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Design, Fabrication and Testing of Solar Air Dryer

[1]Shyam Mohan P, [2]Dr. L. Rekha
[1]PG Scholar, [2]Assistant Professor,
Govt Engineering College
Thrissur, Kerala, India

***Abstract*-The Solar Powered Air Dryer is new technology basing on blending Solar Thermal. In our project the solar panel is used to convert the light energy to heat energy by flat plate collector method. The machine, solar air dryer, we introduce through our project is mainly useful for drying seeds, fruits and wherever moisture contents. In our project, the solar air dryer consists of four main parts such as solar panel, battery, heating element and blower. The blower is used to passing the hot air to the required place, so that the moisture contents in the place was removed. The size of our project is also portable. So we can move the ground dryer to any place very easily.**

Keywords— Solar Drying, Efficiency Comparison, Drying Rate.

INTRODUCTION

Energy is the primary measure of all kind of work by human beings and nature. Everything happening in the world is the of flow of energy in one of its form. Over the last 200 years, people have become more and more dependent of the energy that they dig out of the ground. In 1700"s almost all our energy came sources like wind, water, firewood. Our windmill and sailing ships were powered by wind. Water powered our water wheels. Cooking and heating of our homes were done using firewood. Man power did just about everything else. All these energy source came from sun since solar energy drove wind and rain, grew trees and grew crops to nourish our animals and ourselves. All these energy sources are also renewable since wind kept blowing river kept flowing and the trees and the crops kept growing. By 1800, we get much of our energy from the coal dug out from the ground and by 1900; we began to drill for oil and natural gas. By 1950, this fossil fuel had mainly displayed the older energy sources . Some fuels like fossil fuels come from decayed remains of prehistoric plants and the animals, so their energy also comes originally from sun, in some parts of the world, new fossil fuels are being formed even today.

LITERATURE REVIEW

Mahesh Kumar n, Sunil Kumar Sansaniwal, Pankaj Khatak [2] have done an experiment on the solar drying process for the drying of the various commodities and resulted that solar drying of various products is one of the most important potential applications of the solar energy. In developing countries, such drying exercises are being carried out using conventional drying methods .But these methods are trapped with some severe drawbacks and cause loss of the products during their drying which is estimated to be 25–40% of the total production in developing countries. The best alternative to overcome the problems of traditional drying methods is the development of solar dryers.

Lalit M. Bal, Santosh Satya, S.N. Naik [4] developed efficient and effective dryer using solar energy with thermal energy storage system for drying of agricultural products at moderate temperature (40–75 8C) and has become a substitute for fuel in many developing countries. Storage of solar energy has the power to reduce the time between supply of energy and the demand of energy, hence playing a great role in energy conservation. The rural and urban populations depend mainly, on fuels which are non commercial to meet their energy needs. Solar drying is one possible solution but its acceptance has been limited partially due to some difficulties. A great deal of experimental work over the last few decades has already shown that agricultural products can be dehydrated using solar energy

A.G.M.B.Mustayen, S.Mekhilef, R.Saidur [8] presented a paper on the study on the design, performance, and application of different types of solar dryers. The types examined are the direct, indirect, mixed-mode, active, and passive solar dryers. It is performed either using fossil fuels in an artificial mechanical drying process or by placing the crop in the presence of direct solar rays. The first method is costly and has a negative impact on the environment, while the second is completely depending on the climate. By contrast, using a solar dryer is comparatively cheaper and more efficient. Some solar dryers run without electrical energy or by the usage of fossil fuels.

COMPONENTS AND DESCRIPTION

The components that are used in the project SOLAR AIR DRYER are as follows,

- Solar panel,
- Battery,
- DC blower,
- Frame,
- Drying container.

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DESIGN OF SOLAR DRYER

The system is to be designed considering certain design parameters components wise and is fabricated with design specifications. The main components are blower, a solar collector, and a drying chamber. The fabrication is done as per the design values and available materials in mechanical and welding workshop. The fabricated components are tested to check the operation and errors in design or fabricated which may damage the system; design of each component is explained below.

