Design and Development a Wind Tunnel using the Honeycomb as a Wind Turbine Characterization Instrument

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Abstract. In this research, an open circuit wind tunnel system was developed with variations in the use of the honeycomb and not in the settling chamber. This system will be used as an instrument for testing the characteristics of wind turbines. Settling chamber, cylindrical with a diameter of 56.4 mm with a length of 150 mm. Contraction cone, a truncated cone with a large diameter of 564 mm and a small diameter of 460 mm and a height of 300 mm. The test section is cylindrical in shape with a diameter of 460 mm and a length of 500 mm. Diffuser, in the form of a truncated cone with a large diameter of 560 mm and a small diameter of 460 mm and a height of 400 mm. The use of honeycomb is aimed at reducing the value of the intensity of turbulence. The honeycomb consists of a PVC cylinder with a diameter of 8.5 mm and a length of 100 mm, placed in the settling chamber. The intensity of turbulence is defined as the ratio of the standard deviation to the mean value of the wind speed. The wind speed in the test section was measured using an anemometer at nine different measuring points around the center of a cross section of the test section. The nine-point wind speed was used to calculate the intensity of the turbulence. The turbulence intensity of the wind tunnel without honeycomb and with honeycomb in the settling chamber is approximately 0.864 and 0.178, respectively.

1. Introduction
The wind tunnel is an important measuring instrument for aerodynamic research. Wind tunnels are used to characterize the flow of air or gas during the passage of certain objects such as the design or modernization of airplanes, vehicles, bridges, high-rise buildings and wind turbines [1]. Open type wind tunnels can be used as a means of developing the field of aerodynamics, in particular wind turbine testing. The open line type of wind tunnel is used with several considerations, including lower costs and smaller building area than the closed type [2]. In the wind tunnel simulation, the model is assumed to be at rest and the wind is moving at a certain speed. Therefore, the air flow in the wind tunnel test section must meet certain requirements, including low intensity of turbulence. Various methods have been described to describe the behavior of wind speed characteristics in a certain area. Stochastic modeling uses the parameters of mean wind speed and turbulence intensity to configure each resulting model. The best parameterization of the Ornstein-Uhlenbeck (OU) process was used by comparing the set of wind speeds in seconds and their characteristics and determined by turbulence intensity analysis [3, 4]. In another study, the distribution of flexible families was used which was compared to the Weibull distribution to analyze the distribution of wind speed [5]. In an effort to minimize the estimated error, the Johnson distribution with the multi-parameter distribution is also used in addition to the Weibull distribution to determine the flow characteristics of wind speed [6].
The use of ten two-component mixed models including gamma, Weibull, Gumbel and truncated normal mixtures was also used to characterize the wind speed distribution [7 – 9].

Wind tunnel dengan desain rentang kecepatan angin 30 sampai 100 m/s dengan rentang tekanan penggunaan 0.15 sampai 1.0 atm berpotensi digunakan pada pengujian-penguji micro-aerodynamic [10]. In another study, a two-dimensional incompressible flow breaker simulation based on a finite volume scheme was used, successfully predicting flow along the core and near the wall from three preselected wall shape contractions [11]. The use of three-dimensional geometry in open circuit wind tunnel results in the recommended contraction ratio, maximum uniformity values in the central plane of the part, prevention of separation, absence of Gortler vortices contraction and minimization of the thickness of the boundary layer at the entrance to the workpiece [12].

The low intensity turbulence of wind tunnel is a major requirement. An aluminum honeycomb tested in a wind tunnel at the Central Aerohydrodynamic Institute (TsAGI) exhibits good free flow conditions. [13]. The use of honeycombs and sails, in an open-circuit wind tunnel, installed at the Indian Institute of Technology in Guwahati (IITG) has demonstrated a significant reduction in turbulence, a key component of subsonic wind tunnels [14].

In this research, an open circuit wind tunnel is designed and developed. The intensity of the turbulence in the test chamber was reduced using honeycomb made of PVC tubes. The turbulence intensity reduction test was performed using the main method. The reduction in intensity that occurs in the test chamber is clearly shown in the experiment.

2. Method
The open-circuit wind tunnel is made using an iron plate formed into a cylinder consisting of four main parts. At the very front is a settling chamber in which there is a removable honeycomb. Air enters through the cone of contraction to the test section, finally exiting the diffuser. Figures 1 (a) and (b) show cinematic and photographic diagrams of the developed wind tunnel.

![Figure 1](attachment:figure1.png)

(a) Schematic diagram in a wind tunnel, (b) photographic drawing developed in a wind tunnel.
Settling chamber, cylindrical with a diameter of 56.4 mm with a length of 150 mm. Contraction cone, a truncated cone with a large diameter of 564 mm and a small diameter of 460 mm and a height of 300 mm. The test section is cylindrical in shape with a diameter of 460 mm and a length of 500 mm. Diffuser, in the form of a truncated cone with a large diameter of 560 mm and a small diameter of 460 mm and a height of 400 mm. A digital anemometer is used to measure the wind speed in the cross section of the test chamber. Figure 2 (a) shows a schematic diagram of nine wind speed test points in the test section, the midpoint of the cross section of the test section is positioned at the point of origin. Figure 2 (b) shows a photographic image of the cross section of the test section in the process of collecting wind speed data.

Figure 2. (a) Nine wind speed test points in the test section, (b) photographic image of the cross section of the test section.

Figure 3 shows the honeycomb which is attached to the settling chamber. The honeycomb is made of 8.5 mm diameter PCV tubes that are arranged tightly. The space that forms between the two tubes is sealed with an adhesive so that the air only circulates through the holes in the pipe.

Figure 3. Honeycomb with length 100 mm and diameter 8.5 mm.
the intensity of the turbulence and is defined as follows [15]:

\[ I = \frac{\sigma}{U} \]

with

\[ \sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} x_i^2 - \left( \frac{\sum_{i=1}^{N} x_i}{N} \right)^2} \]

\[ \bar{U} = \frac{\sum_{i=1}^{N} x_i}{N} \]

Where \( \sigma \) is the standard deviation of the variation in wind speed and \( U \) is the mean wind speed.

3. Results and Discussion

Figure 4 shows the distribution of wind speed in the cross section of the test section when the wind tunnel is not attached to the honeycomb in the settling chamber.

![Figure 4](image)

**Figure 4.** The distribution of wind speeds in the cross section of the test section without honeycomb.

In the calculation, we get \( \sigma \) approximately 2.63 and \( U \) approximately 3.05. The turbulence intensity (I) of the first model is approximately 0.864.

![Figure 5](image)

**Figure 5.** The distribution of wind speeds in the cross section of the test section with honeycomb.

Figure 5 shows the distribution of wind speed in the cross section of the test section when the wind tunnel is attached to the honeycomb in the settling chamber. In the calculation, we get \( \sigma \) approximately
1.88 and \( U \) approximately 10.99. The turbulence intensity (I) of the first model is approximately 0.171. Based on the measurement results, the use of honeycomb in the wind tunnel reduces the intensity of wind turbulence in the test section by 0.69 points, or about 80%.

4. Conclusion

A wind tunnel was designed and developed using an open circuit design. The wind tunnel is made by forming a steel plate into a column consisting of four main parts, namely the settling chamber, the contraction cone, the test section and the truncated cone. The intensity of the turbulence in the defined section of the wind tunnel was measured using a mean method. The turbulence intensity in the section sets for the honeycomb-free blower in the settling chamber shows a relatively large value compared to the use of honeycomb in the settling chamber. In further research, the appropriate honeycomb design variation can be used to achieve a smaller turbulence intensity value.

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