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A REVIEW: WASTE HEAT RECOVERY SYSTEM I.E. DRYER WITH HEAT PIPE

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ABSTRACT

Heat recovery from waste heat by using heat pipe is considered as standard method of preventing the global warming and saving the energy. In this paper a literature review of different conventional heat pipe used for waste heat recovery is done. Recovery and reuse of part of this heat appears feasible .This approach of using HPHE is to recover waste heat and reduce energy requirements for grain drying. The purpose of review is to give an overview of different drying methods and waste heat recovery methods used in drying .Some of most extensive drying methods has been discussed. There are various topologies that must be considered while drying. The nutritional value of dried foodstuff must to be maintained. The review focuses on conventional type of drying, quality of foodstuffs preserved; method to increase the efficiency of dryer, cost effectiveness .It also focuses on how the heat pipe is used for utilizing waste heat of the system.

Keywords: Dryer, Heat Pipe, Efficiency, Waste Heat Recovery, Simulation.

I. INTRODUCTION

Drying of foodstuffs is considered as an important method of preservation which is applicable to a wide range of industrial and agriculture products [1]. The waste heat recovery using heat pipe in dryer applications helps to get better performance of dryer .the energy saving in dryer can be done with the help of heat pipe. In literature there is wide range of drying methods available in both industrial and commercial applications .heat pipe heat exchanger is considered as efficient air to air heat recovery device. The HPHE (Heat pipe heat exchanger) is applied in many fields [2].

Drying with the help of sun is very simple, since it is practiced from ancient times this process is slow process .To improve the drying rate various methods or applications have been developed .to remove moisture content from a product or material is termed as drying .for this to happen moisture content has to leave the core, congregate over the surface, evaporate and dissipate into atmosphere.Drying has a great industrial significance since the applications such as wood and foodstuffs drying are a major part and requires large amount of energy .drying mechanisms of potato slices were studied by V P Chandra Mohan et al [3].

Natural and forced convections drying have been developed in time being. Naturally operated dryer are best suitable for fruits and vegetables drying. Dryer fired using furnace oil was in use in early times. As petroleum

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prices increased they got exhausted and new versions were made available. Now the conventional dryer were shifted towards nonconventional dryer .the furnaces are not only used in paddy processing but also used for food industries.

In order to store any type of product the product need to be dried properly. There are different methods are used based on food consumption, food processing technologies. The nutritional characteristics, ingredients must not vary after drying. The heat pipe heat exchanger for heat recovery used in dryer system are reviewed .

II. TYPES OF DRYER AND HEAT PIPE HEAT EXCHANGERS.

2.1 Fluidized Bed Dryer

The fluidized bed dryer system is the first low cost dryer systems available. It has found wide applications in drying of foodstuffs, ceramic, agriculture, pharmaceutical industries [4]. .Mujumdar and Devatric et al found the fluidized bed dryer advantages such as high drying rate, smaller flow area, high thermal efficiency, ease of control etc.In FBD system hot air is forced out of bed at required rate on particles. A simple diagram is shown in fig no. 1.

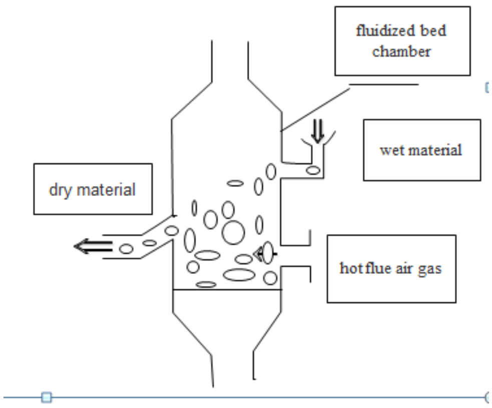

Fig.1 Fluidized bed dryer

It is constricted using steel sheets and frames ,and wooden flanks.in drying zone wet feed enters from one side. The hot air moves upwards from downside through percoalated plate and passes over product or wet feed .the hot air causes the wet feed to liberate moisture content from it causing it to dry.

2.2 Infrared Drying

Infrared drying is second method available for drying. It is nothing but artificial sun drying. Sandu (1986) stated following advantages of using IR to foodstuffs were simplicity of required equipment, versatility, fast response to drying and heating, and ease of installation of cost.

