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Experimental and CFD Investigation of improved Solar Dryer

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Abstract: *The principle objective of the current work is to upgrade the warming presentation with further developed plan of nursery sun oriented dryer involving Computational liquid dynamic for Bhopal area it is 23.25° and 77.33° to have scope and longitude. This examination is performed on most sweltering day may 21th in the year to obtain greatest potential outcomes. Three different plan of sunlight based dryer have been utilized to anticipate warming execution on upward, mid and base planes. The mathematical boundaries for the sun oriented dryers are 1.2 x 1.2 x 1.5 m, the tallness of the side dividers from ground is 0.65 m, bay hole on four side of the dryer 0.01 m and the negative mass stream pace of the fan arrangement measurement of 0.15 m. Polycarbonate sheet is covered over the rooftop which assists with permitting the infrared radiation inside the dryer. Results show that the greatest temperature of 56.81oC where seen at 02 pm on mid plane inside the sun powered dryer for proposed plan which was more than base model since most extreme sun oriented radiation fall on the rooftop and caught inside the sun based dryer which makes nursery impact.*
Keywords: *solar, CFD, CAD, Dryer , Efficiency Evaluation.*

I. INTRODUCTION

Drying or dehydration of a material say by employing solar energy means removal of moisture from the interior of the material to the surface and then to remove this moisture from the surface of the drying material [1]. Drying is the removal of moisture from the food product by passing either ambient or hot air through the product or it is the heat and mass transfer solar dehydration process.

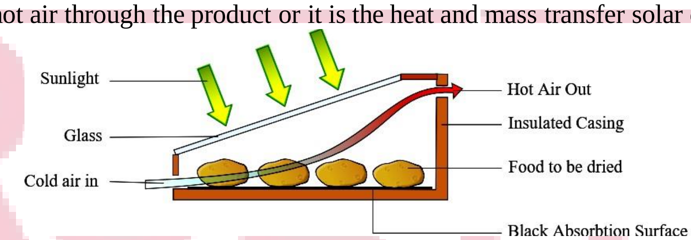

Figure 01: Direct type solar dryer

Norton & Brian have suggested two broad categories of solar dryers, direct dryers and indirect dryers, direct solar dryers exposed the substance to be dehydrated or dried to direct sunlight. They have a black absorbing surface which collects sunlight and converts it into heat; the substance that needs to be dried is placed directly on the surface for drying [2][3][4]. These dryers may have enclosure, glass covers and or vents in order to increase efficiency. In indirect solar dryers a black absorption surface absorbs sunlight and converts it into heat. A vent allows air to flow across the hot surface, the flowing air gains heat as it passes over the absorption surface. The hot air is then made to pass through the substance that needs to be dried. The air takes of moisture from the substance thus dehydrating it and is removed off via a chimney [5][6].

II. LITERATURE REVIEW

Petros Demissie at el. [1] In this paper solar power indirect solar dryer is designed and developed. The solar dryer unit consists of solar collector unit drying chamber with two columns of four rack shelves, chimney for the exhaust air, and a solar powered fan. The outlet of the dryer is designed in truncated pyramid geometry so that precipitation of condensed water would be minimized and additional heating of the drying air is possible at the exit. The dryer is developed and manufactured in Mekelle, Ethiopia. Computational Fluid Dynamics, CFD is employed for predicting a transient three dimensional flow field and temperature distribution within the drying chamber using a symmetric flow domain.

Noureddine Choaba at el. [2] This paper provides an updated literature review about greenhouse systems and helps to identify the most preferable characteristics of a greenhouse for diverse climates and operating conditions. Data on appropriate properties of the covering materials and comparisons of several cladding materials were extensively discussed. Rasaq. O. Lamidi at el. [3] this paper aims to present a state of the art review on the contributions of combined power and drying, application of phase change materials and hybrid drying systems with regard to agricultural products. Based on this comprehensive summarization, it is indicated that deployment of biomass powered combined heat and power systems might be a good solution to post-harvest wastes since both electricity and heat for drying of agricultural products can be simultaneously obtained.

