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Design And Analysis of Flat Plate Solar Air Collector

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Abstract:
Solar energy is an economical, freely available, and inexhaustible source of energy. Traditionally solar energy is used for drying and heating applications. It sustains life on the Earth. Due to the global oil crisis in 1973,solar energy demand increases, and all researchers concentrated on solar appliances. Uses of solar energy have increased in recent years due to decreasing fissile fuel resources and air pollution and global warming. Lots of research work is going on to use the maximum available solar energy.

In our project mainly focused on different insulation material (glass wool & polyurethane) performance checking. It's based on the Model created in CREO parametric software and evaluates the temperature difference in different insulation material, finally better material choosing based on CFD using ANSYS software.

Keywords: *Solar energy, Drying & Heating, Insulation Material, CREO Parametric & ANSYS Software*

I. INTRODUCTION

The solar air heater is cheaper and widely used as solar energy collection devices to deliver heated air at low moderated temperatures for space heating, exposure to agricultural air products like Fruits, seeds, vegetables, and some industrial applications. The drying process is consuming huge amounts of energy through industrial processes. In many industrialized countries, about 7 to 15% of industrial consumption energy for the drying process. The panel consists of glass, absorber plate, and many parameters affecting the solar flat plate air dryer efficiency example, collector length, height, depth, wind speed, glass, absorber plate, etc.…..

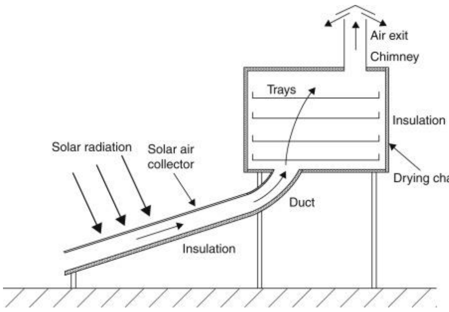

Figure 1 solar dryer arrangement

Forced Convection & Natural Convection Solar Dryer:

Forced Convection:

This dryer air category is forced through a solar collector & the product bed by a fan or a blower, generally referred to as an active dryer.

Natural Convection:

In this dryer,thenatural movement of air takes place, thus as passive dryers. The thermal gradient induces the heated airflow.

II. LITERATURE REVIEW

The purpose of this chapter is to provide a literature review of past research efforts such as journals or articles or documents related to the solar dryer. In addition, a review of other relevant research studies is made to provide additional information to understand more of this study. **Bhandari et al. (August 2012)** The current work involves a relative study of performance analysis of various kinds of flat plate solar air heaters. A Matrix laboratory program code is generating to take out the entire analysis.**ManashDey et al. (October 2013). The friction factor's value**reduces sharply at low Reynolds Number & then reduces very slightly in relation to low Reynolds Number.

SantoshVyas et al. (November 2014) The overall thermal efficiencies of those designs are 14.91%, 17.24% & 20.04% correspondingly. It's also been seen that the thermal gradient tends to decrease with an increasing inefficiency. **Ravish Kumar Srivastava et al., (December 2016)** Analytical Thermal model for the flat plate solar air heater is presented. Experimental clarifications were created in Indian (25°N, 81°E) climate conditions.

BabuSasi Kumar et al. (June 2017)An insulate the glass wool of thickness 25mm covers a collector of about 10cm thickness & inside are used on the attachment's surface. These tests were conducted to gather data from various atmospheric conditions. **Umayorupagam et al. (June 2017)** It was sensible that thermal potency was raised by 9.4%, whereas using the glass plate absorbent material compared to the galvanized iron

(GI) sheet absorber plate. The flat plate solar air heaters are widely used as a group device for solar power utilization as they're easy and economical. The solar air heater's potency may be a low convective heat transfer coefficient between the absorber plate and air. Low heat transfer from the absorber plate will increase its temperature higher heat losses to the surroundings, say the **Kumar Kundan et al. (Sep-2017).**

