iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** XI **Month of publication:** November 2016

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

An Experimental Investigation of Thermal Performance of Solar Air Heater with 'W' Wire Mesh

Madhav Durusoju[1], Chetan Goyal[2], Imran Sheikh[3], Akash Dongre[4], Lalit Marbate[5], Kumar Rohit[6], V.P.Katekar[7]
[1,2,3,4,5,6,7]*Department of Mechanical Engineering, S.B. Jain Institute of Technology Management & Research, Nagpur, India*

Abstract: Solar air heater is one of the most valuable heat sources with variety of applications such as space heating, industrial process heating and drying of fruits and vegetables etc. Needless to say that it is a renewable and pollution free method to produce space heating and when is used in commercial buildings or industries could be very cost effective. The solar air heating is a technology in which the radiant energy emitted by the sun is captured in an absorber plate and is used for space heating. Improvement in the thermal performance of a solar air heater can be done by enhancing the heat transfer. Providing an artificial roughness on a heat transferring surface is one of the methods for effective passive heat transfer, the other is to introduce the copper wire mesh screen matrix to enhance the rate of heat transfer by passing the fluid through it. Conventionally, flat plate collectors are used but several modifications in design have been made in which a wire mesh absorber matrix collector is used instead of a flat plate collector. Our project deals with the utilization of solar energy by creating w-shaped turbulator artificial roughness geometry on solar air heater using a copper wire mesh matrix collector. Our objective is to absorb the maximum possible solar radiations to heat the air for effective working of solar dryer. This heated air is then used in Forced convection active mixed mode type Solar dryer for drying of various agricultural products.
Keywords: Solar Air Heater, Copper Wire Mesh Collector, W-shaped Geometry, Solar Dryer.

I. INTRODUCTION

Present world is dealing with the energy crisis. We all know that the conventional energy sources will totally depleted one day, it is therefore necessary to move towards the alternative energy sources. Sun is the ultimate source of energy. The easiest methodology for making the proper use of solar energy is its conversion to thermal energy using solar collector. These solar collectors are the part of solar air heater which is used to heat air by utilizing solar energy and employed in many applications requiring low to moderate temperature below 100^o C for drying purposes. Solar air heaters provides the efficient use of solar energy, which uses the absorber plate to absorb the incoming solar radiations, converting it to thermal energy at its surface, and transferring this thermal energy to the fluid flowing through the collector. It has been observed that the efficiency of the flat plate solar air heater is low because of low convective heat transfer coefficient between the absorber plate and the air flowing over it. The most common and effective way to improve the performance of the solar air heater is to provide artificial roughness elements on the underside of the absorber plate by disrupting the laminar sub layer and creating turbulence very near to the absorber surface which results in reducing the thermal resistance to the flow of heat and thereby makes the system efficient.

Conventionally, flat plate collectors are used but several modifications in design have been made in which a wire mesh absorber matrix collector is used instead of a flat plate collector. Our project deals with the utilization of solar energy by creating w-shaped turbulator artificial roughness geometry on solar air heater using a copper wire mesh matrix collector. Our objective is to absorb the maximum possible solar radiations to heat the air for effective working of solar dryer. This heated air is then used in Forced convection active mixed mode type Solar dryer for drying of various agricultural products.

A. Solar Air Heater

Solar air heaters are the simplest device for converting the solar energy into heat energy. Solar air heater consists of a flat plate collector with an absorber plate, transparent cover system at the top and insulation at the bottom and on the sides. Whole assembly is enclosed in a sheet metal container. Air is a working fluid and the passage for its flow varies according to the type of solar air heater. fig 1.1 shows solar air heater.

Volume 4 Issue XI, November 2016
ISSN: 2321-9653

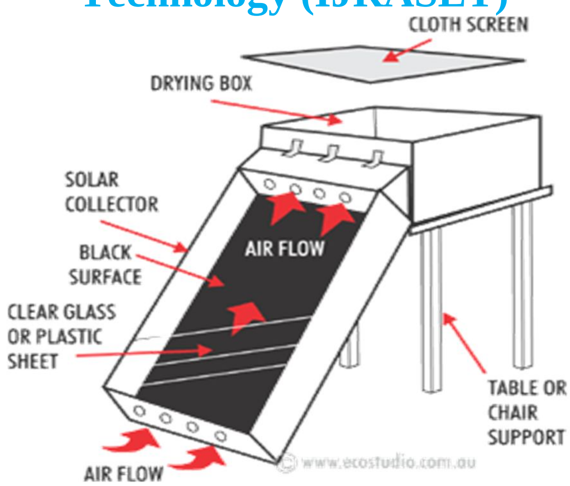


Fig 1.1 Solar air heater

1) *Components of Solar Air Heater*

a) *Absorber Plate:* The absorber plate should have high thermal conductivity and good corrosion resistance. Copper is generally preferred because of its extremely high conductivity and resistance to corrosion. Collectors are also constructed with aluminum, steel, Galvanized Iron (GI) sheets and various thermoplastics and metal ions. Figure 1.2 shows the absorber plate.