Messaoud Sandali at el. [4] Aiming to improve the thermal performance of a direct solar dryer, a new technique of heat supply was proposed and investigated using a double level tubular heat exchanger with geothermal water, constructed in LENREZA laboratory.

The heat exchanger was placed deliberately above the absorber plate facing the holes so as to enable the air penetration. The temperature of the circulating water was set to 70°C analogically to that of geothermal water in southern regions of Algeria. The experiment was carried out in LENREZA laboratory, University of Ouargla, Algeria. Atta Ullah at el. [5] In this work, they have tried to briefly summarize the CFD simulations of biomass systems especially after the year 2010 with focus on the drag models being used under the framework of Eulerian methodology.

III. OBJECTIVE

There are following objective of the present work

1. To perform Computational Fluid Dynamics analysis on base model to predict the effect of maximum heating inside the greenhouse solar dryer for Bhopal city.
2. To create new different models of solar dryer for maximizing the heating performance.
3. To perform Computational Fluid Dynamics analysis on proposed design of solar dryer for maximizing the heating performance.
4. To compare the results and proposed enhance model of greenhouse solar dryer with highest drying rate.

IV. METHODOLOGY

Drying is a process used to transfer the heat to the product from the source and remove moisture from the product to its confined space [7][8]. In solar drying, the heat necessary for drying is mainly obtained from solar energy. The air circulation to the dryer can bemade using forced or by natural convection. In natural greenhouse solar dryer the motion of the fluid is occurred by buoyancy forces which are induced by the differences in densities due to the temperature variation in the fluid. In forced greenhouse solar dryer the fluid flow is achieved by external sources like fan, fans can increase the thermal performance of the dryer and payback time can be reduced. The quality of products obtained in the greenhouse solar dryer is high, Greenhouse solar dryer is one of the best among other types of dryers and has 2-5 times more effective device for drying purpose. Greenhouse solar dryer is an enclosed structure which has transparent walls and roof.

The dimensions of the greenhouse dryer are 1.2 x 1.2 x 1.5 m. The height of the sidewalls from ground is 0.65 m, inlet gap on four side of the dryer 0.01 m and the negative mass flow rate of the fan provision diameter of 0.15 m. A DC fan is used for forced mode and also to provide thermal heating which creates a greenhouse environment. A ultra violate stabilized polycarbonate sheet is covered over the roof which helps to allow the radiation inside the dryer.

I. CAD MODELING:

In the present work a three dimensional CAD model of greenhouse solar dryer is created with the help of design modular of ANSYS workbench. The length and width of the solar dryer is 1200 mm and height is 1500, inlet gap on four sides of the 100 mm is provided for in hot air, a circular hole for fan of 150 mm is provided for forcing air inside the green house solar dryer as shown in figure No 2.

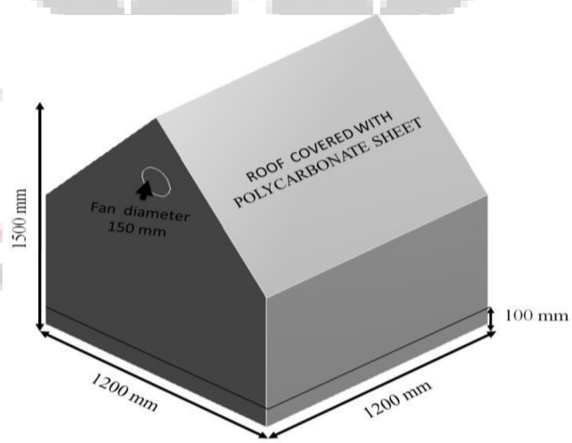

Figure 02: Three Dimensional CAD model of solar dryer [10]

Mehing: Meshing is a operation in which CAD geometry is divided into large numbers of nodes and elements and the procedure to converting into small pieces or elements are called mesh. After completing of three dimensional CAD geometry of greenhouse solar dryer is imported in ANSYS workbench for further CFD analysis and the next step is meshing. The size of elements is set as 10 mm to generate mesh and the total no of nodes generated in the present work is 1213451 and total No. of Elements is 1404147. Types of elements used are hexahedral which is a rectangular in shape with eight nodes on each element.

