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A Review Paper on Design, fabrication and experimental investigation of solar hybrid dryer with biomass burner for farmers.

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ABSTRACT —*Solar-biomass hybrid dryer systems is primarily set to use this burners which is a supporting source of heat to raise the temperature of the air prior to charging it in the drying chamber. The flue gases are produced from biomass combustion. They have a considerable amount of heat and are exhausted into the atmosphere. This paper presents a new approach that uses the co-generation (Co-Gen) technique in utilizing the flue gas exhausts from the burner. This approach enhances the circulation of warm air in the drying chamber and eliminates the need for an extraction fan. The exhaust gas mixtures are fed inside the chimney at the upper side part to raise the natural stack effect caused by the increase in temperature and decrease in pressure. This technique might not be theoretically proven but it was successfully performed and proven experimentally; the dryer is tested with and without Co-Gen by drying red chili. it is observed that efficiency of the biomass mode system with Co-Gen is raised by 5.7%.*

Along with the increase in the efficiency, the most advantage of this approach is that it is eliminating the electricity, as long as the Co-Gen technique replaces the electrical extractor. This benefit will make the hybrid solar drying applicable in rural and remote areas.

Keywords-*Drying, thermal, biomass,co-generation technique, hybrid, process, material*

I.INTRODUCTION

Grid-connected electricity and other non-renewable or conventional energy resources are mainly responsible for pollutions, and then they are unavailable, unreliable, or too costly to many farmers in many of the rural areas. So to dry the crops, use of motorized fans or electrical heating in crop- drying systems are therefore not applicable in such remote areas. Due to the large initial investments and operating costs of fossil fuel-driven dryers, the small-scale farm owners and the operators are rarely adopting tofossil fuel-driven dryers. So, to overcome these financial barriers, the traditional method of open sun drying is preferred by small-scale farmers but this technique has many intrinsic limitations, such as high crop losses caused by inadequate drying, fungal attacks, unexpected rains, attackof birds, rodents and insects and other effects of weather conditions. As such, solar crop dryers are now continuously gaining attraction towards as the commercial propositions. Because of the energy crisis and atmospheric pollutants problems, almost all governments are trying to find the optimum solution to develop green energy solution to alleviate such problems. To dry the agriculturalcrops, the most effective way to improve the economic efficiency of drying process, is to minimize the energy consumption for drying systems[4]. Consumption energy of drying system is primarily affected by two major factors; first one is the dried product and second is energy efficiency of the crop drying system. By using a conventional energy source, hot air convection drying technique is not a very effective and sustainable way of drying the crops[5]. Due touse a conventional energy source, the drying system inherently becomeshigh capital investment system with highrunning costs and pollution is another issues came along with it. However, the actual implementation of solar drying system requiresthe support from other forms of energy because of the fluctuation of solar energy, less heat collection efficiency, weather wise change and lots of other factor. Therefore, many of the researchers are working on the solar drying and most of them have been conducted experiments over the past few years. Solar drying techniqueis classified into four major categories: direct solar drying technique, indirect solar drying technique, open sun drying technique and hybrid solar drying technique [17]. Some researchers have studied various types of the design of a solar dryer. In past literature studies, it is observed that solar thermal components are the main component which play very crucial role in the different solar drying systems and that's why, Hybrid Photovoltaic Thermal (PV/T), solar air collector types, green houses, etc. have been accepted. J.Banout, P. Ehl, J. Havlik, B. Lojka, Z. Polesny, V. Verner,in paper entited "Design and performance evaluation of a Double-pass solardrier for drying of redchilli (CapsicumannumL.)", [1] have devloped designed of an actual model of double-pass solar drier and conducted experiments on it under tropical conditions in central Vietnam on specific crop i.e. red chili. Sumit Tiwari, G. N. Tiwari andI. M. Al-Helal, in the paper, "Performance analysis of photovoltaic-thermal (PVT) mixed modegreen house solar dryer", [9] proposed a hybrid photovoltaic-thermal (PVT) green house solar dryerunder mixed mode. A.E. Kabeel, Mohamed Abdelgaied, " Performance of novel solar dryer",

[10] in this work, they have explained the effect of rotary desiccant wheel on thethermal performance of solar drying units. And they have validated their numerically proven model with the previousexperimental work.
The main motive behind this paper is to propose hybrid drying system which is to be built to integrate the mixed-mode solar dryer with biomass burner. The benefit of this review is to controlthe suitable air drying temperature for drying system. Moving forward, energy efficiency, economic andenvironmental pollution due to the drying operation process were also considered here.Hybrid solar dryers do not require any auxiliaryequipment and it also protects the food items, crops from external dust, contamination and unfavorable conditions. This solar dryer with biomass burner is to be used to deliver the hot air to the drying chamber during the day time as well as the night time.

