International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Solar Induced Ventilation – A Review

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Abstract: ***High air temperatures, high relative humidity and low air velocities are the major characteristics of the modern cities and tropical regions leading uncomfortable environmental conditions. To make the environment comfortable and ventilation huge energy is required for the operation of mechanical devices such as air conditioners and other means. One of the alternative sources to provide ventilation using solar energy is solar induced ventilation. The present paper presents the solar induced ventilation, its types and undergoing research work to find its potential applications, technology development and system design. Detailed literature review shows that the solar induced ventilation is useful in providing ventilation and winter heating and summer cooling may be obtained in the residential and commercial places and huge conventional energy can be saved.***

Keywords: Solar Chimney, Ventilation, Thermal Analysis

1. Introduction

Solar energy in the form of sun's energy and light is being used to produce electricity, lighting and heating and cooling of residential, commercial and industrial spaces through appropriate technology. Varieties of solar technologies are available for use as:

- Photovoltaic Systems which can directly produce electricity from sunlight.
- Solar Heating systems utilising solar energy to heat air, water etc.
- Solar Cooling Systems to produce cooling from solar energy
- Solar electricity using solar energy in the form of heat to produce electricity.
- Solar lighting systems to heat and light the buildings.
- Using solar energy to heat and light buildings.
- Solar Process Heating and Cooling to use sun's heat for process heating and cooling.

Chimneys are ducts or channels that are used to exhaust the gases from the spaces to keep them ventilated. They are used to remove smoke and other gases that are produced from the combustion of fuel, domestic or industrial process, fireplace or other processes producing smoke or gases. These gases are removed from the roof of the building. The Chimney's operation is based on the fact that the hot air being less dense rises than the cold air.

In modern cities having dense population of building structures, more commercial and industrial activities and huge human population, environment is found to have higher temperatures and humidity. Tropical regions are also having higher temperature and humidity levels. The passive cooling is difficult to achieve and less effective than the conventional active cooling using air conditioning to solve these problem. The initial cost of the active systems and their operational costs are very high which limit their uses. In Malasiya, passive cooling systems are widely being used with lesser internal thermal comfort as shown in the researches [1] &[2].

2. Fluid Flow

The motion of fluid is governed by the concepts and principles of fluid mechanics as the Navier-Stokes equations of the fluid dynamics including continuity, momentum and energy equation. Reynolds number, Bernoulli's equation, pressure loss equations etc. in their usual form to represent the fluid flow characteristics.

In the fluid flow due to the density difference buoyancy along with gravity is involved. In case when the air is flowing between a warm and cold region due to the variation in density as the warm air has low density than the cold air, the effect is known as stake effect [3], the pressure difference of the stake effect is given by:

$$\Delta P_{stake} = \Delta \rho g H$$

This driving force causes problems in the solution due to the connection with the energy and momentum equation. A faster solution to the problem is obtained from the Boussinesq Model. This model treats the density term a constant except in the buoyancy term of the momentum equation.

$$\Delta P_{buoyancy} = \rho g H \beta \Delta T$$

3. Solar Chimney

Chimneys are the passages used to remove the hot gases from the roof of the building structures. Solar chimneys are the chimneys which uses solar energy to increase the temperature of the inside air so that the stake effect could be produced to make the gas flow through it. This will cause the improvement in the natural ventilation in the building spaces. Solar chimney in bigger sizes as in Manzanares, Spain was 195m high producing a maximum power output of 50 KW.

Solar chimney type depends upon the latitude of the place, type of solar collector, building height etc. The chimney should be so placed to get the solar radiations to enter the chimney to produce the stake effect.