Material to be dried: handmade paper of A4 size (21.0×29.7) cm

Moisture content in wet sheet = 50% = 0.5

Moisture content to be obtained after drying = 7% = 0.07

Number of paper to be dried at a time = 20

Weight of 1 wet sheet, M =22g = 0.022 kg

Amount of moisture content to be removed from wet sheet,

$$M_m = \frac{M(Wet\% - Dry\%)}{(100\% - Dry\%)} kg$$

$$M_m = \frac{0.022 \times (0.5 - 0.07)}{(100\% - 0.07)} kg$$

$$M_m = 0.01 \text{ kg}$$

Therefore, we have to remove 0.01 kg of water from 1 paper in order to get the required value added product.
The amount of heat required to remove the moisture content for 1 paper is given by,

$$Q_R = M_m h_{fg} + M_m h_f$$

Where,

h_{fg}= Specific enthalpy of water at latent heat of evaporation,

h_f = Enthalpy of water,

At 100°C,

h_{fg}= 2256.4 kJ/kg,

h_f = 419.17 kJ/kg,

Therefore, $Q_R = M_m h_{fg} + M_m h_f$

$= [(0.01 \times 2256.4) + (0.01 \times 419.17)]$

Q_R = 26.76 kJ of heat for drying 1 paper

That is, rate of energy Q = (26.75×1000) / (60×60) J/s

Q = 7.4 W

Therefore, Q for drying 20 papers in 1 hour = 7.4 × 20

= 148 W

Collector design

Average solar irradiance in Hubli, I_t = 5.2875 kWh/m^2/day

= (5.2875× 1000) / 12, for 12 hours

= 440 W/m^2

The useful heat delivered by the collector,

$$Q_u = A_c [I_t \langle\tau.\alpha\rangle - U_L (T_c - T_a)] F_R$$

Where,

A_c = Area of collector (m^2)

I_t = Solar irradiance (W/m^2)

τ = Transmissivity of glass cover = 0.88

α = Absorptivity of glass cover =0.9

U_L = Overall heat loss coefficient = 5 W/m^2°C

T_c = Average temperature of the upper surface of the absorber = 40°C

T_a = Average atmospheric temperature = 24°C

F_R = Heat removal factor for collector = 0.9

$\langle\tau.\alpha\rangle$ = Transmissivity – Absorptivity product

$$\langle\tau.\alpha\rangle = (\tau \times \alpha) / [1 - (1-\alpha)\rho_d]$$

$$= \frac{(0.88 \times 0.9)}{[1-(1-0.9)\times 0.16]}$$

$$= 0.804$$

Where, ρ_d= diffuse reflectance for 1 glass cover = 0.16

As per the working of the dryer, Q =Q_u

Therefore for 1 paper

$$Q_u = A_c [I_t \langle\tau.\alpha\rangle - U_L (T_c - T_a)] F_R$$

$7.4 = A_c [(440 \times 0.804) - 5(40-24)] \times 0.9$

$= A_c [353.76 - 80] \times 0.9$

$= A_c \times 273.76 \times 0.9$

$7.4 = A_c \times 246.38$

Therefore, A_c = 7.4/246.38 = 0.03m^2 for 1 paper

For 20 papers,

Area of collector, A_c = 0.03 × 20 = 0.6 m^2

Therefore size of the flat plate collector = 0.8m × 0.8m

Blower design

Amount of heat transferred,

$$Q = C_p \times \dot{m} \times \Delta T$$

Where, C_p = Specific heat of air = 1.005 kJ/kg K

ΔT = Temperature reduction within the chamber = 20K

$\dot{m}$ = Mass flow rate of air through the blower

Here, $\dot{m}$ = Volumetric flow of air × Density of air

$= v \times \rho$

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Where, ρ of air = 1.225 kg/m^3

Therefore above equation becomes, Q=Cp × v × ρ × ΔT

For drying 20 papers, (26.76×20) / (60×60) kJ/s = 1.005×v×1.225×20

Therefore, volumetric flow rate,

$$v = \frac{(26.76\times20)}{(60\times60\times1.005\times1.225\times20)}$$

$$= 0.006\ m^3/s$$

$$= 0.006\times60$$

Therefore, $v = 0.36\ m^3/min$

Drying chamber design

Our requirement is to dry 20 papers of A4 size in 1 hour.

