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Experimental Determination of the Effect of Number of Impeller Blades on the Air Flow Rate and Power Consumption of Centrifugal Blowers

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Abstract

Design parameters for a centrifugal blower includes, power of a motor, impeller diameter, impeller width, impeller rotational speed, volume flow rate and number of blades in an impeller, while relationship among several of this parameters are well defined in literature, it is unclear as to how the number of impellers blades affect the performance of a blower. In this work, an experimental method to determine the effect of number of blades in an impeller is described. The blower has been tested at three different speeds using five fabricated impellers with 4, 5, 6, 7 and 8 blades respectively. It is found that, for all 3 selected blower speeds, air flow rate increase by about 19% by increasing the number of impeller blades from 4 to 8. It is also found that increasing blower speed has a significant increase in flow rate; that is, more that 80% increase upon doubling the number of impeller blades. It is also found that there is slight variation in power consumption due to change in number of blades. It is therefore proposed that changing the number of impeller blades can only be applied to fine tune the blower design within 15-20% flow rate variation. However nominal flow rate has to be established using blower speed and dimensions. Power consumption if found to increase slightly with maximum variation of 3% on increasing blade number from 4 to 8. The results are useful in the design or re-design of fabricated blowers and selection of suitable speed. When space is a constraint, increase in the number of blades or blower speed can respectively be applied to increase air flow rate depending on the magnitude of the increase required.

Keywords: blower air flow rate; blower design parameters; blower power consumption; centrifugal blower; number of impeller blades.

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1. Introduction

Centrifugal blowers are used to convey gases at higher flow rates and pressure. In a centrifugal blower, gases are drawn axially into the impeller and accelerated radially through the impeller. An increase in pressure, head and velocity of gases is therefore achieved. Blowers are used in many manufacturing, process installations and many equipment and machinery. They are used for various applications including supplying high air flows for various applications including factory and mine ventilation, air conditioning, cooling and combustion. Common types of blowers (or fans) are the axial blowers and centrifugal blowers. In a centrifugal blower, the impeller blades move the air by centrifugal force, literally throwing the air out of the impeller periphery thereby creating suction inside the wheel. There are several types design used for centrifugal blower impellers. Impeller blades can be radial tip, forward curved and backward curved. A survey done in local fabrication workshops show that most fabricated blowers have radial tip blade and have blades ranging from 4 to 8. The air mass flow rate of a blower is dependent on the several parameters. It is directly proportional to the width of the impeller and to the square of the radius of an impeller. Literature does not show the concrete relationship between the number of impeller blades and blower performance like flow rate, pressure and power consumption. However some works had proposed empirical formulae for determining the number of impeller blades. Authors [1] have reported various empirical equations for estimating number of impeller blades of a centrifugal fan. Authors [2] determined the effect of number of impeller blades of a centrifugal pump. They used numerical simulation and experimental verification. The head were found to increase when the number of blades was increased from 4 to 7. Similar results were reported by other researchers [3]. Authors [4] noted an increase in head and decrease in efficiency upon increasing number of blades from 7 to 9. These results are not necessarily applicable for centrifugal blowers. Authors in [5] used numerical analysis and experimental data to determine the effect of blade number on the performance of a centrifugal fan. Both flow rate and power consumption increased with an increase in blade number. According to their work, there is a certain blade number which gives maximum efficiency.

2. Methods and Materials

A blower was fabricated with five (5) interchangeable impellers of 4, 5, 6, 7 and 8 blades respectively. One of impeller design (with six blades) used in the experiments is shown in Figure 1. All the impellers had the same dimensions, that is, radius and width, and there were fabricated from 2 mm thick mild steel sheet. The blower was tested with three speeds. Tachometer was used to measure blower shaft speed. In each of the speeds all the five impellers were tested while measuring air volume flow velocity, line voltage and current. For each speed and number of impeller blades, the air volume flow rate and power consumption were computed. Clamp meter were used to measure line currents and line voltages.