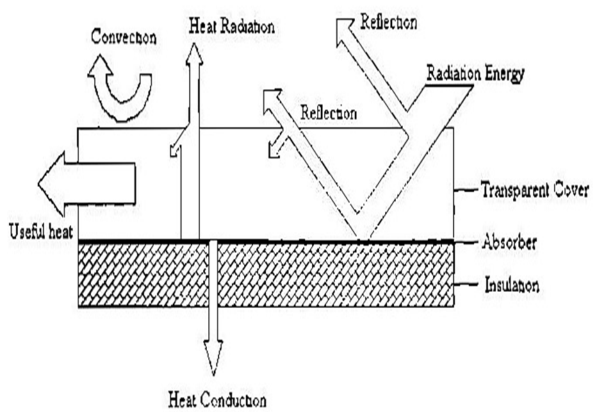


Fig. 1.2 Fundamentals of a flat plate solar air collector with flow over the absorber

b) *Cover Plate:* Purposes of cover plates are

i. To transmit as much as solar energy as possible to the absorber plate.

ii. To minimize the loss from the absorber plate to the environment.

iii. To shield the absorber plate from direct exposure to weathering.

Glass is the most common cover material for collectors. Cover plates for solar Collectors normally should be at least 0.33cm thick.

c) *Insulation:* Insulation is used to prevent loss of heat from the absorber plate due to conduction or convection. Usually insulating materials are rock wool or glass wool.

2) Classification of Solar Air Heater: Depending on the absorber plate, air heaters can be classified into two types- porous collector and non porous collector.

a) *Nonporous Type Solar Air Heaters*

i. *Type I:* In this type, Figure 1.3 air steam does not flow through the absorber plate, but may flow above or below it. No separate passage is required and air flows between transparent cover system and absorber plate. This type of air heater has a disadvantage. Due to the flow of hot air above the absorber, cover receives much of the heat and in turn losses it to the atmosphere.

Volume 4 Issue XI, November 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

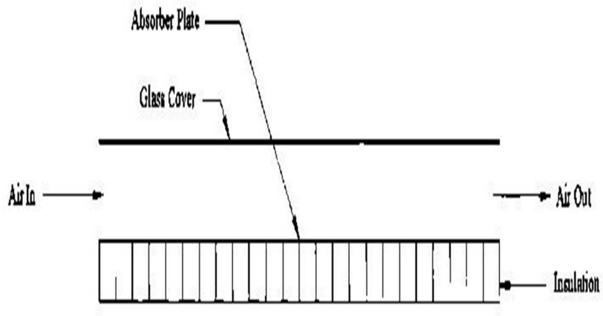


Fig. 1.3 Type I Non-porous solar air heaters (flow above the absorber)

ii.*Type II:* In this type, Figure 1.4 air passage is below absorber plate. A plate parallel to the absorber plate is provided in between absorber and insulation, forming the passage.

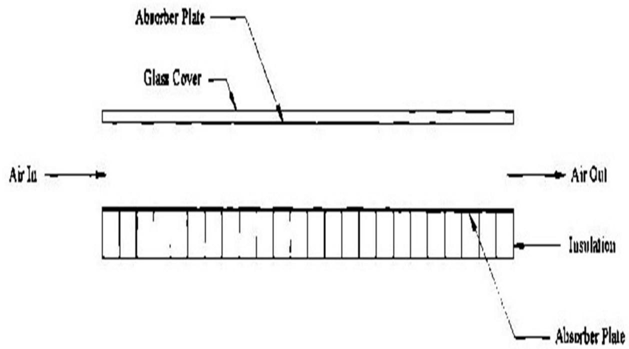


Fig. 1.4 Type II Non-porous solar air heater (flow under the absorber

iii. *Type III*: In Figure 1.5 absorber plate is cooled by air stream flowing on both sides of the plate.

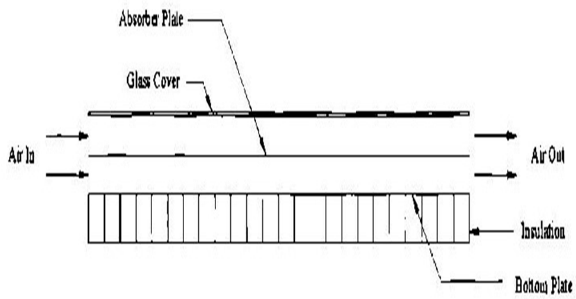


Fig.1.5 Type III Non-porous solar air heater (flow both above and beneath the absorber)

b) *Porous Type Solar Air Heaters:* In porous type solar air heaters, absorber plate is porous. This type of heaters has several advantages. Solar radiation penetrates to greater depth and is absorbed along its path. As a result, radiation loss decreases.

i.*Matrix type solar air heaters:* In matrix air heater, the fluid flows through a porous matrix on which solar radiation is incident directly. Radiation penetrates through the matrix and is gradually absorbed. Air is introduced at top and is heated as it flows down through the matrix in reverse manner.

ii. *Honeycomb porous-bed solar air heater:* The use of honeycomb structure Figure 1.6 between cover and absorber reduces top convective losses. Air is passed through honeycomb structure. Honeycomb structure is rectangular or hexagonal shape. The honeycomb structures reduce convection and radiation to cover glass.

