Comparation of 2 types of Diffuser Interior

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(Student exchange - experimental report)
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1 Introduction

Wind as energy resources has been as an alternative. Extracting power from wind is achieveable and have a long story in mankind history. Wind speed in Indonesia's land region is relatively low compared to other places such as sub-tropical areas. Wind speed in Indonesia is in average mostly less than 5 m/s [1]. One way to extract energy from the wind is using wind turbine. Unfortunately, wind turbines in the market are designed mostly for high wind speed, i.e. with average speed around 10 m/s which suitable for many sub-tropical country in Europe and America. Therefore in order to utilize wind energy in Indonesia with such speed effectively still need more effort. Two ways of approach to answer such problems are by developing rotor technology suitable for low wind speed and by manipulating wind flow in order to achieve higher wind speed when attacking the rotor.

We are here more interested with the second approach. One developing efforts is the Diffuser-Augmented Wind Turbine, which is claimed to have augmentation power of two up to four times in comparison to the conventional wind turbines of the same size. This effort manipulate the wind speed by increasing it before attack the rotor. Diffuser-Augmented Wind Turbine or shorted as DAWT is actually a

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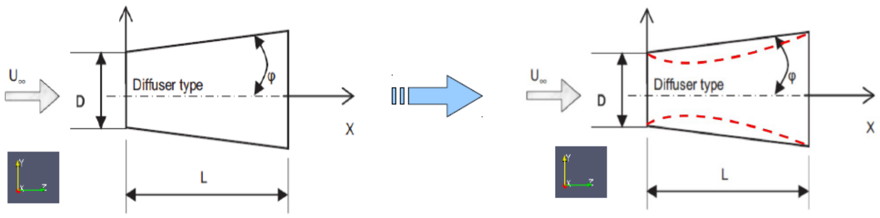

(a) Plain Cone (b) Curved Cone

Fig. 1.1: Experimental Ilustration

kind of Horizontal Axis Wind Turbine that have a shroud or duct wrapped its rotor. The shroud in general is conical with bigger diameter in the downstream region in compare to the upstream one. Until recently the rotor is positioned near upstream of the shroud.

One further development was a flanged-diffuser [2]. This diffuser is a conical diffuser with large flange attached on diffuser rear-end. The 2D profile of originally developed flanged-diffuser is like a flat plane, so it still have possibility to make it better. The idea is to add curved interior in the diffuser that inspired by the shape of the airplane's wings. The effect of curved interior addition will be studied. This study can be described with Figure 1.1

2 Theories

When the free stream laminar flow pass through a pipe-like object, before inlet of the object the velocity, it may suffer 3 type of effects which is accelerate, decelerate, and no-effect. These effects is based on Ohya's measurement result comparing 3 types of hollow objects which is diffuser type, nozzle type, and cylindrical type [2].

In this section will state a brief explanation about physics laws that used as mind frame to explain the phenomenon occurs during experiment and analyze the result of measurement. The phenomenon of the flow is wind flow through a cone-like diffuser and have acceleration inside the diffuser. The event can be divide into 3 section which is near inlet, inside of diffuser, and the wake after outlet. In the near-front of inlet there is happening velocity increase that continue until a certain distance inside a diffuser from inlet. Then the flow behave like an inner flow where the velocity obey the Mass Conservation Law. This law state that for incompressible flow [3].

$$\int_{CS} (V.n)dA = 0 \tag{2.1}$$

In one-dimensional inlet and outlet, it can be described as

$$\sum_i (V_i A_i)_{out} = \sum_i (V_i A_i)_{in}$$

$$\Sigma Q_{out} = \Sigma Q_{in} \tag{2.2}$$

where $Q_i = V_i A_i$ is called volume flow that pass through the given cross section. So when the cross section area is narrower then the velocity on that section is faster.

The turbulence may arise inside the diffuser due to flow separation and also in the wake that caused by velocity difference between the external flow and the flow from inside of diffuser. These turbulence cause a drop pressure in the outlet that attract more mass flow inside the diffuser thus the velocity increase is happening in a distance after the inlet[2]. Turbulence flow can be identified roughly by parameter called turbulence intensity. Turbulence intensity (TI) is define as the standar deviation of the flow measurement σ divided by mean of the flow measurement $\overline{u}$.

$$TI = \frac{\sigma}{\overline{u}} \tag{2.3}$$

3 Comparation Method

The experiments was done by measured the flow velocity inside two diffuser with different interior using hot wire as the wind velocity sensor. By measurement data can be derived other parameters of the flow such as velocity augmentation and turbulence intensity. The first measurement is done using a plain cone as the object. After that, curvature surface can be added to plain cone. The second measurement can begin after the surface had added. So the measurement data can be compared and the effect of interior changes can be derived as well.

