Performance Analysis of Triangular Air Heating System Using Solar Energy

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Abstract: *Among all available nonconventional source of energy, solar energy is the most reliable one. It can be utilized by various compatible solar thermal systems. The triangular solar air heater is one such system which can be used for heating of air. The triangular air heater is an innovative design which can absorb the irradiance and convert it into thermal energy at the absorbing surface and transfer this energy to air flowing through the triangular passage. The solar air heater is found in several solar applications for space heating, textile industry, timber seasoning, and agriculture drying. The main element of the triangular air heater such as triangular duct, glazing, blower, insulation, thermocouple and absorber tray. In this study, an experimental investigation was conducted for a triangular solar air heater for space heating purpose. This paper presents the design and modeling of the heat transfer of a triangular air heating system and evaluates the thermal performance of the system. Besides this, some benefits by using the triangular air heater have been discussed.*

Keywords: Solar, energy, Thermal Performance, Triangular System

1.1 Introduction

Energy plays a part in social development and economic, The world population growing so obviously this requirement of the energy should also be increased to fulfill the requirement of transportation and industrialization. The continuous use of petroleum fuel product. It is energy degradation and pollution of the atmosphere is increased. It is a problem of the human and environment also. To problem secondary source of requirements for the future to complete the demand of energy. problem but solar energy is the best way for this purpose. towards the continuously increasing the demand for energy, Which is available free .universal and a very important source of energy, Thee solar energy provides noiseless energy production. to convert into thermal energy with the help of a different type of devices. Solar air heaters are used for and industrial applications. Some of used a solar energy like space heating, textile industry, re-generating dehumidification purpose, timber seasoning, cooking and marine product etc[1].

The energy provides two types, It may be and non-renewable energy resources. the form of energy, the sun is a very powerful source and it is a one of energy source for the future. received from the sun by the earth is approximate 3500 total energy. [2]

In fact of these restrictions, solar the source of energy resources. The total world received the average intensity of solar about 2200 kWh/m2 but used only 2000 kWh/m2 [3].

The main problem of the triangular solar air heater use is low overall thermal efficiency due to low convective heat transfer coefficient between heat absorbing surface and flowing air. The heat transfer between the heat absorbing surface plate i.e. heat transfer surface of triangular solar air heater and flowing air can be obtained by either increasing the heat transfer surface using extended and roughened surfaces without increases heat transfer coefficient and on the other hand by increasing heat transfer coefficient using the tabulators in the form of artificial surface which is modification on absorbing surface plate. [4]

It is complete from the comprehensive review on the nature of fluid flow and heat transfer rate in triangular solar air heater that gives the thermo-hydraulic performance of the triangular heater and it can be improved by rounding of corners or modify the design and shape of the triangular heater and roughness of the absorbing surface etc. [5].

Few Studies [6], the free convective heat transfer in an inclined rectangular obstacle with low width to height ratio and the experiment is carried out by both type experimental and analysis of computational fluid dynamics (CFD). They also conducted an experiment of both cavity angle inclination and width to height ratio and increase the rate of natural convection air flow or increase the heat transfer rate. They are used different width to height ratio of 1 to 8 of between two intervals and conducted the experiment at inclination 150 to 900 of the angle range. [6]

For a better understanding of the triangular solar heater, studies have been carried out in Past [7] using a device to convert solar radiation into the heating application. In this paper, two different parameters have been considered and their values (P/e) ranges from 5 to 13 and 0.013 to 0.05 with Reynolds number is varies in between 3900 to 17900.

Few studies [8], four different triangular ducts of apex angle is varied from 300,600,900 and 1100 and the roughness height is considered 0.016 to 0.038 with Reynolds Number varies 2000 to 16000.

Few studies [9], 3 D simulation has been carried out using the turbulence model. Here the tabulators used in v down shape with an angle range from 300 to 900, for different values of Reynolds number in between ranging from 6000 to 18000.

Few studies[10], The numerical investigation Solar air heater, tabulators used in conical form (P/e) varies in the range start from 6 to 12 and with respect to height varies 0.020 to 0.044 with a Reynolds Number varies from 4000 to 16000.

1.2 Triangular solar air heater Type

Triangular solar air heater absorbs the solar radiation energy and transfers this energy into heat with the help of air which can be used here as a flowing fluid inside the triangular heater system. This energy transfer to the sun and the air from the natural increase the temperature of the air at a certain level.