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2.3 Electrically Operated Drier

An experimental dryer model of osmotic dehydrator with 5kg holding capacity has been developed at Coimbatore center of post-harvest technology scheme (PHTS) containing osmotic reactor ,mixing chamber ,pan for holding fruit ,an impeller and a pumping system .The performance of unit was evaluated using banana and grapes.

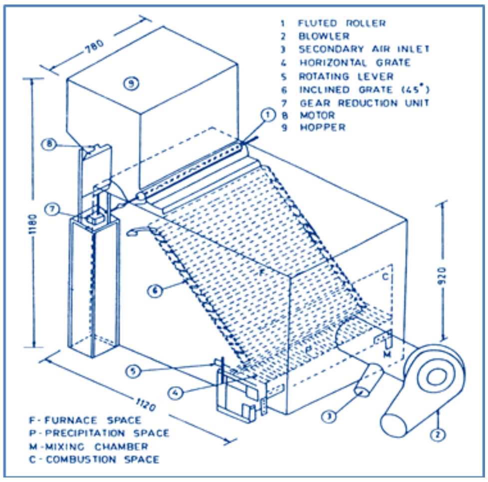


Fig. 2 Electrically Operated Drier

Flow rates of sugar syrup in the range of4, 8 and 12 l/min were used. The temperature of the osmotic syrup was maintained at 50 ºC throughout. A maximum water loss of 42.5 % in bananas and 24.6 % i n g rapes was observed after 5 h of osmosis at a flow rate of 12 l/min and, under static conditions, the water loss was 38.5 and 22.7 %, respectively. Solid gain under static conditions was 9.1 and 0.9 % for bananas and grapes, respectively.

In case of heat pipe heat exchanger the latent heat of vaporization is used to transfer heat over a long distance with small change in temperature [2]. Generally closed loop heat pipe with working fluid are used. Heat pipe are classified generally into three types i.e. 1) Simple heat pipe, 2) Two phase closed thermo syphon and 3) Oscillating heat pipe.

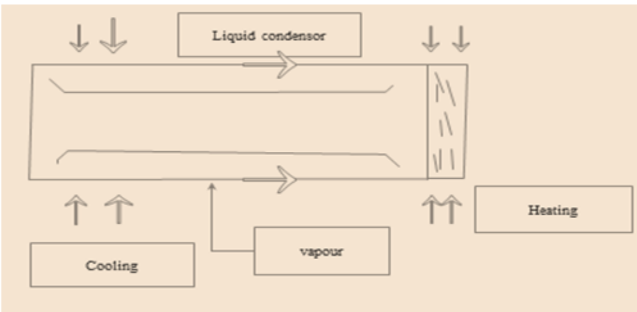


Fig.3 Simple Heat Pipe

TPCT consists of wick structure. It makes use of gravity to make heat transfer. In TPCT evaporated section is situated below condenser section. It is composed of three sections i.e. evaporator at one end, where heat is absorbed and fluid is vaporized, a condenser section at other end where vapor is condensed and heat is rejected and adiabatic section in between where liquid and vapor phases of fluid flow in opposite direction through core and wick.

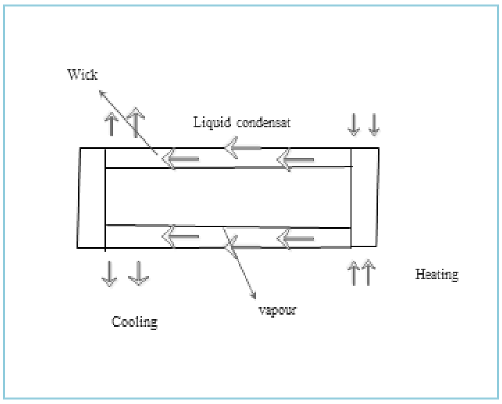


Fig. 4 Two phase closed thermo syphon

The closed loop oscillating heat pipe has advantageous when used in dryer application. It is very useful heat transfer device .the CLOHP has a capillary tube bent into number of turns with condenser section and evaporator section into turns [5].

