CFD Analysis of Drying Chamber for Solar Dryer

Shantanu S. Kulkarni[1], Prof. S.M. Ranade[2]

[1]PG - Student, Mechanical- Heat Power Engineering, Walchand College of Engineering Sangli, Maharashtra, India
[2]Professor – Mechanical Engineering Department, College of Engineering Sangli, Maharashtra, India

---***---

Abstract - *This research paper presents analysis of solar drying chamber for the drying of agricultural products. The design and analysis was done in ANSYS FLUENT. ANSYS FLUENT is Computational Fluid Dynamic (CFD) software in which flow fields and some physical quantities are calculated in detail for engineering applications. The analysis was carried out to analyze temperature and velocity distribution. Temperature and velocity are termed as most important parameters that affect the drying rate of product. The analysis results are then compared with experimental results. Coriander leaves were used as a drying material to carry out the experiments. These coriander leaves were kept inside drying chamber in three trays. To generate 3D model of the drying chamber the basic information of drying chamber is required such as dimensions of drying chamber inlet air temperature and velocity. CFD is good quantitative and qualitative technique for analyzing effect of variation of temperature and velocity on drying of the product inside said drying chamber.*

Key Words: **Solar Drying Chamber, ANSYS FLUENT, CFD, Drying Chamber, Coriander**

1. INTRODUCTION

Sun drying is most normal technique used to preserve agricultural item generally in tropical and subtropical region. Open sun drying is most commonly utilized strategy for drying to produce ever known to man and it include basically laying to the agricultural items in sun on mats, rooftops and drying floor. This has numerous disadvantages in sight of the fact that the farm produce dried in open sky and there is danger of spoilage because of adverse climatic condition, loss of item to creepy crawlies, flying creature, absolutely relying upon climatic condition and moderate drying rate with threat of shape development subsequently causing deterioration of item. The procedure is requiring exceptionally huge region of land, require significant investment and profoundly labor incentive.

Another choice to open sun drying is solar dryer, improve drying by controlling airflow and hoisting the temperature of drying air utilizing sun based insulation. It occupies less room, time and generally economical contrasted with artificial mechanical drying. The drying time can be abbreviated to 65% contrasted with sun drying since, inside dryer is hotter the outside; the nature of dried items can be improved as far as cleanliness, safe dampness substance, shading and taste.

2. EXPERIMENTAL SETUP

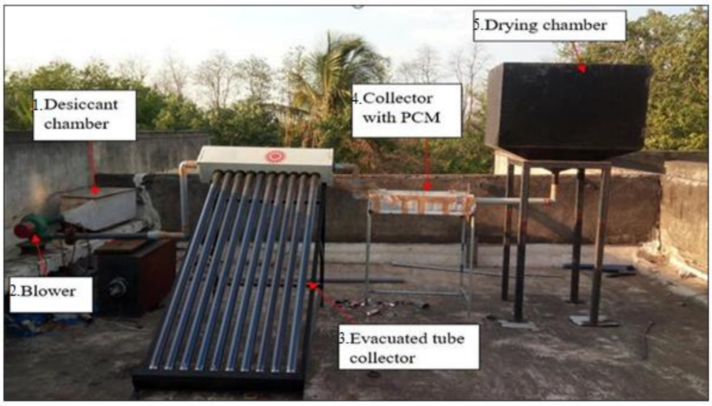

Fig. 1 Solar Dryer experimental setup

Fig. 1 shows the experimental setup of solar dryer. This setup mainly consists of a blower, evacuated tube collector, a collector with PCM and drying chamber.
As appeared in figure the system is sun based collector and it will warm the air through characteristic sun oriented radiation. The heated air flows to drying chamber by using blower. This blower is operated by using electric supply. The hot air is passes to drying chamber to dry the products with same drying rate. We are going to analyze the effect of forced convection on the product.

2.1 DRYING CHAMBER

The drying chamber is insulated enclosed structure. The drying material is placed in the drying chamber. Trays are present in the drying chamber for placing drying material. There is one door for loading and unloading drying material. To reduce heat losses to the surrounding drying chamber must be insulated.

Fig. 2 Drying Chamber

3. METHODOLOGY

The drying chamber is made up of galvanized iron sheet. The dimensions of the drying chamber are 1m×0.6m×0.6m. The drying chamber consists of 3 numbers of trays. The trays are made up of a 2 mm lattice of stainless steel. The gap between two successive trays is 0.12 m. The drying chamber has a door to load and unload the drying material. The drying chamber has inlet at the bottom and chimney as an outlet at the top. Blower is used to increase the velocity of inlet air where as tube will absorb heat from the sun and heated the air that are flowing in the piping system.