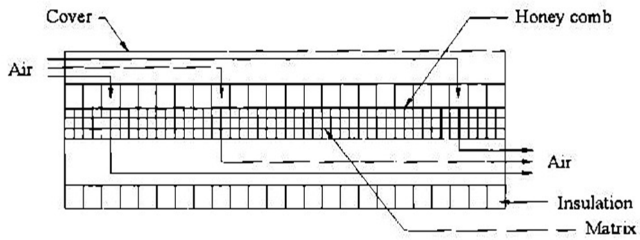


Fig.1.6 Honeycomb porous bed solar air heater

iii. *Overlapped glass plate air heater:* This type of air heater consists of a series of overlapping parallel glass plates in which the lower part is blackened shown in Figure 1.7. Advantages of overlapped glass plate air heaters are the low-pressure drop and high collector face area.

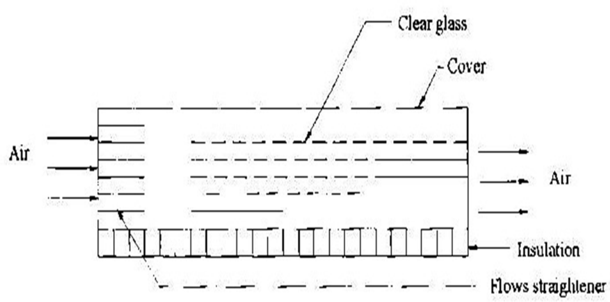


Fig.1.7 Overlapped glass plate solar air heater

iv. *Jet plate solar air heater:* In jet plate solar heater, an additional Glass plate called a jet plate is introduced between the absorber and the bottom plate Figure 1.8. The jet plate has a number of equally spaced holes drilled in it. The impinging air jet increases value of convective heat transfer coefficient from bottom of absorber plate. This results in a significant improvement in useful heat gain and the collection efficiency.

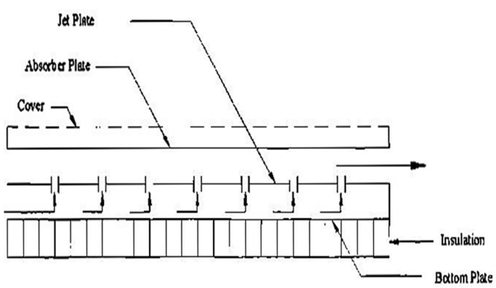


Fig.1.8 jet plate solar air heater

The main problem of using solar air heater is low heat transfer to air because viscous laminar sub layer is present in turbulent boundary layer adjacent to the absorber plate. So all the heat is not able to reaches the absorber plate. Laminar sub layer should be destroyed to increase the heat transfer. Viscous laminar sub layer can be destroyed by roughening the surface. The most common and effective way to improve the performance of the solar air heater is to provide artificial roughness elements on the underside of the absorber plate.

B. Solar Dryers

1) Drying Process: Drying means preservation of food, fruits and vegetables for long time with good quality. It is a process of moisture removal due to simultaneous heat and mass transfer. Agricultural products, especially fruits and vegetables require hot air in the temperature range of 45–60˚C for safe drying. When any agricultural product is drying under controlled condition at specific humidity as well as temperature it gives rapid superior quality of dry product. Drying involves the application of heat to vaporize moisture and some means of removing water vapor after its separation from the food products. It is thus a combined and simultaneous heat and mass transfer operation for which energy must be supplied. Figure 1.9 shows simultaneous heat & mass transfer process on food surface.

2) Need of Solar Drying: Solar energy which is a form of sustainable energy has a great potential for wide variety of applications because it is abundant and accessible, especially for countries located in the tropical region like India. Grains, vegetables and fruits are agricultural products that are known for their rich vitamins, high concentration of moisture and low fats. These are seasonal crops and are mostly available during the production season. The demand for vegetables by the growing population has not been met despite the increase. This is as a result of wastes that result from biological and biochemical activities taking place in the fresh product and unfavorable storage conditions, inefficient handling, transportation, inadequate post-harvest infrastructure and poor market outlets. Sun drying is still the most common method used to preserve agricultural products like grains and vegetables in most tropical and subtropical countries. The main advantages of sun drying are low capital and operating costs and the fact that little expertise is required. Sun drying is only possible in areas where, in an average year, the weather allows foods to be dried immediately after harvest. However, being unprotected from rain, wind and dust, damage by birds, insects and other animals, products degraded to such extent that there is a loss of food quality in the dried products and have adverse economic effects on domestics and international markets.Direct exposure to sunlight reduces the quality (colour and vitamin content) of some fruits and vegetables. Some of the problems associated with open-air sun drying can be solved through the use of a solar dryer who comprises of collector, a drying chamber and sometimes a chimney. Solar drying of fruits and vegetables overcomes the drawbacks of traditional open sun drying such as, contamination from dust, insects, birds and animals lack of control over drying conditions, possibility of chemical and microbial spoilage due to long drying times. Solar drying is advantageous over normal convective dryers like hot air dryer, which requires enormous fuel and energy cost. Due to abundant availability of solar radiation there are number of ways to utilize this renewable energy for a number of applications. Among these dehydration of food & non-food items is an important sector. This solar drying enables Good Manufacturing Practices (GMP) & yields export worthy processed foods with long shelf life meeting the sanitary standards of the importing countries. This novel technology is a very viable & valuable one.