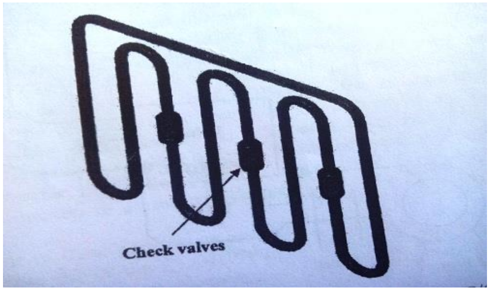


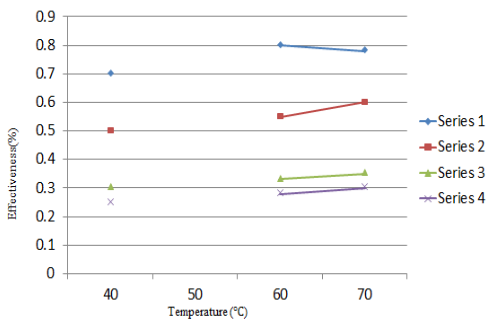
Fig.5Closed loop heat pipe

III. EXPERIMENTAL STUDIES

3.1 Effect of tube blank and fin shape on effectiveness

The effectiveness of heat pipe is inversely proportional to tube blank. The different shape such as plain fins, spine fins affect effectiveness[2]. The heat pipe with plain fin has more effectiveness.shape.

The following graph shows the variation of effectiveness with tube blank and fin shape.



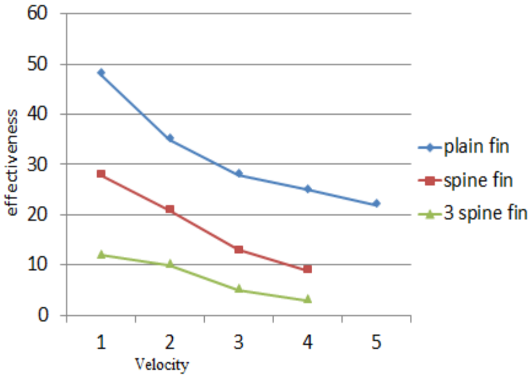


Fig. 6aeffectiveness v/s temperature,andbeffectiveness v/s velocity.

3.2 Effect of entering temperature at heat pipe on effectiveness

The above graph indicates the effectiveness variation with entering temperature. The different set of inlet conditions was used to find the correlation between entering temperature, air velocity and effectiveness [2].

3.3 Effect of air temperature

The heat transfer rate varies accordingly with air temperature [5]. If we change the inlet condition of temperature there is change in outlet conditions of temperature. There is slightly change in obtained and calculated values of heat transfer.

The heat transfer rate is calculated suing the equation as,

$$Q = Axq \quad \text{and} \quad Q_{min} = C_{min}(T_{hi} - T_{ci}), C_{min} = \rho ACp$$

Where Q is heat transfer rate (W), A=area(m^2),q=heat flux (W/m^2),ρ=density (kg/m^3),V=velocity, Cp=specific

heat constant,T=temperature ,h=hot, c= cold at ith position.

The effectiveness of CLOHP has a great influence of air temperature. The effectiveness rises with rise in inlet air temperature i.e. it is directly proportional to inlet temperature. The effect of inlet temperature can be seen from the following graph.

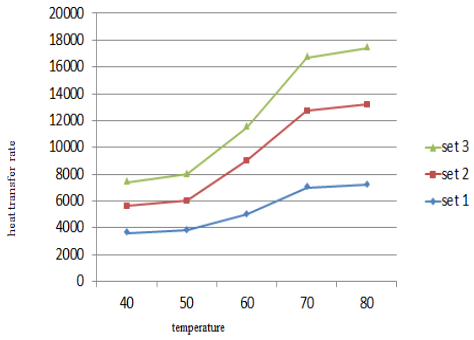


Fig. 7 Heat transfer rate v/s temperature

S .Wannapahke et al [6] had shown the effect of air temperature for the purpose of saving electrical energy at the equilibrium conditions. The rise in air temperature is obtained with the help of heat pipe with check valve arrangement.