The first speed were obtained from a variable speed motor while the other two were separately obtained from different motor using star and delta connections respectively. This method was chosen just because of its convenience in implementing in the laboratory. The blower speeds used were 580 rpm, 1496 rpm and 2990 rpm.

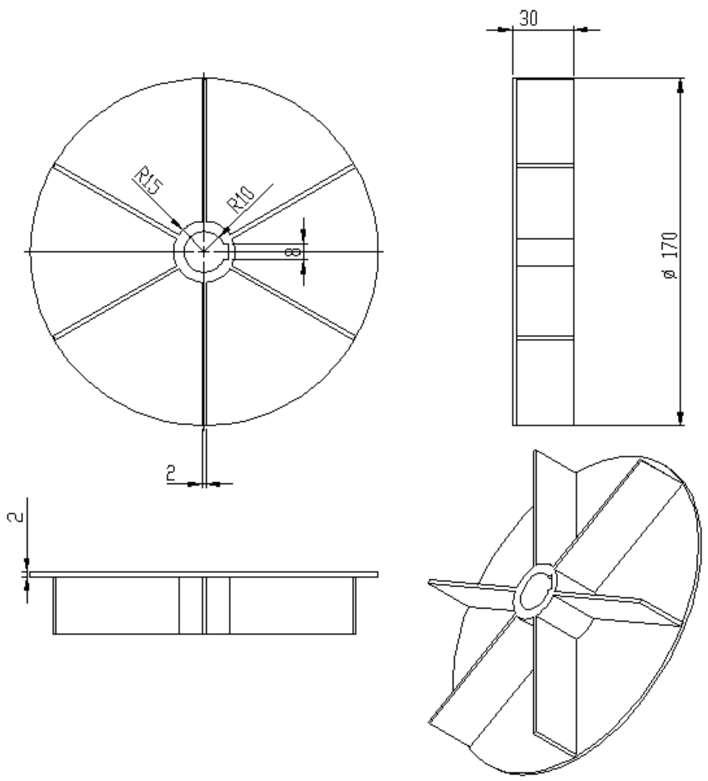

Figure 1: An impeller with six blades

3. Results

Experimental results are shown in Table 1 and Table 2.

Results show that significant increase in flow rate is obtained by increasing blower speed as compared to increasing number of blades. For example increasing blower speed from 1496 rpm to 2990 rpm (roughly doubling) increases flow rate by more than 80% while increasing number of blades from 4 to 8 (doubling) increases flow velocity from 13 to 15.5 m/s (19.2 % increase for speed of 2990 rpm); from 7.7 to 9.2 m/s (19.4 % increase for speed of 1496 rpm); and from 3.5 to 4.2 m/s (20 % increase for speed of 580 rpm). Furthermore, experimental results indicate that air flow tend to increase linearly against blower speed (Figure 3). The results suggest that effect of increasing number of blades on air flow rate is consistent and is less dependent on blower speed.

4. Discussion

The results show that both aspects can be used in design optimization though increasing the number of blades can be applied when fine tuning the design to adjust the blower output within 15-20% of the flow rate without altering blower dimensions including the width and radius of the impeller. However the nominal flow rate can be established from blower speed and dimensions. Both approaches i.e. varying the number of blades and blower speed have an advantage that they can be achieved without a change in overall blower dimensions.

Regarding power consumption, results show that there is a general slight increase in the power consumption when the number of blades increases. The increase might be due to increase in inertia load due to increase in the number of blades and a change in air flow dynamics. Maximum power variation for 2990 rpm speed was about 3% and almost the same for 1496 rpm speed. This suggests that higher efficiencies are associated with higher number of blades than low number of blades. These results can be very applicable in design or redesign of fabricated blowers where in many cases impellers with blades ranging from 4 to 8 are made. In this experiment, difficulty in maintaining consistent and most central position of measuring air flow with anemometer might have contributed to some errors in the results. In fact an anemometer was held by hand during measurements.

