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Design And Analysis of Flat Plate Solar Air Dryer

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Abstract:

Solar dryers are equipment and using solar energy for drying substances, especially food. There are two common types of solar dryers: Direct & indirect. This is a dryer type in which the product to be dried directly absorbs the solar radiation.It is also referred to as a natural convection cabinet dryer because the solar radiation falls directly on the surface; the product quality is reduced. Heated air from the drying chamber is blown through.

A solar dryer's basic function is to heat air with solar energy to a constant temperature, which enables the moisture extraction from crops within a drying chamber. The flat plate solar air dryer model's main objectiveis based onthetray & with tray chamber in Creo parametric software & computational fluid dynamics in Ansys software. Generally, a solar air dryer is heat loss is possible, so it's reduced withinsulation material (glass wool &Polyurethane). To predict the temperature difference in various airflow with insulation material. Furthermore, choose the better insulation material &contrast between with & without tray chamber.

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

I. INTRODUCTION

A significant portion of the foodservice industry is devoted to drying food products for the cost of good, long-term storage and exports. In India, a large chunk of the drying is still done by drying the product out in the sun. This not only takes a lot of time (usually in days) but is also very unhygienic because of possible contamination.

Solar Dryers are used more effectively; they improve the removal of moisture, thus speeding up the drying process while reducing contamination chances.In this way, using Industrial Solar Dryer decreases your drying time and thus helps you to increase your output volume.

In a solar dryer, air reaches the drying chamber through the natural convection cycle or an external source such as a ventilator, pump, suction system, etc. As it moves through the container, the air gets heated and then partly cools as it absorbs moisture from the food product put in the container.

Fig. 1 solar air dryer arrangement

II. LITERATURE REVIEW

Papade&Boda (December 2014) storing energy in latent heat storing material is very useful because it stores the maximum amount of energy compared to sensible heat-storing materials at an equal quantity of material. Phase Change Materials (PCM's) are convenient to store solar energy. Analyzing the results convergent section is correct since the inlet air velocity is the same for both cases. Still, the outlet velocity is measured in the convergent section as almost doubled inlet velocity.

SushrutHalewadimath et al. (June 2015)solar air dryer is best suited for the drying process; one of the most important potential solar energy applications is the solar drying of agricultural products. The post-harvest losses of agricultural products can be reduced drastically by using well designed solar drying systems. The indirect mode forced solar convection dryer has good velocity and drying efficiency among the different types of solar dryers.During the harvest season from February to April, the built solar air dryer with a collector area of $2m^2$ dries agricultural products from 89.6 percent to 13 percent humidity content under ambient conditions.

Pankaj Gupta (October 2015) Numericalmodeling of a direct type solar dryer was performed, and airflow and temperature distribution inside the dryer chamber was analyzed. The computational domain considered was two-dimensional. The study focused on the effect of the inlet and outlet vents' effect on the flow field and temperature field inside the chamber. All other conditions remain the same. It can be concluded that airflow and temperature distributions are more uniform when the inlet vents are placed at the bottom wall, and the outlet vent is placed at the top wall of the drying chamber. Moreover, a three-dimensional analysis can obtain more detailed information on airflow and temperature distribution.

Nicholas MusembiMaundu et al. (2017) conducted the study by designing, manufacturing, and testing the efficiency of a natural convection solar dryer suitable for mid-latitude applications. For airflow distribution and flow visualization, the PIV technique was successfully applied. Thermal imaging was found useful in providing an idea of temperature distribution within the drying chamber. From the PIV report, air distribution across the trays was relatively uniform, and that conformed to the findings of experiments suggesting uniform drying of the product across the trays.

Miguel Andrés Daza Gómez et al., (April 2018) To understand the convective drying process, a CFD simulation was implemented using a transient system model with the k-ε model turbulence and the CFL criterion. This is a useful and powerful tool to achieve the desired assessment allowing identifying the temperature and air profiles in the convective drying chamber. The air distribution results show that there are two specific areas of low air velocity that tend to create recirculation. They are located at the air exit and the other at the bottom of the chamber, resulting in poor drying. Besides this, the temperature profile shows only a homogeneous drying in half of the trays, reducing drying efficiency drastically, especially for the bottom ones.

