Investigation of turbine ventilator performance after added wind cup for room exhaust air applications

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Abstract. The turbine ventilator is a wind turbine with a vertical axis that has a combined function of the wind turbine and a suction fan. In this study, the turbine ventilator modified by adding a wind cup on the top (cap) turbine ventilator. The purpose of this experiment is to investigated the effect of the addition of wind cup on the turbine ventilator. Turbine ventilator used is type v30 and wind cup with diameter 77 mm. The experiment was conducted using a triangular pentagon model space chamber which was cut off to place the ventilator turbine ventilation cup with a volume of 0.983 m$^3$ (equivalent to 1 mm$^3$). The results of this study indicate that at an average wind speed of 1.8 m/s, the rotation of the turbine produced without a wind cup is 60.6 rpm while with the addition of a wind cup in the turbine ventilator is 69 rpm. The average increase of rotation turbine after added win cup is 8.4 rpm and the efficiency improvement of turbine ventilator is 1.7 %.

1. Introduction
Turbine ventilator is widely used in the roof of factories as additional ventilation. Installation of turbine ventilator is beneficial to improve room air quality, furthermore to reduce the usage of air conditioning (AC). The turbine ventilator is one of equipment to dispose of exhaust airflow through negative pressure down-stream end in the air by using turbine rotating. The efficiency of turbine ventilators has been investigated by varied of three sizes with no inner vanes, such as 6", 14" and 20". One Ventilator with 0.5 m has inner vanes [1]. The result shows the better ventilators with inner vanes. Turbine ventilator is very helpful to improve ventilation for building and factory ventilation.

The prototype of rooftop turbine ventilator hybrid by wind and photovoltaic energy has been developed and investigated. The rotation speed recommended is 1500 rpm best performance to add the inner fan at turbine ventilator [2]. The influence of inclined roof can extend safety limits of turbine ventilator by reducing wind force applied to the ventilator [3]. Turbine ventilator was used to cool down the photovoltaic (PV) cell. The result can be seen the performance of combination between wind-driven and turbine ventilator can increase the output power PV cell up to 46.54 % [4]. The testing of flow rates conducted to four commercial turbine ventilators have been studied. Different wind speed affected by rotational speed and ventilation flow rates, it is has tested by comparing open column and two vent hats. It was found that the throat diameter, blade configuration and construction material of the ventilator impact on the ventilator's capacity to induce flow [5].

This experiment aims to investigate the performance (such as wind velocity, temperature, humidity, and rotation) of turbine ventilator before and after added wind cup.
2. Materials and Methodology
The parameters that influencing the performance of the turbine ventilator are the rotation produced from the ventilator turbine \( n \), the velocity of free stream fluid \( U_\infty \), the fluid density \( \rho \), and the diameter of the funnel pipe of turbine ventilator \( D \). Data collected in some locations and the experiment scheme as shown in figure 1. This study uses a fan with three variations of distance, resulting in different wind speeds. The fan distance is 1, 2, and 3 meters from the turbine ventilator that has been added to the wind cup. Temperature and humidity data of the chamber are recorded in the area indicated by the red dot in figure 1. The rotation data is obtained by measuring the turbine ventilator of the cause by the fan with the distance variation (red dot point).

![Figure 1. Experimental scheme and location measured of static pressure at the tested model.](image)

The efficiency of turbine ventilator can be calculated by equation (1) [6].

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\eta = \frac{n \times 100}{v}
\]

where the efficiencies of turbine ventilator \( \eta \), rotation of turbine ventilator, rpm \( n \), wind velocity, m/s \( v \).

In this study, the turbine ventilator is modified by adding a wind cup on the top of the turbine ventilator that connected by a shaft. The wind cup can increase the speed rotation of turbine ventilator which serves to absorb the existing hot air in the room. The scheme of turbine ventilator combines with wind cup that modified, and the tested chamber was modeled was developed in this experiment. The model tested chamber consisted of wall glass, aluminum frame and floor chamber of the aluminum plate. A fan used for wind speed that was varied with three-speed variations in this experiment.