II. PROBLEM DEFINITION, OBJECTIVES & RESEARCH METHODOLOGY

2.1 Problem definition and Objective

The solar drying process is suffering from the lack of sunlight interruption during cloudy and rainy days as well as throughout the night.In many countries, food products and agricultural products are dried under the open sun. However, this way of drying deteriorates the quality of the dried products due to intrusion from external contaminations and solar light instability causes the uneven drying rates. Integration of the solar dryer with another resource of energy is the most appropriate practical solution to get continuity in dryingprocess.
Thus, the hybrid solar dryer technique with biomass burneris the practical solution on the above stated problem.
The proposedhybrid solarbiomass burner is feasible for providing hot air suitable for the drying of any type of agriculture crops, food products and forest items. The advantage of using such a system is important in the rural and remote areas, becausesolar dryer with biomass burner operates and performs hybrid drying and it is also free from grid-connected electricity.

III. LITERATURE SURVEY

Different drying techniques have been implemented to dry various types of food and agricultural products. Every drying technique comes along with its own benefits and limitations. Selecting the proper drying technique is therefore become important in the process of drying these perishable products. Hybrid solar dryer has been incorporated in the biomass stove to reduce the stove's dependence on solar radiation for its operation and to improve its quality of drying. This approach extends the period of drying of high-value products beyond sunshine hours and possibly during night. Biomass, particularly wood, is a major source of energy and is very obviously burned using inefficient technologies in most of the developing countries.
Among the previously studied solar hybrid dryer, Tadahmun A. Yassena & Hussain H. Al-Kayiema, "Solar-Biomass Hybrid Dryer Enhanced by the Co-Gen Technique", [9]have developed the model and test results of Solar-biomass hybrid dryer systems which uses biomass burners as the back-up source of heat towarm the air in case to charge it in the drying chamber. In this paper, they have presented a new approach that uses the co-generation (Co-Gen) technique inutilizing the flue gas exhausts from the burner. They have used Co-Gentechnique on the circulation of air inside the dryer was investigated using red chili, with aninitial moisture content of 70%. The volumetric flow rate was enhanced by 23% in thesystem with the Co-Gen technique. The overall drying efficiency by the thermal backmode was 9.9% and 10.5% in the system with and without the Co-Gen technique, respectively. Enhancing the circulation of air inside the dryer enhanced the overall dryingefficiency by 6%.
S. K. Sansaniwal, M. Kumar[10] havefabricateda natural convection indirect solar cabinet dryer to study the drying behavior of ginger rhizomes in terms of its convective heat transfer coefficient and moisture removing rate. They have found that the average values of convective heat transfer coefficient varied from 1.78 to 4.74W/m^{2}°C and 0.59 to 5.42W/m^{2}°C for 78 and 48 numbers of ginger samples respectively. The convective heat transfer coefficients for ginger samples decrease significantly with increase in the mass of ginger samples. The average collector efficiency during the drying process was also calculated and observed to vary from 14.97 to 16.14%.in this study it is observed that the moisture removing rate was found to be rise with rise in the mass of ginger samples and it significantly reduces with the progression of drying days.
A. Madhlopa, G. Ngwalo, "Solar dryer with thermal storage and biomass back-up heater",[15] have designed, constructed, andevaluated an indirect type natural convection solar dryer integrated with collector-storage solar and biomass back-up heaters. Their results showed that the volumetric flow rates were ranged from 0.017m^{3}/s to 0.036m^{3}/s at the inlet of the dryer, and the overall drying efficiency of the system for drying pineapple in the night mode was 11%. A total of 50 kg of wood per night was used in the burner, and the temperature recorded in the drying chamber was 65ºC. Here, Madhlopa and Ngwalo designed and fabricated the biomass burner, which was composed of drum, rectangular ductand flue gas chimney. The burner designed by them was having drum length of 0.89m and0.58m diameter. The flue gas chimney height was 2.12m and diameter 0.12m.Wood shaving was used as the fuel in the burner. The rate of fuel feeding was 8kg per night. The maximum temperature recorded inside the dryer was in therange of 41 to 56ºC[15].

