Design And Analysis of Solar Heat Pipe Dryer For Withering Tea Leaves

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Abstract- *Nowadays tea leaves are dried using various types of heaters which consume more amount of non-renewable energy. This project intends to design, analyze a tea leave dryer which uses solar heat pipes to harness solar energy, a renewable form of energy which is available freely. Duct and fins are to be designed and analyzed to see that a minimum pressure drop occurs when air is blown through the manifold without compromise in the surface area so that effective heat transfer takes place in the manifold. The drying chamber is designed and analyzed see that stagnation areas are not formed inside the dryer and the hot air flows evenly over the surface of tea leaves which are to be placed on the tray inside the drying chamber.*

Keywords- Tea leaves, renewable energy, Duct, Fin, Manifold, Drying chamber

I. INTRODUCTION

Open sun drying is a traditional method practiced widely in tropical climates for drying agricultural products. Considerable savings can be made with this type of drying since the source of energy is free and sustainable. However, this method of drying is extremely weather dependent and has the problems of contamination, infestation, microbial attacks, etc., thus affecting the product quality. Additionally, the drying time required for a give commodity can be quite long and result in post-harvest losses. Among the different techniques of preservation available, dehydration using solar energy has been accepted as the cheapest and simplest approach.

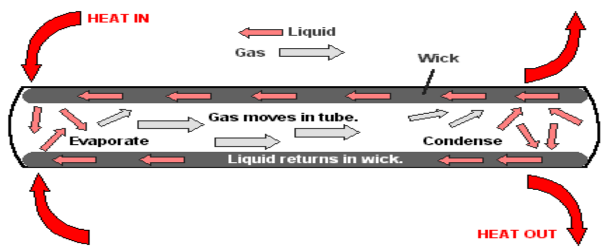
Solar dryers can broadly be categorized into direct, indirect and specialized solar dryers. Direct solar dryers have the material to be dried placed in an enclosure, with a transparent cover on it. Heat is generated by absorption of solar radiation on the product itself as well as on the internal surfaces of the drying chamber. In indirect solar dryers, solar radiation is not directly incident on the material to be dried. Air is heated in a solar collector and then ducted to the drying chamber to dry the product. Specialized dryers are normally designed with a specific product in mind and may include hybrid systems where other forms of energy are also used. Although indirect dryers are less compact when compared to direct solar dryers, they are generally more efficiency. Hybrid solar systems allow for faster rate of drying by using other sources of heat energy to supplement solar heat.

II.CONCEPT OF THE PROJECT

The dryer used in this project is an indirect solar dryer. Three main components of the dryer are identified. Solar heat pipe which utilizes heat energy from sun intensifies it and transfers it to the condenser region in the heat pipe. Fins are attached to the heat pipe in the condenser region are used to enhance heat transfer from the heat pipe to air inside the duct. In the drying chamber, the tea leaves to be dried are placed. As hot air passes over the leaves it absorbs the moisture and it escapes to the surroundings.

The longer wavelength solar radiation passes through the glass cover and reaches the inner copper tube and the coating beneath the glass prevents the shorter wavelength infrared rays from escaping outside. Thus, it helps in providing greenhouse effect. The temperature of the air should be maintained or else the color of the leaves will change hence it will effect the quality and cost of the end product. So, temperature sensors are to be placed to vary the flow rate of air. Thus, a total of four sensors are to be placed, one at the inlet of the manifold to read the temperature at initial phase. Another sensor is placed at outlet of the manifold to read the temperature that comes out of the air, the third sensor is placed at the inlet of the drying chamber to read temperature, so that it can help to maintain steady flow rate if any variation takes place. And the final sensor is placed at the outlet of the drying chamber to read temperature of the air that comes out of the it. Which can be used to calculate the amount of moisture content absorbed by the hot air.

