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A Review of Detailed Performance Analysis of different Ventilation Systems, Case Studies and Approaches for Modifying Existing Ventilators

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Abstract—*Rooftop turbine ventilation system is being thought as an apt replacement of air conditioning unit which is basically allied with global warming, fossil fuel exhaustion etc. Now a day, roof top ventilators are extensively used in industrial, institutional, commercial and residential areas. Most of the natural roof top ventilators are not consuming convention electric supply. From this aspect, it is an energy saving system. This type of system can be broadly classified as active ventilation system and passive ventilation system. Theory behind the said systems are also been discussed in this paper. In this paper, different processes of ventilation are discussed along with several case studies. Experimental studies are also been focused with some climatic and functional constraints. A few approaches for amendment of existing roof top ventilation systems like introducing high bride turbine ventilation (HTV) or by varying blade size, shape, diameter of turbine, ventilator throat size are revealed in detail. Software like FUENT CFD simulation software, Reynold's Stress model (RSM), PHOENIC CFD software are mentioned in brief in this work.*

Keywords*: Roof top turbine ventilator, active ventilation, passive ventilation, HTV, FUENT CFD, RSM, PHOENIC CFD.*

1. INTRODUCTION

The turbine ventilator is an emerging alternative to conventional air-conditioning system due to its cheapness, reduced energy consumption and easier installation features. Many studies and experiments have found its efficacy in improving indoor air quality, providing better thermal comfort etc. It has already found its place in many industrial, institutional and residential sectors replacing air conditioners. The rooftop wind-driven turbine ventilator acts in both active and passive ways. When wind blows, the blade of the ventilator rotate producing centrifugal force that sucks out the hot stale air and cools down the interior space. This is the active ventilation strategy. On the other hand, the turbine ventilator also works passively in the absence of wind. This occurs due to gap between vertical blades that creates a stack effect and extract hot air from the building provided a temperature differential between inside and outside.

The turbine ventilator was studied by Savonius (1932) and Black (1932) but was not considered for ages. With the start of the millennia, many took interest in the device when the threatening scenario of depleting fossil fuel and incrementing energy consumption became clear and unavoidable. Till now, it has been studied under different climates and in different places across the globe and the outcome has been so far positive. But at low- wind velocity, the device lacked in good performance as the airflow got blocked in connecting ducts of the turbine. However, researchers claim of possible improvement in the device as they keep trying hard in modifying its design and adding new features to it. This paper discusses on aspects like the application of turbine ventilator, its efficiency under different climates, effect of configuration variables and different methods and procedures undertaken for its study.

This paper follows as: II. Different ventilation process from ancient age III. Experimental Analysis of Turbine Ventilator IV. Various types of ventilation systems V. Brief Discussion on a Few Software VI. Future Possibilities of Ventilation System . VII. Conclusion.

2. DIFFERENT VENTILATION PROCESS FROM ANCIENT AGE

- In Minoan period wind mills and building height were used as a ventilation process [1].
- In 4000-5000BC chimneys were used by rural villagers and outlet openings were used by Anasazi Pueblo Kiva to reduce temperature.
- In Roman age holes at walls were used as a ventilation process.
- In Industrial age (19th century) in England open-fires and exhaust were used and in America Kin-vent ventilation processes were used.

3. EXPERIMENTAL ANALYSIS OF TURBINE VENTILATOR

The image of very commonly used roof top ventilator has been shown in fig. 1 [7].

Fig. 1: Roof top ventilator.

To understand and study the functioning of turbine ventilator, experiments were conducted on the device under different climates and situations and the results were published in different reports. In recent years, turbine ventilators have caught much attention and many undertook the task to study its performance. Its performance was determined in terms of ventilation rate (1/s, m^3/s, ACH and CMH), air velocity (m/s) and reduction in air temperature (^{0}C) [2].

Dale and Ackerman (1993) studied the behaviour of 12'' diameter attic turbine ventilators in temperate and windy condition of US. The study revealed the turbine ventilator reduced the attic temperature only by 0.56^{0}C and increased ventilation rates by 15% from 5.3ACH to 6.1ACH. The study disclosed very important information that wind direction also plays an important role in determining the ventilation rates of turbine ventilator [2].