On the solar collector design integrated with hybrid dryer, Leon and Kumar [16] experimentally investigated a hybrid dryer system that combined an unglazed transpired solar collector, rock bed, and a biomass gasifier stove with a heat exchanger. A solar biomass hybrid air heating systemhas been developed that does not need a conventional auxiliary heater but can still provide a daily load fraction exceeding 90% and supply hot air at a steady temperature and flow rate continuously for 24 h a day. The system was evaluated by drying chilli using air at 60°C and 90 m^3/h. The chilli was dried from 76.7% moisture to 8.4% over 32.5 h of continuous drying. The dryer reduced the drying time by 66% compared to open sun drying and provided 91.6% load fraction during the 24-h operation. The temperature of hot air supplied was stable at 60±3°C for about 21 h during the entire drying duration. Eight trials were conducted for drying mackerelby a solar biomass hybrid cabinet dryer and compared the results with open sun drying atair temperatures of 32.4 – 57.7°C, relative humidity 23.9 – 85.8%, and air flow of 0.20 –0.60 m /s.

In conclusion, there are some attempts on investigation of integration solar dryers integrated with different types of thermal

IV. METHODOLOGY

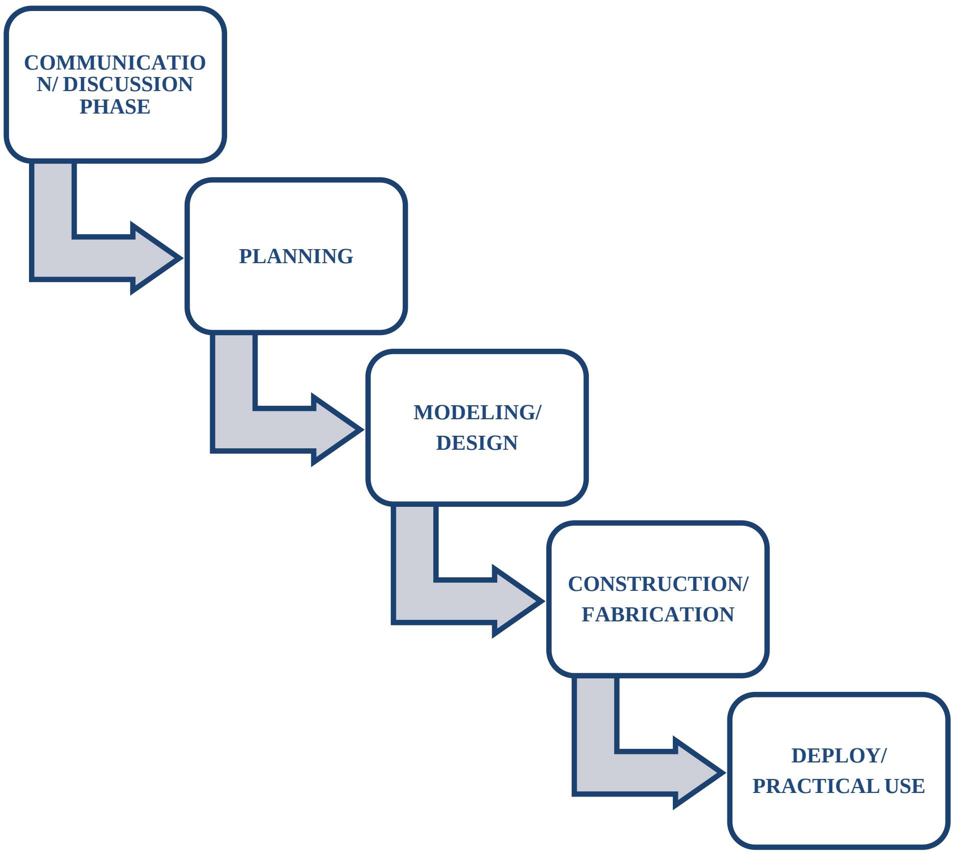

Figure 1.Waterfall Model

We have decided to complete the project in simple waterfall model

Communication Phase: Communication phase includes:

i. Discussion of topic with guide
ii. Actual farm visit and understanding the various method
iii. Literature study
iv. Problem identification
v. Problem analysis
vi. Concept development
vii. Discussing various certainties and uncertainties