3.4 Effect of air velocity

The heat transfer rate of CLOHP air preheater varies accordingly with air velocity. The below graph shown indicates the heat transfer rate variation with inlet air velocity.

The effectiveness also has effect of change in inlet air velocity. The effectiveness increases with air velocity increase due to change in highest temperature.

If the inlet air velocity is increased there is decrease in saving of electrical energy which affects the drying conditions [6].

3.5 Effect of air drying conditions

D. A.Tzempelikos et al[7] had done research about the various parameters such as velocity, different temperature, moisture content variation, drying rate.

The moisture content decreases with increase in temperature of drying chamber.

3.6 Effect of drying rate

At equilibrium condition the initial moisture content increases with decrease in relative humidity and material sample size. It increases with drying temperature.

Therelation used to obtain the drying rate is as

$$\frac{\partial M}{\partial \tau} = D_{eff} \cdot \nabla^2 M = D_{eff}\left(\frac{\partial^2 M}{\partial x^2} + \frac{\partial^2 M}{\partial y^2} + \frac{\partial^2 M}{\partial z^2}\right)$$

Where M-moisture content(kg), τ-time(hours), D_{eff}- effective moisture diffusivity

Ivan Zlatanic et al [7] experimented drying of apple cubesto find out different parameter.

3.7 Effect of mass flow rate of drying air

The process exergy efficiency is inversely proportional to humidity. As the humidity is decreased better quality of drying is obtained. The humidity is also an important parameter which can be varied. The exergy of system varies with different mass flow rate.

Dincer et al [9] presented a paper on exergy and energy analysis of drying process. The exergy efficiency is inversely proportional to mass flow rate as well as temperature of drying air. This variation can be seen from below fig.

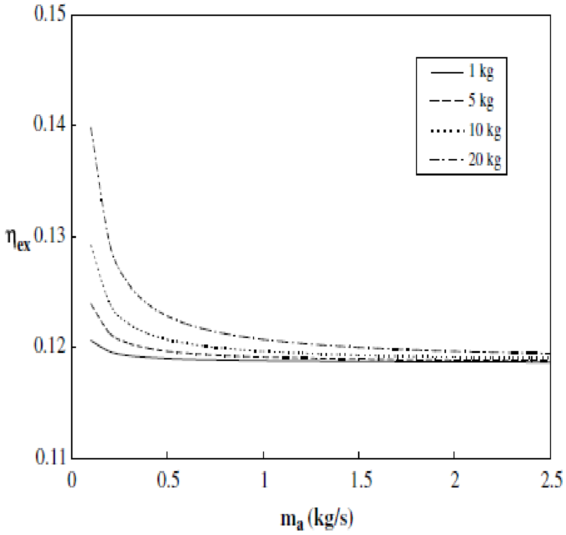


Fig. 8 Enthalpy ratio v/s mass flow rate graph

3.8 Effect of working fluid

Jnyana R. Pati et al.[10] used a PCM for heat transfer into drying of sliced ginger. The PCM melting time was reduced due to waste heat recovery from the system. Due to this the drying time was reduced. The sensible heat storage material was also used to investigate the drying characteristics of sliced ginger. The color, texture and aroma were also retained.

The energy efficiency of R134a was better than R22 and R502. Similarly the coefficient of performanceobtained was also better for R134a. The R134a increases the performance of air conditioning system.The heat flux also varies with different working fluid which affects the heat transfer rate and drying time.

3.9 Effect on enthalpy ratio

The enthalpy ratio is directly proportional to inlet fresh air temperature for both condenser and evaporator side. Mass flow ratio is inversely proportional to enthalpy ratio [11]. The two factors mass flow ratio and inlet fresh air temperature are important as regards to heat pipe heat exchanger. The variation of enthalpy ratio with air temperature and can be seen from following graph.

