International Journal of Mechanical and Industrial Technology **ISSN 2348-7593 (Online)**
Vol. 4, Issue 1, pp: (128-135), Month: April 2016 - September 2016, Available at: **www.researchpublish.com**

Investigation on Solar Air Dryer by Using Forced Convection with Thermal Storage System

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Abstract: **This project presents Various Thermal analysis in solar air dryer with Force convection and thermal storage to be done & the various parameters are considered such as Time, solar radiation, ambient temperature, Drying chamber temperatures, Moisture content, drying rates, Air mass flow, Collector efficiency, Heat storage rate, Heat release rate for thermal storage. The system consists of a flat plate solar air heater with heat storage unit, a drying chamber and a centrifugal blower. Drying experiments have been performed at an uniform air flow rate. Drying of agricultural crop or wood in a forced convection in solar drier reduces the moisture content.**

Keywords: **Investigation on Solar, ambient temperature, moisture content.**

1. INRODUCTION

Thermal analysis is to be done for enhancing the efficiency of the solar air dryer & also enhancing the drying rate by the way of using forced convection with thermal storage system.

The main objective of this work is to improve the efficiency of the solar air dryer by making some modifications in the solar air dryer. Thus a thermal storage unit is included.

In India, sun drying is the most commonly used method to dry the agricultural materials like grains, fruits and vegetables. In sun drying, the crop is spread in a thin layer on the ground and exposed directly to solar radiation and other ambient conditions. The rate of drying depends on various parameters such as solar radiation, ambient temperature, wind velocity, relative humidity, initial moisture content, type of crops, crop absorbtivity and mass of product per unit exposed area .

Abhishek Saxena et al (1) made to enhance the heat transfer rate to improve the efficiency simple fabricated solar air heater. “granular carbon” has introduced as long term heat absorbing media inside solar air heater. The Thermal performance evaluation of solar air heater has been carried out on four different configuration by operating it on natural & forced convection. The thermal behaviour of the system has also been evaluated by operating it on auxiliary power by placing a halogen tube (300w) inside the inlet and outlet ducts. Because of using halogen lights the system is feasible to perform in night or bad climatic conditions

A.Boulemtafes-Boukadoum et al (2) analysed CFD based analysis of heat transfer enhancement in solar air heater provided with transverse rectangular ribs.A numerical analysis of convective heat transfer enhancement in solar air heaters with artificially roughened absorber.The air flows in forced convection and the absorber is heated with uniform flux. Since the flow is turbulent, by use the RANS formulation to model the flow.Continuity, Momentum and energy equations in turbulent mode using four closure models K-Ɛ RNG , K-Ɛ RZ , K-Ꞷ Standard , K-Ꞷ SST

Mahmud M.Alkilani et al (3) made Studies are involved to the type of collection with the type of storage .The recent researches focused on the phase change materials (PCM s) as latent heat storage is more efficient than sensible heat storage .It has been appeared the PCM with high latent heat and suitable geometry are required for optimum thermal performance of solar air heater. The recent designs of solar air heaters with thermal storage units reduced the cost and volume when integrated in one product

P.Gbaha et al (4) had designed, constructed and tested a solar dryer with natural convection, drying rate increases.. 0.502 m x 0.2 m – 0.002 m thick steel sheet painted black. 0.004 m thickness glass cover. Analysis in drying kinetics i)Drying time Vs moisture content,ii) Drying rate Vs time, iii)Air mass flow Vs Efficiency.Drying rate increases with drying air temperature and drying air mass flow

I.N.Simate et al(5) investigated the comparision of optimized mixed mode and indirect mode natural convection solar dryers. The solar drying simulations are combined with the cost of dryer materials and a search technique that finds the dryer dimensions at the minimum drying cost. Optimization gave a shorter collector length for the mixed mode solar dryer (1.8m) than for the indirect mode dryer (3.34m) of the same grain capacity (90Kg)