As per our assumption, a chamber of 1.5 feet in length, breadth and height can accommodate 12 papers at a time to dry.

Therefore, if for 12 papers, chamber size is as said above, that is 0.45m in length, breadth and height, then for drying 20 papers of A4 size at a time,

$$\text{Chamber size} = (\frac{0.45}{12}\times 20)\times(\frac{0.45}{12}\times 20)\times(\frac{0.45}{12}\times 20)$$

$$= 0.75m \times 0.75m \times 0.75m$$

After adding enough space for air circulation, chamber size was decided as 0.9m × 0.9m × 0.9m.

ANALYSIS

At each hour starting from 9.00 AM to 5.00 PM various parameters tabulated below were notted.With the results obtained comparison between drying of paper using solar dryer and open sun drying were done.

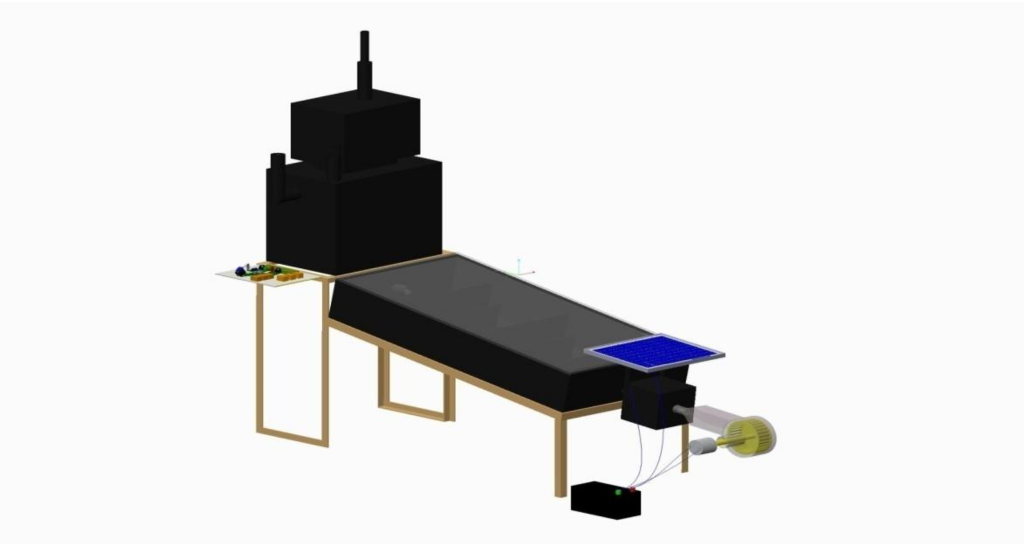
ANALYSIS WITH PAPER

Initially the A4 sheets were weighed and found to be weighing 22 grams. The paper were then hung inside the drying chamber for drying purpose. The testing were carried out 4 times a day. As per the design the papers must be dried in one hour. So a set of 20 sheets were kept inside the drying chamber. First set of papers were hung at 9.00 AM, then at 11.00 AM second set of papers were hung and at 1.00PM third set of papers were hung inside the drying chamber and finally at 4.00 PM forth set of papers were hung inside the chamber. For each sets the inlet and outlet temperatures and volume flow rate were calculated in three different time intervals. The observations were noted when papers are placed inside the chamber. Then after 30 minutes the values were again noted. After completion of one hour the observations were made again. Every time company experts were present while the readings were noted. The duration of drying were affected by atmospheric conditions.

COMPARISON WITH NORMAL DRYING

A comparison between the drying of the papers using the solar dryer and open sun drying was carried out in the company by the company experts. A set of 20 sheets were kept for drying in the solar dryer at 9.00 AM. At the same time another set of 20 similar A4 sheets were kept for normal drying. The normal drying includes the sun drying and drying by hanging sheets under a fan.