Planning Phase:

Planning phase includes:

i. Process planning
ii. Raw material planning
iii. Force analysis
iv. Process scheduling

Modeling Phase/ Design Phase:

Modeling phase includes:

i. Design of each part.
ii. CAD modeling of parts.
iii. Assembly model of parts.
iv. Prototype or sample model preparation.

Construction and Testing/Fabrication:

Fabrication phase includes:

i. Selection of proper manufacturing methods
ii. Working as per process scheduling and plan
iii. Testing of equipment on field
iv. Error analysis
v. Repair if any

Deployment/Practical Implementation:

Comparing the project with the designed output

i. Preparation of testing results
ii. Preparation of project report,Final submission of project

V. DESIGN AND FABRICATION

5.1.Frame

The main step in the fabrication is to select proper material for the various part of a system. Designing point of view, we must be familiar with the effect of the fabrication process and heat treatment will have on the properties of materials. The selection of material for engineering purposes depends upon the following factors:

i. Its availability
ii. Cost
iii. Material properties: 1. Physical properties 2. Chemical properties. 3. Mechanical Properties.
iv. Sustainability and suitability of material for application.

5.2. Specification of Bottom

- Frame Dimension: 36’’ x 24’’
- Material: MS Angle 20 feet
- Weight/m: 4.50kg/m
- Total weight of base frame: 9.4 kg

Material: Mild Steel

Reasons for selecting mild steel(MS) material for frames:

- MS is easily available.
- Economical.
- Standard sizes are easily available.
- Machinable.
- Factor of safety(fos) is moderate to avoid unexpected failure.
- Good tensile strength.

5.3. Components Design:

A) Design of transverse with fillet welded joint.

Figure 2. Welded Joint

Hence, for selecting weld rod size = 3.2mm
Area of Weld = 0.707 x Weld Size x L(length)
= 0.707 x 3.2 x 12
= 27.15 mm^2
Stress induced = Force Exerted / Area of Weld
21 = F / 27.15
F= 570.21 N = 58.12 kg
Maximum Allowable Stress for Welded Joints = 21 N/mm^2

5.4. Fabrication Process:

Once designing phase is over, actual fabrication process will take place. By using dimension as per the design, usingfabrication process, we will start making the productby using proper material.There are various methods which can be used to fabricate a product, like machining, grinding, folding, punching, shearing,stamping, welding etc. Fabrication process is a process to make only one product rather the manufacturing process was used at the whole system production. This way include part by fabrication until assembly to others component.

In order to make the design come reality, fabrication process needs to be done first. The fabrication process begins from dimensioning of the raw material unless it finishes to an expected product. The processes involved are as follows:

A) Getting material
Huge amount of market for material is available in the world now, with required dimensions. This competition will have more types of steellike L- shape sheet, rectangular hollow steel, rectangular steel etc.available with minimum cost.

B) Measurement and marking
Once the material is with us, then next step is to take measurements and starts fabrication as per like the design. The equipment used in this process is measuring tape, scales, calculator and pen. The scale is from solid work software and this scale is actual one.

C) Cutting material
Cutting processes work by causing fracture of the material that is processed. Usually, the portion that is fractured away is in small sized pieces, called chips. Common cutting processes include sawing, shaping (or planning), broaching, drilling, grinding, turning and milling. Although the actual machines, tools and processes for cutting look very different from each other, the basic mechanism for causing the fracture can be understood by just a simple model called for orthogonal cutting.
In all machining processes, the work piece is a shape that can entirely cover the final part shape. The objective is to cut away the excess material and obtain the final part. This cutting usually requires to be completed in several steps – in each step, the part is held in a fixture, and the exposed portion can be accessed by the tool to machine in that portion. Common fixtures

include vise, clamps, 3-jaw or 4-jaw chucks, etc. Each position of holding the part is called a setup. One or more cutting operations may be performed, using one or more cutting tools, in each setup. To switch from one setup to the next, we must release the part from the previous fixture, change the fixture on the machine, clamp the part in the new position on the new fixture, set the coordinates of the machine tool with respect to the new location of the part, and finally start the machining operations for this setup. Therefore, setup changes are time-consuming and expensive, and so we should try to do the entire cutting process in a minimum number of setups; the task of determining the sequence of the individual operations, grouping them into (a minimum number of) setups, and determination of the fixture used for each setup, is called process planning.