V.Shanmugam et al (6) fabricated an indirect forced convection and desiccant integrated solar dryer . The system consists of a flat plate solar air collector, Drying chamber and a desiccant unit. The desiccant unit is designed to hold $CaCl_2$ based solid desiccant consisting of 60% bentonite , 10% calcium chloride,20%vermiculite and 10% cement. Drying experiments have been performed for green peas at different air flow rate. The equilibrium moisture content Me is reached in 14 hours at an air flow rate of 0.03 Kg/s. The system pick up efficiency, Specific moisture extraction rate, dimension less mass loss, mass shrinkage ratio and drying rate are discussed .

Mohammed M.Farid et al (7) review s previous work on latent heat storage and provides an insight to recent efforts to develop new classes of phase change materials (PCMs) for use in energy storage. There are large numbers of phase change materials that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. Paraffin waxes are cheap and have moderate thermal energy storage density but low thermal conductivity and hence require large surface area. Hydrated salts have larger energy storage density and high thermal conductivity but experience super cooling and phase segregation , and hence their application requires the use of some nucleating and thickening agents. The Main advantages of PCM encapsulation are providing large heat transfer area, reduction of the PCM s reactivity towards the outside environment and controlling the changes in volume of the storage materials as phase change occurs.

Pavel Charvat et al (8) designed Numerical and experimental Investigation of a PCM – based thermal storage unit for solar air systems. A heat storage unit containing 100 aluminium panels filled with a paraffin-based PCM was used in the Investigations. The experiments were carried out in a lab environment with an electric air heater as a heat source. A Numerical Model of the unit was developed and implemented as a type in the TRNSYS 17 simulation Tool. To performed investigations showed a potential of the use of latent heat thermal storage in air-based thermal systems with a narrow temperature operation range.

Abhay B.Lingayat , Yogesh R. Suple (9) reviews on phase change material as thermal energy storage medium and also identifies that Phase change materials (PCMs) are becoming more and more attractive for space heating and cooling in buidings, solar applications, off- Peak energy storage and heat exchanger improvements, Latent heat thermal energy storage (LHTES) offers a huge opportunity to reduce fuel dependency and environmental impact created by fossil fuel consumption

2. MEASUREMENT

i) Time in hours, ii) Incident Solar Radiation,

iii) AmbientTemperature ,iv) Drying chamber Temperature, v) MoistureContent, vi) DryingRate,

vii) Air Mass Flow, viii) Collector Efficiency, ix)Heat Storage Rate, x)Heat Release Rate

3. EXPERIMENTAL SET-UP

Main parts for solar air dryer are i)Solar collector, ii)Air inlet , iii)Hot air exit , iv)Drying chamber , v)Blower, vi)Thermal storage units, and vii)Trays.

One side of the collector was connected to the blower with the help of reducer and the other side was attached with dryer cabin. The 300-mm gap between the absorber and insulation was filled with concrete bricks to store the heat during sunshine hours and to obtain hot air during off sunshine hours

The **drying chamber** is made up of mild steel sheet of 2 mm thickness with width, depth and height of (1.5×1.5×1.5) feet respectively. The drier is capable of holding about 5 Kg per batch. The drying chamber having 2 Trays with wire mesh.

The **solar air heater(collector)** was tilted to an angle about 10^o with respect to horizontal. The system is oriented to face south to maximize the solar radiation incident on the solar collector. On the basis of measurements, (9° 10' 0" N, 77° 52‘0" E) ... Latitude and Longitude of the Kovilpatti), where the experiment is to be conducted had about 9 hours 30 min of sunshine, but potential sunshine duration was about 8 hours per day only. Solar collector has total volume of 0.3645 cubic meter with thermal storage and insulation. Working volume is 0.09 cubic meter.

Fig.1: Experimental setup

Air blower has 1.5 H.P & Single phase motor is used & running at 1500 RPM.

Concrete Brick is used as thermal storage under absorber plate made up of mild steel with 2 mm thickness.