Lai (2003) studied the performance of turbine ventilator under windy and tropical condition of Taiwan and concluded that the device works effectively in improving the indoor thermal condition. But under zero to low wind velocity condition, the device showed negative results, as the turbine blocked the airflow in the connecting pipeline [6]. Porfirio (2004) added a new feature in the device. He induced electric fan and observed a drastic change in the ventilation rate of the device under the temperate climate of Brazil. The ventilation rate jumped from 9ACH to 11ACH.

Kuo and Lai (2005) combined the conventional turbine ventilator with extractor fan and observed the improvement in overall indoor air quality under the tropical climate of Taiwan. The study also revealed that the combined system produced a negative pressure that reduced leakage of odours and moisture to the rest of the building [5].

The study of turbine ventilator was also performed in temperate climate of South Africa by Cox et al. (2011) in four primary care clinic rooms. The study revealed positive results in three rooms and met the standard ventilation level for each patient as recommended by the World Health Organization (WHO). While the other (fourth) room showed lower ventilation rate as the wind velocity was feeble and the turbine ventilator installed was smaller in size.

4. VARIOUS TYPES OF VENTILATION SYSTEMS

a) Natural stack ventilation

In natural stack ventilation system, indoor temperature is reduced by open air. This system can be enhanced by using atrium, stack devices and ventilation shafts shown in fig. -2 [1].

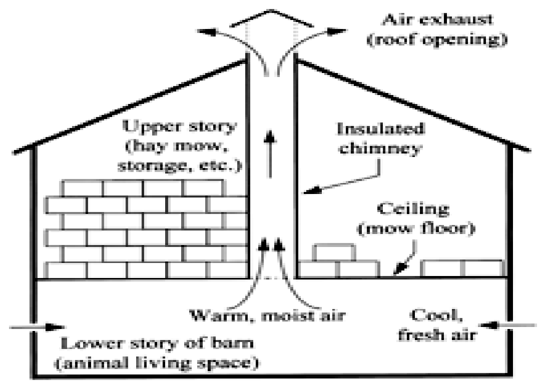

Fig. 2: Natural stack ventilation.

This system is divided in two types-

I) *Solar stack ventilation*: In this system chimney-air heated by sun makes temperature difference and this create stack ventilation shown in fig. -3.

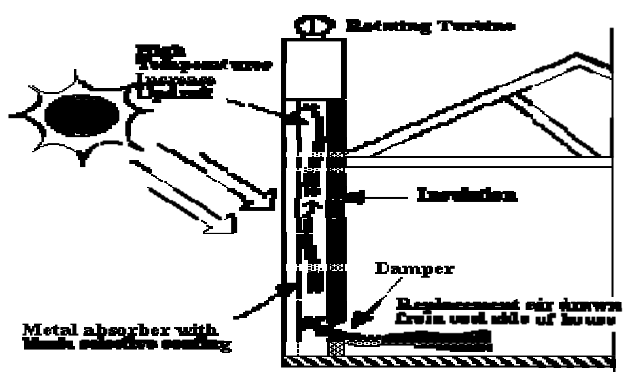

Fig. 3: Solar stack ventilation.

II) *Wind stack ventilation*: In this system wind creates negative pressure above the roof and then stack ventilation happens, shown in fig. -4 [2], [5].

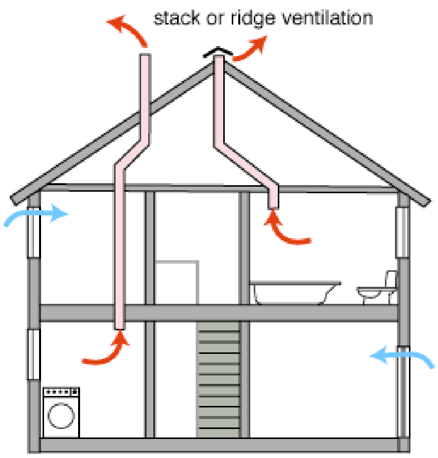

Fig. 4; Wind stack ventilation.

b) Fan control ventilation

In this type of ventilation system we use house fan and attic extractor fan, shown in fig. -5.