III. WORKING OF HEAT PIPES



Once the sun's rays pass through the vacuum, the tube retains up to 97% of the heat absorbed (full light spectrum). A copper heat pipe within the center of the vacuum tube absorbs the available heat causing a refrigerant within the tube to boil (boils at 6^0C). The rising vapour causes the bulb at the top of the tube to heat up to as much as 250^0C. This bulb, one of many, is inserted into a manifold through which the water flows. Heat transfer then takes place between the bulb and the water with the bulb effectively actingasamini element. The special selective coating changes the short-wave solar radiation into long wave heat radiation and is almost 94% efficient meaning only 6% of the sun's energy is lost!

Inside the container is a liquid under its own pressure, that enters the pores of the capillary material, wetting all internal surfaces. Applying heat at any point along the surface of the heat pipe causes the liquid at that point to boil and enter a vapor state. When that happens, the liquid picks up the latent heat of vaporization. The gas, which then has a higher pressure, moves inside the sealed container to a colder location where it condenses. Thus, the gas gives up the latent heat of vaporization and moves heat from the input to the output end of the heat pipe.

IV. FORMULAS

1.HEAT UTILIZATION FACTOR (HUF)

This may be defined as the ratio of temperature decreases to cooling of the air during and the temperature increase due to heating of air**.**

$$\mathbf{HUF= \{(t_1-t_2) / (t_1-t_0)\}}$$

where to, t1 and t2 are dry bulb temperature of ambient air, drying chamber inlet air, and drying chamber outlet air in [K], respectively. HUF may be more than unity under certain drying conditions. HUF for a heat pump assisted dryer should be as high as possible to achieve a higher drying rate. At higher HUF values, moisture carried away from the leaves by the drying air is at maximum.

2. COEFFICIENT OF PERFORMANCE (COP)

$COP= \{t_2-t_0/t_1-t_0)\}$
t_2=d.b.t. of exhaust air
t_1=d.b.t. of drying air
t_0=d.b.t. of ambient air
COP+HUF=1

3. MOISTURE CONTENT

The percentage of moisture content (M) of oolong tea leaves is calculated by Equation

$$M = \frac{Wi - Wd}{Wi} \times 100$$

where, wi and wd are mass of the sample before drying and after drying. The moisture content in freshly harvested leaves is 77 %wb to91 %wb while that required for storage is 7 %wb to10 %wb.

4. MOISTURE RATIO

Moisture ratio (MR) of oolong leaves is calculated by Equation:

$$MR = \frac{Mt - Me}{Mt - Mi}$$

where, Mt,Mi, and Me are the moisture content at t, initial moisture content, and equilibrium moisture content, respectively. The values of Me are too smallto be compared to Mt or MI for a long period and hence, Eq. (5) for MR is finally written as Mt /Mi.

5. WEIGHT OF DRY MATERIAL

Weight of dry material (wd') is calculated by Equation

$$Wd = Wi\left(\frac{100 - M}{100}\right)$$

where, wi is the initial weight of the sample in grams and M is the moisture content of sample feed in %wb.

6. DRYING RATE

The drying rate (R) in a gram of water per min per 100 g of dry matter during drying experiments is calculated by using Equation

Wd
R =t×Wd g
100 where t is the drying time
in minutes

7. MOISTURE EXTRACTION RATE

Moisture extraction rate (MER) [kg/h] is defined as a kilogram of moisture removed per hour and indicates the dryer capacity or throughput rate. MER is given by

$$MER = \frac{(Wi - Wd)}{t}$$

where, (wi – wd) is the amount of water removed during drying.