The merits of this solar technology is a very simple process. It is an entirely effective technology for the summer session in the houses. It does not produce any harmful effect on the atmosphere. For the use of this technology indoor and outdoor environment of the house or building is changed at a good level.

The present applications of triangular solar air heater on different mode basis. These are three types such as passive heaters, active and hybrid heaters.

2.1 Detail of experimental Setup:

The schematic and sectional pictorial view of the equilateral triangular duct is shown in Fig. above. The duct is fabricated from the aluminum of same cross-sections. The length of the triangular test section is 1 m. The input side of the entrance and exit of the output side both length are kept same and the lengths are 400 mm. Therefore, the flow of air inside the triangular solar heater can be assumed as a fully developed and turbulent flow. Inlet and outlet length are required in order to minimize the end effects in the triangular test section. The sun produces a heat flux of 1000 W/m2. The atmospheric air is sucked by centrifugal pump blower driven by 1.5 kW electric motor, one phase of 230 VAC supply and it produces maximum rotation of 2500 rpm. For flow control of the air through the system, both sides of the solar heater two valves are provided, one on the outlet side and other on the inlet side of the blower.

The experimental work consists of the fabrication and design of triangular solar heater as shown in pictorial view in figure 1. In the figure shows the two sides of the triangle are absorbing surface and one side is glass cover.
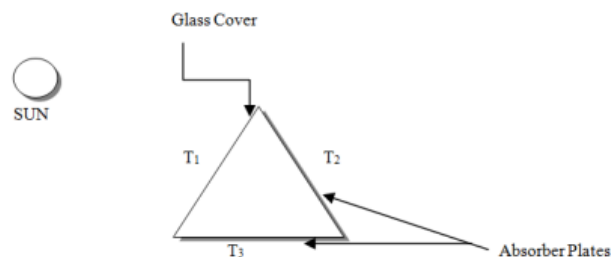
Figure 1: Experimental Setup Pictorial view of Triangular Solar Heater System

2.2 Design of a Triangular solar air heater

There are different types of TSAHs and the main components of these systems are a blackened absorbing surface plate of a thin sheet of Aluminum. An insulation material, an electric air blower centrifugal pump, the duct, and a thin transparent glass sheet which is called glazing.

Therefore a transparent glass is used to allow solar light radiation inside the triangular duct and the other two side aluminum black coated energy absorbing surface which absorb the sufficient solar energy. The insulation material is used for the coating surface, which is to reduce the conduction losses. This insulation material is used in the corner and bottom of the triangular duct. An electric air blower is used for the air flow in forced convection.

- **The Duct**

The triangular ducts are used to supply the atmospheric air and in the output of TSAH, hot or warm air is formed by the method of forced convection. Here the air velocity is very important for the efficiency of the triangular solar heater. Many methods have been employed out in various designs of the triangular ducts to investigate the improvement of efficiency and also increment in the rate of heat transfer.

- **Glass Cover (Glazing)**

A transparent glass plays a very important role to allow the incident solar radiation for entering the device and considerably restrict the infrared energy losses through radiation. A transparent glass should be used for an extensively opaque to long (or infrared) wavelength solar radiation and high transmissivity to the solar spectrum [11].
The transparent material is many types such as glass, acrylics, plastic, fiberglass and other transparent materials. The different type of glass is used for the passive solar

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designer to meet the requirement of the structure of the solar heater. [12].

On the other hand, some solar heater is used the single or double transparent sheet that is used to transfer the energy from the solar radiation to the triangular solar air heater or absorber inside the triangular solar system. The transparent glazing is purposely used to reduce convection losses from the absorber to the atmosphere through the restraint of the stagnant fluid layer in between the absorber and transparent glass plate. [13].

- **Absorber Surface**

Absorber surface plate is the main component of a TSAH and it gives a very important effect on the thermal performance of a triangular solar thermal system. The main part will be with different materials as applied to triangular solar collectors with a reflection to material properties as they affect the triangular solar overall performance of the system.

- **Insulation**

The insulation is the one method to decreases the heat loss and protects the heat leakage from the surface. It is mainly used to achieve a suitable amount of energy usage especially in the case of solar thermal systems. Insulation plays a very important function in the triangular solar heater i.e.to reduce heat energy losses, to reduce the heat loss and heat gain, to maintain the operation of the system and to prevent condensation.

2.3 Instrumentation In TASH

- **Temperature Measurement**

Calibrated copper-constant (T type), thermocouples were used for the temperature measurement of air and the absorber surface. Six Thermocouples were mounted on the absorbing surface plate to measure its mean temperature and location of thermocouples on the absorber surface. One thermocouple was inserted at the inlet section and other at the outlet section which measures the temperature of air to the inlet and outlet.