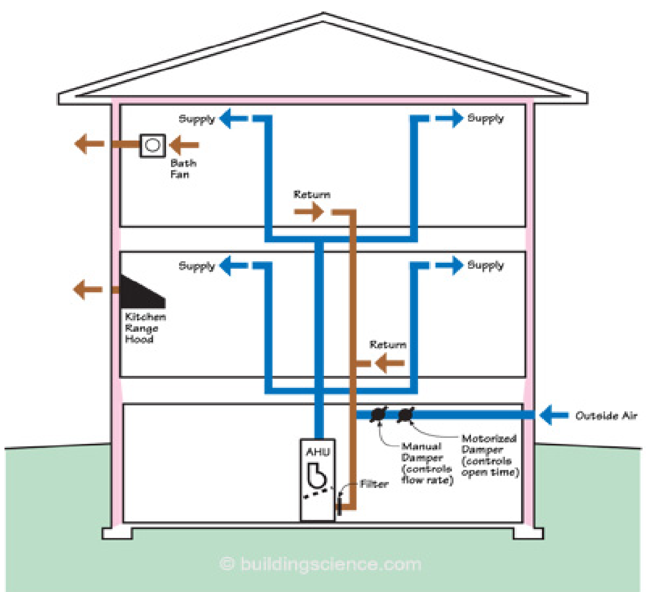

Fig. 5: Fan control ventilation.

5. BRIEF DISCUSSION ON A FEW SOFTWARE

To assess or analyse the working of turbine ventilator, many softwares and research tools are employed. Computational Fluid Dynamics (CFD), a software, use simulation to determine the performance of turbine ventilator. CFD is a numerical approach for wind-tunnel study, laboratory study etc.

Another software, FLUENT CFD use simulation to assess the airflow behaviour inside and outside the turbine ventilator. It is also used to investigate the aerodynamic forces acting on the ventilator during its rotation.

PHOENIC CFD is used to analyse the airflow behaviour and determine temperature condition. Using PHOENIC CFD software, Sheih et al. (2010) determined that the ventilation rate of Hybrid Turbine Ventilator (HTV) is 4 times that of conventional one.

Besides, another software, known as Reynolds Stress Model have been widely used to design and remodel turbine ventilator.

ASHRAE software provides a user-friendly interface for calculating thermal comfort parameters and making thermal comfort predictions using several existing thermal comfort models

6. FUTURE POSSIBILITIES OF VENTILATION SYSTEM

Natural cross ventilation which utilizes wind force to function is not the preferred choice for builders and architects in warmer climate and denser built environment. Hence, stack ventilation system is employed which induces upward movement of air due to temperature buoyancy. As a consequence, advanced ventilation system like solar induced ventilation, wind-stack driven ventilation and fan induced stack ventilation are coming into existence. Developers and researchers are trying to develop a more convenient, reliable and efficient ventilation system that even works at low temperature difference and low wind speed. Stack ventilation system have been found to be providing better cooling effect and effective airflow through the ducts. Hence, it is considered to be one of the preferable choices of ventilation system in the near future. According to Ismail and Abdul Rahman, HTV possessing inner duct and free upper outlet area facilitates better airflow and provides better thermal comfort [3], [4]. By modifying the available solar-powered turbine ventilator by fixing two lightweight solar panels at the top surface of the turbine, enhancement in working of the device could be achieved. All these studies are being taken into account to redesign ventilation system for more improved results

7. CONCLUSION

From this review, it is concluded that the stack ventilation technique is the most efficient for ventilation purpose; especially in odd climate. HTV is an modified ventilation method to increase the ventilation rate. In upcoming days, it is expected that the stack ventilation will not only be an efficient technique for controlling the thermal condition of a building but also to enhance the outlook of the construction of the building also.

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