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EFFECT OF CHANGING SEPARATOR POSITION TO VELOCITY DISTRIBUTION AND TURBULENCE INTENSITY OF A CROSS FLOW FAN

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Abstract

Two dimensional flow patterns of a cross flow fan had been measured using DANTEC hot wire anemometer and a grid of yarn for visualization. The objective of this experiment was to get the cross flow fan velocity distributions and turbulent intensity under several variations of the separator position and gap to the fan casing. The rotor employed in this study had 75 mm inner diameter, 110 mm outer diameter, 115 mm height, and 24 blades.

The variables measured in this investigation were velocity distributions, turbulent intensities, static and total pressure distributions. Velocity distributions and turbulent intensity were measured using hot wire anemometer. Static pressure was measured using static pressure tapping, while the total pressure was measured using pitot tube. Both were connected to an inclined manometer. The gap between the rotor and separator had been varied 5 mm, 10 mm and 15 mm. While the place of the separator were varied 10 mm to the right, 0 mm and 10 mm to the left of the rotor axis.

The result of the research showed that the wider the separator gap, the flow pattern became more uniform. As the axial gap increased from the rotor, there was turbulent intensity amplification due to the production of turbulent kinetic energy. In this research a reversed flow pattern on one side of casing was also identified using flow visualization.

Key words : cross flow fan, velocity, turbulence, separator

INTRODUCTION

In the last ten years, many installations used cross flow fan for their blowing systems. Unfortunately, due to the complexity of its flow pattern, the cross flow fan was among the turbo machineries which had rarely been explored. Many factors affected the flow pattern of cross flow fan, one of them was the separator. The flow pattern of a cross flow fan were unique where an air flow entering from a half side of the rotor and would come out through the other half side of the rotor. Hence the rotor in this turbomachines behaved like a two stage rotor (Lakshminarayana, 1996).

Mutama and Hall (1996) studied the aerodynamics character of jet fan in a wind tunnel. Velocity distribution was measured using HWA probe and anemometer. It was found that the wider the gap between the jet fan position and the wall, the increase of pressure along the wind tunnel occurred faster. Reversed flow was also detected in this work. The area of this reversed flow became smaller when the position of jet fan were moved farther away from its wall.

Qin and Tsukamoto (1997) explored the effect of a volute. In this study the gaps between the impeller outlet and the tongue were 3, 8 and 13 %. They found that the pressure on the wall increase when the distance were reduced. It was also found that the pressure was reduced to 50 % from its initial value when the gap was increased 3% - 13%.

Hiromu (1997) applied visualization method to evaluate the flow pattern of a cross flow fan. Particle Tracking Velocimetry (PTV) and random numeric method were used to perform the study. Through this study it was proven that the eccentric vortex circulation was equal to the sum of the integral of vorticity and circulation of the impeller.

In practice, generally the fluid motion behaves as turbulent flow. Turbulent fluid motion is an irregular condition of flow in which the various quantities show a random variation with time and space coordinate (Hinze, 1959). Since turbulent flow is very complex, it is difficult to be defined and solved in mathematics manner. Usually the definition and its solution in mathematics is made in form of semi empirical using statistical method and data from many researches.

Turbulent level of a fluid flow is defined as turbulent intensity which is defined mathematically as (Streeter and Wylie, 1985; Tennekes and Limley, 1972)

$$TI = \left[\frac{\sqrt{\overline{u'^2}}}{\overline{u}} \right] \qquad (1)$$

While the turbulent kinetic energy is given by:

$$k = \tfrac{1}{2}.\rho(\overline{u'^2} + \overline{v'^2} + \overline{w'^2}) \qquad (2)$$

And fluctuation rate of turbulent kinetic energy per mass unit is expressed by:

$$\frac{Dk}{Dt} = -\frac{\partial}{\partial x_j}\overline{u'_j\left[\frac{P}{\rho} + \frac{u'_i\, u'_i}{2}\right]} - \overline{u'_i\, u'_j}\,\frac{\partial \overline{u}_i}{\partial x_j} + \upsilon\frac{\partial}{\partial x_j}\overline{u'_i\left[\frac{\partial u'_j}{\partial x_i} + \frac{\partial u'_i}{\partial x_j}\right]} - \upsilon\overline{\left[\frac{\partial u'_j}{\partial x_i} + \frac{\partial u'_i}{\partial x_j}\right]\frac{\partial u'_i}{\partial x_j}} \qquad (3)$$