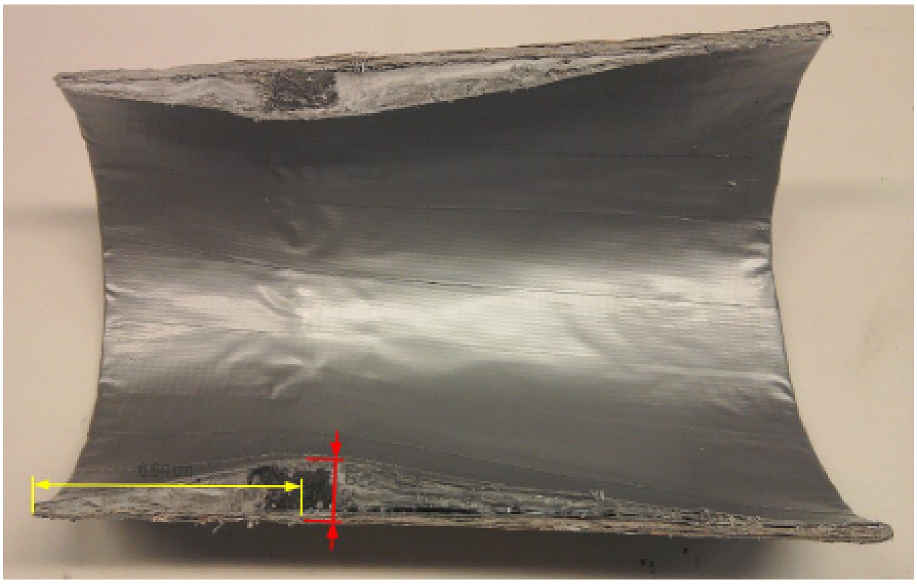

Fig. 4.1: Curve dimension

4 Experimental Setup

The experiments was done using a set of equipments such as wind speed controllable square duct with laminar output until 50 cm downstream and size 10 cm x 10 cm; Dantec Streamline set of flow measurement with hotwire and support; PC for measurement control with Streamware application for configuration and TwiSt made Labview application for measurement; PC controlled traverse motor to move sensor between measurement points.

The first diffuser made was plain cone diffuser from paper. It was piled on diffuser frame and glued on each layer. When it was dried, cut with length 20 cm. It was to get ratio of 2 between the length and the inlet diameter of 10 cm. The paste and tape were then added to get the smooth surface in the interior. The opening angle was 3.718o. After first measurement, then additional curvature is added to plain cone diffuser using paste as filling and covered with tape to get the smooth surface. The curved-cone diffuser are made with maximum height 1.52 cm at 6.24 cm from inlet so minimum diameter of cross section area become 7.36 cm as described in Figure 4.1.

For hotwire measurement setting, each point was done within 30 seconds. Each point of measurement consist of 20 times measurement with 15 kHz of frequency

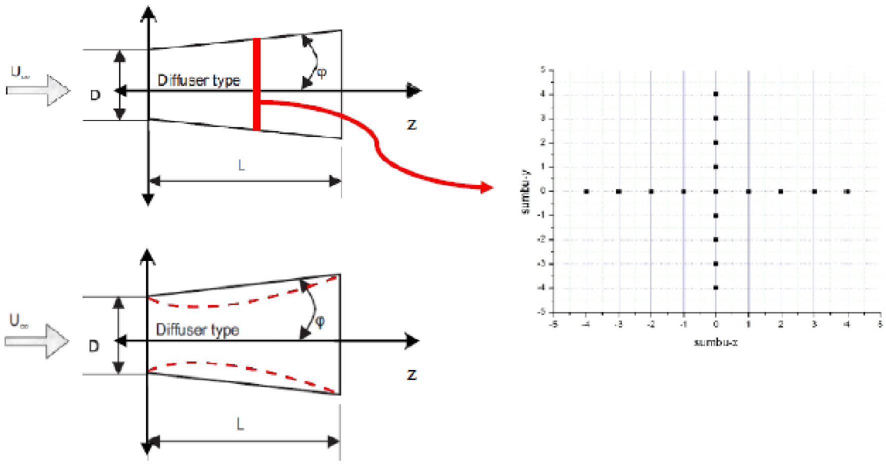

Fig. 4.2: Measurement method

sampling and 15000 data. Measurement points location is described in figure 3 for plain cone (a) and curved cone (b) measurement. The measurement was done in x-y plane along the axial (z axis). Due to time limitation, measurement points was not in the same interval. For plain cone, measurement point is detail with 1 cm interval in the near inlet area because maximal velocity augmentation was happened in that location. It got lesser detail from 6 cm to 12 cm from the inlet with interval 2 cm, from 12 cm until 20 cm (outlet) with interval 4 cm but it got more detail with interval 2 cm in the wake. And for curved cone measurement, it got detail in the first 8 cm from inlet with interval 1 cm, from 8 cm to 12 cm use 2 cm interval, from 12 cm to 20 cm use 4 cm interval, and used 2 cm interval in the wake.

