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# Improving the performance of the Flat Plate Collector in a Solar Dryer

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**Abstract -** *Due to increasing population growth and pollution, there is a demand for conventional sources of energy. To overcome this problem the efficient usage of renewable sources of energy in place of the conventional sources of energy is to be done. Solar energy is one of the abundant sources of energy available in earth. Solar dryer is used for drying food materials and agricultural products and helps in reducing the wastage. Generally, Flat Plate Collector is used in the solar dryers to heat the fluid passing through it. The Flat Plate Collector can work effectively even in cloudy days because of the absorption of both direct and diffuse solar radiation. This paper aims in improving the performance of the collector compared to the commercial one.*

***Key Words*: Absorber plate, solar energy, Flat Plate Collector, performance, insulation.**

## 1. INTRODUCTION

Traditionally, Sun is used for drying the food and agricultural products by the direct heat from the sun. Though it provides a cheap and pollution free method, there are some disadvantages in it which includes improper weather conditions, dirt, dust and insects. To overcome this problem, solar drying comes into picture with more advantages than the traditional method of drying. Solar drying is carried out by the solar dryer. There are two main types of solar dryer are available (1) Natural convection solar dryer (2) Forced convection solar dryer. In natural convection solar dryer air flow is the function of buoyancy and in forced convection solar dryer air flow is the function of blower (electrical or solar). Forced convection solar dryer is discussed in our project. A typical solar dryer consists of three important components in it which includes solar collector, drying chamber and blower. Out of these solar collectors contributes more in the performance of the solar dryer.

### 1.1 Function of a Flat Plate Collector

Flat Plate Collector is the most common type of collectors used in air and water heating systems. The collector contains a glass plate(glazing), absorber plate, tubes for fluid flow, insulation and casing. The principle element in the collector is absorber plate with dark coating on it to increase the heat gain. The solar radiation fall on the absorber plate is converted into heat and passed to the fluid used for drying the products.

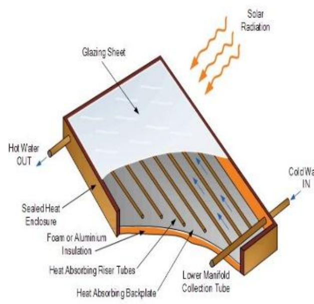


**Fig -1**: Flat Plate Collector

Most of the commercial solar dryers are not performing efficiently due to the minimal useful heat gain and maximal heat loss (conductive, convective and radiative) in the collector. This paper discusses about minimizing the heat loss and improving the efficiency of the Flat Plate Collector by bringing some modifications in an existing collector.

## 2. LITERATURE REVIEW

A typical Flat Plate Collector consists of the following components and the performance of the collector depends mostly on working of these components

1. Glazing cover plate – transmits solar radiation to absorber plate

2. Absorber plate – absorbs the radiation and convert into heat

3. Flow tubes – transfers the absorbed heat to the fluid

4. Insulation – minimize the heat loss

**Ramadhani Bakari et.al (2014)** A set of samples with different thickness of glazing material was chosen and analyzed. The result shows that the performance of the air solar collector is increased by 7.6% in 4mm thickness glazing material over the 3mm, 5mm and 6mm glass materials.

**Shubo Li et.al (2020)** Although high strength can be achieved in Mg–RE series alloys, it is still a challenge to develop Mg-RE alloys with high thermal conductivity because of some well-known difficulties such as the difference in chemical valences, radius and extra-nuclear electrons between RE and Mg atoms.

**Liping Zhong et.al (2016)** The material selection for heat exchangers is discussed in this paper. A magnesium alloy is selected and its properties are obtained from the research. Thermal conductivity-139.7 W/m2K, Ultimate tensile strength-295.9MPa, Yield strength- 320.9 MPa, Elongation – 9.6%, Cost efficient and good manufacturability.

**Mirza Muneer Baig et.al (2017)** An alternate material for aluminium was chosen as mild steel. The efficiency of the flat plate collector using mild steel as absorber plate is 13.2% which is comparatively low than Aluminium but the cost of Aluminium is higher than Mild steel.

**Gun-Young Oh et.al (2015)** The tensile yield strengths and ultimate tensile strengths were improved as the Y-content increased due to the increased volume fraction of the W-phases. Regardless of the Y-content in the Mg-4Zn-0.5Ca alloys, their elongations were similar to that of the Mg-4Zn-0.5Ca alloy.

### 2.1 Absorber Plate

Absorber plate serves as the principle element in a Flat Plate Collector. It is usually coated with a special absorber coating to increase the heat. The black paint is coated on the top surface of the absorber plate. It absorbs the incident radiation from the sun through the glass cover plate on the top of the collector. The material with high thermal conductivity is used for absorber plate in order to increase the absorption of heat from the solar radiation.