RamadhaniBakari et al. (January 2018) noted that collectors with 2,3,4 & 8 baffles had a mean efficiency of 29.2%, 31.3%, 33.1%, and 33.7, respectively, while with no baffles was 28.9%. A development hybrid solar drying system may be used for drying varied agriculture products like spices, fruits, and vegetables. The appliance has been coupled to an electrical air heater heaving a dominant auto facility and the blackened surface of absorbent for improved drying potency to say the **Ramesh HarajibhaiChaudhari et al., (2018).** It is used most efficiently by using the solar appliance, as a solar appliance reduces the time needed for drying and improves the standard and lifetime of the merchandise to be dried. There is a need to develop a cost-effective solar dryer in which different agricultural products can be dried to say the **Shiva Kumar et al., (May-2019).**

III. PROBLEM IDENTIFICATION

The solar dryer is an old concept, but many different parameters have been considered during its design in the modern world. The design of solar dryers based on some merits and demerits such as vibration, friction losses at the reducing cross-section, and air leakages at small portions cannot be identified. Considering all factors, we have decided to make solar dryers less costly and more efficient for poor people.

IV. PROPOSED SYSTEM

In our project mainly focused on rectifying the problem identification. The first solar dryer setup is generally glass, and an absorber plate is needed, the outer portion covered the wood. But heat losses reduced to use the different insulation material, glass wool, and Polyurethane. Furthermore, to evaluate the various flow rate and time differenceusingCFD in ANSYS software.

V. MATERIAL PROPERTIES

Table 1 Material Property

Description	**Glass**	**Aluminum**	**Glass wool**	**Polyurethane**	**Wood**
Density (kg/m^3)	2500	2719	65	32	700
Specific Heat (j/kg-k)	1090	1004.832	837	1450	2310
Thermal Conductivity (w/m-k)	0.8	235.222	0.049	0.020	0.173

Air Property

Table 2 Air Property

Description	**Units**	**Air at 30°C**
Density	kg/m^3	1.225
Specific Heat	j/kg-k	1006.43
Thermal Conductivity	w/m-k	0.0242
Viscosity	Kg/m-s	$1.7894e^{-5}$

VI. WORKING METHODOLOGY

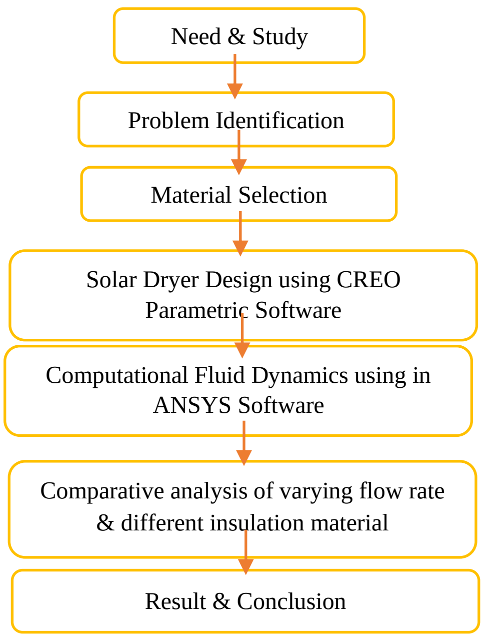

Figure 2 Working Methodologies

VII. INTRODUCTION TO CAD/CAM

CAD/CAM is the time because this CAD & CAM technology worried about using virtual computers to function in design and production. This technology is shifting within the route of more integration of layout and manufacturing, which have traditionally been dealt with as district and separate capabilities in a manufacturing company. In the long run, CAD/CAM will provide the generation base for the computer-incorporated manufacturing facility of the future.

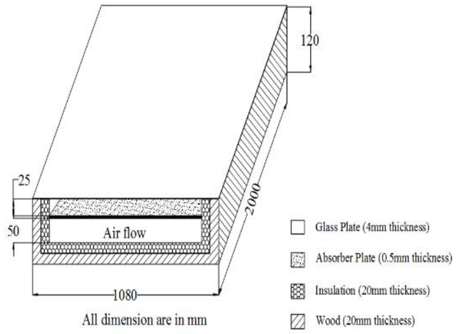

Figure 3 Solar Air collector 2D Layout

A. Introduction of Creo Parametric:

Creo is a parametric technology corporation that develops a suite of computer-aided design apps supporting product design for discrete producers. The suites include apps; each delivers a distinct set of abilities for a person's role within product improvement.