Figure 3.Cutting of Material

D) Drilling

The geometry of the common twist drill tool (called drill bit) is complex; it has straight cutting teeth at the bottom – these teeth do most of the metal cutting, and it has curved cutting teeth along its cylindrical surface (Figure 6). The grooves created by the helical teeth are called flutes, and are useful in pushing the chips out from the hole as it is being machined. Clearly, the velocity of the tip of the drill is zero, and so this region of the tool cannot do much cutting. Therefore it is common to machine a small hole in the material, called a center-hole, before utilizing the drill. Center-holes are made by special drills called center-drills; they also provide a good way for the drill bit to get aligned with the location of the center of the hole. There are hundreds of different types of drill shapes and sizes; here, we will only restrict ourselves to some general facts about drills.

Countersink/counter bore drills have multiple diameters – they make a chamfered/stepped hole, which is useful for inserting screws/bolts – the larger diameter part of the hole accommodates the screw/bolt head. Internal threads can be cut into holes that mate with screws/bolts. These are cut by using tapping tools.

Figure 4. Drilling Machine for Drilling Operation

E)* Welding process*:

Welding is a fabrication process in which two or more components are fused together by means of heat, pressure or both forming a join as the parts get cool. For actual product, it involves joining together of many individual components. To join the parts permanently, welding is a very easy and good option. Other possible processes such as brazing, soldering, and use of adhesives will are considered in the design module.

Several welding processes are based on heating with an electric arc, only a few are considered here, starting with the oldest, simple arc welding, also known as shielded metal arc welding(SMAW). In this, an electrical machine (which may be DC or AC, but nowadays usually AC current is supplied to an electrode holder which carries an electrode which is normally coated with a mixture of chemicals or flux. An earth cable connects the work piece to the welding machine to provide a return path for the current. The weld is initiated by tapping ('striking') the tip of the electrode against the work piece which initiates an electric arc. The high temperature generated (about 6000^{o}C) almost instantly produces a molten pool and the end of the electrode continuously melts into this pool and forms the joint.The operator needs to control the gap between the electrode tip and the work piece while moving the electrode along the joint.

Figure 5. Arc Welding Operation

F) Abrasive Saw

An abrasive saw, also referred to as a cut-off saw or metal chop saw, may be a machine which is usually use to cut hard materials, like metals. The cutting action is performed by an abrasive disc, almost like a thin grinding wheel. Technical point of view, it doesn't use regularly shaped edges (teeth) for cutting. The abrasive saw generally features a built-in vies or other clamping arrangement, and has the cutting wheel and motor mounted on a pivoting arm attached to a hard and fast base plate.

Figure 6.Abrasive Cutting Machine

They typically use composite friction disk blades to abrasively cut through the steel. The disks are consumable items as they wear throughout the cut. The abrasive disks for these saws are typically 14 in (360 mm) in diameter and 7⁄64 in (2.8 mm) thick. Larger saws use 410 mm (16 in) diameter blades. Disks are available for steel and stainless steel. Since their introduction, portable metal cut-off saws have made many building site jobs easier. With these saws, lightweight steel fabrication previously performed in workshops using stationary power band saws or cold saws can be done on-site. Abrasive saws have replaced more expensive and hazardous acetylene torches in many applications, such as cutting rebar.

G) Threading Operation

Dies, taps are tools used to create screw threads. It is called threading process. There aremany cutting tools. A tap is used to form the internal threads of the mating paire.g. nut. A die is used to form the external threads e.g. a bolt. The process of forming the threads using a tap is called tapping and the process of forming the threads using a die is called threading. Both tools can be used to clean up a thread and it is called as chasing.