5 Result and Analysis

Wind velocity inside of both type diffuser was measured. Based on velocity data, the augmentation of velocity compared to inflow velocity and turbulence intensity was derived. By those three parameters, flow profile inside both diffusers was mapped, plotted and can be analyzed. It can be seen in Figure 5.1. Figure 5.1(left) is measurement result of plain cone and Figure 5.1(right) is measurement result of curved cone.

By the result plotted in Figure 5.1, it is clear that there was velocity augmentation downstream near after the entrance. This result is in accordance to experiment

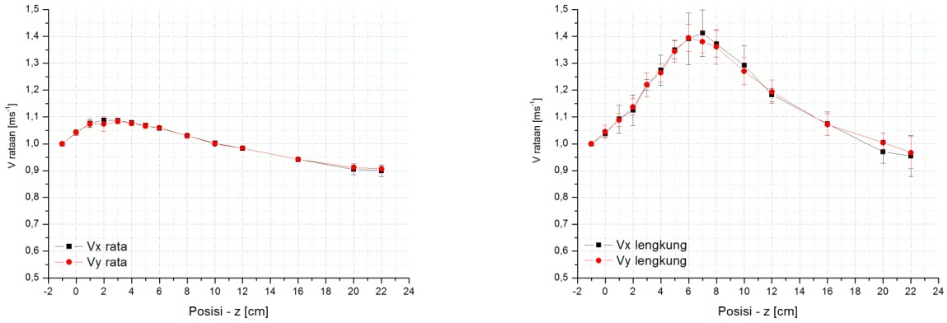

Fig. 5.1: Velocity profile (left) plain cone; (right) curved cone

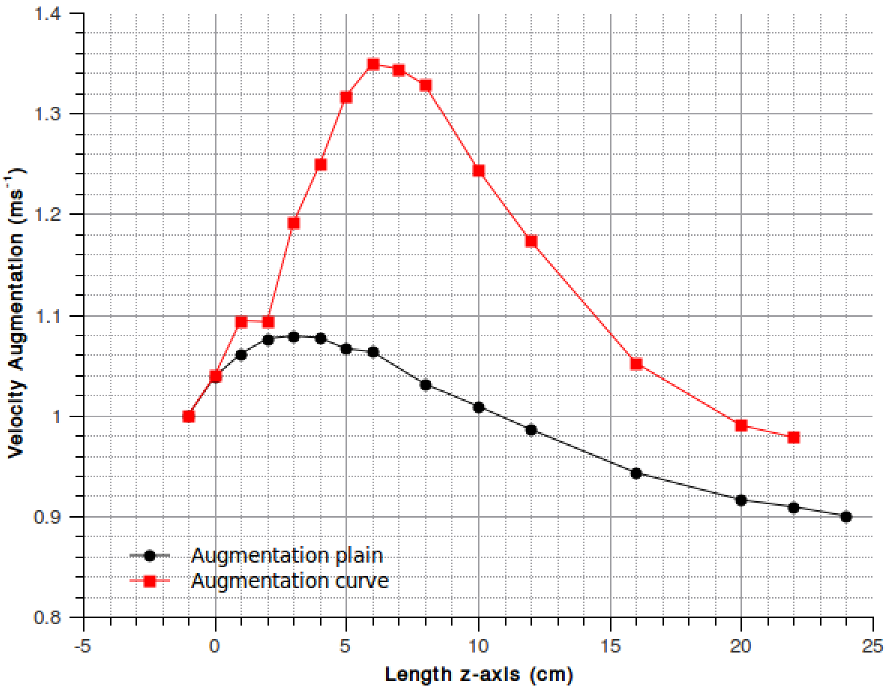

Fig. 5.2: Axial augmentation

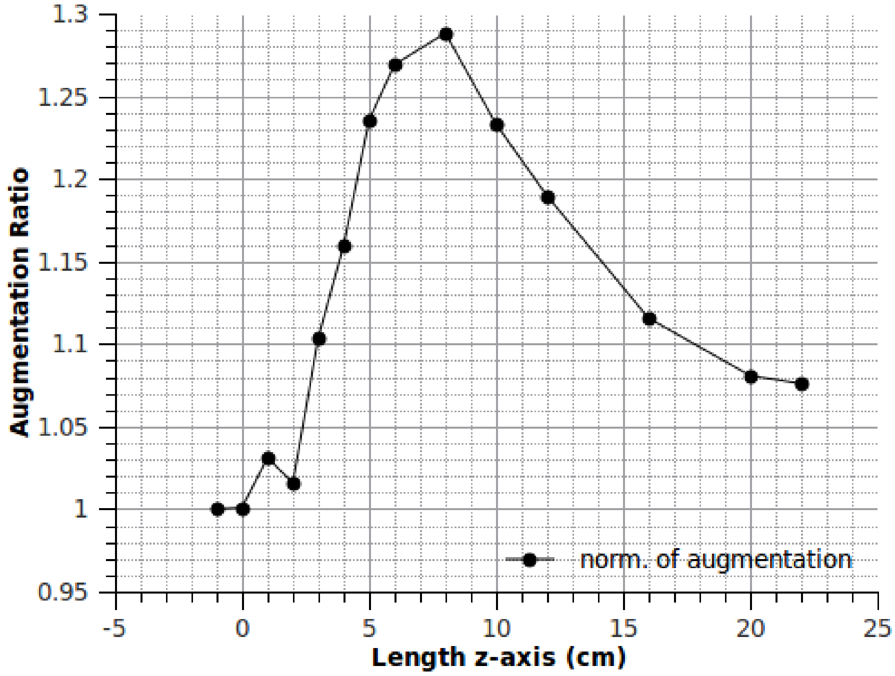

Fig. 5.3: Curve effect in augmentation

result done in [2]. In the plain cone, axial velocity increased from 4.25 m/s at 1 cm in front of inlet to maximum 4.59 m/s at 3 cm after inlet. And in the curved cone, axial velocity was increased from 4.03 m/s at 1 cm in front of inlet to maximum 5.43 m/s at 6 cm after the inlet. This position of 6 cm is at the maximum height of the curve. The comparation can be viewed in parameter of augmentation. By augmentation, the curved cone got higher 27% than augmentation by plain cone which was 1.08% as can be seen in Figure 5.2.

The augmentation of velocity in the plain cone might be caused by pressure drop in the outlet that was caused by turbulence, thus attract more airflow inside the diffuser. The addition of curve inside the diffuser increase the augmentation higher. It seem the augmentation in the curved cone is happened because the cross-section area is decrease in addition to the same effect in the plain cone. Comparation the measurement result with calculation using conservation of mass, at maximum height of the curve, it is fit with error 0.01. The augmentation of velocity measured is 1.30 while the calculation is 1.29.