Release history

Table 3 Creo Release History

Version	Release date
Creo 1.0	6 January 2011
Creo 2.0	27 March 2012
Creo 3.0	17 June 2014
Creo 4.0	15 December 2016
Creo 5.0	19 March 2018
Creo 6.0	19 March 2019

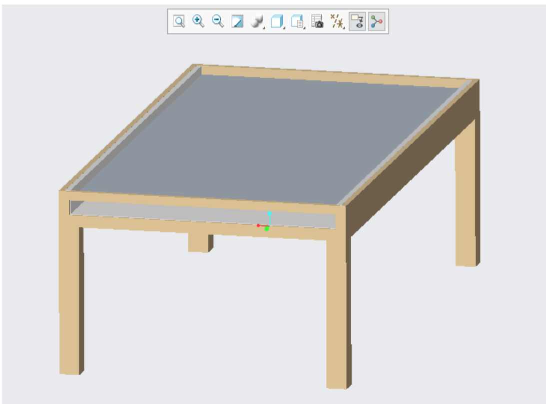

Figure 4 Solar Air Collectors in 3D Model

B. Import & Export

The import & export are useful to the file transfer one software to other software&it's mostly used in two methods. They are; IGES, Parasolid

The IGES full form of Initial Graphics Exchange Specification is a supplier-impartial report format that lets in the digital trade of facts amongst (CAD) structures.

VIII. INTRODUCTION OF FEM

The FEM is a mathematical performance for outcome nearby experimental solutions to various computational domains. Numerical analysis done using FEM is commonly mentioned as a Finite Element Analysis (FEA). Typical FEA applications consist of structural, thermal, electromagnetic, and fluid field problems. Engineers usage it to decrease the several physical models & tests & optimize components in their design segment to improve better products quicker.

FEA Works

FEA, as useful in engineering, possibly will be a machine tool for performance arts engineering analysis. It consists of mesh creation techniques for dividing a difficult problem into tiny parts because of the use of software package program coded with FEM rule.

Purpose of the Mesh

Equations area unit resolved at cell/nodal locations. The domain is needed to be divided into separate cells (meshed)

Mesh (Nodes & Elements)

Table 4 Nodes & Elements

Mesh Sizing	Number of Element	Number of Nodes
50 mm	11636	10507

Analysis Procedure:

Step 1: Model should create in creo parametric software, furthermore part file converted to IGES file.

Step 2: Analysis using computational fluid dynamics (fluid flow fluent) in ANSYS software. Geometry – double click – file – import geometry file (Para solid file) – generate

Step 3: Mesh – double click – mesh right-click – generate mesh – Model faces one by one right-clicks to create named selection – mesh update.

Step 4: Setup – double click – double-precision tick

Step 5: Model – energy on & viscous standard k-e, standard wall function.

Step 6: Materials – fluid – edit – fluid database – choose (air) – to change the properties (30-degree property show in table 2) – solid – edit – fluid database – change solid – choose (Aluminium, Glass, Glass Wool, Polyurethane, Wood property show in table 1).

Step 7: Cell zone condition – include properties (Glass & Absorber plate, Insulation, Wood)

Step 8: Boundary condition – input and output apply (Air Flow)

Step 9: Solution initialization – hybrid initialization

Step 10: Run calculation – Number of iteration (time-based) – calculate

Step 11: Results – report – surface integral – set up – report type (area-weighted average) – field variable (temperature) – surface select (inlet & outlets) – compute.