4. MATERIALS AND METHODS

From local market of Sangli fresh coriander were purchased. Fresh samples of coriander leaves was washed with clean water, weighed and stems were removed from coriander by using knife of stainless steel to avoid blackening on the surface.

The properties of coriander are used for analysis of drying chamber for finding the properties such as density, specific heat and thermal conductivity are shown in following table. These properties are used to obtaining the result.

Table 1 Drying material Properties

Material	Density (kg/m^3)	Specific Heat (J/kg-K)	Thermal Conductivity (W/m-K)
Coriander	258	2372	0.06975

5. EXPERIMENTATION

Experiments have been performed at Sangli, Maharashtra (India). [Sangli is located at latitude 16°85′N, longitude 74°58′E. It has an average elevation of 549 meters.] Sun powered radiation throughout the year on level surface in Sangli is seen as 5.82 KWh/m^2/day and it is greatest (1250 w/m2) during summer and normal sun powered radiation discovered was 242.5 w/m^2 during Feb. to March.

6. EXPERIMENTAL RESULTS

Table 2 Experimental results

Time (Hours of the day)	Ambient air Temperature	Drying chamber inlet	Drying chamber Outlet
	T1 (K)	T2 (K)	T3 (K)
10.30 am	303	320	312
11.00 am	304	323	314
11.30 am	305	329	320
12.00 pm	304	329	321
12.30 pm	305	328	320
1.00 pm	306	329	321
1.30 pm	308	332	324
2.00 pm	307	332	324
2.30 pm	305	330	322
3.00 pm	307	332	323
3.30 pm	306	331	322
4.00 pm	304	327	318
4.30 pm	303	323	314

7. SAMPLE CALCULATIONS

1) Moisture loss

$$ML = W_i - W_f$$

=1300-280

=1020 gms

2) Drying rate

$$DR = \frac{dM}{dt}$$

= 255 gms/hr

3) Loss of moisture on wet basis

The loss of moisture on wet basis is given by,

$$M_w = \frac{Wi - Wf}{Wi} \times 100$$

= 78.46%

4) System drying efficiency

The system drying efficiency given by,

$$\eta_d = \frac{\text{Moisture loss} \times \text{latent heat of vaporisation}}{\text{Area of collector} \times \text{Average solar radiations} \times \text{Time}} \times 100$$

= 26.26%

8. GRAPHS

8.1 Time vs. Temperature

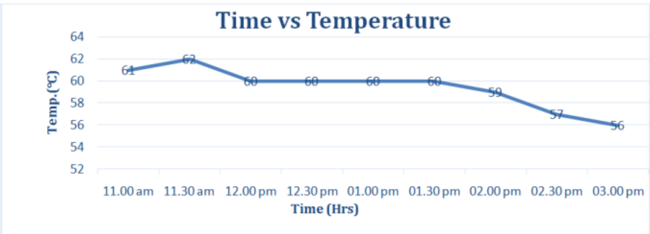

Chart 1 Time vs. Temperature

8.2 Time vs. Mass

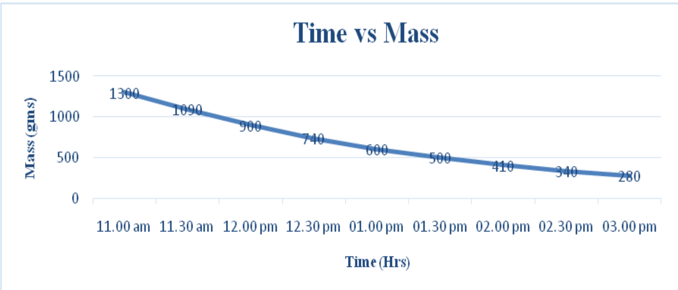

Chart 2 Time vs. Mass

8.3 Time vs. Drying Rate

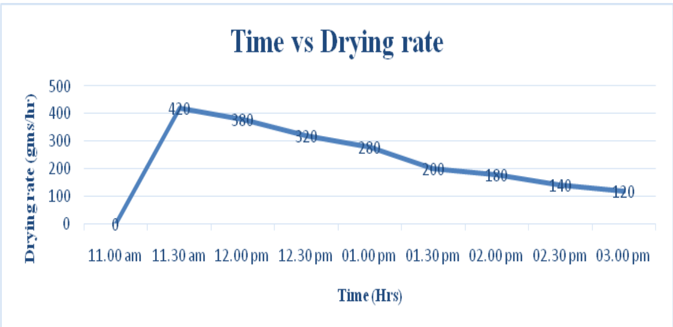

Chart 3 Time vs. Drying Rate

9. DRYING SAMPLE

Figure shows coriander before and after drying process.