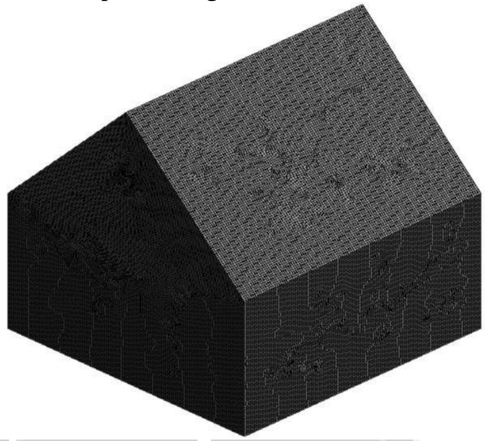

Figure 03: Meshing for greenhouse solar dryer

II. CAD GEOMETRY SOLAR DRYER PROPOSED DESIGN:

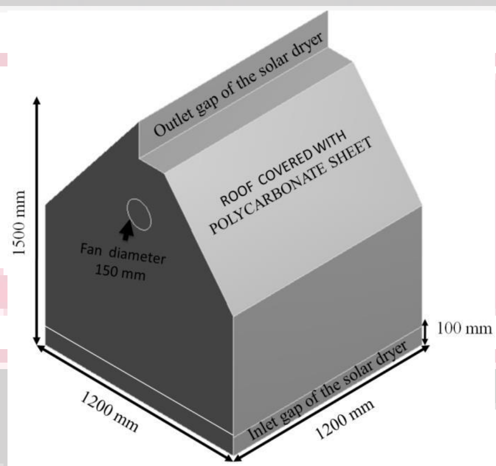

Figure 04: Three Dimensional CAD model of solar dryer proposed design

The length and width of the solar dryer is 1200 mm and height is 1500, inlet gap on four side of the 100 mm is provided for in hot air, a circular hole fan of 150 mm is provided for forcing air inside the green house solar dryer and 0.02 m opening at top of the solar dryer as shown in figure No 04.

Meshing: The size of elements is set as 10 mm to generate mesh and the total no of nodes generated in the present work is 256593 and total No. of Elements is 149969. Types of elements used are hexahedral which is a tetrahedral in shape with eight nodes on each element.

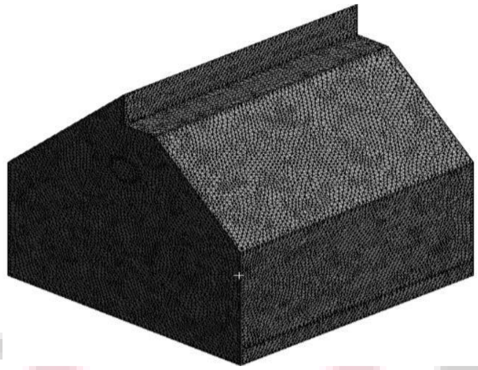

Figure 05: Meshing for greenhouse solar dryer proposed design

III. BOUNDARY CONDITION:

- To determine the temperature distribution inside the greenhouse solar dryer need to on energy equation.
- Defining of material property, set working fluid as air and roof covered with Polycarbonate sheet with thermal conductivity of 0.218W/m^{-} and Transmissibility, Reflectability & Emissivity 0.89, 0.8 and 0.95 respectively.
- Mass flow rate of 0.025 kg/sec, 0.05 kg/sec and 0.075 kg/sec used.
- For the outlet boundary condition the gauge pressure needs to be set as zero because the flow of air inside the greenhouse solardryer is atmospheric.
- Solar radiations were used on roof of the greenhouse solar dryer.