SuhaimiMisha et al. (December 2018), a kenaf core drying experiment using a solar-assisted solid desiccant dryer were performed under average solar radiation of 834 W/m2. CFD simulation was used to predict airflow distribution in the drying chamber by considering the porous media product. The experimental and simulation data were in good agreement. The product's drying rate was significantly affected by the average air velocity above the tray.

JherssonCastaño-Rodríguez et al., (2018),the direction of the air flux is relevant factors in the design of hot air dehydration systems; due to the connection with the turbulences generations that avoid the adequate food moisture extraction obtain a partial dry. This can be avoiding choosing more of one outlet with the opposite direction of the air flux. Comparing the results get is concluded that the configuration with the best performance is the option with an outlet on both sides and horizontal trays inclination.

Mani et al. (February 2019), the solar dryer, was made up of locally available material. Such simple materials like wood, glass, pipe, etc.… In this is solar drying very useful for formers to dry and prevent the agricultural produce. Compared to the open drying method, the solar drying method is very efficient because it will be high compared to the open dry process.

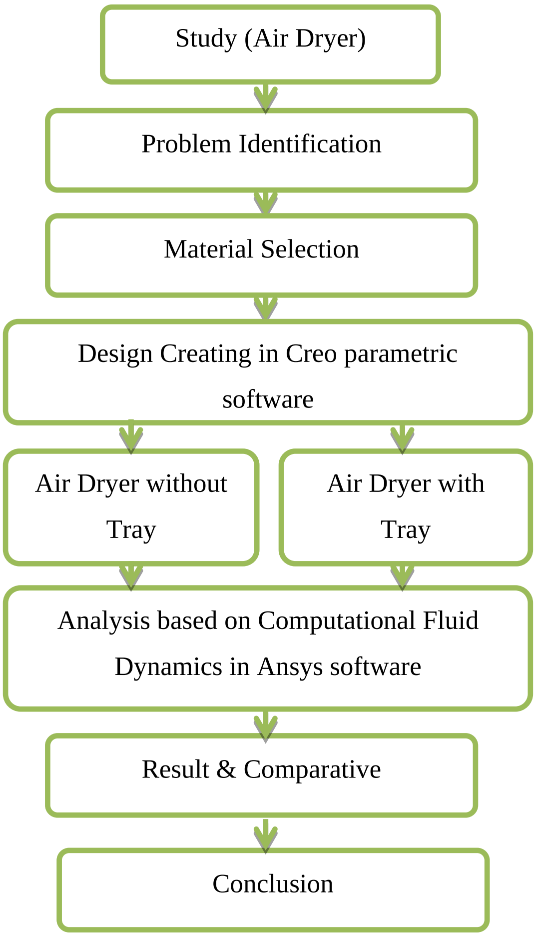
AbhishekDasore& Ramakrishna Konijeti (September 2019) Patterns of air velocity and temperature within the tray dryer cabinet are analyzed numerically using ANSYS Fluent 15.0. Drying air temperatures in simple type are higher than that of other geometries. The hood type with deflector design is reasonably best among the three designs. A good agreement has been found between reference data and predicted results from current work for steady movement of air and temperature dispersals in the cabinet fruit dryer.

Salve et al. (February 2020), through comparison of Experimental and CFD temperatures of drying cabinet, observed that around 5°Cbetween the temperatures obtained in experimental measurements and CFD calculations. It can be seen from the temperature plots of the drying cabinet that from 09:00 Hrs. to 25:00 Hrs. the temperature of air measured above 40°Cwith PCM case, compared to 09:00 Hrs. to 18:00 Hrs, without the PCM issue. The required drying temperature (above 40°C) was maintained in the dryer for 7 more hours due to the use of PCM.