Solar drying of agricultural produce permits

a) Early harvest.
b) Planning of the harvest season.
c) Long-term storage without deterioration.
d) Taking advantage of a higher price a few months after harvest.
e) Maintenance of the availability of seeds and finally selling a better quality product.

II. LITERATURE REVIEW

A. Introduction

Literature review is the basic step for initialization of the project. It gives us the idea about our topic in which the project is being carried out by the researchers & also it is the backbone of the project to be carried out after the review. Various Research papers related to the topic generating optimization in context to the project are as below.

B. Performance Evaluation of a Wire Mesh Solar Air Heater

1) Ahmad, Saini, & Varma, 1995 "use of matrix collector in which wire mesh absorber is used instead of flat plate collector to get high thermal enhancement":-

Flat plate collectors are the conventional type of solar air heater and in order to improve the efficiency, several modifications in design have been evolved out over many years of research. One such design is matrix collector in which a wire mesh absorber is used instead of a flat plate. There is a considerable thermal enhancement in such kind of collectors and this is due to the influence of geometrical parameters of absorber matrix such as depth to bed element size ratio, porosity of the bed and extinction coefficient.

2) Aldabbagh, Egelioglu, & Ilkan , 2010 ***"Analyzed Single And Double Pass Solar Air Heater With Wire Mesh As Packing Bed.":-***
The collector design consists of 10 layers of steel wire mesh as absorber. The porosity of the packing was above 0.85. System was studied for different mass flow rates.

3) Dhiman, Thakur, & Chauhan, 2012 "Thermal and thermo-hydraulic performance of the system for parallel and counter flow was studied both theoretically and experimentally with varying bed porosities and mass flow rates":-

It had 2 mm thick aluminium sheet as absorber plate and several layers of wire mesh screens packed one above the other. The study reported that thermal efficiency of packed bed heater decreased as the porosity increased. Fig 2.2 shows schematic view of counter flow & parallel flow solar air heaters.

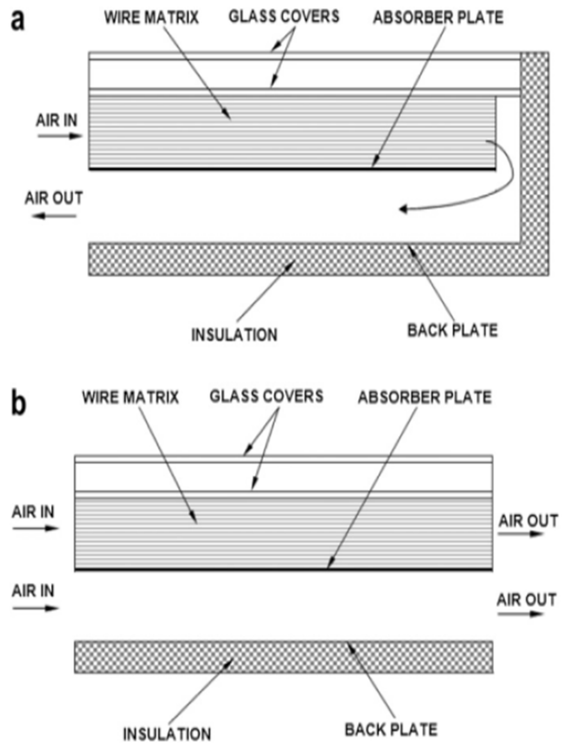


Fig 2.2 schematic view of solar air heater a) counter flow b) parallel flow

4) *Elkhawajah, Aldabbagh, & Egelioglu , 2011* **"**The effect of using fins in between the wire mesh absorber was studied**"**

In their study, twelve sheets of steel wire mesh arranged in 6 layers with 3, 3, 2, 2, 1, 1 sheets from bottom to top respectively. The diameter of the wire used was 0.02 cm with 0.18 cm × 0.18 cm cross sectional opening of the layers. Results show that thermal efficiency increases with increasing mass flow rate between 0.0121 kg/s and 0.042 kg/s and maximum efficiency reached 85.9 % at 0.042 kg/s