Above equation can be expressed as:

$$\frac{Dk}{Dt} = -\frac{\partial}{\partial x_j}\mathrm{D}_j + \mathrm{P} - \in$$

Where Dk/Dt is the rate of change in the kinetic energy of turbulent, $\partial D_j / \partial x_j$ is the diffusion of turbulent energy, P is the production of turbulent energy and $\in$ is the dissipation of turbulent energy (Bejan, 1984)

Method of The Investigation

The equipment required to perform this study includes hot wire anemometry, inclined manometer, digital AVO-meter, stroboscope and dimmer. Velocity distribution and turbulent intensity are measured in upstream and downstream regions using HWA.

Measurement procedure is as follows: (Brunn, 1995)

a. installation of test cross flow fan
   cross flow fan is assembled to its casing. The separator is placed to its first position, 0.5 cm from the rotor and 1 cm from the backside of rotor axis. Holes are made in outlet and inlet regions to measure static pressure.
b. set up of hot wire anemometry
   - make the database and project
   - choose the A/D and traverse driver
   - determine the system configurations, includes choose the probe, probe support, connecting cable, frame streamline, CTA module and A/D board channel.
   - Choose the hardware setup
   - Set the velocity and direction calibration
   - Determine conversion /reduction setup
   - Define traversing, that is probe motion from one position to another.
   - Define the experiment
   - Hot wire anemometry is ready to measure velocity distribution and turbulent intensity with the above defined setup.
c. measurement procedure
   variables varied in this work are position and gap of the separator. The examination is as follows:

1. experimental rig is arranged as shown in figure 1

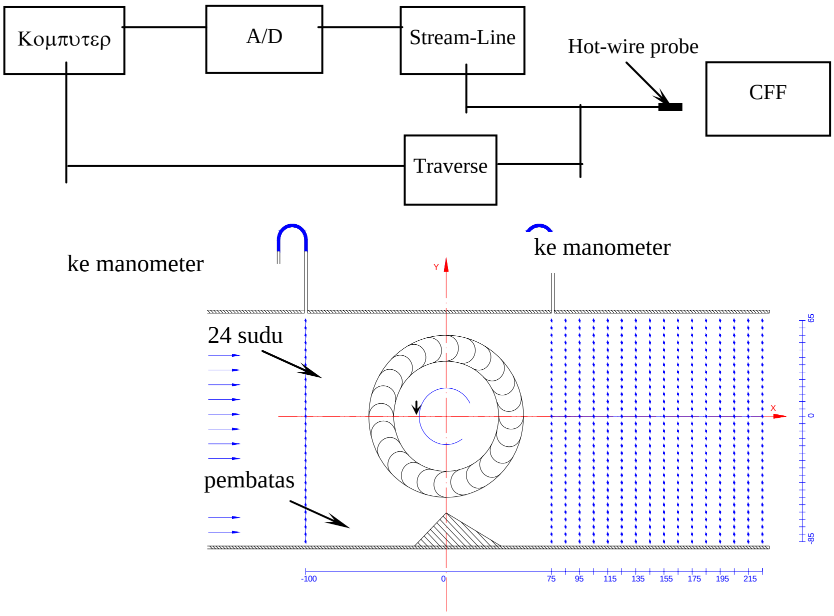

Figure 1. Test rig arrangement

2. HWA is set as mentioned earlier
3. Probe is positioned to zero position, that is with the distance of 75 mm from the rotor axis and –85 from the axis line of the rotor
4. After the electric motor has been turned on and the power of the motor has been set to a certain value, then measure the current and voltage of the motor.
5. After rotation reaches its steadiness, measure the rotor rotation using stroboscope
6. Velocity distribution and turbulent intensity is measured by operating the HWA with the earlier definition
7. Static pressure is acquired on the measurement nodes. Dynamics pressure gradient is acquired from data of velocity measurement
8. Step 3 to 7 are repeated with different separator gap
9. Step 3 to 8 are repeated with different separator position

RESULT AND DISCUSSION

Result data of the measurement using hot wire anemometry include data of instantaneous velocity, mean velocity, root mean square of velocity fluctuation and turbulent intensity of each velocity component.

