Feasibility study of a roof top Solar room heater

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Abstract:

The present work describes a low cost solar space heater. The device is the replacement of the concrete cantilevers used above the windows in houses facing the south direction. An experiment was conducting by making a suitable device for use for the purpose. It has been observed that the device can be used to heat the space for the south facing room windows directly and for the other directions by circulating the air through the device kept at the roof top making an angle of about 38 degree with the roof top.

Key words: duct, draught, heat transfer, rooftop, solar collector, solar chimney, ventilation.

1. Introduction

With the exponential growth of energy demand, efforts are being made all over the world to conserve energy. As non-renewable sources are consumed, the mankind must turn its attention to longer-term, permanent type of energy sources. Solar energy one of the abundant source promise of becoming a dependable energy because it is environmentally clean source of energy and available free of cost. Solar energy has been identified as one of the promising alternative energy source for the future.

On average the extraterrestrial irradiance is 1367 W/m^2, which is also known as Solar Constant. Total power from the sun intercepted by the earth is approximately 1.8 X 10^{11} MW, which is many thousand of times larger than the present consumption rate on earth. In addition to its size, solar energy can be used in a decentralized manner, reducing the cost of transmission and distribution of power.

There are two distinct methods for converting solar energy to work: thermodynamic conversion and direct conversion. In thermodynamic conversion, solar collectors first convert solar energy to heat. This heat is then partially converted to work in accordance with second law of thermodynamics. There is a well defined theoretical upper limit to the efficiency of any process that converts heat to work. Efficiencies of direct conversion processes are not limited by second law of thermodynamics, but they have their own practical limitations.

There are some problems associated with the use of solar energy. The main problem is that it is a dilute source of energy. Even in the hottest regions on earth, the solar radiation flux available rarely exceeds 1 KW/m^2 and total radiation over a day is best about 7 KW/m^2. These are low values from the point of view of technological utilization. Consequently large collecting areas are required in many applications and these results in excessive costs.

The major technical obstacle for solar thermal application is the intermittent nature of the source, both on daily and short time scale. The intermittent nature leads to a storage requirement, generally not present in non solar systems. The extra cost and complexity of storage is a negative point to solar systems. Solar systems also require a good solar climate for efficient operation. This is favorable in case of India: land for solar collector is abundant and where energy demand is high, the solar flux is also high and direct beam component maximum. Finally, solar system must meet the criteria of economic competitiveness in order to be widely accepted. On the other hand, solar energy has an advantageous position compared with scarce fossil fuels. Most of the energy demands in India (and elsewhere also) can be met by simple solar systems. There are very few new components like collectors, controls which are complex. By proper application of solar techniques, an excellent thermodynamic match between the solar energy resources and many end-uses can be achieved.

2. Solar Chimney

Like natural draught chimney, solar chimney is a vertical tubular structure of transparent material, steel, reinforced concrete or reinforced plastic built for the purpose of enclosing a column of hot air heated by the solar collector. So, solar chimney has one side (facing the sun) made of transparent material like glass to absorb solar energy. The draught produced by the chimney is due to the density difference between the column of hot air inside the chimney and the cold air outside. The efficiency of the chimney is directly proportional to the height of the chimney.There are mainly two applications of solar chimneys[1,2].

2.1 Ventilation in buildings

Ventilation is a widely used technique for removal of indoor contaminants as a measure of pollutant source control. Natural ventilation is usually used in regions with mild climates and in spaces where some variation in indoor climate is tolerable. A solar chimney is a good configuration to implement natural ventilation in buildings where solar energy is available. It is similar to a conventional chimney except that the south wall is replaced by glazing, which enables solar energy collection. The flow caused is directly influenced by the pressure distribution on the building envelope and the characteristics of the different openings. The pressure distribution is the driving force for ventilation while the characteristics of each opening, among other things, determine the flow resistance[3,4].

2.2 Solar Chimney Turbine

Solar Chimney Turbine utilizes the airflow inside the chimney to run a turbine. The turbine being coupled to a generator produces electric power. Turbines are always placed at the base of the chimney. Using turbines, mechanical output in the form of rotational energy can be derived from the air current in the chimney. Turbines in a solar chimney do not work with staged velocity as a free running wind energy converter, but as a cased pressure-staged wind turbo generator, in which similar to a hydroelectric power station, static pressure is converted to rotational energy using a cased turbine.