5) *K. Rajarajeswari A. Sreekumar ,Dec 2014* **"**Performance of the developed matrix air heater in drying application was evaluated and established using the absorber wire mesh made up of Galvanized Iron (GI)**"**

A solar drier integrated with a matrix solar air heater having an area of 6 m2 was developed and undertaken a detailed performance analysis to explore the techno-commercial feasibility of the system. The absorber comprises of two parallel layers of selective coated wire mesh made up of Galvanized Iron (GI), which is separated by a spacing of 2 mm each other. The diameter of the wire is 1 mm and pitch is 3.175 mm. The maximum temperature recorded at the outlet of the air heater was 70 °C, when the system was subjected to no loaded condition. The dryer was loaded with 30 kg fresh tomato of 4 mm thick slices. The initial moisture content of 90.62 % reduced to 18.28 % in 3 hours. The economics of the drier was analyzed in detail by three methods namely annualized cost, present worth of annual savings and present worth of cumulative savings. The dryer proved efficient and economic for drying fruits. Experiments were conducted with 4 mm tomato slices having an initial moisture content of 90.62 % took 3 hours to bring down to a safe moisture level of 18.28 %, which is propitious for storage. Economic analysis showed that the cumulative present worth of annual savings for drying tomatoes over the life of the dryer was Rs. 28, 52, 503.00. The capital investment of the dryer was Rs. 1, 40,000.00 and the payback period of the dryer was calculated to be 1.05 years (263 solar days) which is very short comparing the life time of the dryer. Figure 2.4 shows the indirect type active solar dryer (forced convection).

Volume 4 Issue XI, November 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

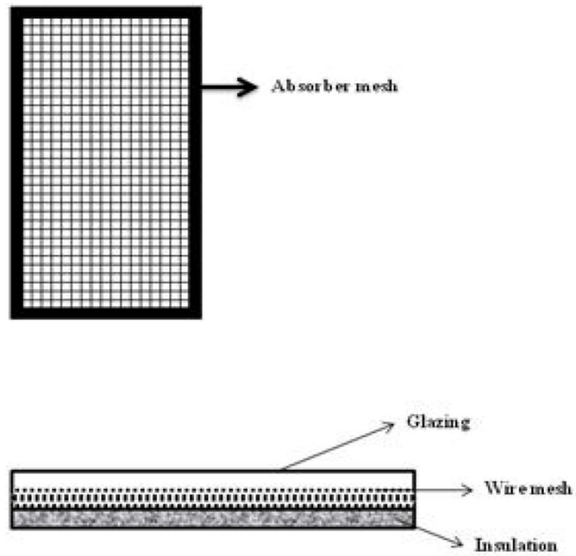


Fig 2.4 Indirect type active solar dryer (forced convection) in which front view & side view of collector can be seen

C. Numerical and CFD Based Analysis of Porous Media Solar Air Heater

1) *Mittal* "investigates the thermo hydraulic performance on a packed bed solar air Heater having its duct packed with blackened wire screen matrices of different geometrical parameters (wire diameter and pitch)".

To obtain the effective efficiency a mathematical model has been developed on the basis of energy transfer mechanism in the bed. The following assumptions have been made during the development of the mathematical model:

a) Edge and back losses have been neglected.

b) Environmental temperature and wind velocity have been assumed to be Constant. Figure 2.5 shows the packed bed solar air heater.

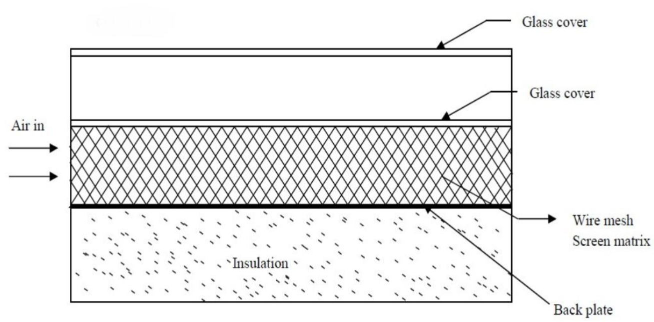


Fig. 2.5 packed bed solar air heater

The mathematical modeling is done for predicting the heat transfer characteristics and the performance of solar air heater with and without porous media. The solar air heater with porous media gives higher thermal performance than without porous media. The thermal conductivity of porous media has significant effect on the thermal performance of the solar air heater. Numerical results and CFD analysis has predicted that the effect of depth on outlet temperature for both porous and non-porous solar air heater illustrates that with increase of depth the outlet temperature decreases. This is due to the low convective heat transfer coefficient between the absorber plate and air. Increasing the depth results increase in for given mass flow rates.

