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# DESIGN, FABRICATION AND TESTING OF A SOLAR PAPER DRYER

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**Abstract -** ***Paper is one of the essential commodities and paper industry forms the core sector of our country's economy. Paper and paper products contributes various sections such as communication, education and product packaging. The uses and applications of paper and paper products are many and new innovative products are being developed nowadays. The Indian paper industry has made a drastic progress since independence. Kirti Papers Private Limited (KPPL) is a small scale industry registered under the District Industry Centre, Govt. of Karnataka, Dharwad, and also recognised by Khadi and Village Industries Commission as a genuine handmade paper manufacturers. The company produces 250 kilograms to 300 kilograms of finished paper product per day on average. But one main problem faced by the company is in paper drying. The sheets are dried by hanging over the wire ropes. It takes 24 hours for drying and in rainy seasons its takes 48 hours or more. This paper aims at the design, fabrication and testing of a solar dryer which envisages to utilise the solar energy for rapid drying of handmade paper. The performance of the dryer was tested and the dryer took 65 to 75 minutes for drying. A cost benefit analysis was carried out and the payback period was found to be 95 days.***

***Key Words:*** *Solar dryer, Handmade papers*

## 1. INTRODUCTION

Renewable energy technology bridges the gap between mounting global energy demand and decreasing supply of finite conventional energy sources. The efficiency of such application and the economics of installing it should be seriously considered.

In today's environment, the energy needs are increasing along with environmental concern. This energy need concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. Solar energy is one such alternative which reduces the use of non-renewable sources.

The energy produced directly by the sun is simply called as solar energy. This incoming solar energy is collected elsewhere, normally the Earth. The sun produce its energy by many thermonuclear reactions which creates large amount of heat and electromagnetic radiations. The heat produced remains in the sun and helps in maintaining the thermonuclear reactions. The electromagnetic radiation including visible rays, infra-red rays, and ultra-violet radiation streams out into space in all directions. Out of these radiations, only a very small fraction of radiation reaches the Earth. Almost every type of energy used today uses this small fraction of incoming radiation as their indirect source.

The solar technologies are classified as either passive or active, depending on the way they capture, convert and distribute sunlight. Active solar techniques include the use of solar panels, solar thermal collectors to convert sunlight into useful outputs. Passive solar techniques include orienting a building to the sun, which is made with materials having favorable thermal mass or light dispersing properties, thereby designing spaces inside the building itself that naturally circulate air. In India, the utilisation of solar energy is of great importance since it lies in a temperate climatic region of the world where plenty of sun light is available for a major part of the year.

The technology uses solar energy in various forms such as solar thermal applications have been in energy conversion devices, central heating, drying, cooking and even refrigeration. Drying is an absolutely necessary operation in many industrial process and daily needs, requiring substantial conventional energy. The current project is an attempt to fabricate and develop a dryer based on solar energy which can redress the problem of drying of papers in handmade paper industry effectively and thus prove to be an efficient alternate form of a dryer.

## 2. HANDMADE PAPER INDUSTRY

Handmade paper is often produced in countries with less access to energy sources and more access to cheap labour. The energy intensive drying process has therefore often utilized so called 'sun drying' to dry the papers. This mean that the papers are either placed on a frame and then placed under direct sunlight to be dried by the sun or dried by just hanging them over the ropes. There are some important drawbacks with sun drying. Firstly, it is highly

dependent on the weather because papers can only be dried when the sun is shining, when the wind is calm and when there is no risk of rain. This limits the amount of days of the year when paper can be dried in the sun and can therefore create a bottleneck in the production. Secondly, it takes very long time to dry thicker papers even under optimal conditions when using sun drying, because the temperatures are lower. The other disadvantages of this method are contamination, theft or damage by birds, rats or insects; encourages mould growth and may result in a relatively high final moisture content; low and variable quality of products due to over or under drying; large areas of land needed for drying; laborious since the crop must be turned, moved if it rains; direct exposure to sunlight reduces the quality (colour and texture) of the products. Moreover, since sun drying depends on many uncontrollable factors, production of uniform and standard products cannot be always expected. In order to overcome the limitations inherent with open sun drying, improvements are necessary. Design and fabrication of a solar dryer which uses solar energy would lead to the elimination of the drawbacks in existing drying method and thereby fastening the drying rates.

## 3. KIRTI PAPERS PRIVATE LIMITED

Kirti Papers Private Limited (KPPL) is located at K I A D B's industrial area, Tarihal about 12 km from Hubli district. The company was started in the year 1986. This is a small scale industry registered under the District Industry Centre, Govt. of Karnataka, Dharwad, and also recognized by Khadi and Village Industries Commission as a genuine handmade paper manufacturers.