8. SPECIFIC MOISTURE EXTRACTION RATE

The specific moisture extraction rate (SMER) [kg/(kWh)] describes the effectiveness of the energy used in the drying process. SMER is defined as a kilogram of moisture removed per kilowatt-hour consumed energy and is related to the total power to the dryer, including the fan power and the efficiencies of the electrical devices. SMER is calculated by Eq. (9) given below

$$SMER = \frac{(Wi - Wd)}{Ec}$$

where, Ec is the total energy supplied in the drying process

9. Drying Efficiency

The effective heat efficiency is mathematically defined by
$\eta d = t1 - t2t1 - tw$;where tw is bulb temperature

V. FLOW ANALYSIS OF MANIFOLD

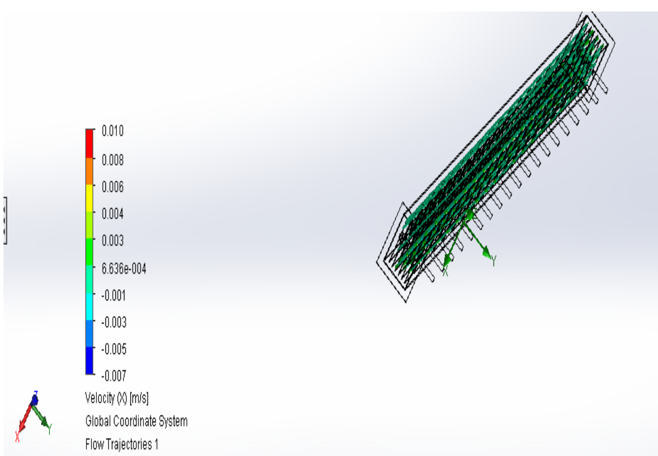