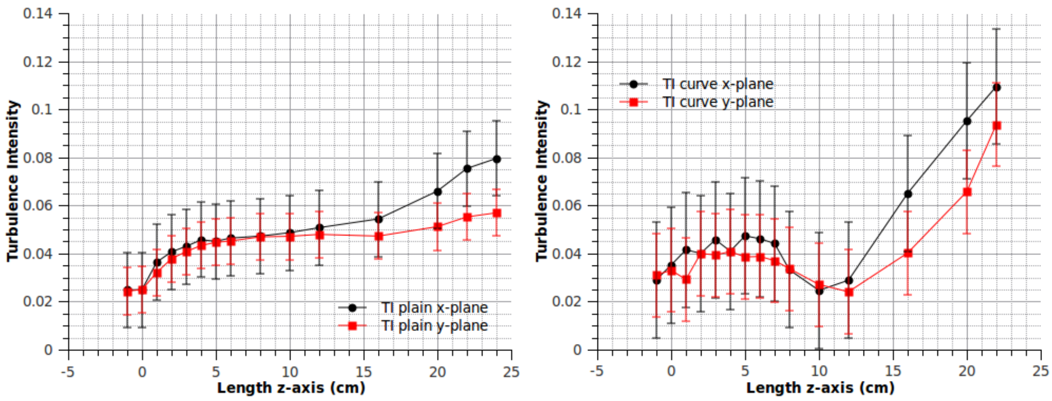

Fig. 5.4: Averaged Turbulence Intensity. (left) plain; (right) curved

To understand the effect of curve addition, some parameters is checked. In Figure 5.3, it is shown that the result of axial augmentation in curved cone is normalized with axial augmentation in plain cone. It seem happen two augmentation, which is happen near after the inlet and near after the curve maximum height. The curve affecting the augmentation near after the inlet by 1.03 and near after the curve maximum height by 1.29.

Another parameter that is taken into analysis is Turbulence Intensity. It is to see whether the flow is having fluctuation or not. The turbulence intensity calculation result can be seen in 5.4. The TI is starting to increase both in plain and curved cone after 1 cm from inlet. By the higher TI in the downstream may be referred as lower static pressure that create augmentation near after the inlet.

6 Conclusion

Curve addition into the diffuser interior made the wind flow faster compared to plain cone. This effect of velocity augmentation in the plain cone may be affected by higher turbulence intensity in the outlet. In case of curved cone, the augmentation is added by the reduce of cross-sectional of flow area that can be explained by conservation of mass. Comparation between the calculation using conservation of mass and the measurement shows error 0.01. Effect of the curve itself compared to initial augmentation by diffuser structure is 1.29 at 2 cm after the maximum height of the curve location 6.24 cm from inlet.

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