Wax is used for another thermal storage with hollow cylinder unit . In middle aluminium pipe used for air passage & hot air from collector (heat) is transferred to wax which kept surrounding of aluminium pipe. Outer shell is made up of mild steel.

4. RESULT AND DISCUSSION

4.1 Time Vs Solar Radiation measurement:

Table 1 TimeVs Solar Radiation,Air Inlet Temperature, Drying Chamber Temperature

Time In Hours	Incident Solar Radiation (W/m^2)	Air Inlet Temperature (°C)	*Drying* Chamber Air Temperature (°C)
12 Noon	900	44.3	45.7
1 Pm	850	44.4	45.7
2 Pm	820	44.5	46.0
3 Pm	810	44.5	47.9
4 Pm	750	38.4	46.3
5 Pm	450	38.0	40.5
6 Pm	---	36.9	37.8

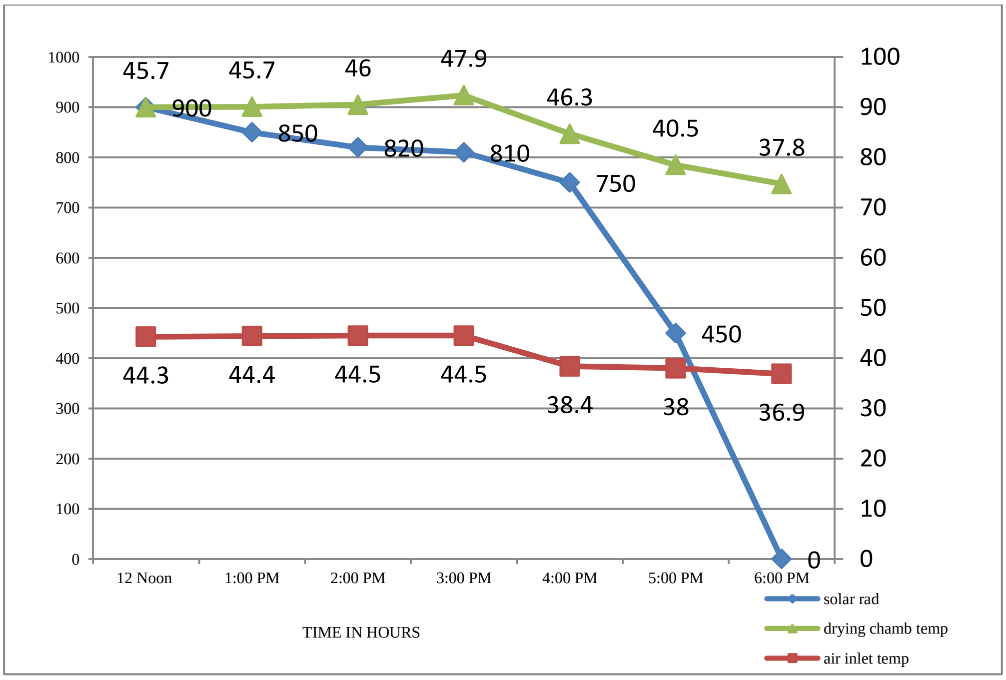


Fig.2: shows the TimeVs Solar Radiation (w/m^2)

4.2 Time Vs. Solar Radiation Air inlet Temperature, Drying Chamber Temperature & Match Stick Temperature when air drying on 21.03.2016:

Table.2: Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Match Stick Temperature when air drying

Time In Hours	Incident Solar Radiation (W/m^2)	Air Inlet Temperature (°C)	*Drying* Chamber Air Temperature (°C)	Match Stick Temperature (°C)
2:45 Pm	815	44.5	45.2	39.0
2:55 Pm	810	44.5	45.3	39.8
3:05 Pm	805	44.5	45.4	40.4
3:15 Pm	805	44.5	45.8	42.0