D. Solar Air Heater Using W-Shaped Artificial Roughness Ribs

1) *Manish Kumar Tated, Dinkar Prasad Singh and Sudhanshu Dogra,* "An experimental investigation has been carried out to

show the effect of relative roughness pitch on heat transfer and friction factor of double pass solar air heater having W-shaped artificial roughness on both sides of absorber plate.**"**

This investigation represents the effect of artificial roughness with W-shaped geometry as shown in figure 2.6 on heat transfer and friction factor of Double Pass Solar Heater having rectangular duct. Aspect ratio (W/H) of the duct is 10. Reynolds number for experiment varies from 6900 to 14000. W-shaped ribs attached on both sides of absorber plate at fixed inclination angle (α) 450, relative roughness height(e/Dh) is fixed0.044 and relative roughness pitch (p/e) is varies from 5 to 20. It has been observed that at relative roughness pitch (p/e) of 10 maximum heat transfer and friction factor occurs. The enhancement in the heat transfer is found to be 1.4 times of the smooth plate. On the basis of experimental investigation it is found that by providing artificial roughness on both sides of absorber plate both heat transfer and friction factor enhanced. It has been seen that Nusselt number increases continuously with increase in Reynolds number whereas friction factor continuously decreases with increase in Reynolds number. At relative roughness pitch (p/e) of 10 maximum heat transfer and friction factor occurs. Nusselt number enhanced 1.4 times as compare to smooth duct.

Fig 2.6 pictorial view of W-shaped roughness geometry on absorber plate.

III. PROPOSED MODEL

A. *Introduction*

Our project deals with the utilization of solar energy by creating w-shaped turbulator artificial roughness geometry on solar air heater using a copper wire mesh matrix collector. Improvement in the thermal performance of a solar air heater can be done by enhancing the heat transfer. Providing an artificial roughness on a heat transferring surface is the one method for effective passive heat transfer technique to enhance the rate of heat transfer to fluid flow. The other is to introduce the copper wire mesh screen matrix to enhance the rate of heat transfer by passing the fluid through it.

The layout of proposed solar air heater is shown below, this model is made in 3D-CAD modelling software i.e. CREO PARAMETRIC, this model is actual resemblance of the solar air heater on which we are working.

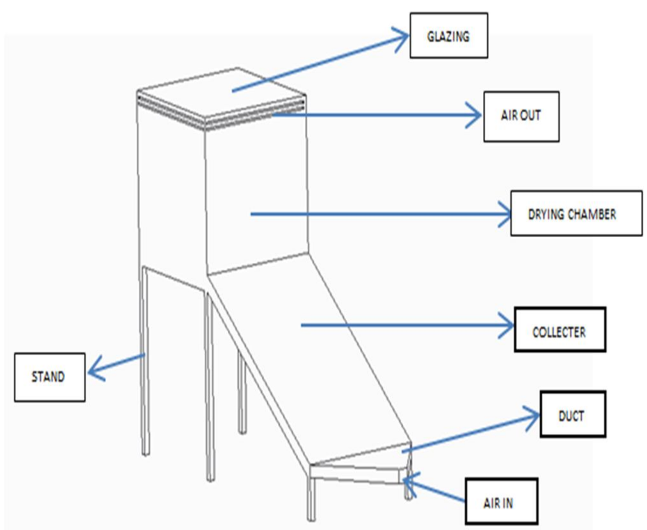


Fig.3.1 Layout of Proposed Solar Air Heater

Volume 4 Issue XI, November 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Pic.3.1 Layout of Proposed Solar Air Heater

B. Transverse View of Proposed Wire Mesh Collector

The transverse view of the proposed wire mesh collector of solar air heater is shown below here the wire mesh is the W-shaped geometry and the air is being passed through it. Below wire mesh a copper plate is provided so that it can absorb the radiation which is escaped by the wire mesh which is normally used in conventional type solar air heater. A glazing is also provided above the copper wire mesh so that air passed through the wire mesh should pass through a guided space and should not leak to outside environment causing decrease in efficiency of solar air heater. At the lowest part i.e. below the absorber plate there is insulation provided so that the whole collector is thermodynamically insulated. The comparison between the diagrams of proposed model and conventional model is given below.

The Transverse view of proposed solar air heater is shown below, this model is made in 3D-CAD modelling software i.e. CREO PARAMETRIC, this model is actual resemblance of the solar air heater on which we are working.