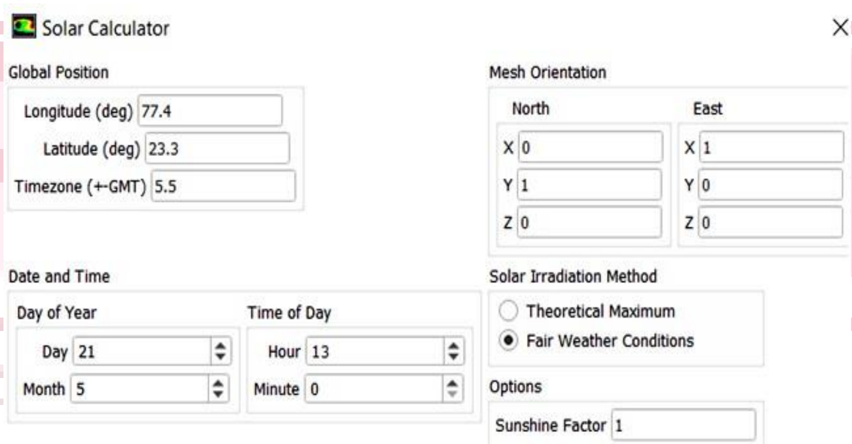

Figure 06: Solar load calculator

{Fair Weather Conditions:
Sun Direction Vector: X: 0.527902, Y: 0.0101271, Z: 0.849245
Sunshine Fraction: 1
Direct Normal Solar Irradiation (at Earth's surface) [W/m^2]: 876.47
Diffuse Solar Irradiation - vertical surface: [W/m^2]: 92.0533
Diffuse Solar Irradiation - horizontal surface [W/m^2]: 106.053
Ground Reflected Solar Irradiation - vertical surface [W/m^2]: 85.039}

- The fluent solver is used for steady analysis.

V. RESULT ANALYSIS

For the validation of this work the three dimensional CAD geometry of solar dryer is taken from a research paper of *M.Purusothaman & T.N.Valarmathi "Computational Fluid Dynamics Analysis of Greenhouse Solar Dryer" International Journal of Ambient Energy (2018), Taylor & Francis & Informa UK Limited, trading as Taylor & Francis, DOI:10.1080/01430750.2018.1437567.* The radiation model is used for Bhopal location having latitude and longitude is 23.25°N and 77.33°E [9] respectively.

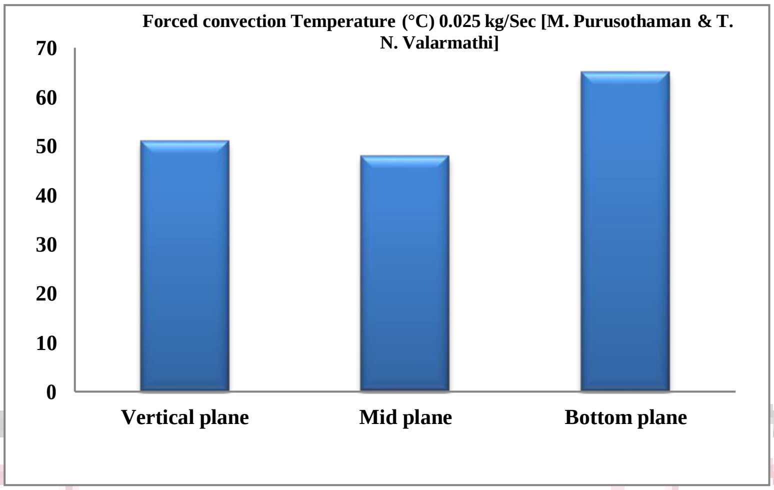

Figure 07: Forced convection Temperature (°C) 0.025 kg/Sec [M. Purusothaman & T. N. Valarmathi]

The compared result between base paper [10] and present work with same boundary conditions it is clearly observed that the maximum temperature at different planes considered (vertical, mid and bottom planes) for mass flow rate at 0.025 kg/sec for both base paper and present work with 9.98 to 15.2% difference due to selected location which show a very good agreement between base paper and present work.

