Performance Testing Of A Modified Centrifugal Fan With Serrated Blade Impeller

Zaimar, Mursalim, H. Abbas, Supratomo

Abstract: Changes of shape, dimension, and component part of impeller might change of characteristic fluid flow so that pressure static in the fan housing changed. Changing some geometric characteristics of the centrifugal fan has more efficiency taking with energy crises into consideration. Several factors that can affect fan performance, namely: design and type, size, rotation speed, air condition or gas through a fan, operating point on the nature of the relationship between a volume of air flow and pressure. The purpose of this research was to test of fan performance of the modified centrifugal fan with the serrated blade impeller. The addition of a percentage of closing the inlet causes the air volumetric rate, the airflow energy, BHP and total efficiency (except for the fan total and static pressure). The experimental test results, there are static pressure data and the resulting total pressure is different or distorted (10-17% of deviation) from calculation data based on the fan laws. This is possible because of changes in the shape of the blade with serrated on the inside of the impeller. Based on the performance curve shows that the selection of impeller speeds of 800 RPM produces a relatively high air volumetric rate is proportional to the total pressure of the fan and the flow energy so that it is more efficient than other impeller speeds.

Index Terms: Impeller speed, fan performance, fluid characteristic, performance test

1 Introduction

A centrifugal fan used to clean the air depending on the type of fan used primarily in sucking air containing contaminants in the form of solid particles. The high speed of centrifugal as a cleaner generally contaminant removed or placed at the collection point, so that the fan and floor machines are kept in good condition [3]. The fan uses the kinetic energy from rotating of the impeller blade to increase the supplied air pressure. Therefore, their efficiency depends on the design of the impeller blade. In this scenario, the industry sets different design parameters and materials for each blade to get maximum performance from each blade. The requirement is an effective design for impellers with the same design parameters that provide improved performance [9]. In selecting the appropriate fan or blower on each application, there are three basics information: airflow volumetric required, static pressure increase to be provided, and gas density on the fan. Another factor that is generally required to choose the proper fan or blower is the type and concentration of contaminants. The centrifugal fan uses a rotating impeller to move air radial outward towards by centrifugal action, and then tangentially away from the blade tips. As the air moves from the impeller hub to the blade tips, it gains kinetic energy. This kinetic energy is then converted to a static pressure and increase the pressure of the air or gas stream which in turn moves them against the resistance caused by ducts, dampers and other components [4].

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The impeller is always placed directly to the axis of the suction motor so that it rotates at a very high speed. The effect of the centrifugal force acting on the air rotates in the impeller creating suction. As the impeller rotates, then it moves the air spins out, creating a partial vacuum that causes more air to flow into the impeller [1]. The change of shape, dimension, and component part of impeller might change of characteristic fluid flow so that pressure static in the fan housing changed. Changing some geometric characteristics of the centrifugal fan or blower could cause high efficiency taking with energy crises into consideration [7]. Fan performance is expressed in terms of the relation between air volumetric with pressure (static pressure and total pressure), brake horse power and efficiency, and is based on the air condition and the fan speed that indicated by performance curves. [10] Stated that there are several factors that can affect fan performance, namely: design and type, size, rotation speed, air condition or gas through the fan, operating point on the nature of the relationship between volume of air flow and pressure. Modification of the centrifugal fan with the serrated blade of impeller allows due to change a flow characteristic so that performance changed. Therefore, the purpose of this research was to test of fan performance of the centrifugal fan with the serrated blade impeller.

2 Materials and Method

This research used the main tools: a modified centrifugal fan with four serrated radial blades on the inside of the impeller, and an electric motor of 0.75 HP with rotating of 1340 RPM. The secondary tools were an analog tachometer, Pitot tube, anemometer digital, tang ampere-meter, calculator, and stopwatch. Fan performance test is the setting of the impeller speeds and the adjustment of the air volumetric rate with closing the inlet at each level of the impeller speeds. Setting the impeller speeds is done by replacing the pulleys on the fan shaft. The impeller speeds on level of 400; 600; 800 and 960 RPM, while the adjustment of the air volumetric rate at each impeller speed level is accomplished by closing the inlet with the level of 0; 25; 50; 75; 85 and 100%. (The fluid material is air with a temperature of 28 ^{0}C and air density of 1.225 kg m^{-3}).

