NUMERICAL ANALYSIS OF SOLAR DRYING CHAMBER for AGRICULTURAL PRODUCTS USING CFD

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Abstract - *The unpredictable rise and inadequacy of non-renewable energy sources like "fossil fuel accelerated the continuous look for an alternate power source"[1]. Solar energy is one among the choice sources and it is abundantly available in direct and indirect form. India is the second largest country for producing agricultural products. Most agricultural products are dried under the sun however, the products are dried directly beneath the exposed sun drying has many drawbacks to scale back the quality of products. The solar dryer is used to take care of standard of product. The solar dryer system is not only beneficial, but also it reduces the wastage of agricultural product and helps the preservation of agricultural product. Sun light based freshening chamber is the foremost part of sun oriented dryer system. As it seems a number of researchers have done the improvement of solar drying chamber for dry the agricultural product and evaluate their performance. In this article we are constructing up the model of sun oriented drying chamber using ANSYS FLUENT R15.0.*

Key Words: **Solar Dryer, Solar Drying Chamber, CFD.**

1. INTRODUCTION

Many developed and developing countries are facing the food problem. Now a day's competition is more to maintain the energy and quality of available agricultural product. India is the second largest country producing agricultural products. Many agricultural products are dried underneath the open sun drying. They have lots of disadvantages such as climatic condition changes because of pollution. Products are not purely dried, they losses quality and also time is required to dry the product is large.

COVID-19 Pandemic circumstance, couldn't lead physical experimentation Setup. So the just recreation work is finished.

Solar dryer play a serious role for minimizing the post harvesting damages to understanding the principle and operation with expected performance will go an extended way priority utilization of solar power for drying purposes. The fundamental motivation behind sun powered drying is to evacuate the dampness and water gratified in the item to keep up the nature of product. Solar dryers protect the agricultural products from dust, damages and rains. Tomato and Banana are one of dry vegetables and fruits having worldwide demand to their typical sweet and sour taste. The tomato is a very important vegetable in our diet, it contains high lycopene so it reduces some health issue like, cancer and some acidity problem. Dried tomatoes are widely used as an ingredient in salads, pizza and spicy dishes [11]. Banana is a very nutritious fruit contains a large amount of fiber and also contain vitamin B it is useful to gain the weight.

2. DESIGN of SOLAR DRYING CHAMBER

Solar dryer systems consist of solar dryer, centrifugal blower, solar drying chamber. The absorber plate was made up of an aluminum sheet (2 mm thick and 2 m × 1.4 m × 0.15 m in size) which was fixed in the air heater which was made up of plywood through which air is passed. For connecting the air heater outlet to the inlet of dryer chamber, a connector made from plastic pipe (stable up to 200°C) was provided. The drying chamber made of plywood (12 mm thick and 6ft × 4ft). In the dryer cabinet, an arrangement was made to keep five numbers of trays on which tomatoes and banana slices were placed on the tray to produce dried slice and chips form. But since of this

2.1 Mass of Water Content

$$m_w = m_P \times \frac{m_i - m_f}{100 - m_f} = 4.70 \text{ kg.}$$

Where, m_p = mass of product
m_i = primary mass of product
m_f = finial mass of item

This quantity of moisture is removed from tomato and banana slices for making chips.

2.2 Amount of Heat Required

$$Q = m_w \times h_{fg} = 11450.75 \text{ KJ}.$$

Where, m_w = mass of water contain
h_{fg} = latent heat of vaporization

2.3 Mass of Air

$$m_a = \frac{mw}{(wo - wi)\times t} = 78.33 \text{ kg/hr}$$

$$= 0.02176 \text{ kg/sec}$$

Where, m_w = mass of water contain, w_o = outlet humidity of air from heater, w_i = inlet humidity of air from heater