Figure 2 shows result of measurement of axial velocity distribution. It is seen that the axial velocity distributions of separator having position of 10 mm, are relatively linear on the upstream region. The exception for this linearity is found in region near to separator which is begun from y = -85 (left side of the casing) to y = -40. In this region the velocity distribution forms a parabolic curve. It is occurred since on the inlet region the axial velocity suffer a perturbation caused by the reversed flow from the downstream. Such reversed flow appears since there a gap gap between the rotor and the separator. The perturbated region become wider as the gap is increased. This area for the position 1, 2, 3 are –85<y<-50, -85<y<-40 and –85<y<-30, respectively. It is also seen that as the gap is increased 5 mm, the region of the axial velocity that form parabolic curve increase 10 mm.

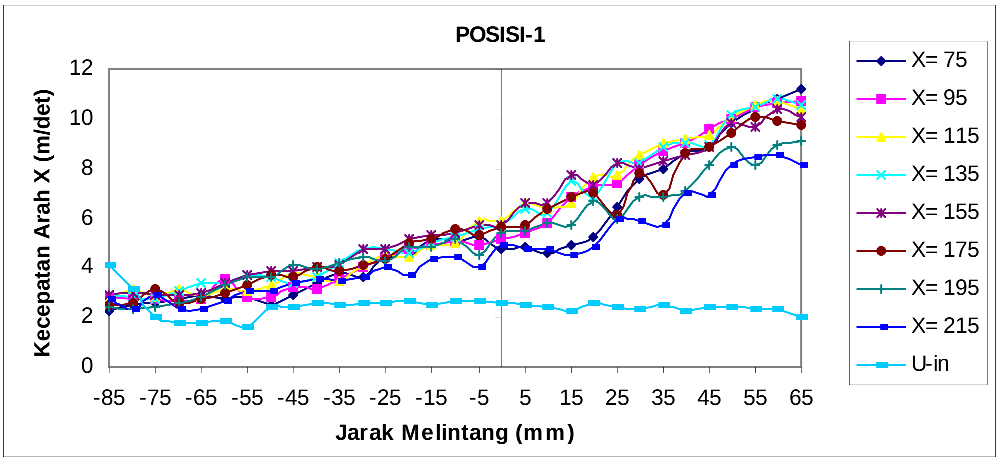

Figure 2. Axial velocity distribution

From figure 2, it is shown that as the distance of the separator is increased, more uniform velocity distribution is resulted. It means that the distance of separator affected the uniformity of air flow. The larger the distance of the separator, the more uniform the air flow.

Axial velocity with the nearest distance from the rotor which is the value of X is 75, deviates from the axial velocity of the next distance. It is happened since the vortex begin to occurs in the flow at X = 75. While at another distances, there are no significant differences. It means that separator position has no significant effect on the characteristic of a cross flow fan.

Figure 3 shows the result of measurement of tangential velocity distribution. It is seen that tangential velocity has positive values on the region Y > 50, which means that in this region the of velocity vector has right direction. And as the counterpart, at Y < 50, the value is negative, which means that the velocity vector has left direction. On the right direction, velocity distribution is not seen clearly since the value of tangential velocity is small enough compared to the value of axial velocity. This condition causes axial direction dominate the velocity vector. In this region it is considered that tangential velocity component a fan is as small as possible, thus the fan can blow straightforward a large amount of air.

As in case of axial velocity, tangential velocity at X = 75 also deviates enough compared to the velocity distribution of the next X distance. This fact strengthens the prediction of region at which vortex begin to be formed around the rotor. But in this work the measurement with nearer distance from the rotor can not be performed due to the safety consideration of the hot wire probe.