There are large numbers of applications of solar energy, and even larger is the number of systems and their components achieving the energy conversion goal. To maximize the efficiency of any complete system, the efficiencies of the components must be maximized/optimized[5,6].

3. Roof Top Solar System

The solar flat plate collector and the solar chimney concept have been integrated in the present study. An open flat plate solar thermal collector has been fitted with a solar chimney to enhance the speed of the outgoing hot air through the collector the temperature of the air is sufficient to heat the room. Small fan can be installed at the entry to the room for smooth entry of the hot air.

4. Experimental setup

An experimental setup was fabricated for the purpose of study the heating power of an about 1.5 m^2 flat plate collector. The dimensional sizes for collector are 1700 mm X 850 mm X 115mm. The inclination of collector on the stand iskept at 18^0, 28^0, 38^0 and 48^0 by suitably lifting the base of the stand. The collector-chimney assembly is supported by a steel structure and can be tilted at different angles. The absorber plate is 0.6 mm thick GI sheet painted black. The bottom of the collector is insulated using 5 cm thick glass wool. Thermal conductivity of glass wool is 0.04 W/m K. Two sidewalls are also insulated by 6cm thick glass wool, with 12mm wooden backing. The top cover, the collector is 5mm thick window glass this is in four pieces made airtight using adhesive and transparent cello tape. The properties of Glass and parameters of the setup are as follows.

Thermal Conductivity	0.937 W/m K
Density (at 20º C)	2.44 g/cm^3
Thermal Expansion	8.6 x 10^{-6}/°C
Collector Area	1.445 m^2
Chimney Exit Area	0.00866 m^2
Hot air flow rate	0.01014 * V
Enthalpy change of air	$m C_p \Delta T$

Where,

ΔT Temperature difference

V Velocity of air in m/s is

The air temperature inside the channel was recorded by eleven k-type thermocouples. Six arranged at a spacing of 25cm along the centre line of the absorber plate along the airflow direction and five arranged in the chimney at spacing of 20cm. The distance from the channel inlet to these temperature measurement sections were 450, 700, 950, 1200, 1450, 1700, 1900, 2100, 2300, 2500 and 2700 mm, respectively. Atmospheric temperature noted made by k-type thermocouple, which is portable with the display unit, this thermocouple is named thermocouple number 1.

The velocity of air at outlet of the channel is measured by a vane type anemometer. For pressure measurement in the chimney section static pressure ports were also provided and connected to water tube manometer. As there were not any significant pressure changes in the system, so these ports were closed in the early experimentation stage.

Figure-1 Photo of the Experimental Setup

5. Results And Discussions

Experiments were carried out at different inclination angles of the collector and at different times of the day. Various angles taken were 18^0, 28^0, 38^0, 48^0 the collector. Measurements were made from 9:00 to 17:00h, at an interval of one hour. The measured and calculated values of the parameters are shown in the following figures.

The most important is to study the effect of collector inclination on the performance of the system. Mass flow rate is directly related with the power output of a solar chimney power plant, hence has been taken as the optimization criteria. Second reason to choose mass flow rate as the controlling factor is due to the size and scale of the system. From a small chimney height and 1.4 m^2 collector area it is not possible to run a turbine and hence take turbine output as the criteria. Solar radiation angle also affects the mass flow rate with inclination. For buoyant flow higher inclination angle causes higher stack pressure for driving natural ventilation. However, under otherwise identical conditions, the convective heat transfer coefficient inside the air channel decreases with the increase of inclination angle, which results in the reduction of natural ventilation airflow rate.

Figure 5 shows that, initially, the natural ventilation air-flow rate enhances with the increase of inclination angle, and then it reaches the peak value at about 38^0 inclination angle. Finally, it begins to fall off, which indicates that the decrease of convection heat transfer overwhelms the increase of stack pressure after the inclination angle is beyond 38^0, the phenomena being also governed by solar angles.