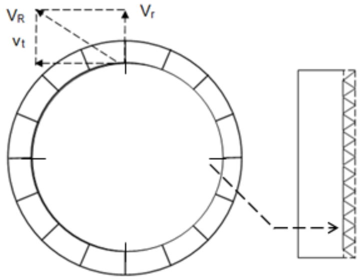

***Fig. 1**: The impeller with four serrated radial blades*

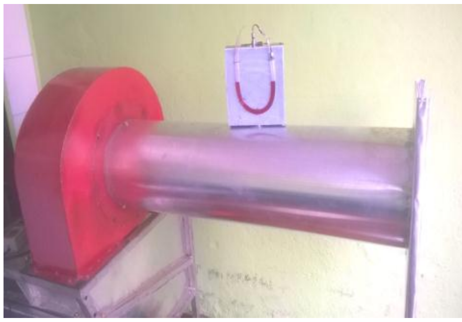

***Fig. 2**: Experimental performance testing of the modified centrifugal fan*

Parameters of fan performance test of the centrifugal fan consist of air volumetric, static pressure, total pressure, airflow energy and power efficiency that were determined using the following equations:

$$v_1 = \frac{c_p \, x \sqrt{(2x\, 9{,}81 \, x \, \Delta p_1 \, x \, \gamma}}{\gamma} \quad [2]$$

$$\gamma = \frac{273 \text{ x } 1{,}293}{273 + t\,^{o}C}$$

$$Q_1 = v_1 \; A_1 \;\text{, and }\; Q_2 = v_2 \; A_2$$

$$p_{v2} = \frac{1}{2}\;\rho\,(v_2^2)$$

$$p_{vf} = p_{v2} \quad \text{, and} \quad p_{tf} = p_{t2} - p_{t1} \;\; [6] \text{ so that}$$

$$p_{sf} = p_{tf} - p_{vf}$$

$$T_{af} = Q_2 \text{ x } P_{tf} \qquad [8]$$

BHP = V I

$$\eta_t = \frac{T_{af}}{BHP} \text{x } 100\,\% \qquad [8]$$

Where v_1 is air velocity of inlet (m s^{-1}), γ is air density (kg m^{-3}), ΔP is pressure different (Pa), Q_1 is air volumetric rate of inlet (m^3 s^{-1}), A_1 is cross sectional of area at inlet (m^2), Q_2 is air volumetric rate of outlet (m^3 s^{-1}), v_2 is air velocity of outlet (m s^{-1}), P_{v2} is velocity pressure of outlet (Pa), P_{vf} is fan pressure (Pa), P_{tf} is total fan pressure (Pa), P_{t1} is total pressure of inlet (Pa), P_{t2} is total pressure of outlet (Pa), P_{sf} is static fan (Pa), T_{af} is energy of airflow (Pa), BHP is brake of horse power (HP), V is voltage (Volt), I is electric current of motor (A), and η_t is fan efficiency (%).

3 RESULTS AND DISCUSSION

The experimental test results are presented in Fig. 3 to 8 and the partial data in Table 1 below:

***Table 1**: Fan performance of the closing inlet of 75 percent*

The impeller speeds (RPM)	Fan total Pressure (Pa)	Fan Dynamic Pressure (Pa)	Fan Static Pressure (Pa)	Airflow Energy (Watt)
400	47.03	4.00	43.03	5.20
600	84.39	6.67	77.72	12.05
800	149.26	11.86	137.40	28.42
960	230.83	12.94	217.89	45.88

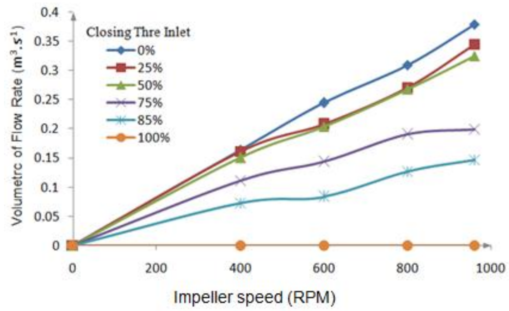

***Fig. 3**: The performance of air volumetric rate*

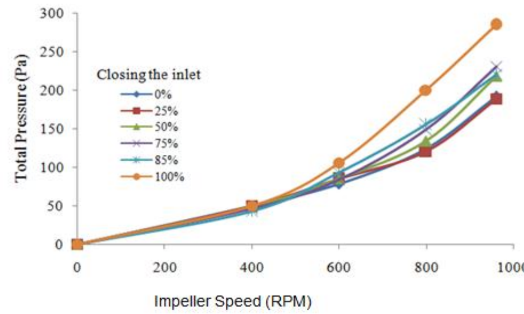

***Fig. 4**: The performance of the fan total pressure*

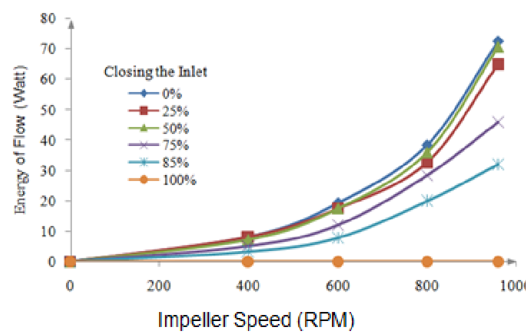

***Fig. 5**: The performance of the airflow energy*

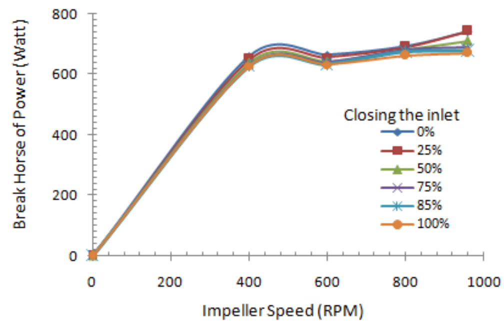

Fig. 6: *The performance of the break of horse power (BHP)*

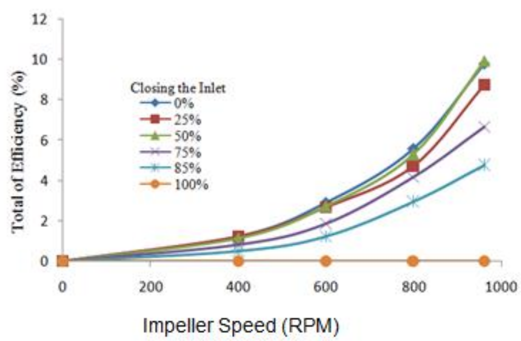

Fig. 7*: The performance of the energy efficiency total*

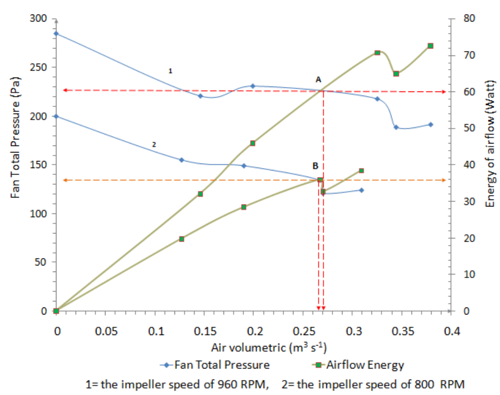

Fig. 8*: Performance curve of the centrifugal fan with the serrated blade impeller*

Addition to percentage of closing the inlet would decrease the air volumetric of the outlet at various levels of the fan speed. The lowest of the air volumetric rate was obtained of 0.073 $m^3 s^{-1}$ at closing the inlet of 85% and the impeller speed of 400 RPM, and the air volumetric rate of 0 $m^3 s^{-1}$ at closing the inlet of 100% for all the impeller speeds. The highest of air volumetric obtained of 0.379 $m^3 s^{-1}$ at closing the inlet of 0% and impeller speed of 960 RPM. With the addition of percentage of closing the inlet causes the air volumetric of the inlet to decrease so that less of air that could be entered to the impeller, which impact on the air volumetric of the inlet and outlet side were decreased. At closing the inlet of 0% occurs the dynamic pressure was lower and get near to the static pressure. This was due that condition where the suction side pressure was almost equal to the outside air pressure and get near to zero so that the fan static pressure becomes low. The impeller speeds affect the pressure on the fan. This effect indicates that the higher the impeller speed caused the higher the pressure produced, either the total pressure and the static pressure or the fan dynamic pressure at all closing the inlet except for 100 % of closing the inlet. [10] Suggest that at the same fan size, fan pressure changes according to the fan speed of the square. In Table 1 show that at the impeller speed of 400 RPM with a static pressure value of 47.03 Pa it could be calculated the pressure value at 960 RPM namely: Pressure value = $(400/960)^2$ x 230.83 Pa = 40.07 Pa which means there is a difference of 6.96 Pa or 17% of deviation. In Figure 5, the decrease in flow energy is proportional to the decrease in the impeller speed and the closing inlet. In the closing inlet range of 50 to 75% reached a peak of airflow energy was obtained of 70.717 Watt at closing the inlet of 50% with the impeller speed of 960 RPM. In Figure 6 shows that the increase of closing the inlet is not much different or the value of BHP is almost the same in all level closing the inlet. It is marked on a curve that almost coincides with each other, while the increase of the impeller speeds would increase BHP power on each closing the inlet. In Figure 7 shows that the highest total efficiency is achieved on closing the inlet of 50% and the impeller speed of 960 RPM was obtained about 9.93%, and the lowest total efficiency is achieved the closing inlet of 0% on all the impeller speeds. The performance curve in Figure 8, there are two operating points of A and B with the position of point A where indicates the air volumetric rate of 0.262 $m^3 s^{-1}$ and fan total pressure of 228 Pa so that produce the energy of airflow of 60 Watt, while in the position of point B indicates the air volumetric rate of 0.254 $m^3 s^{-1}$ and fan total pressure of 135 Pa so that produce the airflow energy of 34 Watt. If considering from energy efficiency, then point B (800 RPM) becomes alternating of the choice. [5] Suggest that two methods could be used to increase the total fan efficiency by reducing airflow energy. The first method is to limit airflow by closing part of the damper in the system. The second method for lowering airflow is to decrease the fan speed and keeping the damper fully open. Lowering the fan speed is a much more efficient method of reducing airflow energy because less energy is consumed.

4 Conclusion

The addition of percentage of closing the inlet causes the air volumetric rate, energy of airflow, BHP and total efficiency (except for the total fan pressure and static pressure) decreased. The higher the impeller speeds caused the higher the pressure produced, either the total pressure, the static pressure or fan dynamic pressure on all closing the inlet except for 100%. Based on the experimental test results, there are static pressure and the total pressure data is different or distorted (6.4 to 17% of deviation) from calculation data based on the fan laws. This is possible because of the change in the shape of blade with serrated on the inside of the impeller. Based on the performance curve shows that the selection of impeller speeds of 800 RPM produces a relatively high air volumetric rate is proportional to the fan total pressure and the airflow energy so that it is more efficient than other impeller speeds.

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