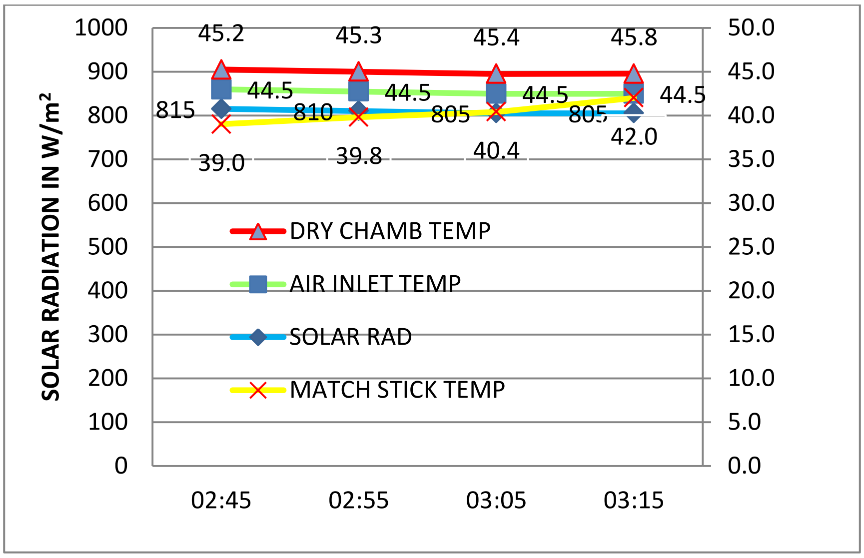
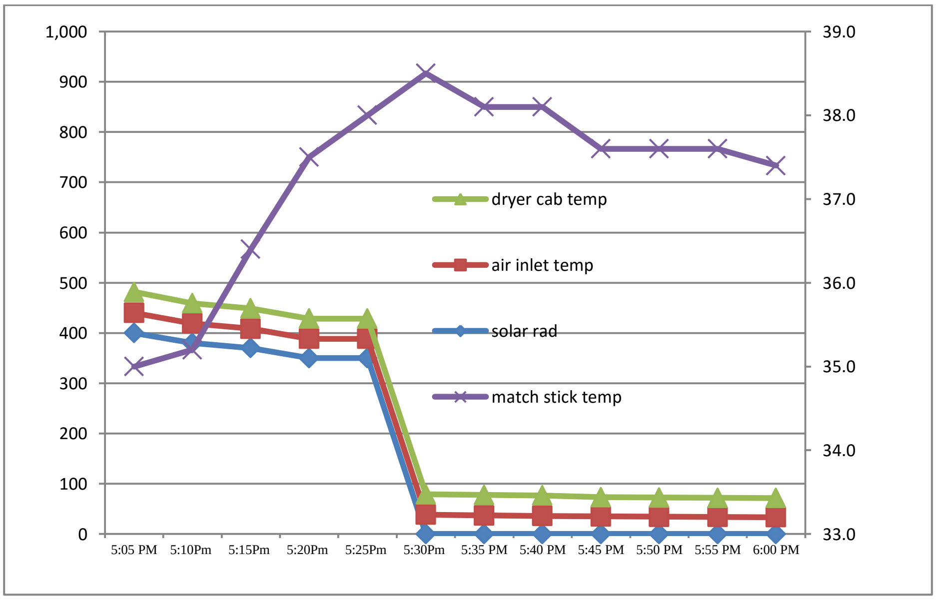


Fig.3: shows the TimeVs Solar Radiation (w/m^2)

4.2.1 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Match Stick Termperature when air drying by using Thermal storage after sun shine hours on 21.03.2016:

Table 3 TimeVs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Match Stick Termperature by using Thermal Storage by using Thermal storage after sun shine hours