For the experimental studies a solar chimney was installed in the EPT-lab of the Norwegian University of Science and Technology [5] as shown in figure (1)

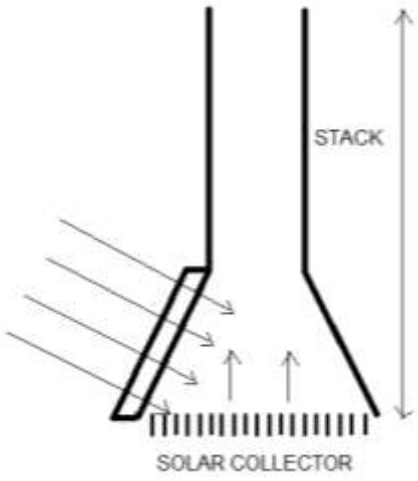

Figure 1: Solar Chimney

In the chimney the solar radiations passes through the glazing wall at the bottom left part of the chimney facing sun and fall on to the solar heat collector at the bottom of the chimney. In the EPT-Lab, the solar collector is having 33 thin parallel metallic fins which receives the solar radiations and increase the temperature of the surfaces. A convective plume is generated between the each fin. The distance between each fin is very small of 4cm so that the plumes touch each other at a height of 9.92 cm. A homogeneous temperature is obtained above this height.

There are several other types of chimneys designed with different designs of glazing walls and solar radiation collector positions.

4. Literature Review

Many studies have been made in the past on the Solar Chimney concept. The research in this concept is continuously going on the building of more designs, their performance analysis which will affect the natural ventilation significantly in the residential or office spaces with the use of solar energy. The literature reviewed fall under the broad categories of experimental, analytical and numerical modeling studies. A general overview of previous studies has been presented in this paper.

Ventilation induced studies at field were conducted [5] for the configurations of a small-scale single-room house were in Thailand. In continuation to this study a study on the performance of a solar chimney system in an air-conditioned small-scale house was conducted [6]. In a 1:12 small-scale model of a building test were performed. The setup includes the roof which functions as a solar chimney [7]. A similar study was performed in a 31m3 volume house in which a metallic solar wall was placed on the south facing side of the house [8].

Literature on many laboratory experiments on small- scale models is also available. Researchers have performed experiments to show the temperature distribution of the air and the surfaces of the walls. The air velocity profiles and the air flow rates were also estimated and analyzed by parametric analysis [9]. A solar chimney of 2m high and a part of a 12m3 room was studied under laboratory conditions [10] and [11] studied a 4.5m high model of solar chimney in Spain under real meteorological conditions.

The performance of a solar chimney under varying ambient conditions is predicted by the thermal resistance network approach adopted to set up the steady-state heat transfer equations in the analytical model[12]. A similar approach to calculate the Air Change per Hour (ACH) induced in a room by a small-sized solar chimney integrated to a normal window was adopted in the study[13]

Numerical investigations are gaining more attraction among the researchers in performing study on the application of solar chimneys. Numerical study on solar heated cavities in multi-storey buildings was performed [14]. Parametric study findings were presented for the use of design and application of the solar chimney.

A experimental study on a model of solar chimney connected with a room presents the effect of the solar chimney in establishing a natural ventilation. [15]. This study clearly shows the temperature variations and the performance variation of the ventilation during the day time variations.

Another CFD study presents the numerical results of flow features in a typical room fitted with a solar chimney. The results are presented in the form of contours and plots. These results show that the room is ventilated and provide the approach of numerical solution in simulating room environment with CFD [16].

5. Conclusion

Solar energy utilization in ventilation of residential and commercial spaces need the solar chimney to be used in passive systems. The research in the design and analysis of solar chimney is going on to find the solutions and impact of building spaces with solar chimney for varied design and applications.

This paper presents literature on the ventilation of buildings with the use of solar energy and solar chimney working principles and fluid flow. The literature review on experimental, numerical and analytical studies is also presented. The review of literature available shows that the solution to the ventilation problem with the use of solar chimney is experimentally and numerically obtained. The numerical studies are very limited in availability but they are giving acceptable results at lesser time and cost. More research work is very much required for the solution of solar chimney problem solution for evaluation of its impact in a building for effective ventilation.

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