Fair Weather Condition:

Table 5 Fair Weather Condition

Description	Units	Value
Direct normal solar irradiation at the earth surface	w/m^2	883.045
Diffuse solar irradiation – vertical surface	w/m^2	76.1078
Diffuse solar irradiation – Horizontal surface	w/m^2	118.328
Ground reflected solar irradiation – vertical surface	w/m^2	98.5636
Ambient flux	w/m^2	84.76

Analysis Model:

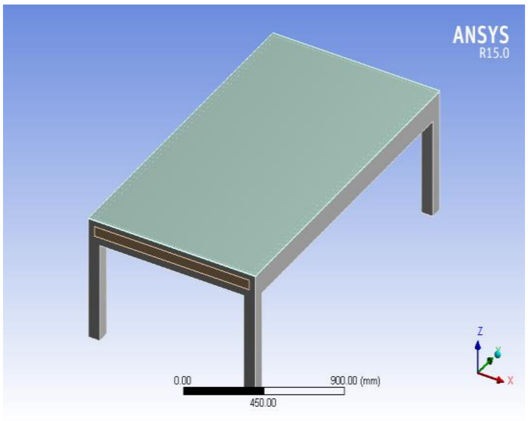

Figure: 5 3D Model in Ansys

Meshing

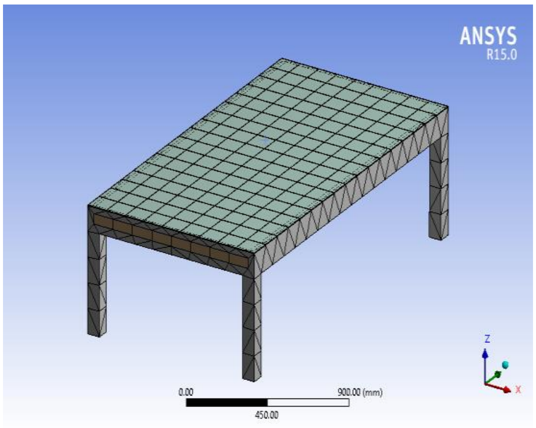

Figure 6 Meshing

The 3D Model consisting of the flat plate solar air collector is shown in Figure 5, and meshing is also shown in Figure 6. Furthermore, it analyzes the various insulation materials and time dependent based on computational fluid dynamics.

Insulation Material (Glass Wool)
Temperature Difference

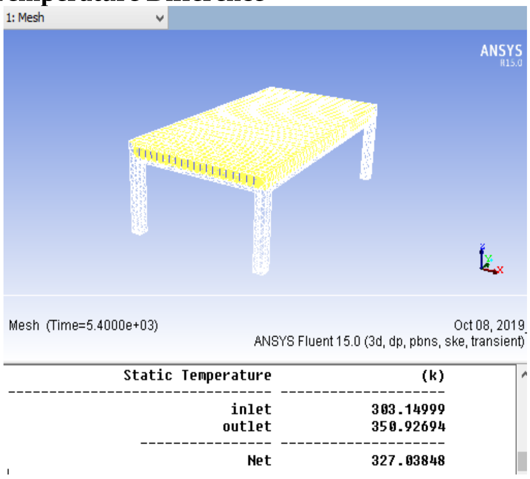

Figure 7 (a) Temperature difference in 90min Glass wool

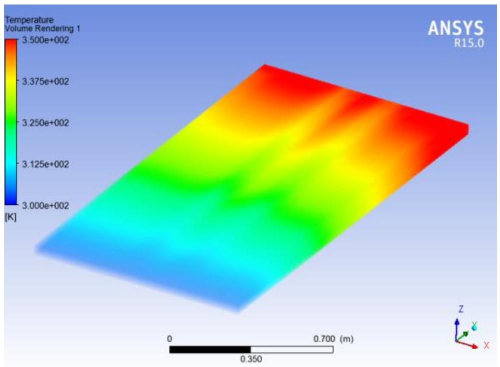

Figure 7 (b) Temperature differences in Glass wool

The various flow rate analysis, but a better performance of 0.01kg/s and inlet temperature is 30°C in 90min running time of airflow. Their results show the above figure 7 (a) & (b).