### 2.2 Insulation material

Insulation is an important component in collector where we can minimize the heat loss in of the collector so that the efficiency will be increase significantly. The insulation material possesses very low thermal conductivity to reduce the conduction of heat to the environment.

### 2.3 Influence of cover plate thickness in collector performance

The thickness of the glazing cover plate is selected as 4mm to increase the performance as per the literature review.

### 2.3 Influence of heat loss in collector performance

Heat loss in a collector takes place in three modes namely conduction, convection and radiation. The heat loss from the side and back walls of the collector is through conduction. The loss from the absorber plate to cover plate is through convection and radiation.

### 2.4 Influence of thermal conductivity in collector performance

The speed of conduction of heat through a material is commonly referred to as thermal conductivity. In solar collector thermal conductivity of absorber plate, flow tubes and insulation material are to be taken into consideration, as they determine the performance of the solar dryer. The absorber plate with good thermal conductivity and insulation material with low thermal conductivity are the modifications to be done on the existing collector (collector manufactured by Thermo Dynamics Ltd) to increase the collector efficiency.

## 3. MATERIAL SELECTION AND ITS PROPERTIES

The effectiveness of the component depends on the material of the component therefore it is crucial that the material chosen provides performance, as well as cost effectiveness and ease of manufacturability.

### 3.1 Materials for Flat Plate Collector

| S. NO | COMPONENTS | MATERIAL |
|---|---|---|
| 1 | Absorber Plate | Mg-0.5Mn-0.3Ce |
| 2 | Surface Treatment | Black Paint Coated |
| 3 | Insulation | Poly Urethane Foam (PUF) |
| 4 | Blowing Pipes | Aluminium |

**Table -1:** Components and materials of FPC

These materials are chosen mainly based on their properties, cost and manufacturability to contribute for the performance of the collector. By the usage of these materials for the Flat Plate Collector, the collector with a high performance will be achieved over the existing collector.

### 3.2 Materials for Absorber Plate

In general, the absorber plate and flow tubes are manufactured by using high conductive materials like copper and aluminium. Magnesium alloy is selected because It has high strength to weight ratio, stiffness and less corrosive and good thermal conductivity. Though Mg-Mn alloy have low thermal conductivity than Aluminium, it provides a good result in performance of the collector.

| Material | Thermal conductivity (w/m2k) | Ultimate Tensile Strength (MPa) | Yield Strength (MPa) |
|---|---|---|---|
| Al | 218 | 310 | 276 |
| Mg-0.5Mn-0.3Ce | 139.7 | 295.9 | 320.9 |

**Table -2:** Absorber Material Properties

### 3.3 Materials for Insulation

| Material | Thermal conductivity (W/m2K) |
|---|---|
| Fiber glass | 0.036 |
| Poly Urethane Foam (PUF) | 0.018 |

**Table -3:** Insulation Material Properties

In general, the material with low thermal conductivity is used for insulation in order to reduce the conductive heat loss in the collector. Fiber glass is used in the conventional system. Poly Urethane Foam (PUF) have good thermal insulation and sound insulation. It helps in reducing the heat loss which will have a great impact in efficiency of the collector.

### 3.4 Materials for Glazing

In general, the material with good transmittance, absorptance, reflectance and emittance are selected for glazing material. In this project low iron glass is used as glazing material having transmittance value ranges from 0.85-0.9 at normal incidence.

## 4. DESIGN CALCULATION AND MODEL

**Existing collector:** Thermo Dynamics Ltd collector (manufacturer and product). The technical data for the calculation of efficiency of the existing collector provided by Thermo Dynamics Ltd.

The formula for calculating the efficiency of the existing collector:

$$\eta = 0.7 - 4.933\left(\frac{T_i - T_a}{I_t}\right)$$

| S.no | Parameter | Value | Unit |
|---|---|---|---|
| 1 | Inlet fluid temperature | 295.8 | K |
| 2 | Ambient temperature | 293.3 | K |
| 3 | Rate of insolation | 808 | W/m$^2$ |

**Table -4:** Technical Data of Existing Collector

On solving this equation

**η = 0.68 or 68%**

**Modified Collector:**

The technical specifications of the modified collector were referred from the existing collector and made the appropriate modifications according to the work.