The company produces 250 - 300 kilograms of paper per day on average. The production of paper depends on the order received. One of the major problem faced by the company is in drying of papers. The papers are dried by hanging them over the wire ropes. It takes 24 hours for drying and 48 hours or more in rainy season. The drying process removes moisture. The disadvantages associated with open drying is that dust get embedded into the paper. Also the drying can take a longer time when there is no sunlight and considerable humidity. The drying can be done quicker with a solar dryer, eliminating the drawbacks in existing drying methods.

The objective of this project is to solve the problem of drying faced by KPPL, by the design and fabrication of a solar paper dryer which envisages to utilise the solar energy for rapid drying of handmade paper.

## 4. SOLAR DRYERS

Drying or dehydration of a material means removal of the moisture from the interior part of the material to the surface and then to remove this moisture from the surface of the material to be dried. Drying basically comprises of two processes: (i) heat is transferred to the material to evaporate liquid, and (ii) within the solid, mass is transferred as a liquid or vapour and as from the surface it is transferred as vapour. The drying rate is determined by the factors governing the rates of these processes. The different dryers uses convection, conduction, radiation, or a combination of these as mode of heat transfer.

Solar dryers are devices that use free, solar energy to dry materials. Solar drying has been used since time immemorial to dry plants, seeds, fruits, meat, fish, wood, paper and other agricultural, forest products. In order to benefit from the free and renewable energy source provided by the sun several attempts have been made in recent years to develop solar drying mainly for preserving agricultural and forest products. However, for large-scale production the limitations of open-air drying are significantly seen. High labour costs, lack of ability to control the drying process, large area requirement, possible degradation due to biochemical or microbiological reactions, insect infestation are some such limitations. This may cause the fastening of the drying time required for a given commodity and may result in losses. Solar drying of agricultural products in enclosed structures by forced convection is an attractive way of reducing post-harvest losses and low quality of dried products associated with traditional open sun-drying methods. In developing countries, there are lot of rural locations. In these places, grid-connected electricity and supplies of other non-renewable sources of energy are either unavailable, unreliable or they are too expensive. In such conditions, solar dryers appears attractive as commercial propositions.

## 5. TYPES OF SOLAR DRYERS

### 5.1 Active Dryers

Active solar dryers are also called forced convection or hybrid solar dryers. Throughout the drying process, optimum air flow can be provided in the dryer and thereby control temperature and moisture in wide ranges. Hence, the capacity and the reliability of the dryers are more compared to the natural convection dryers.

Active dryers require an external means, like fans or pumps; for converting and transferring the solar energy in the form of hot air. This air is transferred from the collector area to the drying chambers. These dryers can be built in almost any size, from very small to very large according to the requirement. The larger systems are the most economical ones. In an active dryer, either air or liquid collectors can be used to collect the solar energy.

### 5.2 Passive Dryers

Passive solar dryers use natural means of radiation and convection to heat the air and move it. The passive dryers can be subdivided into direct and indirect types. In a direct dryer, material to be dried is exposed directly to the sun. This type of dryer typically consists of a drying chamber. This chamber can be covered by transparent glass cover or plastic.

An indirect dryer is one in which the solar rays do not strike the material to be dried. In this system, drying is achieved indirectly by using a collector that passes hot air into a separate drying chamber.

## 6. DIMENTIONAL DESIGN

Material to be dried: HANDMADE PAPER of A4 size
Moisture content in the wet sheet = 50% = 0.5
Moisture content to be obtained after drying = 7% = 0.07
Number of papers to be dried at a time = 20
Weight of 1 wet sheet, M = 22g = 0.022 kg
Amount of moisture content to be removed from wet sheet, Mm = $\frac{M(Wet\% - Dry\%)}{(100\% - Dry\%)}\ kg$

= 0.01 kg of water from 1 wet sheet

The amount of heat required to remove the moisture content for 1 paper is given by,

$$Q_R = Mm\ h_{fg} + Mm\ h_f$$

= 26.76 kJ of heat for drying 1 paper

That is, rate of energy, Q = 7.4 W

Therefore, Q for drying 20 papers in 1 hour = 7.4 × 20

= 148 W

### 6.1 Collector Design

The useful heat delivered by the collector,

$$Qu = Ac\ [I_t < \tau.\alpha > - U_L\ (T_c - T_a)]\ F_R$$

As per the working of the dryer, Q = Qu

Therefore, for 1 paper,
Area of collector, Ac = 7.4 / 246.38 = 0.03 $m^2$ for 1 paper