III. PROBLEM IDENTIFICATION

The heat absorber plate's ability to absorb more heat from the sun and retain the heat is the key toflat plate collectors' success.The heat absorbed by the flat plate collector depends on both the thermal properties and the heat absorber plate design.Because of the thermal properties, heat absorber plate material plays an important role in the heat absorbing performance. But the major problem of heat loss in the collector has reduced heat loss with the help of better insulation material.

IV. WORKING METHODOLOGY



Objective

The project is conducted with the following objectives to be achieved:

- To design a model of flat plate collector & analysis based on computational fluid dynamics.
- To study the effect of glass wool and polyurethane insulation material using flat plate collector efficiency.
- To study the effect of with & without tray in the solar air dryer chamber

Material Property

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

This means that an aluminum absorber plate is a better heat absorber in the sense of this study.Aluminumcan absorb heat and store heat longer than copper and contribute to the flat plate collector's high efficiency. The insulation material useful to heat loss is reduced (Glass wool & Polyurethane).

V. DESIGN &ANALYSIS OF AIR DRYER

Computer-aided drawing is a technology in which engineering drawings are made with the help of a computer. With manual drawing, only the graphical means of representing a design.

Computational fluid dynamics (CFD) is the science of predicting fluid flow, heat transfer, mass transfer, chemical reactions, and related phenomena using a computational method to solve the mathematical equations that control those processes.

Computational Fluid Dynamics (CFD) is the simulation of fluid engineering systems using modeling (mathematical, physical problem formulation) and computational techniques (discretizing techniques, solvers, computational parameters, & grid generations, etc.)

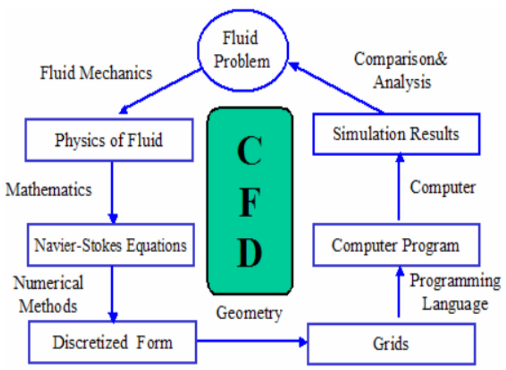


Fig. 2 Process of Computational Fluid Dynamics

It is done in three stages: pre-processing, processing, and post-processing. This involves problem-solving, meshing, and creating a computational model in the pre-processing phase, all of the tasks before the numerical solution process. Processing involves using a computer to solve mathematical equations of fluid flow. This is a very intensive method that typically demands that the machine solve several thousand equations. In each case, the equations are integrated, and boundary conditions are applied to it. This software is used in the post-processing phase to evaluate the data produced by the CFD study.The effects can be evaluated numerically as well as graphically once the model has been resolved.

Air Dryer without Tray Model

Table 2 Comparison of Air Dryer without Tray

Air Flow Rate	Glass wool air outlet tem.			Polyurethane air outlet tem.		
	30 min	**60 min**	**90 min**	**30 min**	**60 min**	**90 min**
Kg/s	℃	℃	℃	℃	℃	℃
0.001	74.37	87.89	97.45	77.09	92.86	103.36
0.002	43.75	48.09	51.15	45.72	50.45	54.15
0.003	39.34	41.92	43.87	40.7	43.58	45.91

The air dryer without tray model analysis based on various flow rates with different insulation material is a comparatively numerical value in Table 2. We concluded the better airflow rate is 0.001 kg/s &the insulation material is Polyurethane. The temperature& velocity difference graphically represented in Fig. 3 & 4.