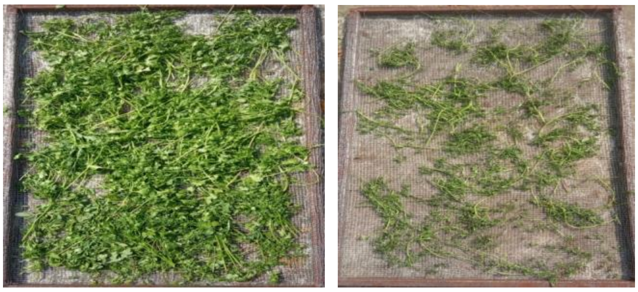

Fig. 3 Drying sample

We use 1300gms of Coriander leaves for drying. After 4 hours we obtained 280 gms of Coriander leaves. Figure 4.1 shows the Coriander leaves before and after drying.

10. CFD Simulation

This chapter deals with the numerical analysis of dehydrating compartment to predict the thermal analysis of drying chamber.

10.1 Drying Chamber Geometry

Geometry is constructed by using Ansys fluent design modeler as shown in figure, by considering all dimension of drying chamber as listed in table.

Table 3 Drying chamber specification

Length(mm)	Width(mm)	Height(mm)
1000	600	600

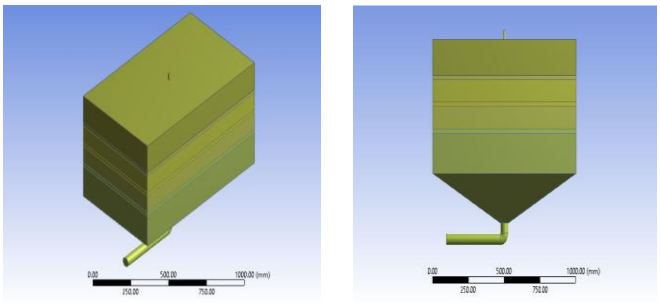

Fig. 4 Drying chamber geometry

10.2 Meshing

Meshing is used to discretize the drying chamber. Following figure shows that the quality of meshing for drying chamber.

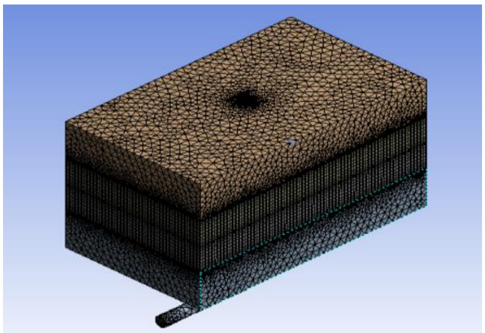

Fig. 5 Meshing of drying chamber

1] Number of nodes =397045

2] Number of elements =918474

10.3 Boundary Conditions

The current problem is assumed as three dimensional, steady, laminar and incompressible flows. The following boundary conditions are used.

Table 4 Boundary conditions

Face	Type of Boundary condition	Velocity Magnitude (m/s)	Temperature (K)
Entrance	Velocity inlet	2.58	324
Exit	Pressure outlet	-	-
Wall	-	No slip condition	-

10.4 CFD Post Processing

In post processing various contours plots, streamline of temperature and velocity are plotted and results obtained. The solver utilized for the examination of 3D-Pressure based solver with standard K-ω model and vitality condition was likewise activated. The unsolidified properties and boundary conditions are determined.

10.4.1 Temperature of air at outlet

After solving model, the hot air is coming into the inlet so the temperature of drying chamber is high so the temperature of drying chamber is decreases and also moisture of product is removed at the outlet. As shown in figure the outlet temperature of air decreases.

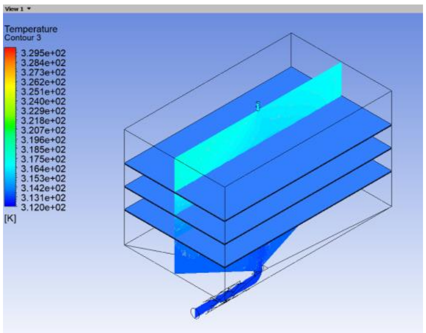

Fig. 6 Temperature contour

10.4.2 Velocity of air at outlet

From figure it observed that contour and streamline plot of velocity flow rate is decreases as compare to inlet.