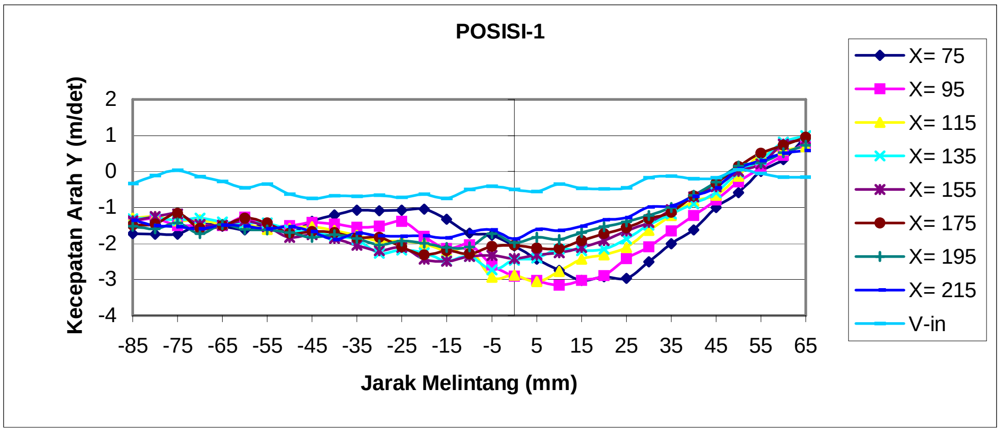

Figure 3. Tangential velocity distribution

The measurement also results high enough of turbulent intensity. It is appeared due to discontinuity of blades motion which in turn cause the flow to be intermittent. As given in figure 4, it is seen that turbulent intensity become larger as the value of X is increased. It means that the larger the distance from the rotor, the larger the turbulent intensity. It indicates the occurrence of turbulent kinetic energy or an energy transfer from meant velocity to fluctuation velocity through shear stress turbulence. From the figure of velocity distribution, the larger distance X the smaller its velocity, which means that it has negative gradient. Since $U_I U_j$ has positive value, then production component in equation of turbulent energy will has positive value. This is the reason for the increase of turbulent energy.

From figure 4, it is shown clearly that there an increase of turbulent intensity in the right region (0 < y < 65). While in the left region (-85 < y < 0) such phenomenon is not clearly seen since the left side is an error region. But turbulent intensity in this left side is also increased due to viscous diffusion of turbulent flow.

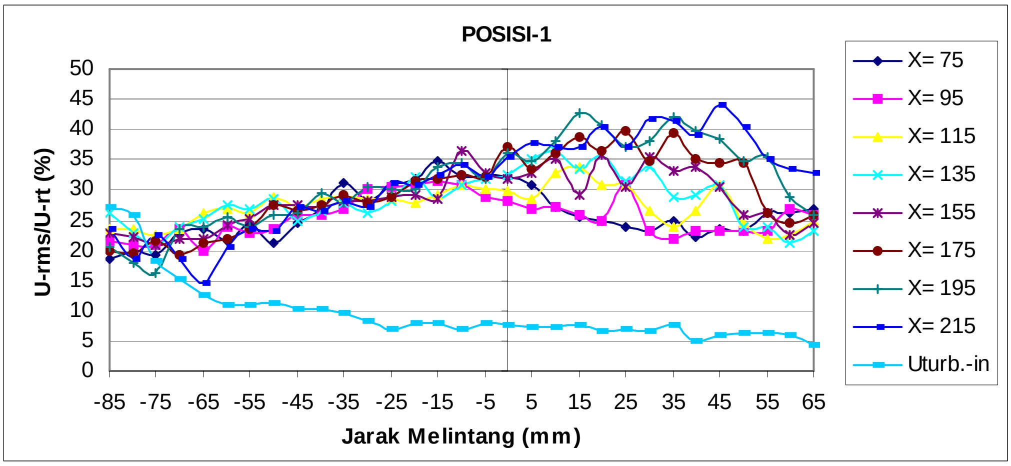

Figure 4.Turbulent intensity

CONCLUSIONS

The conclusion of this work are:

1. The increase of the gap between separator and rotor causes the flow pattern to be more uniform. While separation variation has no significant effect on the flow pattern
2. As the distance of X increases, the turbulent intensity become larger due to the production of turbulent energy
3. Hot wire measurement using two dimensional X probe can be used to detect the positive direction of the flow pattern of a cross flow fan.

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