Overall Glass Wool Reading:

Table 6 Overall Glass Wool Reading

Mass Flow Rate (kg/s)	Inlet Temperature (°C)	Glass Wool (Temperature outlet (°C) based on varying time)		
		30 min	60 min	90 min
0.01	30	67.49	74.69	77.77
0.02	30	55.14	58.99	60.43
0.03	30	49.36	51.94	52.82
0.04	30	45.88	47.80	48.40
0.05	30	43.52	45.04	45.47

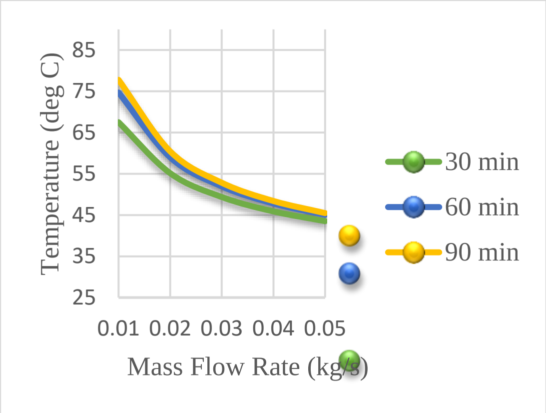

Figure 8 Overall Glass Wool Reading

Overall all glass wool material readings show in table 6 and graphically represented in Figure 8. The comparatively mass flow rate of 0.01 kg/s is the better performance of the heating temperature. The continuous flow of air every 30min check the performance. Its climate also gradually increased in the solar air collector. So the maximum temperature is 77.77°C

Insulation Material (Polyurethane) Temperature Difference

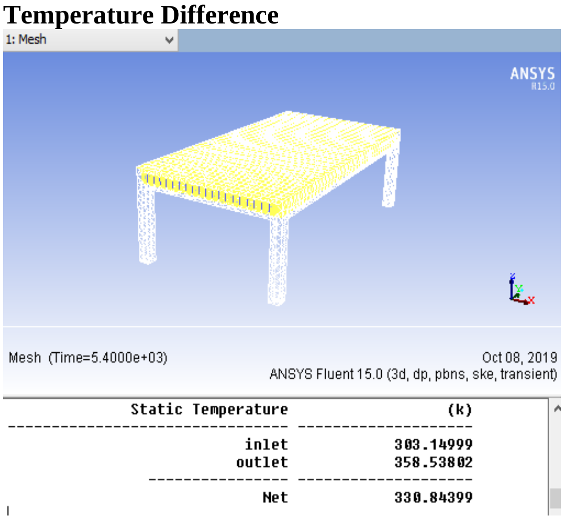

Figure 9 (a) Temperature difference in 90min Polyurethane

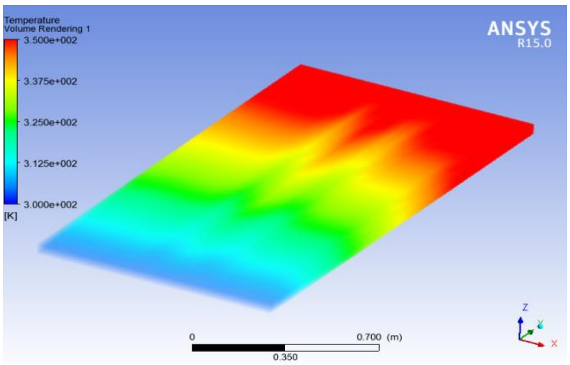

Figure 9 (b) Temperature differences in Polyurethane

The various flow rate analysis, but a better performance of 0.01kg/s and inlet temperature is 30°C in 90min running time of airflow. Their results show the above figure 9 (a) & (b).

Overall Polyurethane Reading:

Table 7 Overall Polyurethane Reading

Mass Flow Rate (kg/s)	Inlet Temperature (°C)	Polyurethane (Temperature outlet (°C) based on varying time)		
		30 min	60 min	90min
0.01	30	76.19	83.40	85.38
0.02	30	58.87	62.44	63.15
0.03	30	51.33	53.63	53.97
0.04	30	47.01	48.67	48.87
0.05	30	44.18	45.48	45.60

