be transmitted inside still. And Hexagonal Pyramid Solar Still shows the same quality. Hence, if tested experimentally, Hexagonal Pyramid Solar Still would bring us best results.
- From the numerical analysis, though the heat flux was a little higher in the house shape structure, the area upon which it is acting was very less. The heat flux value of the Hexagonal Pyramid Top Still was in an average range but the area on which it is exposed is very high. This can be a better option for fabrication even though flux is not as high as house structure, the area upon which the flux is being transmitted is high in Hexagonal Pyramid Solar Still.
- Water output completely depends on the base area, the area through which the heat flux is transmitted, the duration that maximum surfaces that are being exposed to sun and weather conditions. As base area and exposed area increases, output of pure water increases gradually. During a sunny day, we can expect more water output.

6. SCOPE FOR FUTURE

Our project was mainly based on designing and analyzing different solar still structures with same base area and same inclination angles of inclined surfaces and to analyze them theoretically and analytically so that one of the best results giving model can be compared and selected among them.

By considering our theoretical and analytical results, one can verify our results experimentally.

Experimental results of our project can help one to redesign and restructure the solar stills with respect to altitude foe increasing their efficiency.

Solar Stills are still under research and development for the best models for best output with respect to the altitude where they wii be used considering the climatic conditions. There is a lot of scope in this field where one can develop different kinds of structures which can give a better result and can save world from water crisis.

REFERENCES

[1] Manoj Kumar Gautam, Bhupendra Gupta, Jyoti Bhalavi, 2019- A Review on Various Solar Still Designs. IJRTI | 4(6) Pages 43-52

[2] Yield P K Nagarajan and Arunkumar Thirugnansambantham, 2016- Geometrical Variations in Solar Stills for Improving the Fresh Water. Taylor & Francis Journal

[3] Ravishankar Sathyamurthy, D. G. Harris Samuel & S. A. El-Agouz, 2015- A Review of Different Solar Still for Augmenting Fresh Water Yield. 8(6) Pages 244-265

[4] Amitava Bhattacharyya- Solar Stills for Desalination of Water in Rural Households, 2013 International Journal of Environment and Sustainability. | 2(1), Pages 21-30

[5] Kuldeep- Pyramid Solar Still, 2018- A Comprehensive Review. ELSEVIER 81(1), Pages 136-148.

[6] Abdul Jabbar N. Khalifa, 2011- On the effect of cover tilt angle of the simple solar still on its productivity in different seasons and latitudes. ELSEVIER 52(1) Pages 431-436.

[7] Hanane.Aburideh, Adel.Deliou, Brahim.Abbad, Fatma Alaoui, Djilali.Tassalit and Zahia.Tigrine, 2012 - Experimental Study of a Solar Still. Published by Elsevier Ltd. Selection and peer-review under responsibility of ISWEE’11. Pages 475-484

[8] SS Naygaonka 2015- Design and Experimental Analysis of Double Slope Single Basin Solar Still.