Time In Hours	Incident Solar Radiation (W/m^2)	Air Inlet Temperature (°C)	*Drying* Chamber Temperature (°C)	Match Stick Temperature (°C)
5:05 Pm	400	40.0	41.8	35.0
5:10Pm	380	39.0	40.4	35.2
5:15 Pm	370	38.8	40.2	36.4
5:20 Pm	350	38.6	40.0	37.5
5:25 Pm	---	38.5	40.2	38.0
5:30 Pm	---	38.5	40.4	38.5
5:35 Pm	---	37.0	40.6	38.1
5:40Pm	---	36.0	40.9	38.1
5:45 Pm	---	35.1	38.1	37.6
5:50 Pm	---	34.5	38.1	37.6
5:55 Pm	---	34.0	38.1	37.6
6:00 Pm	---	33.5	38.1	37.4



4.2.2 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Tender coconut Termperature combined with thermal storage (brick) when air drying on 22.03.2016:

Table 4 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & tender Termperature when air drying

Time In ours	Incident Solar Radiation (W/m^2)	AirInlet Temperature (°C)	*Drying* Chamber Air Temperature (°C)	coconut Weight in Kg
12:00 Pm	850	42.5	45.2	1.222
1:00 Pm	815	41.5	44.3	1.189
2:00 Pm	805	40.5	44.4	1.180
3:00 Pm	805	41.0	47.9	1.175
4:00 Pm	760	40.3	46.9	1.172
5:00 Pm	410	40.0	45.9	1.170

4.2.3 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Tender coconut Termperature when air drying by using Thermal storage (brick) after sun shine hours on 22.03.2016:

Table 5 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Match Stick Termperature when air drying by using Thermal storage (brick) after sun shine hours

Time In Hours	Incident Solar Radiation (W/m^2)	Air Inlet Temperature (°C)	*Drying* Chamber Temperature (°C)	coconut Weight in Kg
5:05 Pm	400	40.0	41.8	1.170
5:10Pm	380	39.0	40.4	1.170
5:15 Pm	370	38.8	40.2	1.169
5:20 Pm	350	38.6	40.0	1.169
5:25 Pm	---	38.5	40.2	1.168
5:30 Pm	---	38.5	40.4	1.167
5:35 Pm	---	37.0	40.6	1.165
5:40Pm	---	36.0	40.9	1.164
5:45 Pm	---	35.1	38.1	1.163
5:50 Pm	---	34.5	38.1	1.163
5:55 Pm	---	34.0	38.1	1.162
6:00 Pm	---	33.5	38.1	1.160

4.2.4 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Tender coconut Termperature when air drying without Thermal storage (Brick) on 23.03.2016:

Time In Hours	Incident Solar Radiation (W/m^2)	Air Inlet Temperature (°C)	*Drying* Chamber Air Temperature (°C)	coconut Weight (2pieces) in Kg
1:00 Pm	855	43.6	47.3	0.784
1:30 Pm	842	44.5	48.3	0.776
2:00 Pm	805	41.0	47.9	0.764

Note: Absorber plate temperature is 64.1 °C at 2:00 PM & Concrete brick temperature is 66°C at 2:00 PM

4.2.5 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Tender coconut Termperature when air drying with Thermal storage (Brick) & sunshine both combined on 23.03.2016:

Time In Hours	Incident Solar Radiation (W/m^2)	Air Inlet Temperature (°C)	*Drying* Chamber Air Temperature (°C)	coconut Weight (single piece) in Kg
4:30 Pm	560	40.1	40.1	0.246
4:45 Pm	500	37.8	39.1	0.240
5:00 Pm	420	36.6	39.1	0.235

Note: Absorber plate temperature is 65.6 °C at 3:00 PM & Concrete brick temperature is 68.5°C at 3:00 PM

4.2.6 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Tender coconut Termperature when air drying with Thermal storage (Brick) only on 23.03.2016:

Time In Hours	Incident Solar Radiation (W/m^2)	Air Inlet Temperature (°C)	*Drying* Chamber Air Temperature (°C)	Coconut Weight (2pieces) in Kg
2:15 Pm	800	41.0	48.6	0.762
2:30 Pm	780	41.1	48.8	0.754
3:00 Pm	740	43.3	48.9	0.744