- **Air flow Measurement**

The air rate of flow through the circular duct was measured by using a measuring instrument which was fabricated and fitted in the 76.2 mm pipe which is connected to the blower and the test section. The drop of pressure inside the triangular test section was measured with the help of two U-tube manometers.

2.4 Performance of a Triangular air heater

Performance of a triangular solar heater calculated by the relationship is given below, the heat transfer rate Q_a to the air, It is measured by an equation,

$$Q_a = mC_p(T_o - T_i)$$

Where T_o and T_i were determined from temperature values from the outlet side and the inlet side of the test section of the triangular duct.

The heat transfer coefficient calculated by using the above equation is then used to determine the Nusselt Number as given below,

$$N_u = \frac{hD_d}{k}$$

Where D_d is the diameter of the inlet side duct.

Thermal performance is the performance of the system. It is necessary to use electrical energy required for pumping the air while calculating the performance of triangular solar air heater. The power from the thermal output of the collector and it is losing always a considerable part of the energy in conversion. Therefore, the power required is converted to equipment solar energy to obtain evaluated the actual performance of the solar collector in terms of the overall thermal efficiency and is given by:

$$\eta_{th} = \frac{q_u}{I} = \frac{Q_u}{IA_p}$$

The experiment conducting for a smooth triangular duct. The Nusselt number and Reynolds Number calculated from the experimental data for smooth triangular duct have been compared with the concluded value of the Nusselt number and Reynolds Number respectively obtained from the Dittus-Boelter equation is given below:

$$N_u = 0.24 R_e^{0.8} P_r^{0.4}$$
$$R_e = \frac{\rho V D_d}{\mu}$$
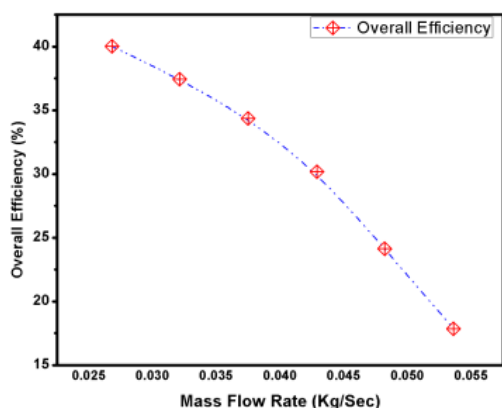
Table 1: Triangular solar Parameter

S.No.	Parameter	Values
1	Width of one face	0.6 m.
2	Length	1.0 m.
3	I	1000 w/m^2
4	Velocity, V	5 to 10 m/sec

3.1 Result and Discussion

In this work the experimentally predict the result of the smooth triangular solar heater by using the above-mentioned equations and experimental data.

#### a.) Effect of mass flow rate and overall efficiency

Figure 2 shows the variation of the overall efficiency and mass flow rate of the triangular heater. It has been found that If mass flow rate value increases then the efficiency of the Triangular solar heater is deceased.

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Figure 2: Variation of Overall Efficiency and mass flow rate

b.)Effect of mass flow rate and outlet Temperature

Figure 3 shows the variation of the mass flow rate and the Outlet temperature of the triangular heater. It has been found that If mass flow rate Increases then the Outlet temperature of the Triangular solar heater is deceased.
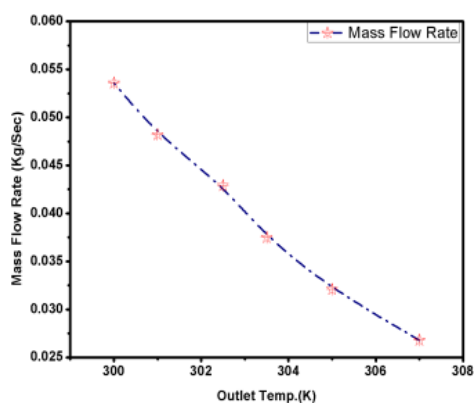
Figure 3: Variation of mass flow rate and outlet temperature

3.2 Conclusion

In this work, experiments were carried out to study the effect of Triangular solar air heater with the variation of different parameters like Outlet Temperature, mass flow rate and Overall Efficiency. Based on the results following conclusions are given below:

➢ Mass flow rate Increases then the efficiency of the Triangular solar heater is decreasing.
➢ Outlet temperature Increases then the Overall Efficiency of the Triangular solar heater is also increased.

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