Fig-1 ANALYSIS OF 6 FINS HEAT PIPE ARE ARRANGED IN SERIES

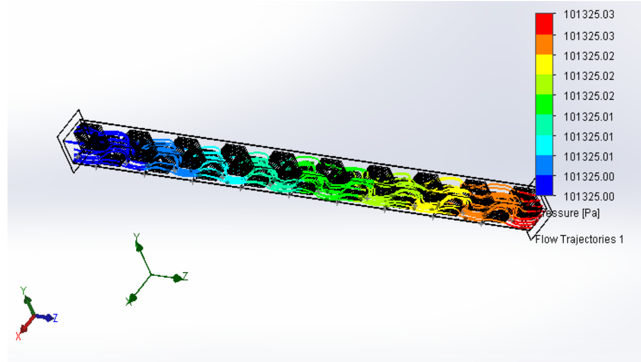


Fig-2 FLOW ANALYSIS OF 6 FINS HEAT PIPE ARE IN BOTTOM-UP ARRANGEMENT

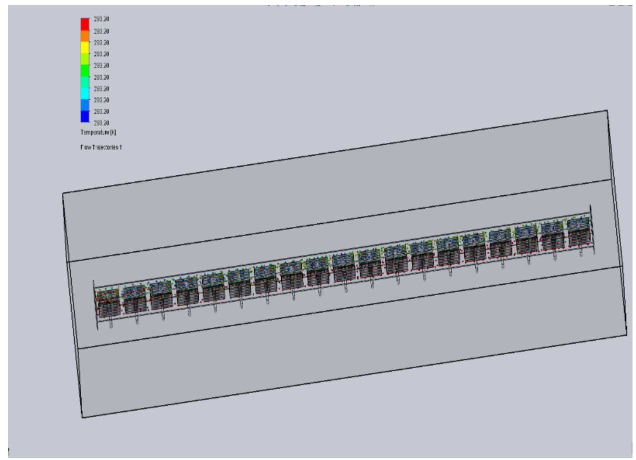


Fig-3 ANALYSIS OF 8 FINS HEAT PIPE IN SERIES ARRANGEMENT

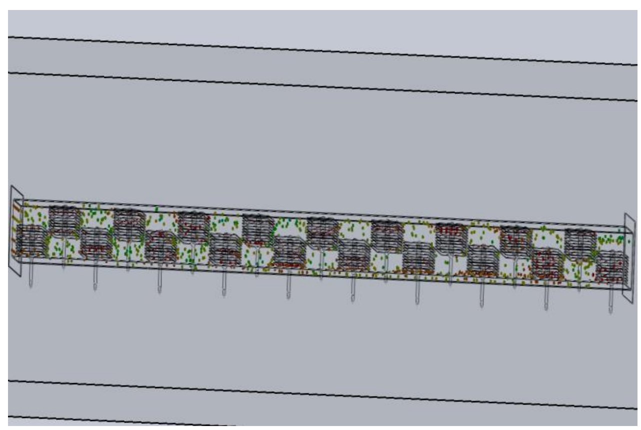


Fig-4 ANALYSIS OF 8 FINS HEAT PIPE IN BOTTOM UP ARRANGEMENT

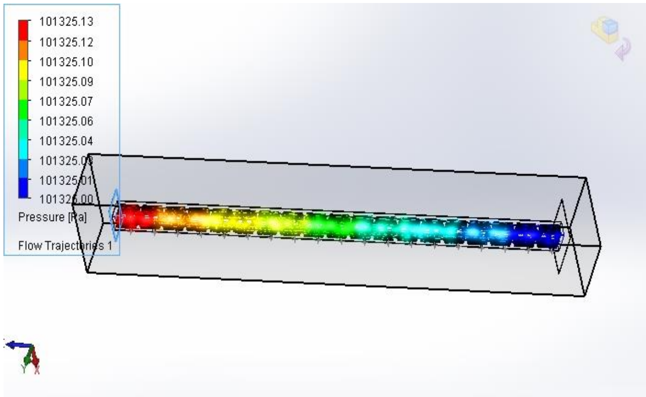


Fig-5 FLOW ANALYSIS OF 10 FINS HEAT PIPE IN SERIES

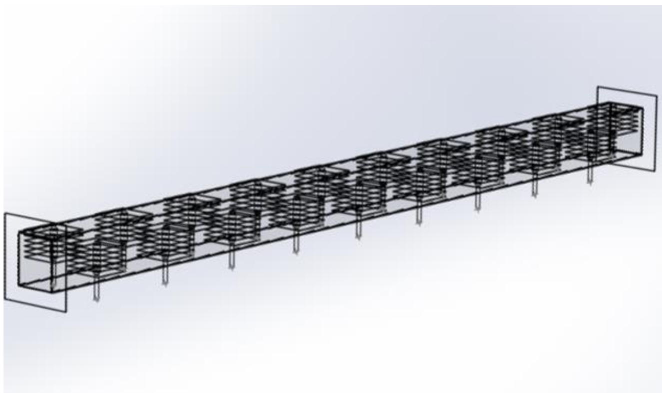


Fig-6 FLOW ANALYSIS OF 10 FINS HEAT PIPE IN BOTTOM-UP ARRANGEMENT

VI. FLOW ANALYSIS OF DRYING CHAMBER

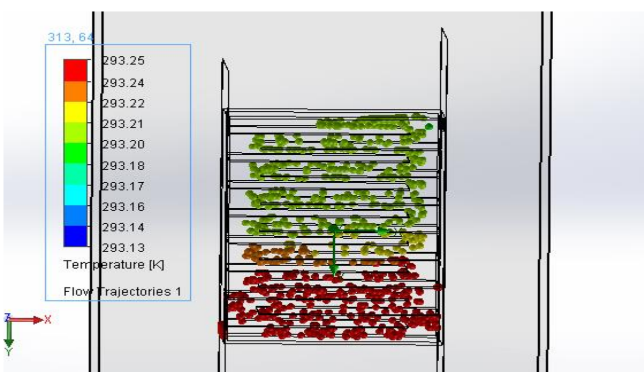


Fig-7 AIR FLOW ANALYSIS IN DRYING CHAMBER WITH PLATE PITCH LENGTH OF (250mm)