For 20 papers,

Area of the collector, Ac = 0.03 × 20 = 0.6 $m^2$
Therefore, Size of flat plate collector = 0.8m × 0.8m

### 6.2 Blower Design

Amount of heat transferred, $Q = C_p \times \dot{m} \times \Delta T$
Here, $\dot{m}$ = Volumetric flow rate of air × Density of air
Therefore above equation becomes, $Q = C_p \times v \times \rho \times \Delta T$
Therefore, volumetric flow rate, v = 0.36 $m^3$/min

### 6.3 Drying Chamber Design

As per M/S Kirti Papers, a chamber of 1.5 feet in length, breadth and height can accommodate 12 papers at a time to dry. Therefore, if for 12 papers, chamber size is as said above, that is 0.45m in length, breadth and height, then for drying 20 papers of A4 size at a time,

Chamber size = 0.75m × 0.75m × 0.75m

After adding enough space for air circulation, chamber size was decided as 0.9m × 0.9m × 0.9m.

## 7. EXPERIMENTAL SETUP

An active solar dryer was fabricated for this project. The dryer was designed to dry twenty sheets of A4 size in one hour. The setup consists of a blower, solar collector and a drying chamber to dry the papers during day time. The blower transfers air to the collector. A solar panel was used to run the blower. During the hours of sunshine, the air over the absorber plate of the collector gets heated and pass this heated air to the drying chamber where the wet papers are hung for drying. The solar collector consisted of an absorber which heats the incoming air. The absorber was kept on an aluminium sheet on which GI channels where made to pass the air. The collector was insulated using glass wool with aluminium foil. A PVC pipe was used to transfer the heated air to the drying chamber. An exhaust was provided at the other end of the drying chamber.

A blower of blowing capacity 0.36 $m^3$/min was chosen from the design calculation for this dryer. The solar collector was made of size 0.8m × 0.8m. The drying chamber was made of aluminium sheet and was insulated using glass wool with aluminium foil. The drying chamber was made of size 0.9m × 0.9m × 0.9m.

**Fig -1**: Experimental Setup of the Solar Dryer

## 8. RESULTS

A set of readings of illuminances, temperatures, flow rate were noted. The temperatures taken were ambient temperature, temperatures at the inlet and outlet of the chamber, temperature at the upper surface of the absorber. Based on the results obtained during the test of dryer, temperature above 70˚C was recorded at the inlet of the drying chamber. Also, temperature above 50˚C was obtained at the upper surface of the absorber. The experiment was conducted for several days. All the readings were noted by analysing the dryer with and without placing the paper. The drying was compared with open sun drying and was found successful. At a time, twenty A4 size papers were dried. The duration of drying depended completely on the solar radiations available and other atmospheric conditions. Since cotton rags which are very strong are mainly used as raw materials for making handmade papers, the quality of the papers are protected.
The time taken for drying the papers using the dryer was compared with the time taken for drying it by natural sun drying. The solar drying took 65 to 75 minutes for drying depending on the solar radiations available at the time of drying. Whereas, the natural sun drying took nearly 24 hours for drying similar set of papers.

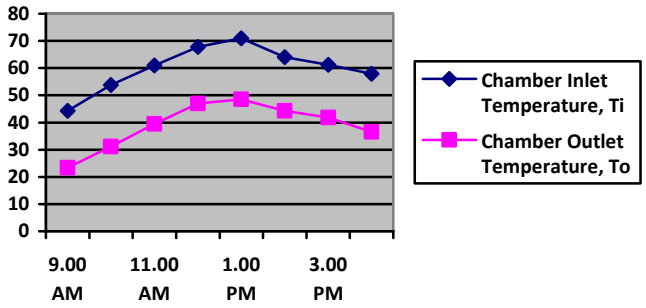


**Fig -2**: Performance of the Dryer

The weight of a single wet sheet which weighed 22 gram before drying was reduced to 10.5 gram after drying. The weight was noted using an electronic balance. A cost benefit analysis was also performed. A payback period of 95 days was obtained after calculation.

## 9. CONCLUSIONS

The aim of this project was to solve the problem of drying faced by Kirti Papers Private Limited (KPPL), by the design and fabrication of a solar paper dryer which envisages to harmonize the solar energy for rapid drying of handmade paper. The main parameters analysed in this project were the time taken for drying the papers using the solar dryer and the effect of this type of drying on the quality of the paper. The disadvantages associated with open drying like embedding of dust get into the paper can be overcome by the use of a solar dryer. Also when there is no sunlight and considerable humidity, the open drying can take a longer time. The experiment result shows that, with a solar dryer, drying can be done quicker, eliminating the drawbacks in existing drying methods.

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