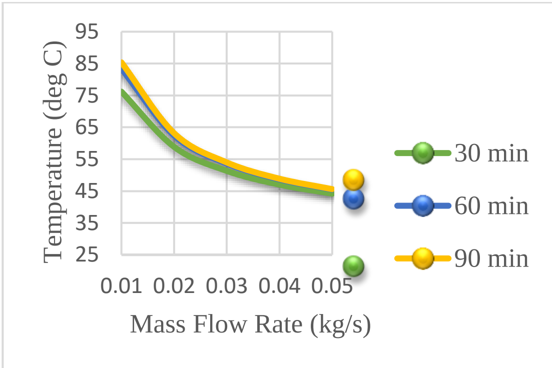

Figure 10 Overall Polyurethane Reading

Overall all polyurethane material readings show in table 7 and graphically represented in Figure 10. The comparatively mass flow rate of 0.01 kg/s is the better performance of the heating temperature. The continuous flow of air every 30min check the performance. Its temperature also gradually increased in the solar air collector. So the maximum temperature is 85.38°C

Polyurethane pressure difference

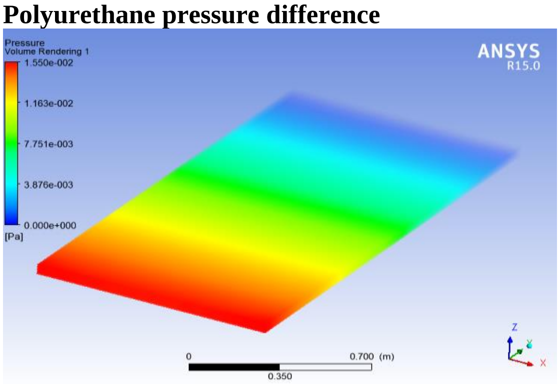

Figure 11 Pressure Difference

Polyurethane Velocity difference

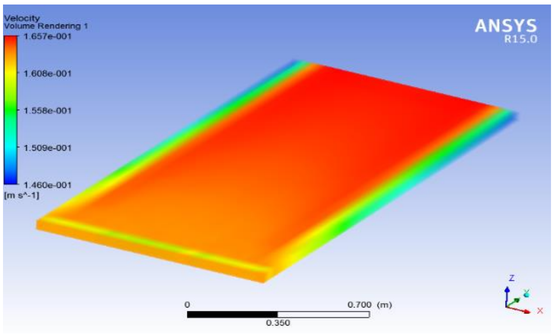

Figure 12 Velocity Difference

The comparatively insulation material better performance of polyurethane maximum temperature is 85.38°C. So, its pressure and velocity to check the time interval of 90min & mass flow rate of 0.01 kg/s are graphically shown in Figures 11 & 12.

IX. Result

Table 8 Comparative of Insulation Material

Mass Flow Rate (kg/s)	Inlet Temp (°C)	Glass Wool Outlet Temp (°C)	Polyurethane Outlet Temp (°C)
0.01	30	77.77	85.38
0.02	30	60.43	63.15
0.03	30	52.82	53.97
0.04	30	48.40	48.87
0.05	30	45.47	45.60

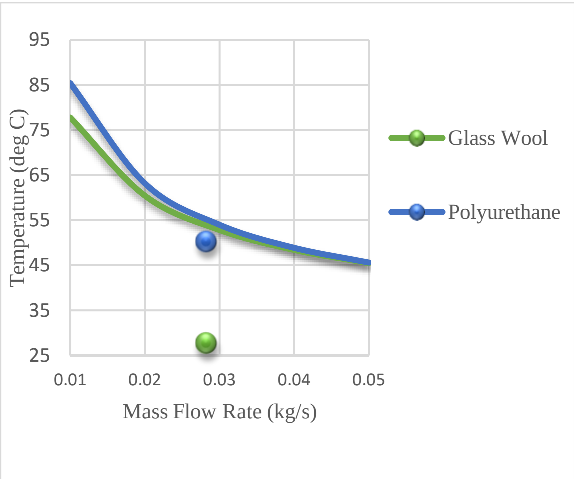

Figure 13 Comparative of Insulation Material

X. Conclusion

A flat plate solar air dryer's performance indicates the following conclusions;To check the varying mass flow rate,airflow slowly flows better heat absorbed in the system.Furthermore to check the insulation materials, it's observed the result of heat loss reduced in the polyurethane material

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