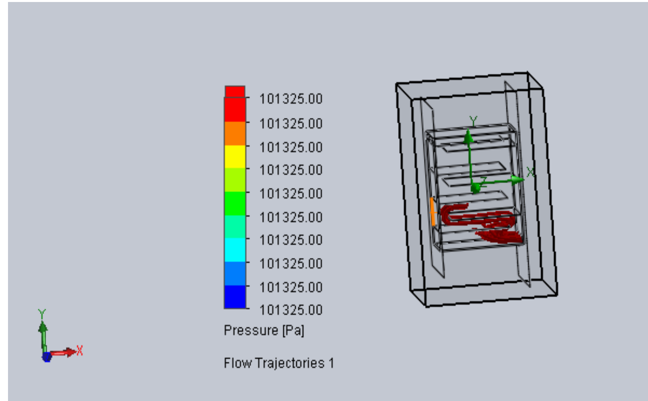


Fig-11.1.9 AIR FLOW ANALYSIS IN DRYING CHAMBER WITH PLATE PITCH LENGTH OF 300mm

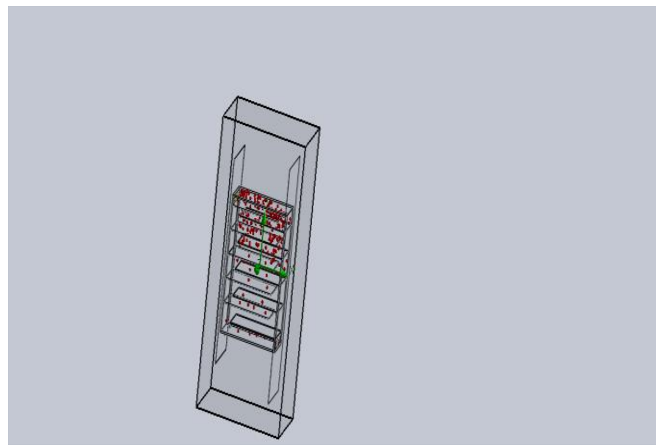
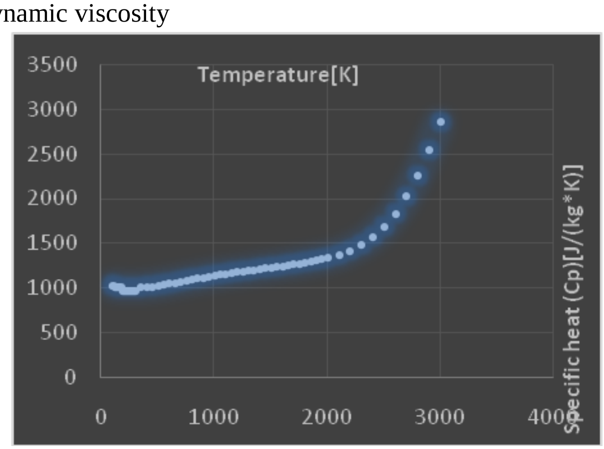


Fig-9 FLOW ANALYSIS OF DRYING CHAMBER WITH PLATE PITCH LENGTH OF 350mm

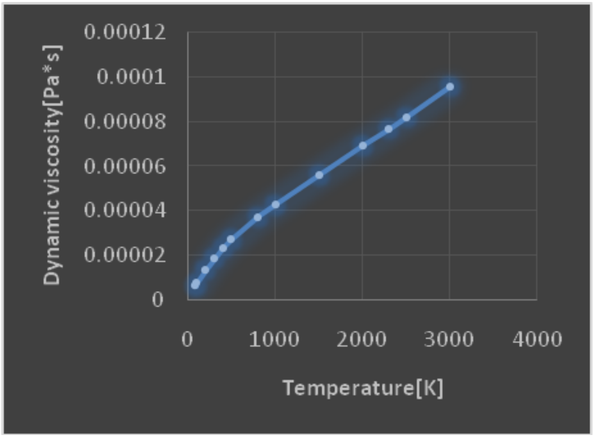
Engineering Database for drying chamber

Gases: Air
Path: Gases Pre-Defined
Specific heat ratio (Cp/Cv): 1.399
Molecular mass: 0.0290 kg/mol