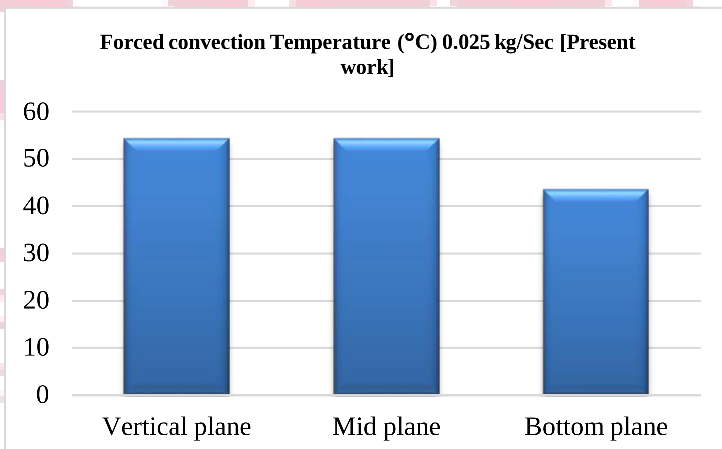

Figure 08: Forced convection Temperature (°C) 0.025 kg/Sec [Present work]

IV. COMPUTATIONAL FLUID DYNAMIC ANALYSIS ON GREENHOUSE SOLAR DRYER FOR BASE MODEL:

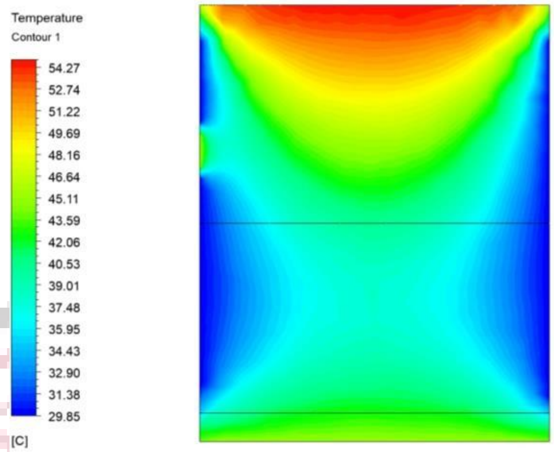

Figure 09: Temperature contour inside the solar dryer at 02 pm on vertical plane

It is observed from the temperature contour diagram at vertical plane at 02 PM ranging from 29.85 ºC to 54.27 ºC. The maximum temperature at the top surface is 54.27 ºC.

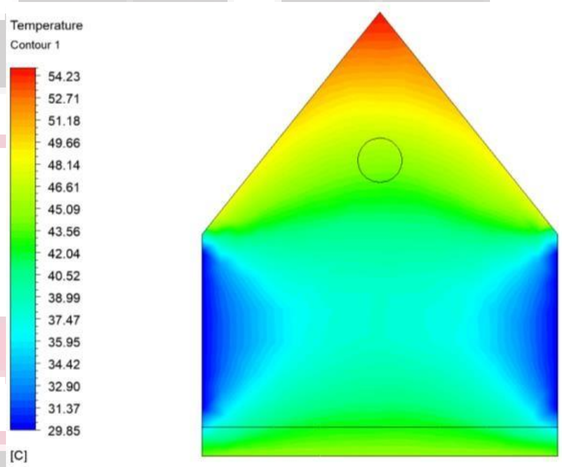

Figure 10: Temperature contour inside the solar dryer at 02 pm on mid plane

After performing computational fluid dynamics analysis it is observed from the temperature contour diagram at mid plane at 02 pmranging from 29.85 ºC to 54.23 ºC. The maximum temperature at the top surface is 54.23 ºC.