Figure 7.Various Taps and Tap Handle

Bottoming tap or plug taps:

The tap illustrated in the top of the image has a continuous cutting edge with almost no taper between 1 and 1.5 threads of taper is typical. This feature enables a bottoming tap to cut threads to the bottom of a blind hole. A bottoming tap is usually used to cut threads in a hole that has already been partially threaded using one of the more tapered types of tap; the tapered end ("tap chamfer") of a bottoming tap is too short to successfully start into an unthreaded hole. In the US, they are commonly known as bottoming taps, but in Australia and Britain they are also known as plug taps.

Intermediate tap, second tap, or plug tap

The tap illustrated in the middle of the figure 7 has tapered cutting edges, which assist in aligning and starting the tap into an untapped hole. The number of tapered threads typically ranges from 3 to 5. Plug taps are the most commonly used type of tap. [Citation needed] In the US, they are commonly known as plug taps, whereas in Australia and Britain they are commonly known as second taps.

Taper tap

The small tap illustrated at the bottom of the figure 7 is similar to an intermediate tap but has a more pronounced taper to the cutting edges. This feature gives the taper tap a very gradual cutting action that is less aggressive than that of the plug tap. The number of tapered threads typically ranges from 8 to 10. A taper tap is most often used when the material to be tapped is difficult to work (e.g., alloy steel) or the tap is of a very small diameter and thus prone to breakage.

Whether manual or automatic, the processing of tapping begins with forming and slightly countersinking a hole to a diameter somewhat smaller than the tap's major diameter. The correct whole diameter may be determined by consulting a drill and tap size chart, a standard reference item found in many machine shops. If the hole is to be drilled, the proper diameter is called the tap drill size.

H) Grinding Operation

Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool.Different types of machines are used for grinding and some of them are mentioned below.

i. Hand-cranked knife-sharpening grindstones.
ii. Bench grinders often found in residential garages and basements
iii. Hand operated power tools e.g. angle grinders and die grinders
iv. Different kinds of costlymachine tools.

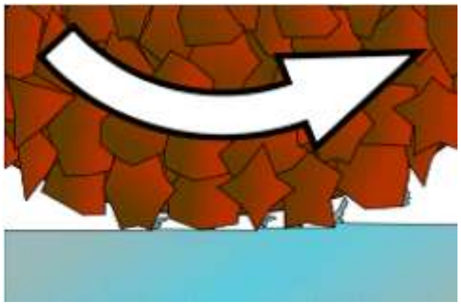

Figure 8.Working of Abrasive Particle from the Metal

Grinding process is a huge and diverse area of manufacturing and tool making. It can have a very fine finishes and very precise dimensions, but in mass production, it can rough out workpiece large volumes of metal with quite fast rate. It is usually used to machine a very hard material than is regular machining, i.e. cutting larger chips with cutting tools such as tool bits or milling cutters, and until recent decades it was the only practical way to machine such materials as hardened steels. Compared to regularmachining, it is also suited to taking very shallow cuts, such as reducing a shaft's diameter by half a thousandth of an inch or 12.7µm.

Lapping and sanding are subsets of grinding.

Surface grinding uses a rotating abrasive wheel to remove material, creating a flat surface. The tolerances that are normally achieved with grinding are ± 2 × 10−4 inches for grinding a flat material, and ± 3×10^{-4} inches for a parallel surface (in metric units: 5µm for flat material and 8µm for parallel surface).The surface grinder is composed of an abrasive wheel, a work holding device known as a chuck, either electromagnetic or vacuum, and a reciprocating table. Grinding is commonly used on cast iron and various types of steel. These materials lend themselves to grinding because they can be held by the magnetic chuck commonly used on grinding machines, and they do not melt into the wheel, clogging it and preventing it from cutting. Materials that are less commonly ground are Aluminum, stainless steel, brass & plastics. These all tend to clog the cutting wheel more than steel & cast iron, but with special techniques it is possible to grind them.

VI. WORKING

The proposed hybrid drying system is to be constructed to integrate the mixed-mode solar dryer with biomass burner. The mixed-mode solar dryer is to be constructed from a solar collector and direct drying chamber. This dryer is to be used to deliver the heat to the drying chamber during the day hours. The TBU is to be constructed from a burner and gas-to-gas heat exchanger. This unit can be used to supply the heat during the night hours.