2.4 Total Energy Required

$$E = m_a \times (h_f - h_i) \times t_d$$

$$E = 7989.66 \text{ KJ}$$

Where, h_f =Final enthalpy of air, h_i =initial enthalpy of air

2.5 Solar Drying Chamber Collector Area:

$$E = A_c \times I \times \eta$$

$$A_c = 1.603 \text{ m}^2$$

Where, I = Intensity of solar radiation, η= Efficiency of solar collector

2.6 Diameter of Pipe:

$$m_a = \varrho \times A \times V$$

Where, m_a = mass of air, V = Velocity of air
ϱ = Density of air

Therefore, $A = \frac{m_a}{\varrho \times V} = \frac{0.02176}{2 \times 1.223} = 0.0088 \text{ m}^2$

$$A = \pi \times D \times L$$

$$D = 0.0737 \text{ m}$$

Standard size of pipe is 0.0762 m. Therefore, diameter of pipe= 0.0762 m = 3 inch

2.7 Selection of Blower: Blower is used forced convective type. Following dimension are selected, CFM-500, RPM- 1440, Motor Rating- 0.5HP.

2.8 Reynolds Number

i. Reynolds number for inlet pipe:

$$R_e = \frac{\varrho \times v \times d}{\mu} = \frac{1.2253 \times 2 \times 0.076}{1.85 \times 10^{-5}} = 9892.063$$

Where, ϱ = density of air, v = density of air ,
d = diameter of pipe, = dynamic viscosity of air,
D_h = Hydraulic diameter of pipe.

ii. Reynolds number for drying chamber:

$$R_e = \frac{\varrho \times v \times Dh}{\mu} = \frac{1.2253 \times 2 \times 0.223}{1.85 \times 10^{-5}} = 28525.50$$

Reynolds number for inlet of the pipe and drying chamber greater than 4000 therefore the flow is turbulent. Both Reynolds numbers represented that the flow in the drying chamber is turbulent, and this flow is used for drying tomatoes to produce chips and powder form.

3. NUMERICAL ANALYSIS of SOLAR DRYING CHAMBER

This part deals with the displaying of solar dryer chamber on the way to forecast the thermal analysis of drying chamber. Following governing equations are used for analysis of drying chamber:

Continuity Equation: $$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (1)$$

Momentum Equation:

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = u\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) - \frac{1}{\varrho} \times \frac{\partial p}{\partial x} \quad (2)$$

Energy Equation:

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \alpha\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) \quad (3)$$

3.1 Geometry of Drying Chamber

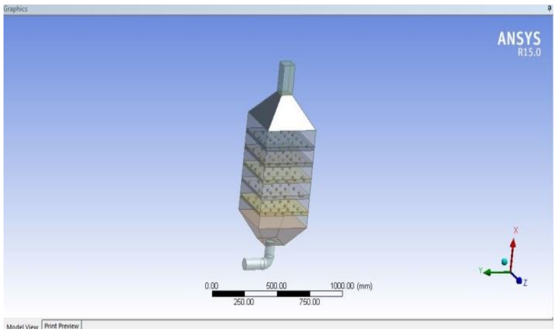

Fig -1: Geometry of Drying Chamber

Geometry is constructed by using Ansys fluent as shown in figure 1, by considering all dimension of drying chamber as listed in table1.

Table -1: Dimension of Drying Chamber

Length(mm)	Breadth(mm)	Altitude(mm)
420	420	660

3.2 Meshing of Drying Chamber

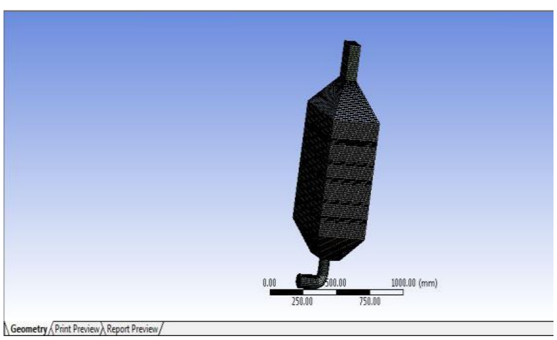

Fig -2: Meshing of Drying Chamber

Figure 2 shows that the meshing of the drying chamber is carried out in ANSYS Fluent. Automatic mesh is used to discretize the drying chamber. Following table shows that the quality of meshing for drying chamber.