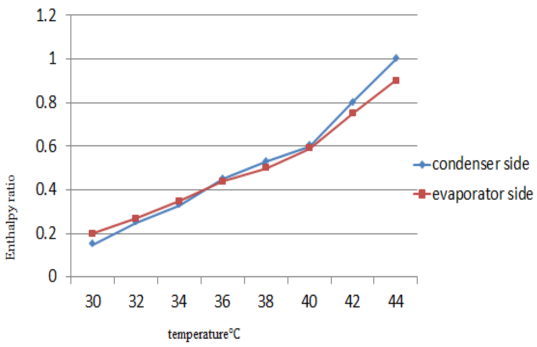


Fig. 9 Enthalpy v/s temperature,

3.10 Effect of indoor design temperature

The cooling load of ac system depends on indoor conditions of temperature. The heat pipe arrangement will affect the AC system if the inlet and outlet conditions vary accordingly. Cooling load decreases with decrease in outdoor temperature. The total energy saving is affected by indoor temperature [11]. The cooling energy decreases with an increase in indoor temperature.

IV. NUMERICAL SIMULATION

Song et al [12] presented a numerical study of heat pipe application in heat recovery system. The paper contained simulation of dehumidification process with HPHE. Various strategies of simulation of heat pipe were presented. The research showed that heat pipe fin stack can be used for optimizing the design. The simulation also showed that the performance of application can be predicted with computational fluid dynamics modeling.

Flowtherm package from computational fluid dynamics was used to evaluate the total drying and heat transfer process. Computational fluid dynamics is a best tool in designing of problem related to m thermal and fluid.The total performance of evaporator and condenser section can be well predicted. The simulation results obtained are better useful for improvement of dehydration process.

Dimitrios A. Tzempelikos et al [13] simulated an laboratory convective dryer using the $k-\varepsilon$ turbulence model.

The drying kinetics of quince slices under different variable conditions was studied. To get a perfect evaluation of complicated geometry computational fluid dynamics can be used based on Reynolds Averaged Naviers Stokes equation model.

The solution of steady state incompressible flow field can be found. The current paper shows the different topology employed for designing and optimizing of laboratory convective dryer.

The simulation variation on laboratory convective dryer were performed with two different conditions i.e. one with heat exchanger, guide vanes, metal tray and honey comb and without the components.

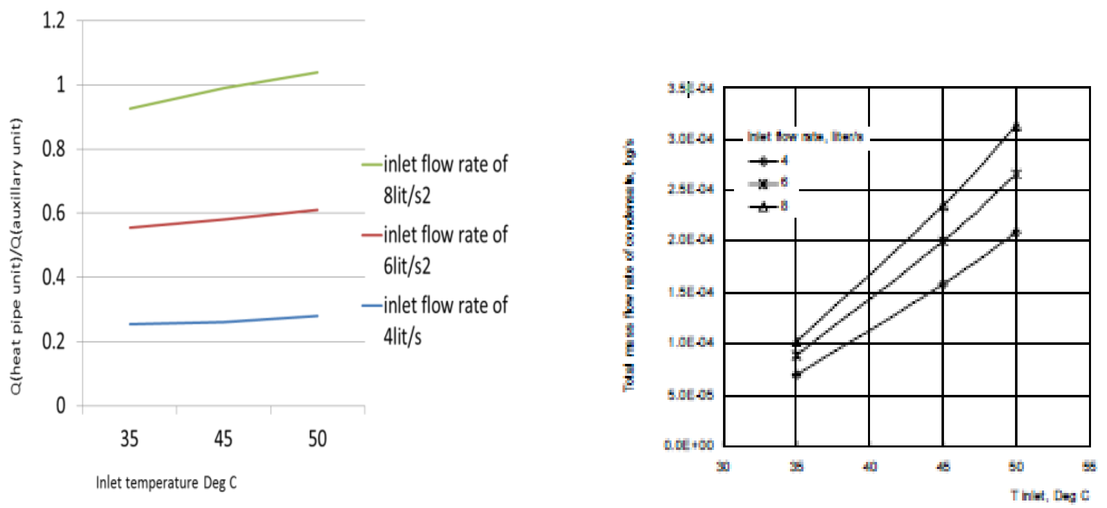


Fig. 10ashown variation of heat input ratio v/s temperature, and b shows variation of condensate

The below relation stated that was used to evaluate laboratory convective dryer [30].

$$U_{var}=\frac{Ui-Umean}{Umean},\ Cp=\frac{Pi,static-Pi,satic\ (inlet)}{1/2\rho u_{mean}}$$

U_{var}- Dimensionless velocity, Ui-velocity at ith position m/s, $Umean - average\ velocity$(m/s)

, $Pi, static$ –static pressure, Cp- pressure coefficient, $Pi, satic\ (inlet)$ –static pressure at inlet , ρ-density of air

(kg/m^3).