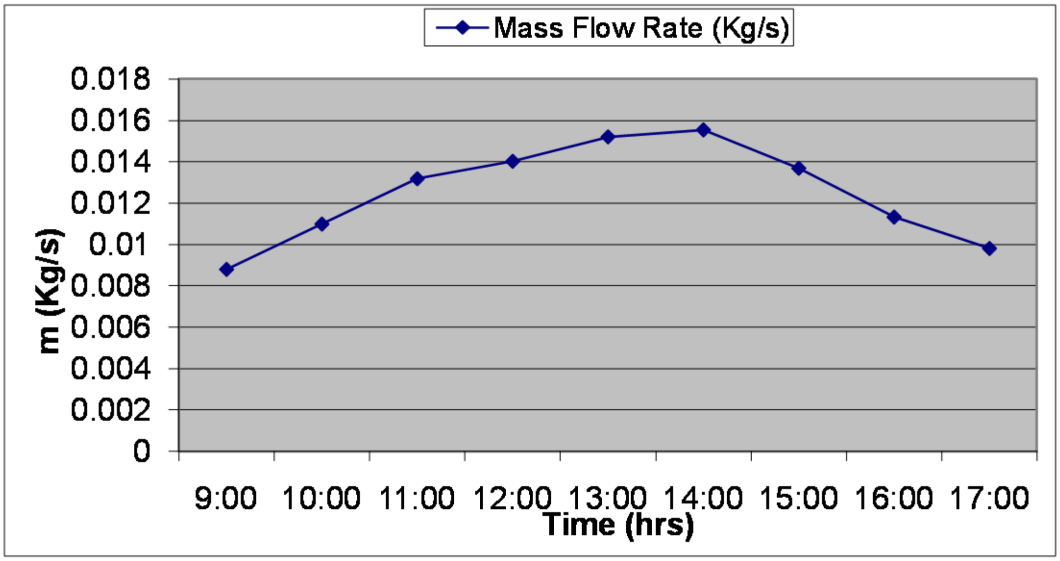

Figure-2. Mass Flow Rate v/s Time at 38^0 inclination

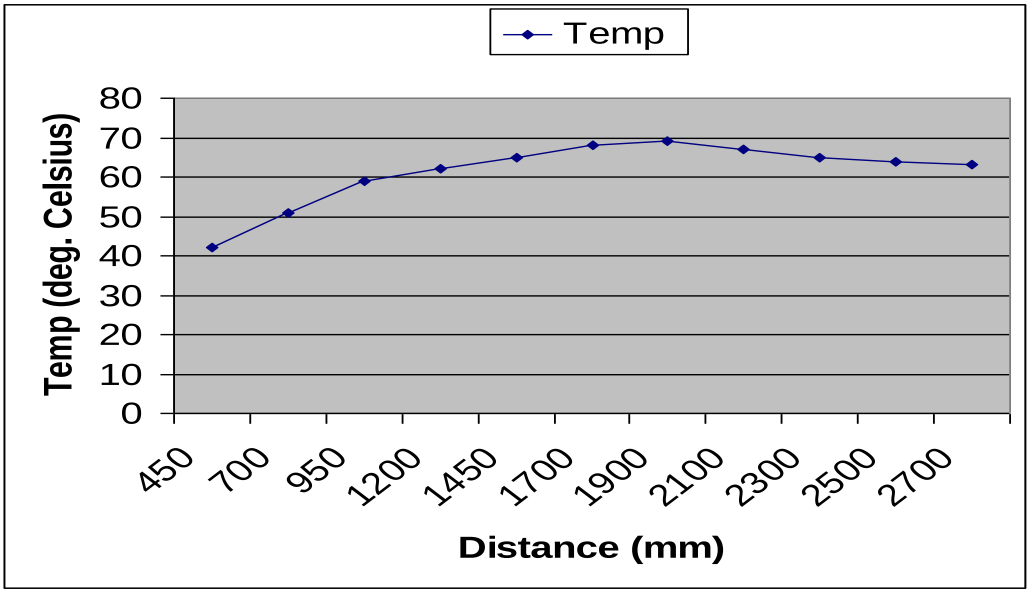

Figure-3 Temperature variation at Collector exit with Distance

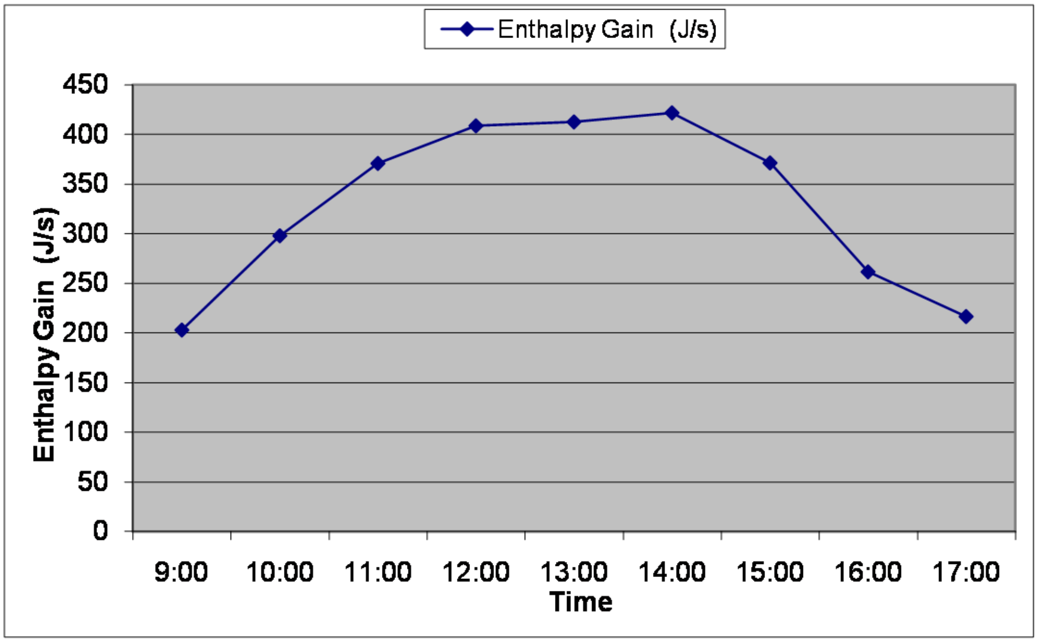

Figure 4. Enthalpy Gain vs. Time at 38^0 inclination

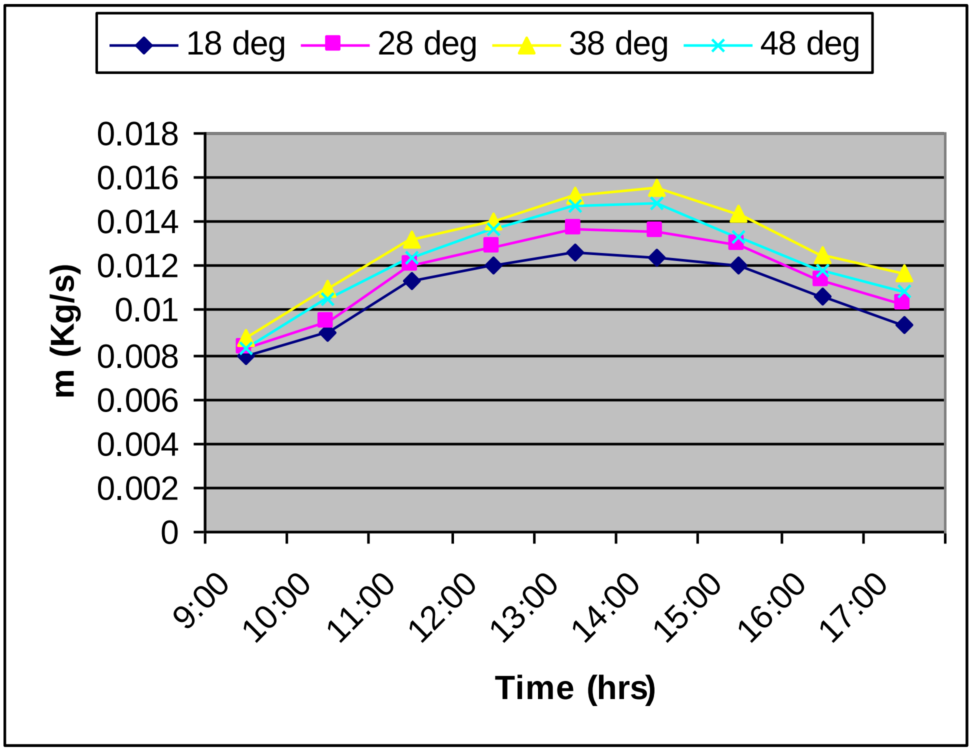

Figure-5 Variation of Mass Flow Rate with Collector Inclination and time

The inclined collector Solar Chimney has the potential to increase the overall performance of Solar Chimney Power Plant. The inclination of collector greatly affects the mass flow through the chimney, which was taken as the optimization parameter. Hence collector ingle inclination should be opted for and must be optimized in solar induced flow inside a solar chimney power plant. By Experimentation the optimum collector tilt angle for Chandigarh (May month) has been found to be in the range 35-40^0. The average power comes out to be 300W. It can be enhanced to 1.5 KW by putting double glass collector and increasing area to 2-3 m^2. Hence it is clear that a solar chimney roof collector is feasible

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