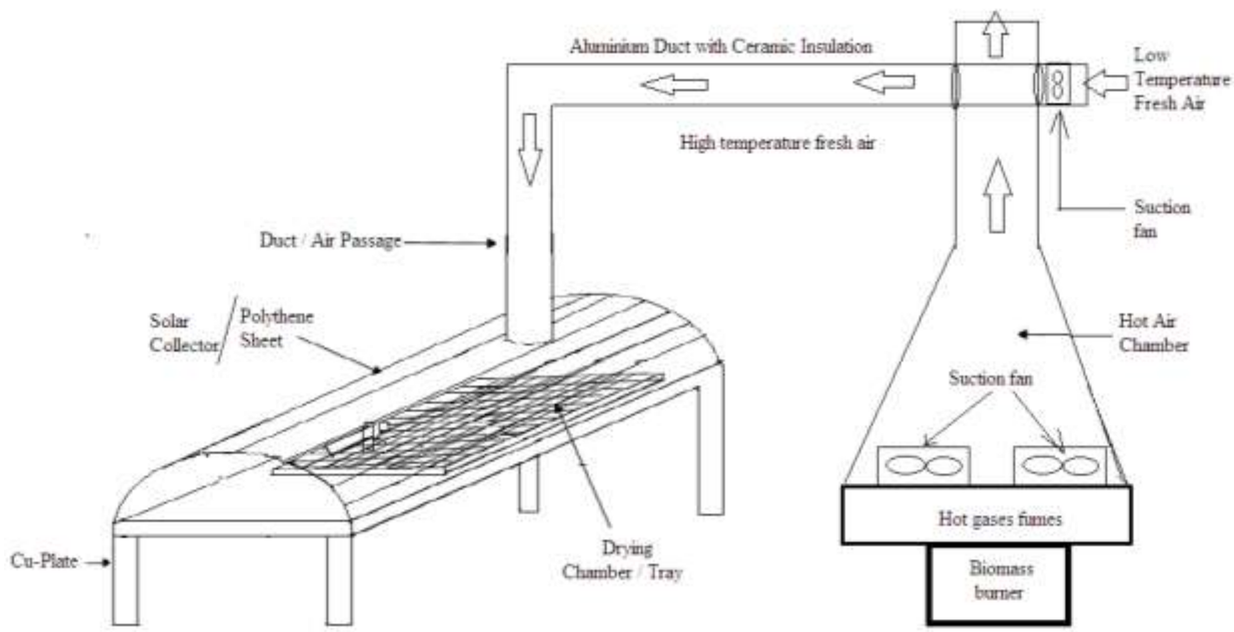

Figure 9. Proposed Schematic Diagram of Solar Dryer Unit

COMPONENTS:

6.1. Solarcollector:

A solar collector is structural framed. It is covered with Ultra-violet (UV) stabilized polythene sheet. Below this collector, drying chamber is present. The air flow rate is controlled by thesuction fan. A sloping rod or semi cylindrical shape will make sure that no otherintruder will enter into the chamber.
Solar collector is mainly depend on the environmental conditions to achieve good output from unit. There are lots of parameters of solar dryer which will have impact on the performance of solar collector, e.g. absorber material of collector, angle set for collection of sunlight, air flow rate, humidity of air, location of site, weather etc. So it is important to evaluate the performance of solar collector, considering those parameters to achieve greatperformance.

Area of solar collector:
Let, area of solar collector is A.

$$A = L \times B$$

Currently, we have considered the dimension for design point of view in figure 9.
As per the figure 9, L=3.625 feet or 1.1049 meter
As we haveconsidered the solar collector as a semi-cylindrical shape equals, so let B be the width of solar collector which is almost equal to diameter ofsemi-cylindrical shape.

$$B = 2\text{feet or } 0.6096 \text{ meter}$$

Therefore,

$$A = L \times B$$
$$A = 1.1049 \times 0.6096$$
$$A = 0.6735\ m^2$$

6.2. Dryingchamber / Tray:

The drying chamber/tray is to be fabricated from angles. It is attached with the a wire mesh base to allow free flow of the hot air through or over the products kept on drying tray. So, it also makes arrangement light weight. The arrangement will contain total three drying trays which are with a wire mesh base.The tray will be painted with black color so that it can absorb maximum of solarradiation to maximize the performance. The tray has 1.5× 2.5 feet area.
Dimensions of Drying chamber / Tray is 18” X 30” X 4”or 1.5ft. X 2.5ft. X 0.33ft. And in total effective drying area of 0.9m2.