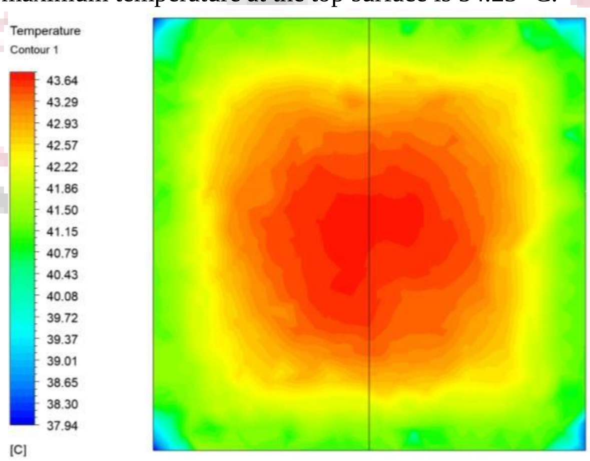

Figure 11: Temperature contour inside the solar dryer at 01 pm on bottom plane

After performing computational fluid dynamics analysis it is observed from the temperature contour diagram at bottom plane at 02 pmranging from 33.85 ºC to 43.64 ºC. The maximum temperature at the top surface is 43.64 ºC.

V. COMPUTATIONAL FLUID DYNAMIC ANALYSIS ON GREENHOUSE SOLAR DRYER FOR PROPOSED DESIGN:

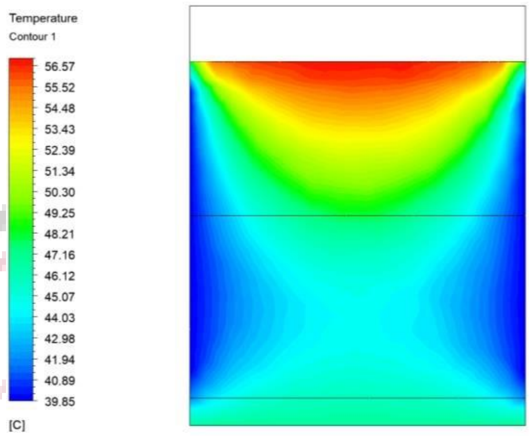

Figure 12: Temperature contour inside the solar dryer at 02 PM on vertical plane

It is observed from the temperature contour diagram at vertical plane at 02 PM ranging from 39.85 ºC to 56.57 ºC. The maximum temperature at the top surface is 56.57 ºC.

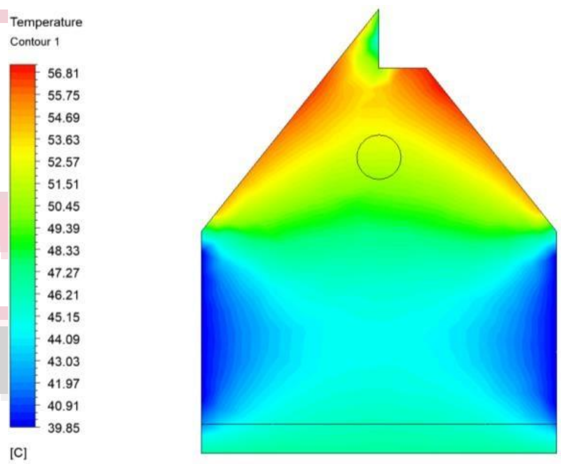

Figure 13: Temperature contour inside the solar dryer at 02 PM on mid plane

After performing computational fluid dynamics analysis it is observed from the temperature contour diagram at mid plane at 02 PM ranging from 39.85 ºC to 56.81 ºC. The maximum temperature at the top surface is 56.81 ºC.

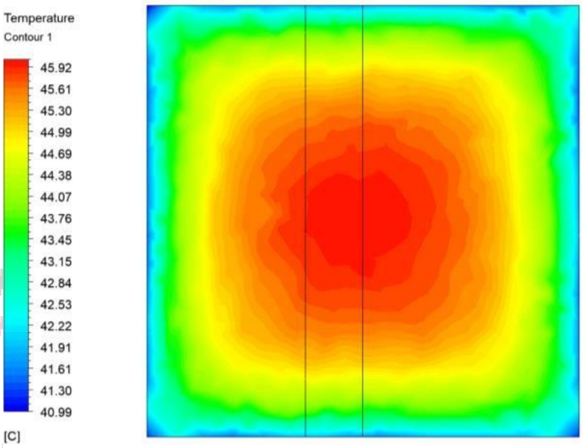

Figure 14: Temperature contour inside the solar dryer at 02 PM on bottom plane

After performing computational fluid dynamics analysis it is observed from the temperature contour diagram at bottom plane at 02 PM ranging from 40.99 ºC to 45.92 ºC. The maximum temperature at the top surface is 45.92 ºC.