Table -2: Quality of Mesh

Nodes	Element	Aspect Ratio	Skewness
194547	161502	1.293	0.6923

3.3 Boundary Conditions

Table -3: Boundary Conditions

No.	Face	Type of Boundary Condition	Velocity Magnitude (m/sec)	Temperature (K)
1	Entrance	Air Flow Inlet	2	325
2	Exist	Pressure Outlet	-	-
3	Wall	-	No Slip Condition	-

Table 3 shows that the boundary condition of drying chamber. Meshing file is imported in the ANSYS Fluent set up. The current problem is assumed as three-dimensional, steady, laminar and incompressible flows.

3.4 Solver Setting

The solver operated for the examination of 3D-Pressure based solver with standard K-ω model and vitality condition was likewise activated. The liquefied properties and boundary conditions are determined. The SIMPLE algorithm for pressure-Velocity coupling was used. Second order upwind plan was used for pressure, momentum, turbulent kinetic energy, specific heat degeneracy rate and vigor.

4. RESULTS and DISCUSSION

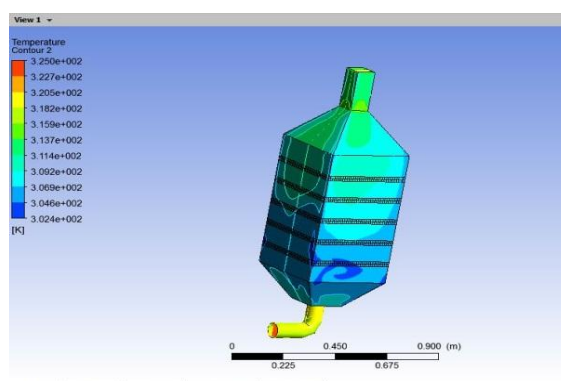

Fig -4 (a): Temperature Distribution of Drying Chamber

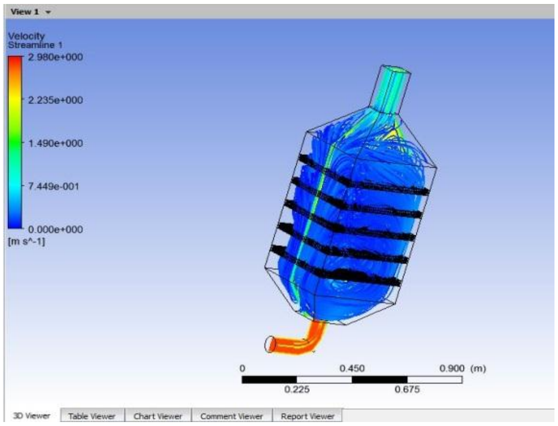

Fig -4 (b): Velocity Distribution of Drying Chamber

Figure 4(a) and 4(b) are shown that outlet temperature and air flow distribution of solar desiccating chamber. The impact of velocity and temperature on dehydrating chamber for agricultural products are observed to be decreases. The table4 shows that the result of velocity and temperature of drying chamber.

Table -4: Temperature and Velocity Distribution Results

Temperature (K)		Velocity(m/sec)	
Inlet	Outlet	Inlet	Outlet
325	318.15	2	1.107

5. CONCLUSION

In this paper, solar drying chamber for agricultural product was successfully simulated using ANSYS 15.0 ACADEMIC. A simulation is run in CFD tool for drying chamber. The evaluation of temperature and velocity at outlet of drying chamber for agricultural products, the temperature is decreases up to 6-10^0 C and velocity also reduce.

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