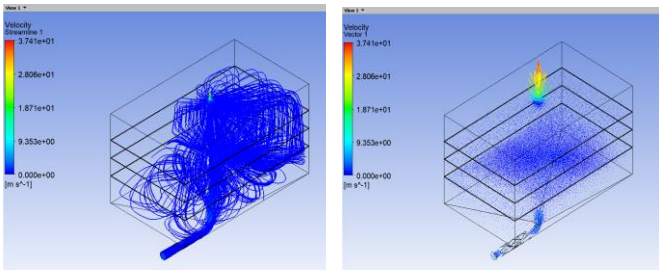

Fig. 7 Velocity Streamlines and vector

11. Validation

Figure shows the validation of temperature in Experimental and Analytical method. The variation in temperature from Experimental and Analytical method is less than 10%.

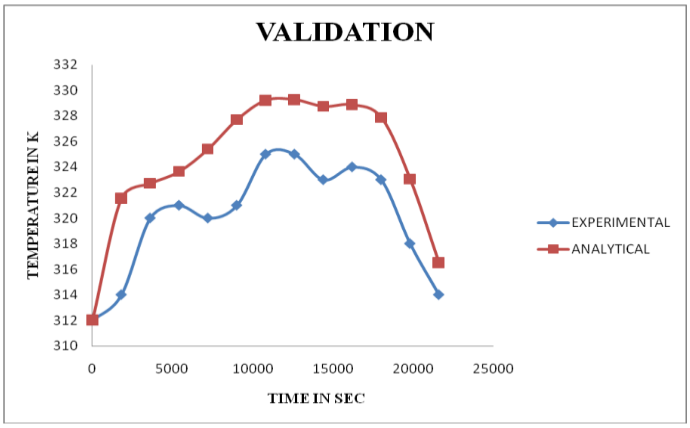

Fig. 8 Validation

REFERENCES

[1] Sapto W.W., Wong C.Y., Kamarul A.M and Nurul Hidayah A, "CFD simulation for tray dryer optimization," International Journal of Engineering and Research Application, 2000

[2] Arina Mohd Noh, Sohif Mat, Mohd Hafidz Ruslan, "CFD Simulation of Temperature and Air Flow Distribution

inside Industrial Scale Solar dryer" Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, Issue 1 (2018) 156-164

[3] Akshay Chopade, Prof. S. M. Ranade "Performance Analysis of Evacuated Tube Solar Dryer with Desiccant Dehumidifier and PCM as Thermal Storage Material" International Research Journal of Engineering and Technology (IRJET). Vol. 6 (2019) 497-500

[4] Swarup R. Joshi, Dr. Suresh M. Sawant "Numerical analysis of solar drying chamber for agricultural products using CFD" International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 10 Oct 2020

[5] A.K. Babu, G. Kumaresan, V. Antony, Aroul Raj, and R. Velraj "CFD studies on different configurations of drying chamber for thin-layer drying of leaves" Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, Apr 2019

[6] Johannes P. Angula and Freddie Inambao "Computational fluid dynamics in solar drying" IJMET Volume 10 Issue 11, November 2019 259-274

[7] A.K. Karthikeyan, S. Murugavelh "Thin layer drying kinetics and exergy analysis of turmeric (Curcuma longa) in a mixed mode forced convection solar tunnel dryer" ELSEVIER, Volume 128, Part A, December 2018, 305-312

CONCLUSIONS

In this project work CFD simulation of drying chamber is carried out. The effect of temperature at outlet, velocity flow rate of air has been evaluated.

Following conclusion are arrived as follow:

1. From the simulations it concludes that the temperature of outlet is decreases up to 7-10 K
2. The inside temperature of solar drying chamber is high then drying rate is increases to get the better quality of agricultural products.
3. The cost is involved in construction of solar drying chamber is much less that mechanic drying chamber.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to **Prof. S. M. Ranade** for their guidance and help extended at every stage of this work. I am deeply indebted to him for giving me a definite direction and moral support without which this report would not be completed.
I express my gratitude and earnest thank to **Prof. Dr. K. H. Inamdar** Head of Mechanical Engineering Department for through their support in my project.
Last but not the least I extend my sincere thanks to other faculty members and non-teaching staff of the Department of Mechanical Engineering and my friends for their valuable advice in every stage of this project.

BIOGRAPHIES

Mr. Shantanu Shivanand Kulkarni is final year M.Tech student at Walchand College of Engineering, Sangli. His research interest is in field of CFD, Renewable Energy, Heat and mass transfer.

Prof. S.M. Ranade is working as assistant professor at Walchand College of engineering from past 5 years. His research interest is in field of Refrigeration and Air conditioning, Food Processing.