Note:-Absorber plate temperature is 51.1 °C at 3:45 PM & Concrete brick temperature is 52°C at 2:00 PM

4.2.7 Time Vs Solar Radiation, Air inlet Temperature, Drying Chamber Temperature & Tender coconut Termperature when air drying with Thermal storage (wax) only on 23.03.2016:

Time In Hours	Incident Solar Radiation (W/m^2)	Air Inlet Temperature (°C)	*Drying* Chamber Air Temperature (°C)	coconut Weight (single piece) in Kg
3:15 Pm	760	41.1	46.1	0.318
3:30 Pm	750	40.8	42.8	0.314
3:45 Pm	740	40.8	43.8	0.310

Note: Wax temperature is 48.1°C at 4:45 PM

5. CONCLUSION

During the test of first day 21.03.2016 , in the dryer combined with thermal storage match stick with 1.05kg is dried with in a hour and the final weight to 1 Kg 5 % of moisture reduced during one hour(2:15 to 3:15 PM).

During the test of second day 22.03.2016, in the dryer combined with thermal storage, Tender coconut with 1.222 Kg is dried into 1.170Kg during 5 Hours. Nearly 5% of moisture reduced during 5 hours(12:00 to 5:00 PM).

During the test of second day 22.03.2016, in the dryer combined with thermal storage, Tender coconut with 1.170 Kg is dried into 1.160Kg during 1 Hour. After sunshine hours Nearly 1% of moisture reduced during 1 hour(5:00 to 6:00 PM).

So according to this investigation of second day, after sunshine hours by using thermal storage (brick) , moisture removal rate is same compare with sunshine hours.

During the test of third day 23.03.2016, in the dryer with out thermal storage, Tender coconut with 0.784 Kg is dried into 0.764 Kg during 1 Hours. Nearly 2.5% of moisture reduced during 1 hour(1:00 to 2:00 PM).

During the test of third day 23.03.2016, in the dryer combined with thermal storage(brick), Tender coconut with 0.762 Kg is dried into 0.744Kg during 1 Hour. After sunshine hours Nearly 2.2% of moisture reduced during 45 minutes(2:15 to 3:00 PM)

REFERENCES

[1] Abhishek Saxena and Nitin Agarwal (2013), 'Design and performance of a solar air heater with long term heat storage', International journal of Heat and Mass transfer 60 (2013) 8–16.

[2] A. Boulemtafes – Boukadoum and A. Benzaoui (2014)'CFD Based analysis of heat transfer enhancement in solar air heater provided with transverse rectangular ribs',Energy Procedia 50(2014) 761- 772

[3] Mahmud M.Alkilani et al Review of solar air collectors with thermal storage units , Renewable and sustainable energy reviews 15(2011) 1476-1490.

[4] P.Gbaha, and H.Yobouet Andoh, (2007), 'Experimental Investigation of solar dryer with natural convective heat flow' Renewable energy 32 (2007) 1817-1829.

[5] I.N.Simate (2003) ,'Optimization of Mixed-mode and Indirect mode Natural convection solar dryers', Renewable energy 28 (2003), 435 -453

[6] V.Shanmugam and E. Natarajan (2006),'Experimental Investigation of forced convection and desiccant integrated solar dryer ,Renewable energy 31 (2006),1239-1251

[7] Mohammed M.Farid et al Review on Phase change energy storage: materials and applications ,Energy conversing and Management 45(2004) 1597-1615 .

[8] Pavel Charvat & Lumbomir Klimes (2014). 'Numrical and experimental investigation of a PCM-based thermal storage unit for solar air systems'.Energy and Buildings 68 (2014)488-497

[9] Abhay B. Lingayat, Yogesh R. supple, International Journal of Engineering Research , Vol3. Issue 4, Jul – Aug 2013, pp 916-921