| Parameter | Value | Unit |
|---|---|---|
| Length | 1.2 | m |
| Breadth | 2.475 | m |
| Height | 0.086 | m |
| Gross area | 2.982 | m$^2$ |
| Aperture area | 2.783 | m$^2$ |
| Absorber area | 2.870 | m$^2$ |
| Thickness of glazing | 4 | mm |
| Glazing-absorber spacing | 25 | mm |
| Tube inner diameter | 60 | mm |
| Tube outer diameter | 70 | mm |
| Header diameter | 28.6 | mm |
| Absorber thickness | 0.5 | mm |
| Plate emissivity | 0.95 | |
| Insulation side thickness | 25 | mm |
| Insulation back thickness | 25 | mm |
| Thermal conductivity | 0.018 | W/ m-K |
| Glass emissivity | 0.88 | |

| | | |
|---|---|---|
| Air flow rate | 0.059 | Kg/s |
| Ambient temperature | 20.3 | $^0$C |
| Inlet fluid temperature | 22.8 | °C |
| Wind velocity | 3.2 | m/s |
| Rate of insolation | 808 | W/ m$^2$ |

**Table -5:** Technical Data of Modified Collector

$$C = 520(1 - 0.000051 * \beta^2) = 466.29$$

$$h_w = 5.7 + 3.8v_w = 17.86$$

$$f = (1 + 0.089h_w - 0.1166h_w\varepsilon_P) * (1 + 0.07866N) = 2.119$$

$$e = 0.430\left(1 - \frac{100}{T_{pm}}\right) = 0.293$$

$$U_t = 3.588$$

$$U_b = \frac{k_i}{L} = 0.72$$

$$U_L = U_t + U_b = 4.3 \text{ W/ m2K}$$

$$m = \sqrt{\frac{u_L}{k\delta}} = 7.846$$

$$F = \frac{tanh[m * (W - D) / 2]}{m * (W - D) / 2} = 0.973$$

$$F' = \frac{\left({}^1/_{U_L}\right)}{\left[\frac{1}{U_L[D + (w - D) * F]} + \frac{1}{C_b} + \frac{1}{\pi D_i h_{fi}}\right] w} = 0.980$$

$$F_R = \frac{\dot{m} * C_p}{A_C U_L}\left[1 - e\left(-\frac{A_C * U_L * F'}{\dot{m} * C_p}\right)\right] = 0.88$$

$$Q_u = A_C * F_R[S - U_L(T_i - T_a)] = 1815.25\ W$$

$$\eta = \frac{Q_u}{A_C * I_t}$$

On solving this equation

**η = 0.75 or 75%**

### 4.1 Model of the Collector

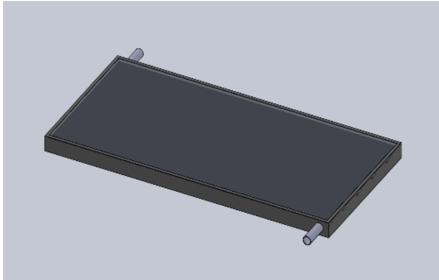

**Fig -2**: Isometric view of the Collector

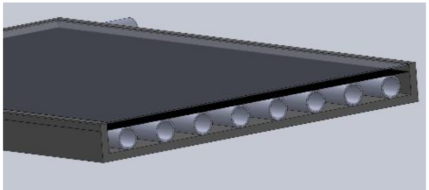

**Fig -3**: Cut section view of the Collector

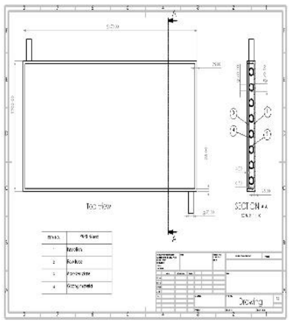

**Fig -4**: 2D Drawing of the Collector

## 5. RESULTS AND DISCUSSIONS

By bringing modifications in the absorber plate and insulation material of the existing collector, the efficiency of the Flat Plate Collector was increased by 7% and the cost comparison for insulation material is listed below

Source: Indiamart (online trading platform)


**Fig -5**: 2D Cost comparison between PUF and Fiber glass

From this comparison it is clear that the usage of Poly Urethane Foam in the Flat Plate Collector reduces the cost of the solar dryer.

## 6. CONCLUSIONS

The solar dryer performance is mainly based on the flat plate collector. The collector performance is influenced by the material properties and design.

1. The absorber plate material is changed from Aluminium to Magnesium alloy and the insulation material is changed from fiber glass to Poly Urethane Foam which reduces the heat loss and contributes in improving the efficiency of the collector.

2. The efficiency of the modified collector with the existing collector is increased by 7% as per the calculations.

3. The useful heat gain of the modified collector is approximately 1.3 times more than the existing collector.

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