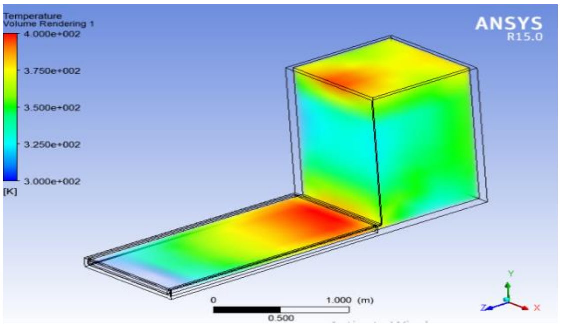


Fig. 3 Polyurethane temperature difference at 90 min

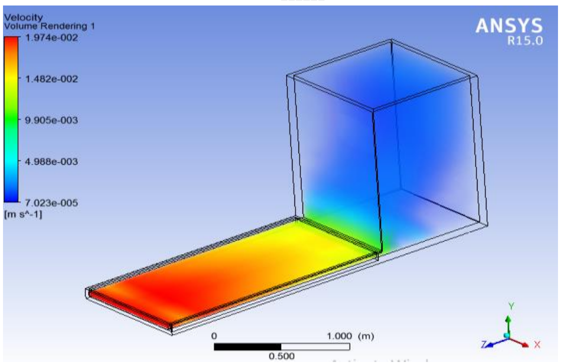


Fig. 4 Polyurethane velocity difference at 90 min

Air Dryer with Tray Model

Table 3 Comparison of Air Dryer with Tray

Air Flow Rate	Glass wool air outlet tem.			Polyurethane air outlet tem.		
	30 min	60 min	90 min	30 min	60 min	90 min
Kg/s	℃	℃	℃	℃	℃	℃
0.001	52.44	57.23	63.29	53.27	58.7	65.19
0.002	37.53	40.79	42.72	38.58	42.11	44.31
0.003	36.43	38.33	39.16	37.27	39.48	40.57

The air dryer with tray model analysis is based on various flow rates with different insulation material. It's a comparatively numerical value in Table 3. We concluded the better airflow rate is 0.001 kg/s &the insulation material is Polyurethane. The temperature & velocity difference graphically represented in Fig. 5 & 6.

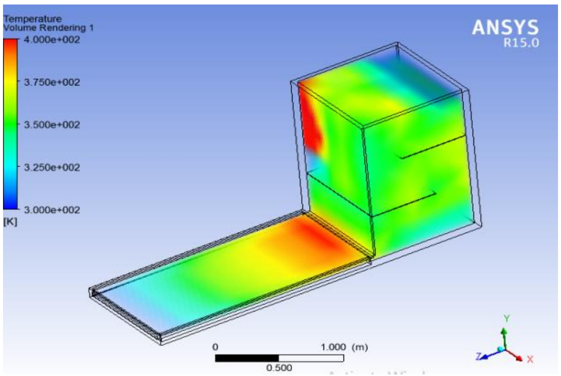


Fig. 5 Polyurethane temperature difference at 90 min

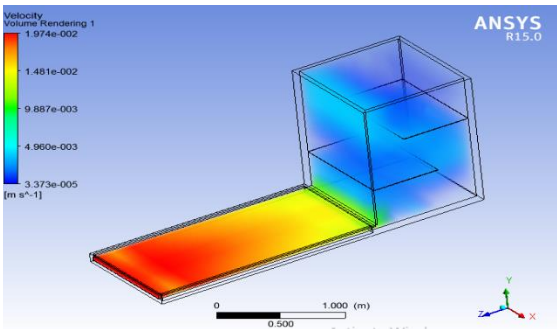


Fig. 6 Polyurethane velocity difference at 90 min

VI. CONCLUSION

To carry out the comparative study, two dryers were analyzed. Between them, one dryer was without a tray, and the other one with a tray, in our main objective of reduced the heat loss with the help of insulation material (Glass wool &Polyurethane). The polyurethane insulation material is of low thermal conductivity. That reason reduced the heat loss of air dryer &The airflow rate is slowly passed in the air dryer is improve the air's outlet temperature. The airflow rate of 0.001 kg/s is given in the air dryer with a tray to get the outlet temperature 65.19℃ in polyurethane insulation. Comparatively, choose the better heat loss reduced of polyurethane insulation material.

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