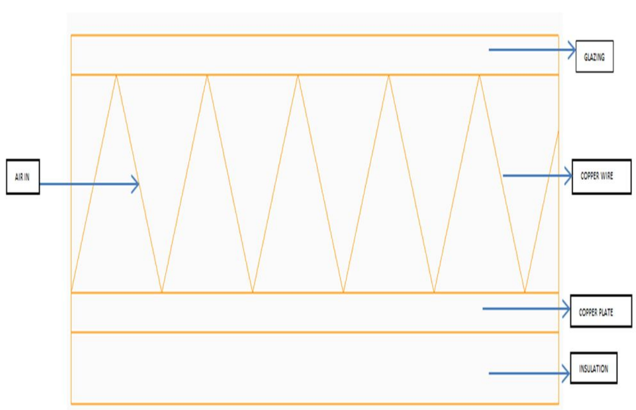


Fig. 3.2 Transverse section of Proposed Wire Mesh collector

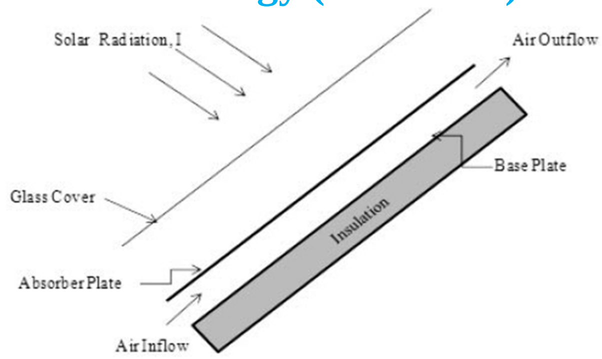


Fig. 3.3 Transverse view of Conventional Solar Flat Plate collector.

IV. CONCLUSION

From the study of literature and research work done till now we came to certain conclusions which are as follow:-

A. Use of Matrix collector with a wire Mesh absorber instead of conventional flat plate collectors proves to be highly beneficial in terms of thermal enhancement & other geometrical parameters. The matrix collector exhibited an improved thermal performance with higher heat transfer rates to the air flow and lower friction losses compared to flat plate air collectors of conventional design.

B. The use of artificial roughness in different forms and shapes is an effective and economic way of improving the performance of solar air heaters & to increase the convective heat transfer coefficient. The study proved that solar air heaters with copper as absorber plate & use of artificial roughness to promote turbulence, exhibited high heat transfer coefficient and efficiency.

C. One of the most important potential applications of solar energy is the solar drying of agricultural products. It has been established that solar drying of fruits and vegetables is technically feasible and economically viable using solar dryer.

D. Solar dryer is the best alternative option to avoid disadvantages of conventional drying methods. It is found that time required for drying in mixed mode solar dryer is less than other type of dryer. Force circulation drying gives better result than natural circulation solar dryer.

REFERENCES

[1] K. Rajarajeswari, “Performance Evaluation Of A Wire Mesh Solar Air Heater”, Voice of Research, Volume 3 Issue 3, December 2014 ISSN No. 2277-7733.

[2] Manish Kumar Tated, Dinkar Prasad Singh and Sudhanshu Dogra, “Heat Transfer and Friction Factor Characteristics of Double Pass Solar Air Heater Using W-Shaped Artificial Roughness Ribs”, IOSR Journal of Mechanical and Civil Engineering, (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, page no.25-30.

[3] Sreekumar, “Development of solar air heaters & Thermal energy storage system for drying Applications in food processing industries”

[4] Jyoti Singh, “Review Paper of Study on Solar Dryer”, Journal of Mechanical and Mechanics Engineering, Volume 1 Issue 1

[5] G.Padmanaban, P.K.Palani, S.Dharmalingam, K.Raja, Rathinam, “A Review on Solar dryer performance reaction on products”, International Journal of ChemTech Research, CODEN (USA): IJCRGG ISSN: 0974-4290, Vol.8, No.1, 2015, page no.098-104

[6] Raj Kumar, Ranchan Chauhan, Muneesh Sethi, ”Thermal Analysis and Recent Developments in Artificially Roughened Solar air Heater”, Journal of Material Science and Mechanical Engineering (JMSME), Print ISSN: 2393-9095; Online ISSN: 2393-9109, Volume 1, Number 1; October, 2014, page no.7-10.

[7] Megha S. Sontakke, Prof. Sanjay P. Salve, “Solar Drying Technologies: A review”, International Refereed Journal of Engineering and Science (IRJES) ISSN 2319-1821 Volume 4, Issue 4 (April 2015) ,page no.29-35

[8] Ching Lik Hii, Sachin Vinayak Jangam, Sze Pheng Ong and Arun Sadashiv Mujumdar, Solar Drying: Fundamentals, Applications and Innovations.

[9] Atul H Patel, Prof. S A Shah, Prof. Hitesh Bhargav, “Review on Solar Dryer for Grains, Vegetables and Fruits.”