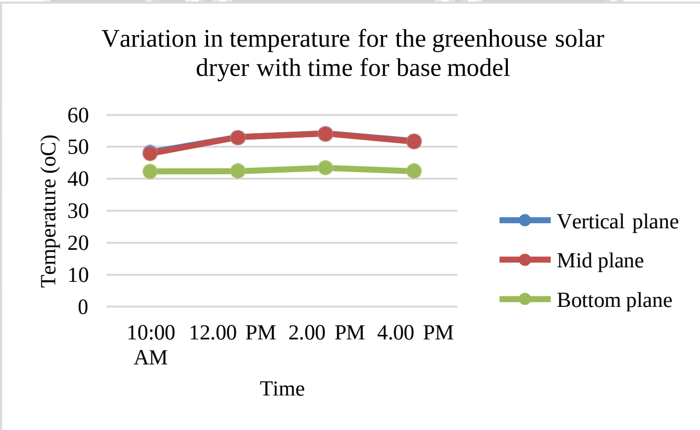

Figure 15: Variation in temperature for the greenhouse solar dryer with time for base model

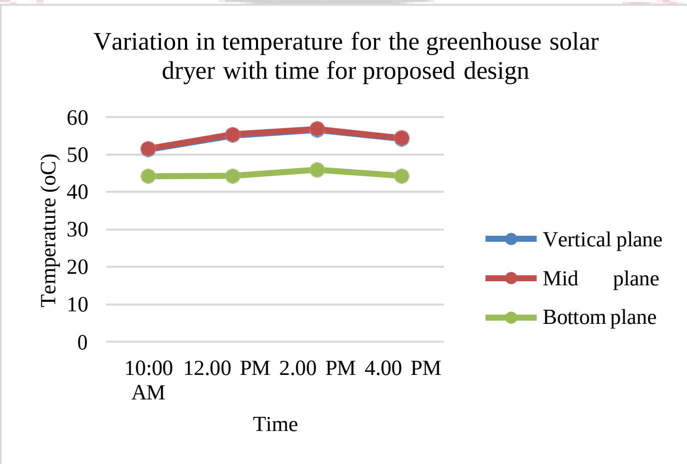

Figure 16: Variation in temperature for the greenhouse solar dryer with time for proposed design

It has been observed from above graph shown in figure no. 4.28 that for proposed design the temperature vary from 44.17 ºC at 10 am on bottom plane to 56.81 ºC at 2 pm on mid plane and also maximum temperature observed at 1.pm due to maximum radiation fall on the top of the solar dryer.

VI. CONCLUSION

After performing Computational Fluid Dynamics analysis on greenhouse solar dryer for base model at 0.025 kg/sec mass flow rate to get temperature distribution inside the solar dryer from 10 am to 04 pm on vertical, mid and bottom planes, it is observed from the contour diagrams that temperature ranges from 42.46ºC to 54.27ºC. The maximum temperature of 54.27ºC is observed at 02 PM on vertical plane inside the solar dryer because maximum solar radiation falls at the top of the vertical plane. The inner temperature of the dryer is higher than the outside temperature because heat is accumulated inside the solar dryer which creates greenhouse effect.

After performing Computational Fluid Dynamics analysis on greenhouse solar dryer for proposed design at 0.025 kg/sec mass flow rate, it is observed from the contour diagrams temperature ranging from 44.17ºC to 56.81ºC. The maximum temperature of 56.81ºC was observed at 02 PM on mid plane inside the solar dryer. The inner temperature of the dryer is higher than the outside temperature because heat is accumulated inside the solar dryer which creates greenhouse effect.

It has been observed from the above conclusion that the maximum temperature on mid plane inside the solar dryer for proposed design which is more than base model and because maximum solar radiation fall on the roof and trapped inside the solar dryer which creates greenhouse effect. Also, suction effect is created due to the shape of the dryer.

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