The limitations of this experimental work includes: Air flow characteristics, like turbulence, cannot be captured by this technique apart from velocity magnitudes; limited range of number of impeller blades hence results being not necessarily applicable for large number of impeller blades e.g. 30 and lastly the work has not been able to develop mathematical or empirical relationship that takes into account the number of impeller blades.

Table 1: Air flow rate as a function of impeller blades

Blower speed (rpm)	Number of Blades, n	Velocity, V(m/s)	Flow Rate, Q = AV (m^3/s)
580	4	3.5	0.0182
	5	3.8	0.01976
	6	3.6	0.01872
	7	3.9	0.0203
	8	4.2	0.02184
1496	4	7.7	0.04004
	5	7.9	0.04108
	6	8.1	0.04212
	7	8.3	0.04316
	8	9.2	0.04784
2990	4	13	0.0676
	5	13.9	0.07228
	6	14.6	0.07592
	7	15	0.078
	8	15.5	0.0806

Table 2: Power consumption as a function of impeller blades**.**

Speed (rpm),	Number of Blades, n	Line Currents (amps)			Average Line current, I (Amps)	Line voltages (Volts)			Average Line voltage, V	Power consumed, P= √3* VI cosφ (kW)
1496	4	3.23	3.36	3.12	3.237	423	425	420	422.67	3.365276
	5	3.19	3.4	3.14	3.243	423	426	420	423	3.373936
	6	3.28	3.42	3.18	3.293	422	424	420	422	3.418968
	7	3.31	3.46	3.2	3.323	424	427	423	424.67	3.470928
	8	3.26	3.31	3.16	3.243	424	426	422	424	3.380864
2990	4	2.8	3.08	2.87	2.917	421	423	419	421	3.278676
	5	2.87	3.09	3.01	2.99	424	425	423	424	3.384328
	6	2.85	3.09	2.99	2.977	423	425	422	423.33	3.365276
	7	2.78	3.19	2.92	2.963	423	426	421	423.33	3.349688
	5. 8	2.95	3.12	2.87	2.98	423	426	422	424.67	3.379132

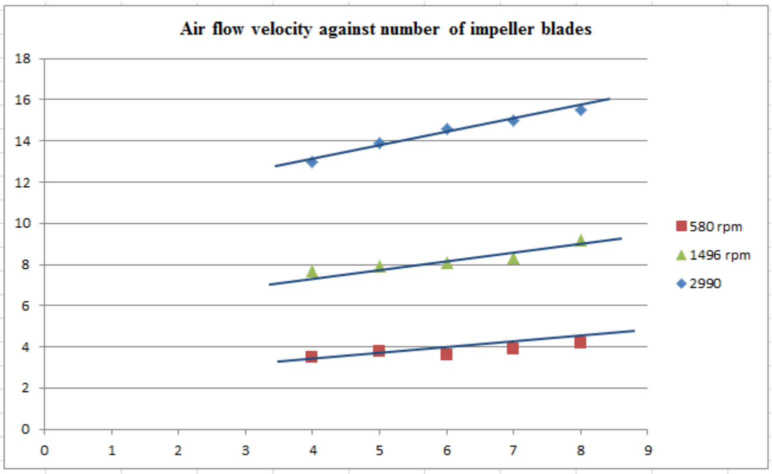

Figure 2: Air flow velocity (m/s) as function of number of impeller blades and speed.

For 5 and 8 number of blades vertical lines were constructed to intersect the three curves and their corresponding flow rates determined from the vertical axis of the graph. The data was put in the Table 3 and Table 4.