[10] Vipin Shrivastava, Anil Kumar, Prashant Baredar3, “Developments in Indirect Solar Dryer: A Review” International Journal of wind and Renewable Energy Volume 3 Issue 4 (pp, 67-74), ISSN: 2277-3975 July 2015

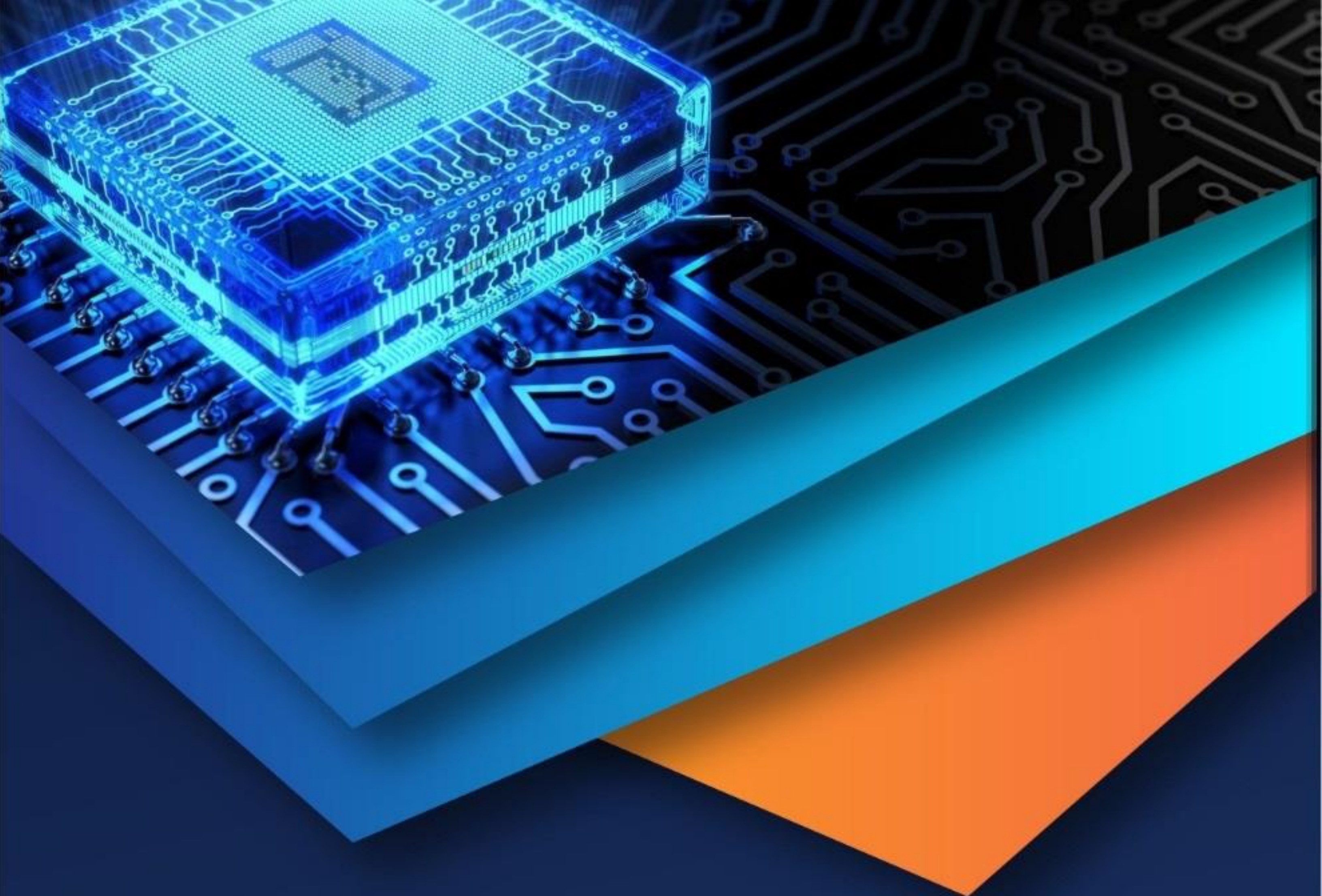
[11] Ajay Kumar Kapardar, Dr. R. P. Sharma, “Numerical and CFD Based Analysis Of Porous Media Solar Air Heater”, International Journal Of Mechanical Engineering And Technology (Ijmet) Issn 0976 – 6340 (Print) Issn 0976 – 6359 (Online) Volume 3, Issue 2, May-August (2012), Pp. 374-386 Journal Impact Factor (2012): 3.8071 (Calculated By Gisi).

[12] Ankit C.Khandelwal, Samir A.Dhatkar, A.B.Kanas-Patil, ”A review on Solar Air Heater using various artificial roughness geometries ” International Journal on Theoretical and Applied Research in Mechanical Engineering (IJTARME).

[13] M. A. Aravindh And A. Sreekumar, “Experimental And Economic Analysis Of A Solar Matrix Collector For Drying Application”, Current Science, Vol. 107, No. 3, 10 August 2014.

[14] Samir A. Dhatkar, Ankit C. Khandelwal, A. B. Kanase-Patil,” A Review of Solar Air Heaters using wire Mesh Absorber”, International Journal on Theoretical and Applied Research in Mechanical Engineering (IJTARME).

[15] Pranav C. Phadke , Pramod V .Walke And Vilayatrai M. Kriplan, “A Review On Indirect Solar Dryers”, Journal Of Engineering And Applied Sciences, Issn 1819-6608 Arpn,Vol. 10, No. 8, May 2015.



10.22214/IJRASET

45.98

IMPACT FACTOR:
7.129

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY