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Performance Charecteristics of Turbo Ventilator: A Review

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Abstract— **Turbo ventilator is an alternative to motor driven ventilating systems. The rooftop turbo ventilator is now widely accepted for industrial ventilation as well becomes important ventilation feature which is used for ventilation of commercial, residential and many institutional buildings. It works effectively at very low wind speeds hence always functional. Many researchers found that performance of turbo ventilator depends on its various operating parameters and environmental conditions. Therefore, study of turbo ventilators in details has become the focus area of research. In this paper detailed study about the current improvements and future scope of the turbo ventilator is done. The results of analytical and the experimental works are analyzed by considering its performance for the various applications.**

Keywords- **Ventilation, Turboventilator, Envioronment, Performance**

I. INTRODUCTION

Proper ventilation is must for any industry to provide safe, efficient, effective working and healthy environment to the human. Ventilation is a process of removing stale hot air and providing fresh cool air. It balances temperature, supplements oxygen and removes harmful products such as moisture, dust, smoke, heat, flying bacteria, carbon dioxide etc. Turbo ventilator operates on natural wind energy hence it is most cost effective in respect of operational and maintenance. These systems are environmental friendly, as no power is consumed in its operation.

The turbo ventilator is always better option to ventilate the buildings which doesn't require any external power. Originally the patent on the concept of turbo ventilator was taken by Meadows. [1] It was considered as a one of the type of the roof ventilator. The same concept developed by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). [1]

Commercial production of turbo ventilator was manufactured by Edmonds of Australia in the year 1934. [1] These devices are commercially available in the market since many years; however a few literatures are available on the design and aerodynamics of the unit.

There are two different modes of ventilation techniques. (Ref. Khan et al. [2])

1. Passive Ventilation Technique

This is simplest method of ventilation with different types of roof openings without any moving parts. There are several types of openings commercially available viz., static vent, dormer vent, gable vent, ridge vent, etc. This ventilation takes place due to stack effect. Stack effects are due to temperature differences between the inside and outside of the room. When the inside room temperature is greater than the outside, warm indoor air will rise up and exit through openings. The vacant volume of hot air replaced by cooler and denser air from doors and windows. Figure 1 shows schematic diagram of this technique.

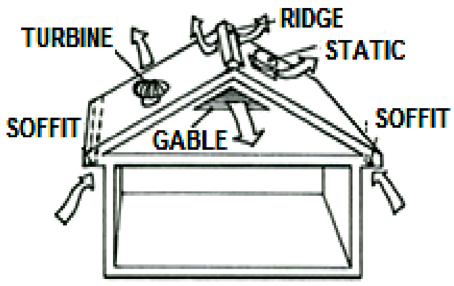

Fig. 1. Passive Ventilation Technique

2. Active Ventilation Technique (Wind Driven)

Active ventilators include fan driven exhaust systems i.e. Turbo ventilators. This system works on natural wind energy. A turbo ventilator consists of number of vertical blades (it may be curved or straight blades) in a spherical array mounted on a frame. At the center, a shaft is supported by upper and lower bearings. A rainproof dome is on top of the frame. When wind blows on the blades the resulting lift and drag forces cause the turbine to rotate. Due to this rotation, produces a negative pressure at the center of the turbine ventilator which extracts hot air. Air enters the turbine axially via the base duct and is then expelled radially. In the absence of wind, a turbo ventilator still remains effective due to stack effects. Figure 2 shows active ventilation technique.

Fig. 2. Active Ventilation Technique

II. REVIEW OF LITERATURE

This literature survey reveals the work done by various scientists on analytical, experimental and CFD (computational Fluid Dynamics) analysis of turbo ventilators and is listed below in chronological order. Some researchers have even analyzed the turbo ventilator with additional extractor fan attached at the bottom of the shaft.

The turbo ventilator performance was discussed in terms of (i) Ventilation rate or mass flow rate and (ii) Rotational speed for different wind speeds and Air temperature.

Alex Ravel [3] used following two wind ventilators for testing.

i) Ventilator A: Edmond's Hurricane H400 Vertical vane ventilators with 400 mm throat diameter.

ii) Ventilator B: IVR's Low line turbo LTV400 Spherical vane ventilators with 400 mm throat diameter.

These tests were carried out at ambient temperature conditions, with zero degree temperature difference between inside and outside air and so obtain the comparative values of flow through the ventilators at wind velocity ranging from 4 to 16 km/hr, the discharge coefficients range obtained is as follows;

Ventilator A --------- $0.43 < C_d < 1.06$

Ventilator B---------- $0.00 < C_d < 0.44$

The discharge coefficient C_d is the ratio of actual flow rate through a turbo ventilator to flow rate through an open circular duct of same throat diameter.

Thus, ventilators A was found to be more effective in air extraction as compared to ventilator B under identical conditions.

The test stand developed for measurement of the flow rate by using a standard nozzle is (AS 2360) as shown in Fig. 3. Frictional losses through nozzle were overcome by an air booster fan.

Dale at el, [4] found that the effect of the diameter on the turbo ventilator in improving ventilation of a room and compared with already fitted with two soffit vents of free vent areas (0.08m²). The study found that decrease in attic temperature by 0.56°C by using the turbo ventilator. 15% increase in ventilation rates from 5.3 ACH (air changes per hour) to 6.1 ACH on average as compared to the existing condition of the test house.

Lai C.M.[5] found that ventilators with larger diameter would induce greater ventilation rates as expected, Tested three different size ventilators of 6, 14 and 20 inches in diameters under wind speeds of between 10 and 30 m/s, but surprisingly the difference between the 14 and 20 in ventilators was 'insignificant'.

Also studied that flow visualization of turbo ventilator with the Gas-Tracing Technology and understand the direction of flow. The flow of air entering the turbo ventilator moves in the same direction as that of the rotation of the turbine and naturally becomes the force to push on the rotation of the turbine. The left-hand side flow then flows along the turbo ventilator to the wake region. The direction of the flow on the right is opposite to that of the rotating turbine, and thus becomes the defected field of airflow that blocks the turbine from rotating. The separation of outer flow takes place and air is forced outside which result in the up rise of air in the duct (Connected to the ventilator). The flow visualization can be clearly identified in Fig. 4 and Fig. 5.

Experimentation carried out air simulated condition at residences and factories in Taiwan, shows the substantial extraction of air through turbo ventilator.

The experiments were also conducted with additional extracted fan at the bottom of the shaft were conducted, which resulted into better mass flow rate as shown in Fig. 6 However, it was concluded that the additional extractor fan at bottom of the turbo ventilator sized 500 mm and 360 mm do not have appreciable changes in the mass flow rate induced. For design and development of any new model of the turbo ventilator structural factors are considered. [5]

Lai and Kuo, [6] found that ventilation for bathrooms was improved by providing a large turbo ventilator. The conclusions were that the turbo ventilator did add to the ventilation rate significantly and the induced negative pressure helped to reduce odors and moisture in the room.

Dale and Ackerman, [7] observed that speed and direction of wind affects on the mass flow rate of the turbo ventilator.

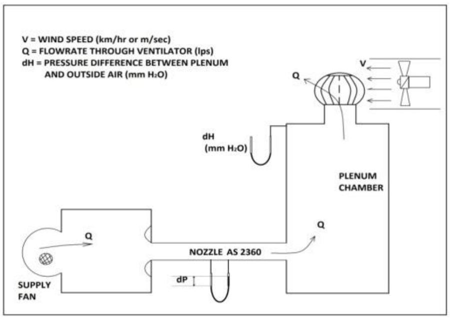

Fig. 3. Scematic Test Stand

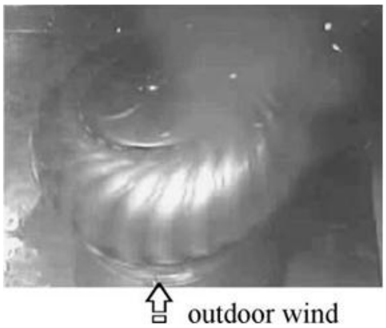

Fig. 4. Top View of Flow Structure

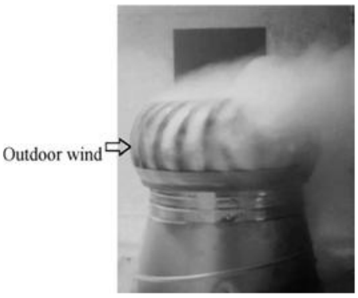

Fig. 5. Flow Structure

West, [8] the effect of blade height on its performance is studied. Long Volume Turbines (LVTs) are taken for the experimental study as shown in Fig. 7.

Experiments are carried out on different blade height like 170, 250 and 340 mm at same wind speed of 12 km/h and found that improvement in mass flow rate could be achieved by 13.5% if the blade height is increased by 50%. It would give different airflow rates of 65, 70 and 75 l/s, respectively.

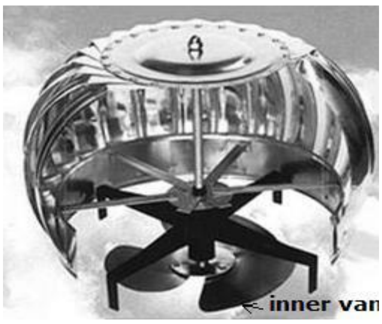

Fig. 6. With Inner Fan

Fig. 7. Variable Blade Height/LVTs

Porfirio R. [10] showed that improvement in air change rate (ACH) by combining the turbo ventilator and electric fan on green houses in Brazil. The study found that turbo ventilators with extractor fan connected at the bottom is having capacity to increase the ventilation rate if turbo ventilators were operated only by natural wind.

Lai C. M. (With Extractor Fan) [9]

Experiment is carried out by combining an air-driven turbo ventilator and extractor fan operated by solar-power, as shown in Fig. 8. The prototype of 500 mm diameter hybrid turbo ventilator developed by Lai [9] which is replaced by the existing inner blade with 400 mm extractor fan showed that it increase the mass flow rate (m^3/s), especially with a rated rotational speed of turbo ventilator is 1500 rpm and at wind speed of up to 5m/s. if the speed goes beyond this fan did not contribute to the airflow. Study found that extractor fan enhancement was negative.

Khan et al., [11] the experiments were carried out on four commercial turbo ventilators as shown in Fig. 9.

1. 300 mm straight vane ventilator (Steel and Aluminum)
2. 300 mm curved vane ventilator (Steel and Aluminum)
3. 250 mm straight vane (Polycarbonate) transparent for day light
4. 250 mm straight vane (Polycarbonate)

Also made test rig to measure the flow rate of turbo ventilator [11] as shown in Fig. 10.

Turbo Ventilator is placed on horizontal roof of plenum. Plenum is a big room from which stale air is to be thrown outside by turbo ventilator. Wind velocity is simulated by the variable speed fan mounted near ventilator which is measured by wind anemometer. When turbo ventilator starts expelling air from plenum air duct will replenish the same amount of air.

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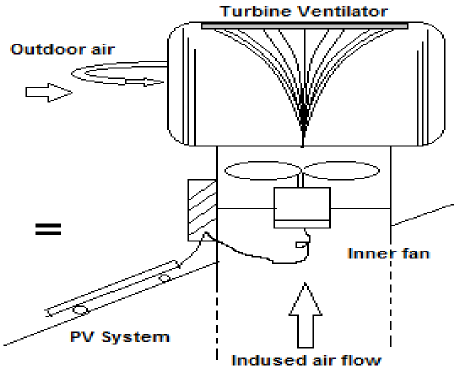

Fig. 8. Prototype Turbo Ventilator

A nozzle meter is installed to measure flow rate going in to plenum this is the flow rate of turbo ventilator. However the air duct and nozzle meter offers resistance to air flow. A Booster fan is provided to overcome this resistance so that net turbo ventilator air flow is directly obtained at Nozzle meter which is measure by manometers provided at the duct. The rotational speeds of the ventilators were measured by optical tachometer.

For comparison purpose tests carried out on 250 mm open column, a 250 mm open column with a plane baffle cap and with a Chinaman's hat, respectively. The standard distance taken between the column and the hat was 0.75 of the column diameter. Also plot the graph of mass flow rate verses average wind speed up to 18 km/h. It is noticed the curved blade of aluminum showed 25% excess mass flow rate than the straight blade ventilator for same velocity of wind. Figure 11 shows the results of various types and shapes of turbines ventilator.

The performance of hybrid turbine ventilator investigated by Ismail and Rahman,[12] for Malaysian climate condition. The turbo ventilator is provided with the opening on the top (80 mm) and solar powered extracted fan at the bottom level as the shown in Fig. 12. The inner duct of diameter 200 mm is fitted inside the turbo ventilator. It is observed that indoor air temperature was drop down by 0.7^0 C and humidity by 1.7 %.

Fig 9. Four Commercial Turbo Ventilator

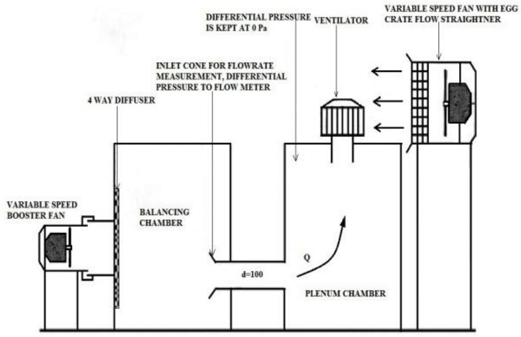

Fig. 10. Schematic View of Test Rig.

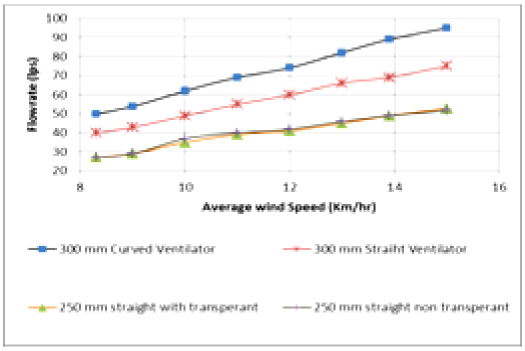

Fig.11. Mass Flow Rate Verses Average Wind Speed

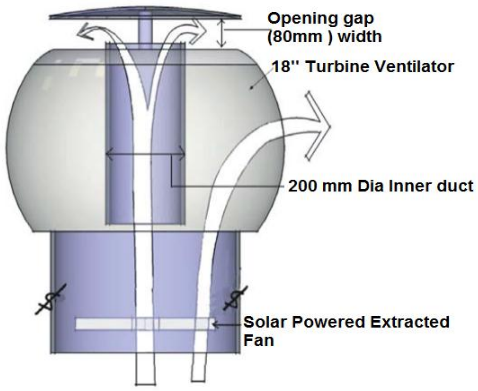

Fig. 12. Hybrid Turbo Ventilator

Shao Ting J. Lien, [13] worked on effect of the inclination angle of the rooftop on the performance of a rotating turbo ventilator. Three inclination angles of 0^0, 15^0, 30^0 are used in the investigation. For this investigation, wind speed was taken between 4 m/s and 15 m/s. The linear relationship with air velocity was found between the forces acting on the ventilator and its rotational speed.

It revealed that if angle of inclination of the roof is increased then total force acting on the ventilator, its rotational speed and extracted mass flow rate decreases and the effect is more at higher wind speeds as shown in Fig. 13

Shao Ting J. Lien et al [14] and other researchers [14-16 and 19] used FLUENT software for CFD study using k-ε turbulence model and also did experimental study to measure the mass flow rate for different blade heights (98 mm, 147 mm, and 196 mm) of the turbo ventilator. Result showed that for larger blade height, the mass flow rate obtained is more compared to the one with smaller blade height as shown in Fig. 14. These results were compared with the experimental results obtained by Khan et al. [11] It is found that by increasing the blade height by 50% and 100% of turbo ventilator, the improvements in exhaust mass flow rate were achieved between 15% and 25%. Three velocity ranges were considered for this CFD simulation viz. 5 m/s, 10 m/s and 15 m/s. It is observed that at all wind speeds, the rotation of the turbo ventilator creates suction at the center. Stream lines of turbo ventilator at 10 m/s as shown in Fig. 15. The stream line seen in this simulation also confirms the pattern observed by the Lai C.M. [5]

Thus CFD analysis helps in future design and development of rooftop turbine ventilators with enhanced performance.

Shieh T. et al. [15] in Taiwan carried out the field study as well as the computational fluid dynamic (CFD) simulations to study flow pattern and estimate the ventilation due to hybrid turbine ventilator which was developed by Lai C. M. [9] for factory. The finding reveled that, due to this device there is approximate increase in mass flow rate which is four times greater than the conventional turbine ventilator.

Farahani A. S. et al. [16] used the FLUENT software for CFD analysis to observe the air flow inside and outside the ventilator and predicted the aerodynamic forces. He had used k-ε and Reynolds stress model (RSM) by taking advantage of moving mesh method. This study showed that used k-ε model gives reasonable performance, however not as the competence as RSM model. The K-ε model required the less computation time.

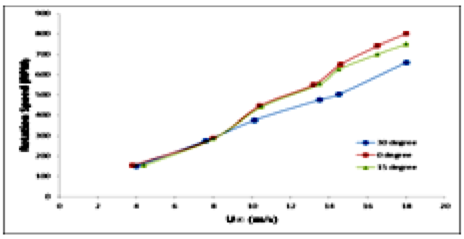

Fig. 13. Rotational Speed Verses Wind Velocity

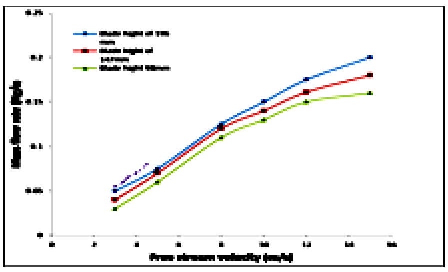

Fig. 14. Mass Flow Rate Verses Wind Velocity

Normayati Nordin et al. [17] in these study three different concepts were used as shown in Fig. 16, 17 and 18. In the first concept mounted the fans at the bottom of shaft, in second concept used the gear system to increase the rotational speed of shaft and in third concept, modified the existing turbine ventilator by providing extracted fan at the bottom as well as put a set of propeller on the top. Concept 3 has been marked to be a best design which gives additional rotational speed and extraction of hot air, result in to a better thermal comfort.

Researchers worked on the turbo ventilator to increase the extraction rate; however I. Daut et al [18] developed the modified roof ventilator which is used to generate electricity. The function of turbine ventilator is to supply fresh air in industry and living area and in addition to that it is used to produce the electrical energy. In this study modified the existing turbine ventilator by providing the extra fin which is 3 inch wide and 20 inch long as shown in Fig. 19. Results showed that used system produce 13 Vdc to 14 Vdc to charge the 12 Vdc batteries system.

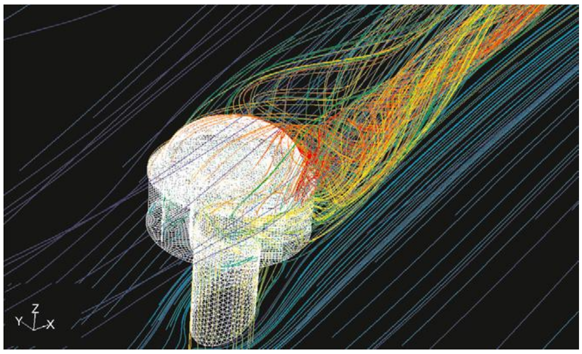

Fig. 15. 3- D Stream Line Of Turbo Ventilator At 10 M/S.

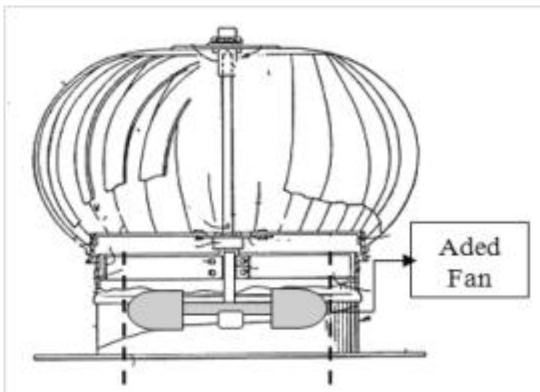

Fig. 16. Concept 1

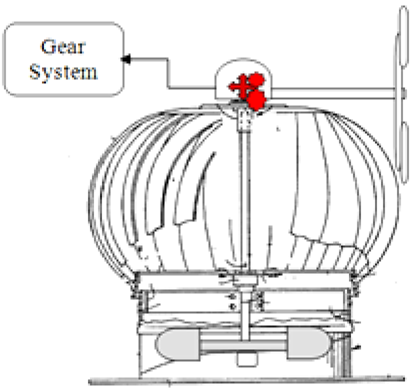

Fig. 17. Concept 2

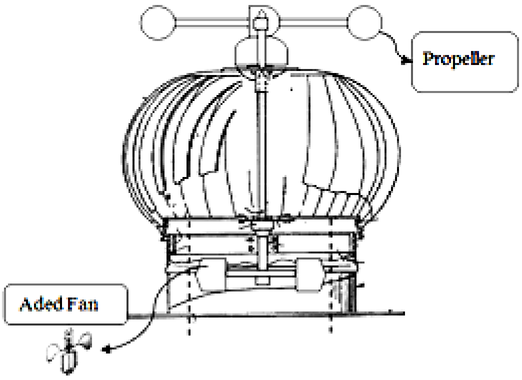

Fig. 18. Concept 3

Researchers worked on the turbo ventilator to increase the extraction rate; however I. Daut et al [18] developed the modified roof ventilator which is used to generate electricity. The function of turbine ventilator is to supply fresh air in industry and living area and in addition to that it is used to produce the electrical energy. In this study modified the existing turbine ventilator by providing the extra fin which is 3 inch wide and 20 inch long as shown in Fig. 19. Results showed that used system produce 13 Vdc to 14 Vdc to charge the 12 Vdc batteries system.

Fig. 19. Modified Turbine Ventilator

III. CONCLUSION

Different wind driven ventilation techniques have been studied and categorized based on review of literature, it was found that very little work has been done on various operating parameters like diameter at throat, diameter of turbo ventilator, blade design, blade width, blade angle for its performance. There is no standard design model or parametric study available.

On the basis of the previous work carried out by experimental and analytical investigation on various aspects of rooftop turbo ventilator application and performance. This paper has focus on the existing study and also the possible development of the turbo ventilator for the coming future. CFD is fairly reliable software and which could be used as a cost effective. It helps in future design and development of rooftop turbo ventilators with enhanced performance.

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