Table 3: Air flow velocity as a function of speed (number of blades =5)

Speed (rpm)	Air Flow velocity (m/s)
580	3.5
1496	8.0
2990	13.8

Table 4: Air flow velocity as a function of speed (number of blades =8)

Speed (rpm)	Air Flow velocity (m/s)
580	4.2
1496	8.8
2990	15.7

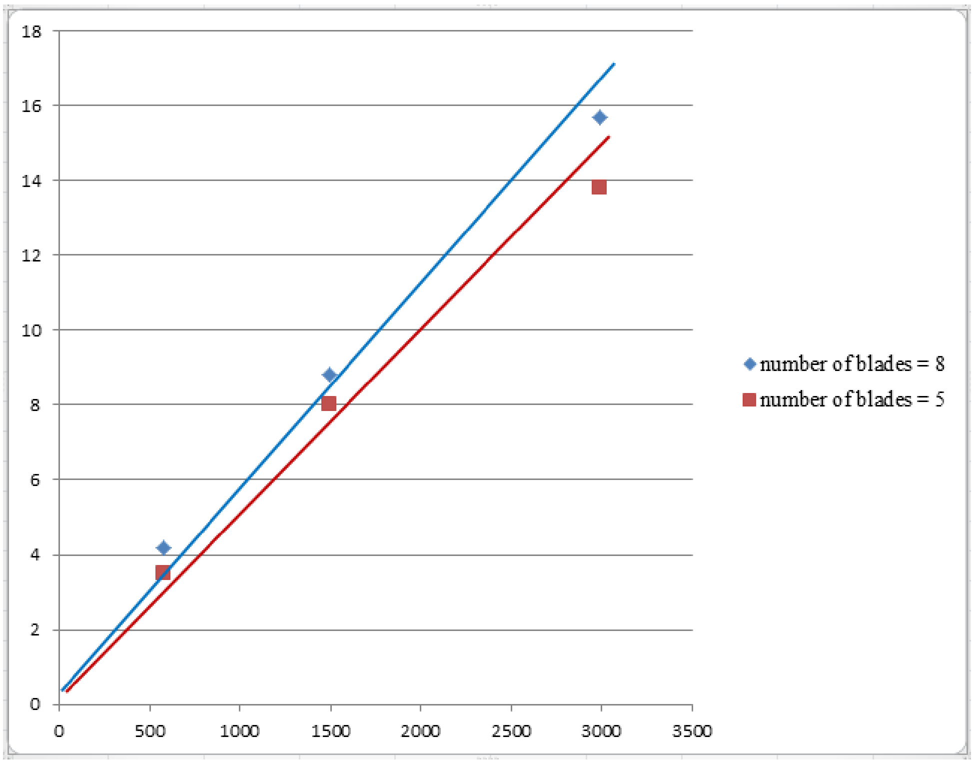

Figure 3: Air flow velcoity (m/s) against blower speed (rpm) for 5 and 8 impeller blades

6. Conclusions and Recommendations

From the experimental results it can be concluded that:

(i) Air flow rate of a blower is a function on numbers of impeller blades.

(ii) However, significant increase in flow rate is obtained by changing blower impeller speed compared to increasing the number of impeller blades.

(iii) Both changing the number of blades and impeller rotational speed can be used to change the air flow rate without changing blower dimensions and that make useful when the size of the blower cannot be changed due to some constraints like space where it is going to be fixed. When size is not a constraint, other parameters e.g. impeller diameter and width can be changed.

(iv) Changing of number of impeller blades can be used to fine tune the design in the context of the required flow rate while changing of blower speed can be used when significant change in flow rate is required.

From the results of this work it is recommended that:

(i) If space to be occupied by a blower is a constraint then changing the number of impeller blades, though it has limited impact is more preferable for improving air flow rate. Also, blower speed can be changed if motor of the same volumetric size with a different speed can be obtained, or if changing the relative sizes of drive pulleys will not require additional space.
(ii) If significant change in flow rate is needed and space is not a constraint, blower speed, impeller width and impeller radius can be changed.
(iii) If the impellers are to be fabricated, this work does not recommend going for more than eight blades as it would make fabrication process costly and inconvenient.

Acknowledgements

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