6.3. Biomass burner:

Biomass burner was designed to operate when there is not much or less solar radiation, e.g. in nighttime and during rainy times that varies the solar lightbecause of the cloudy weather cover as a backup heat source. The burning cylinder designed for incineration of the sawdust and an air circulation section was designed to generate heated air.
Drying chamber / Tray get heated by the heat generated by biomass burner into the hot air chamber. A series of suction fans fixed in the hot air chamber at the bottom as shown in figure 9 which will facilitate high air temperature into the duct. Airs is circulated inside that plate series, get heat and generated convection current. Heated air is delivered to the drying chamber through insulated metal tube connected to the burner. The other end of the metal tube close to the drying chamber is connected with a force feed blower powered by 12 V, 4 A battery.

6.4. Duct / Air Carrying Passage:

This duct will carry the high air temperature from hot air chamber to drying chamber. In short, it connects drying chamber to hot air chamber. This duct is made of aluminium tube which will be covered by ceramic powder insulation. Ceramic powder insulation to duct will minimize the heat losses from hot gases.

VII. ADVANTAGES, DISADVANTAGES AND APPLICATIONS

7.1. Advantages:

A hybrid solar dryer with biomass burner is with enclosed drying chamber, where we are keeping our agricultural products to dry. So, this enclosed chamber will keep the food safe from environmental damages, intruders like insects, rats, birds etc. and unexpected rainfall. This enclosed drying chamber will act as dehydrator, which means that it has been used throughout the year to preserve crops by removing moisture.

Some of other advantages of solar drying units are:

- It will permit early harvesting as well as pre-planning of the harvesting season;
- The system saves the energy as it is free from electricity.
- With solar drying, farmer will able to get better quality product to sell.
- This unit will provide controlled drying and even dry rates.
- Good quality product will automatically come with advantage of a higher price and more benefits.
- Noiseless in operation as it is with no moving parts.
- More robust construction of drying unit makes it a long life storage unit without deterioration.
- Hybrid solar dryer is a compact unit, so initial cost is low as compared to conventional drying units.
- Due to less mechanical part, maintenance cost is very low for hybrid solar dryer unit.

7.2. Disadvantages

A hybrid solar dryer with biomass burner has some disadvantages also and they are listed below:

- This unit is time consuming as compared with the fossil-fuel operated drying units.
- This unit will require laborers.
- As it is compact unit, so it becomes little bit complicated in construction.

7.3. Applications

- Agricultural uses: to dry agricultural crops, like grains, fruits and vegetables
- Domestic uses: to dry fruits and vegetable for pickles etc.
- Medicinal uses:it is also used for medicinal plants like mushrooms, cashews, paddy, tea leaves etc.
- Industrialpurposes: use in drying spices like chilies, coriander, pepper, turmeric, dehydration of fruits and vegetables like mango, sapota etc.
- Some other applications of hybrid solar dryers are for dairy farming, livestock, fish drying etc.

VIII. CONCLUSION

From this review, we came to know that hybrid solar dryerapplication in agricultural products is one of most major economical and potential application of solar energy. In many developing countries, over 30 to 40% of production ofagricultural cropsis lost during drying. These losses can be controlled drastically, if farmers in the developing countries start using the well-designed solar drying units in the rural areas. Use of solar hybrid dryer with biomass burner will definitely improve the efficiency of drying system and drying systemcan be used after sunshine hours. Small scale farmers or operators should use this solar dryer unit for drying their own agriculturalcrops and also they can use it as commercial source. In current scenario, if we talk about only of raisins production in India, about 95% of the raisins are produced by the traditional open sun drying and shed drying, this inferior quality produce can be overtaken by superior quality produce by solar dryers. So, now it's time to take some steps to aware the farmers about the use of solar dryer unit for drying their own agriculturalcrops and it's as commercial source.

This paper also involves design, fabrication and experimental investigation of solar dryer with biomass burner for farmers. It can be concluded as the fire gases produced from biomass combustion has a considerable amount of heat exhausted in to ambient from drying chamber with coordination of solar dryer with different weather conditions, temperature and velocities of air.

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