The testing stages are carried out by preparing the tested room model, the temperature and humidity of the test model chamber were measured and recorded. Install the turbine ventilator with wind cup in the test model chamber. The effect of modification turbine ventilator with adding wind cup is analyzed by a previous comparative study (standard turbine ventilator). The experiment apparatus after modified as shown in figure 2, where wind cup (1), horizontal shaft or with three cups (2), turbine ventilator cap (3), turbine shaft/SS (4), Teflon SS bearings (5), and Neck of turbine ventilator (6).
3. Results and Discussions
Based on the three variations of wind speed that generated by the fan, the results of the measurements obtained in this study are shown in table 1. The results show the rotation of turbine ventilator after modified by wind cup after that three variations of fan distance and then comparing turbine ventilator without wind cup added was conducted in this experiment. Three fan distances are 2, 1.5 and 1 meters for each turbine ventilator.

Figure 2. (a) turbine ventilator modified by adding wind cup, (b) model of the tested chamber.
Table 1. The turbine ventilator with and without wind cup varied by the distance of fan.

| No. | Fan Distance (m) | Wind velocity (Km/h) | Temperature (°C) | Humidity (%) | Rotation (rpm) | Turbine ventilator (With and without wind cup) |
|-----|------------------|----------------------|------------------|--------------|----------------|-----------------------------------------------|
| 1   | 2                | 1.8                  | 30.3             | 55.3         | 60.6           | None                                          |
| 2   | 2                | 1.8                  | 29.9             | 62.6         | 69             | Wind cup                                      |
| 3   | 1.5              | 2.1                  | 30.2             | 57.6         | 67.6           | None                                          |
| 4   | 1.5              | 2.1                  | 29.6             | 64.3         | 84.3           | Wind cup                                      |
| 5   | 1                | 3.5                  | 30                | 58.6         | 91.3           | None                                          |
| 6   | 1                | 3.5                  | 29.3             | 64.6         | 108            | Wind cup                                      |

Figure 3. The rotations of turbine ventilator before and after adding wind cup.

Figure 3 shows the rotation of turbine ventilator comparing with the modified turbine ventilator with added wind cup. Fan distance at 2 meters, the rotation index of turbine ventilator modified by wind cup is increasing when compare with turbine ventilator standard. The increasing rotation value is 8.4 rpm, and average wind speed was constant at 1.8 m/s.

The rotation number of turbine ventilator modified increases when adding the wind cup; it shows a growing from 67.6 to 84.3 rpm when fan position is brought close to the turbine ventilator at 1.5 meters. The average wind speed is 2.1 m/s. Subsequently, when fan distance at 1 meter, the rotation of turbine ventilator standard is 91.3 rpm, it increases after modified by wind cup at 108 rpm. The average of wind speed is 3.5 m/s.

Temperature range from 29.3 to 30.3 °C, it is recorded from the model of tested chamber. The temperature declines from 0.4 to 0.7 °C and humidity reduced from 7.3 to 6 % when fan distance brought closer. The temperature ambient of Banda Aceh-Indonesia is usually increased in the morning and reached the maximum at noon, and then slightly decreased in the afternoon [6,7]. The range of ambient temperature about 29 °C until the maximum at 33 °C. The data collected from drying apparatus on the investigation for drying bilimbi and cocoa.

The turbine ventilator standard and modified illustrate the performance of wind speed increase when the fan distance brought closer to the turbine. The increasing of wind speed value causes the raising rotation of both turbine ventilator (standard and modified). So as an overall it can be concluded that the efficiency of turbine ventilator standard is 12.6 % according to equation (1), while the turbine ventilator after modified by win cup can increase the efficiency until 14.3 %.
4. Conclusions
The addition of wind cups on the turbine ventilator can be taken several conclusions:

1. The efficiency of turbine ventilator is 1.7 % after adding the wind cup.
2. The turbine ventilator with added wind cup can significantly increase the wind speed and the rotation.
3. The turbine ventilator modified can slightly reduce room temperature and humidity.
4. With the addition of wind cups on the turbine, the ventilator can increase the efficiency of the turbine spin of the ventilator.

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