V. CONCLUSION

The review paper briefly explains about various dryers system with different type of heat pipe arrangement. Closed

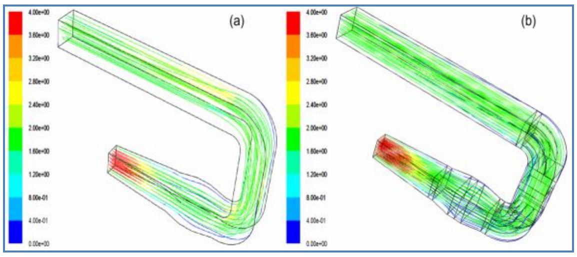


Fig. 11shows the flow of air velocities with different conditions

loop oscillating heat pipe heat exchanger is a promising technology to increase the performance of the dryer system. Wide ranges of dryer system with different arrangement are available for different types of foodstuffs and products. The various products with wide range ofthickness can be dried at an optimized drying period with the help of heat pipe arrangement.

With the help of heat pipe arrangement the waste heat recovery can be done to enhance the performance of the system. The effectiveness of heat pipe is different for different tube banks. It also varies with fin shape. The waste heat recovery system with heat pipe arrangement has various benefits consisting of compactness, light weight, reduced energy consumption etc.

The performance of dryer system is greater influenced by heat pipe arrangement. The working fluid also affects the waste heat recovery system. Atlast the waste heat recovery system consisting of dryer and heat pipe arrangement has greater influence on drying of agriculture products. The design and development of waste heat recovery system is compact.

REFERENCES

[1]. TurhanKoyuncu ,IllkayTosun , YunusPinar. Drying characteristics and heat energy requirement of cornelian cheery fruits, Elsevier journal of food engineering ,78 (2007) 735-739.

[2]. W. Srimaung, P. Amatachaya. A review of applications of heat pipe .heat exchangers for heat recovery, Renewable and Sustainable Energy Reviews, 16(2012) 4303-4315.

[3]. V. P. Chandra Mohan, PrabalTalukdar. Design of an experimental set up for convective drying studies at different drying temperature, Heat Mass transfer,(2013) 49:31-40.

[4]. Mujumdar ,A. S. ,Devahastin.S, Fluidized bed drying, Trends in Food Science and Technology,(2000) vol 1,59-111.

[5]. M. Mohanraj ,P.Chandrasekar. Performance of a forced convection solar dryer integrated with gravel as heat storage material for drying chilly, Journal of Engineering Science and Technology, Volume 4 (2009) No .3 305-314.

[6]. A.Kiniman, S. Rittidech, B. Bubphachot. Application of top heat mode closed loop oscillating heat pipe with check valves air preheater for chili drying, Journal Of applied Sciences,8(3) (2012) 1699-1706.

[7]. Ivan Zlatanovic,MirkoKomatina, DragiAntonijevic. Low temperature convectivedrying of apple cubes, Applied Thermal Engineeeing, 53 (2013) 114-123.

[8]. I .Dincer,A. Z. Sahin. A new model for thermodynamic analysis of a drying process, International Journal of Heat and Mass Transfer 47 (2004) 645-652.

[9]. J W Wan ,J L Zhang,W M Zhang, The heat pipe air handling coil on energy consumption in central air conditioning system, Energy and Buildings, volume 39 (2006) 1035-1040.

[10].Jnyana R. Pati,Santosh K. Hotta, P. Mahanta. Effect of waste heat recovery on drying characteristics of sliced ginger in a natural convection dryer, International Conference on Thermal Engineering,(ICTE2014) 105(2015) 145-152.

[11].Akpinar EK. Energy and exergy analysis of drying of red pepper slices in a convective type dryer ,International Communications in Heat and Mass Transfer Volume 8(2004) 1165-76.

[12].Song lin , John Broadbent, Ryan Mcglen, Numerical study of heat pipe application in heat recovery systems, Applied Thermal Engineering (2005).