FINAL MODEL OF THE DRYER



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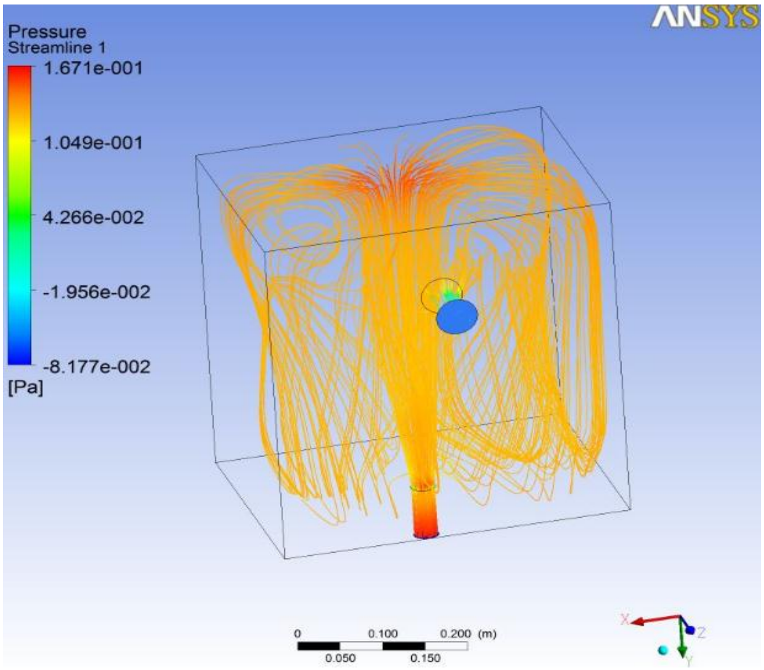
RESULTS

Time in hours	Chamber inlet temperature (ºC)	Chamber outlet temperature (ºC)	Average volumetric flow rate (m^3/min)	Average inlet temperature (ºC)	Average inlet temperature (ºC)	Duration of drying
9.00	44.2	23.3				1 hour 14 minutes
9.30	48.2	27.5	0.27	48.6	27.3	
10.00	53.7	31.1				
11.00	60	39.4				1 hour 5 minutes
11.30	64.3	43.1	0.32	64.3	43.2	
12.00	67.7	46.9				
1.00	71.1	48.4				1 hour 5 minutes
1.30	66.4	46.6	0.33	67.0	46.5	
2.00	63	44.2				
3.00	61.1	41.7	0.29			1 hour 10 minutes
3.30	60.1	38.7		59.7	39.0	
4.00	57.8	36.4				

COMPARISON OF RESULTS

A comparison of solar drying with normal drying was performed in the company. Two sets of A4 sheet with each 20 sheets were kept for drying in solar dryer as well as in open sun drying at 9.00 AM. The papers kept in the solar dryer got dried in 70 minutes and the papers were taken out from the chamber at 10.10 AM but the papers that were kept for open sun drying got dried after one day. On the next day at 10.00 AM the papers were removed after drying. The final weight of the papers in both case were found similar. Thus the solar dryer was found to be more effective than the open sun drying since the duration of time taking was much lesser when using the dryer.