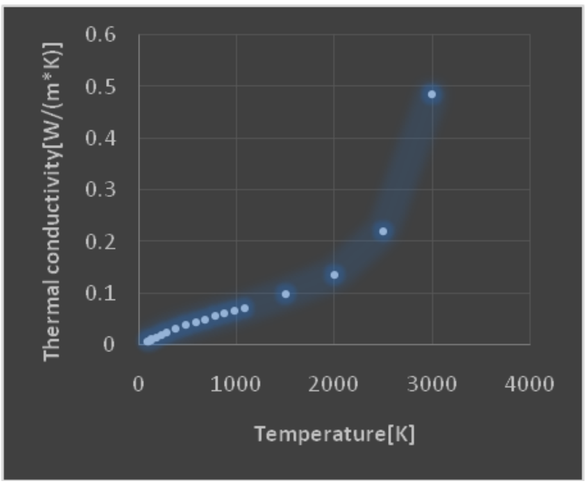
Dynamic viscosity



Specific heat (Cp)



Thermal conductivity



VII. RESULT

COMPARISON TABLE FOR DUCT

S.NO	MODELS CONFIGURATION	PARAMETERS			
		PRESSURE [Pa]	TEMPERATURE [°c]	VELOCITY [m/s]	MASS FLOW RATE [kg/s]
1	6 - FINS HEAT PIPE CONNECTED IN SERIES	10136.9	293.2	19.96	0.07
2	[illegible] - FINS HEAT PIPE CONNECTED IN BOTTOM UP	10251.7	216	20.75	0.08
3	8 - FINS HEAT PIPE CONNECTED IN SERIES	10157.9	293.2	17.26	0.05
4	8 - FINS HEAT PIPE CONNECTED IN BOTTOM UP	10136	293.4	19.5	0.05
5	10- FINS HEAT PIPE CONNECTED IN SERIES	10957.8	216	15.97	0.1
6	10- FINS HEAT PIPE CONNECTED IN BOTTOM UP	10115.7	221.7	19.54	0.1

COMPARISION TABLE FOR DRYING CHAMBER

S.NO	MODEL CONFIGURATION	PARAMETERS			
		PRESSURE [Pa]	TEMPERATURE [°c]	VELOCITY [m/s]	MASS FLOW RATE [kg/s]
1	CHAMBER WITH PLATE PITCH LENGTH OF 250mm	10957.8	145	10	0.075
2	CHAMBER WITH PLATE PITCH LENGTH OF 300mm	10957	172	10	0.0625
3	CHAMBER WITH PLATE PITCH LENGTH OF 350mm	10957.7	96	10	0.0556

- Based on the overall analysis results the numerical results shown on the table above denotes that six fins heat pipes connected in series are more apt compared to fins connected bottom up.
- Chamber with plate length 250 mm has acquired the standard numerical requirement compared to chamber with plate length 300mm.
- Hence chamber with plate length 250mm are more efficient.

VIII. CONCLUSION

- The data signifies that an increase in temperature inside the drying chamber provides a lower humidity rating, which is a significant factor in the drying process. The lower the relative humidity, the faster the drying time during the drying process.
- Three different kinds of copper head holding three different no of fins were modelled and analyzed.
- The results denoted that the copper head holding six fins arranged in series shows optimum condition for achieving maximum temperature.
- Temperature sensors placed in four different points, to take readings, so that temperature variation can be detected and maintained.
- Three drying chambers are modeled and analyzed with varying pitch length for the trays.
- The drying chamber in which the tray having a length of 250mm is comparatively best because, when the hot air enters the drying chamber, it flows over the overall surface area of the drying chamber and absorbs maximum moisture content from the tea leaves placed on the tray inside the chamber.
- Finally, the two efficient models (copper head holding six fins and drying chamber with pitch length of tray 250 mm) are selected and combined to bring optimum output.

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