PRESSURE,VELOCITY,TEMPERATURE DISTRIBUTION INSIDE DRYING CHAMBER



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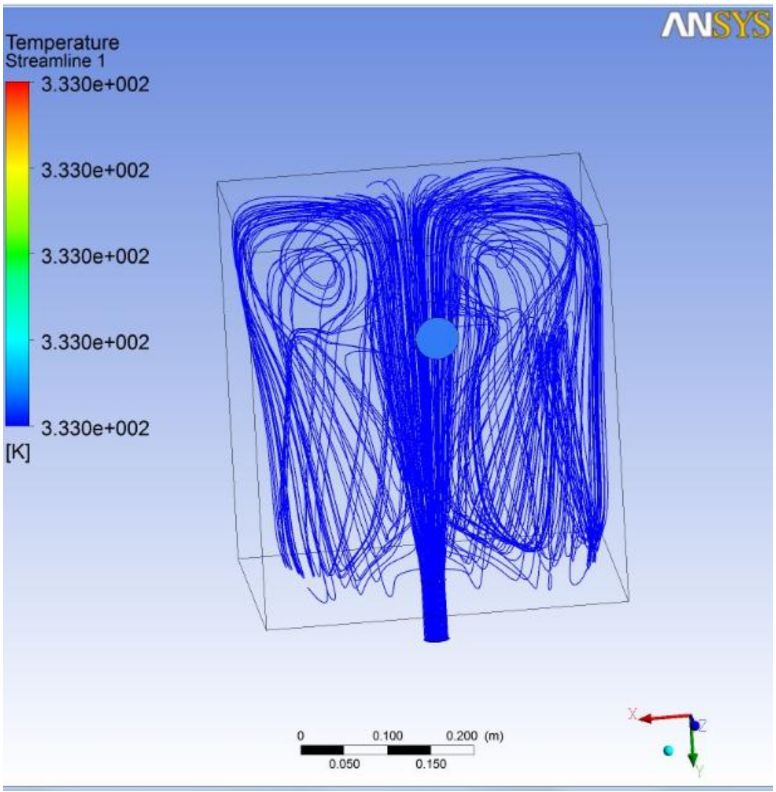

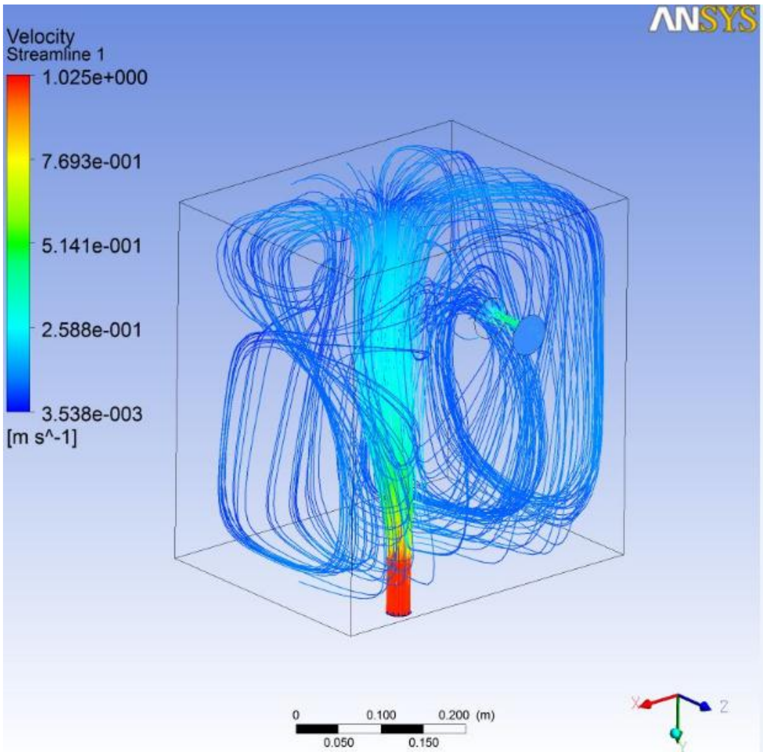

CONCLUSION

The model of the dryer was fabricated to dry 20 papers ofA4 size in one hour. The design, fabrication and analysis were done and the results were obtained. the dryer took 65 to 75 minutes to dry the paper and the open sun drying took one day to dry the same number of papers. The overall performance of the paper depended upon the atmospheric conditions. Larger the intensity of solar energy larger will be the efficiency of the solar dryer. As the cost of fabrication of the dryer is less it gives a better hand over the conventional solar dryer. The solar drying was compared with the normal sun drying and the drying using the solar dryer was very effective and the drying time was very less compared to the normal drying. This technology can be further developed by creating various modifications in the design to increase the effectiveness of drying.

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