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Effect of Variation in Impeller Diameters on Performance of Centrifugal Blower

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ABSTRACT: Centrifugal blower is used to deliver the air or gas with an appreciable rise in pressure against the flow resistance. It plays an important role in various industries for air-conditioning systems, furnaces and dust or fume extraction systems. The backward inclined blade centrifugal blower was considered for study and analysis. The inlet and outlet diameters are varied simultaneously and their effect on the performance of centrifugal blower was analysed numerically and experimentally. The results showed the variation in impeller diameters have large effects on the performance of centrifugal blower. Performance parameters flow rate, total pressure and shaft power increases when impeller diameters are increased and decreases when they are decreased but efficiency increases when impeller diameters are decreased.
INDEX TERMS: Centrifugal blower, Inlet diameter, Outlet diameter.

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I. INTRODUCTION

Centrifugal blower uses for the continuous flow of air or gas that industrial blower generate, including combustion, ventilation, aeration, particulate transport, exhaust, cooling, air-cleaning, and drying as per applications. Centrifugal blower have several advantages over other blower types because of their wide operating ranges and high speed capabilities.

The radial difference between enlarged impeller and original impeller should be within 100 mm, if the oulet diameter of impeller is increased by 5 % and 10 % respectively all the performance parameters increased while efficiency decreses. [1] Pressure developed inside the impeller is not uniform and incresers from suction to outlet duct when impeller diameters are varied. Large impeller gives more pressure fluctuation at a monitoring point near the tongue.[2]

The irregular blade spacing of impeller will have same characteristics implies that alteration in blade spacing do not alter the operating characteristics. Decreasing the impeller outlet diameter will gives better efficiency, higher pressure and homogeneous flow field as compared to the other geometrical change in impeller. Pressure fluctuations are higher for large impeller diameters. [3] Patil et al. studied the effect of volute tongue clearan changes on the performance parameter of the centrifugal blower by numerical and experimental analysis. For numerical and experimental investigation four types of casing with variation of 6%, 8%, 10% and 12.5% in volute tongue clearance were used. The back flow at the region near the volute tongue is reduced drastically which cause the total pressure and efficiency to increase. The results clarify that performance parameters increase with decrease clearance. [4]

As the diffusion of flow is highly complex in centrifugal blower operation, it is necessary to design and develop the geometry of impeller and casing to reduce the flow losses significantly. The performance of centrifugal blower is mainly on design parameters of impeller, by changing some geometrical characteristics of the centrifugal impeller blower has more efficiency.[5] Jayapragasan.C.N et al. made the study on optimization of the alternative blower of travelling cleaner of radial type using CFD. The experiments were carried out for different fan outlet diameters which were 170mm, 180 mm, 190 mm and 200 mm while the different fan blade angles were 60º, 70º, 80º and 90º and finally the different number of blades being 6, 8, 10 and 12. Taguchi orthogonal array method has been implemented and optimum design was found.[6]

Tahsin Engin et al. designed and fabricated three semi-open centrifugal fan impellers using ceramic materials to provide high resistance to temperature. Results shows that use of simple impeller geometries of ceramic materials were less sensitive to the varying tip clearance. Variables affecting performance due to tip clearance found to be impeller specific speed, blade exit angle. [7] O. P.

Singh et al. investigated the effect of geometric parameters of a centrifugal fan with backward- and forward-curved blades. Increase in the number of blades increases the flow coefficient and efficiency due to better flow guidance and reduced losses [8]

Sheam-Chyun Lin et al. comprehensively analyzed performance for backward inclined centrifugal fan through a combined experimental and numerical approach. The numerical visualization of flow-field characteristics provides significant information to improve the inner flow patterns for designers. According to the results of flow visualization, two modification alternatives are performed numerically to effectively reduce the reverse flow patterns and successfully enhance the fan performance.[9]

In this work, the numerical and experimental analysis was carried out on centrifugal blower with variation in in the impeller diameters. The different performance parameters i.e. flow rate, total pressure, efficiency are considered for performance analysis. The impeller inlet and outlet diameter are increased to 5 % and 10 % and decreased to 5 % and 10 % respectively for numerical analysis. For experimental analysis impeller with 5 % increase and decrease in impeller diameters are manufactured. Performance analysis of centrifugal blower is done by analyzing the variation in performance parameters with different impeller diameters.

II. CENTRIFUGAL BLOWER DETAILS

The centrifugal blower setup is specified according to IS: 4894-1987. Main components of original centrifugal blower contain casing, impeller with blades, inlet duct and outlet duct. In this paper original centrifugal blower is indicated by “0”. The various parameters of original centrifugal blower are given in Table 1.

Table 1: Specification of original centrifugal blower

Sr. No.	Parameters	Dimensions
1	Impeller Outlet Diameter	280 mm
2	Impeller Inlet Diameter	140 mm
3	Number of Blades	12
4	Impeller Width	20 mm
5	Impeller Blade Type	Backward Inclined
6	Casing Width	65 mm
7	Impeller Blade Angle	30^o
8	Motor speed (RPM)	2800

Fig. 1 shows the three impeller with original and modified impeller diameters with 5 % increment and decrement in impeller diameters.

(a) (b) (c)

Fig. 1. Impeller of (a) centrifugal blower A_1, (b) centrifugal blower O, (c) centrifugal blower B_1

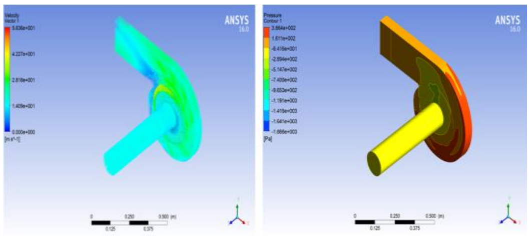
The original centrifugal blower was named as centrifugal blower O and centrifugal blower with 5 % increment and decrement in impeller diameters was named as centrifugal blower A_1 and centrifugal blower B_1 respectively.

III. NUMERICAL ANALYSIS

For numerical analysis of centrifugal blowers ANSYS Fluent 16.0 software was used. The three dimensional model of centrifugal blower having only casing and impeller were first created in Solid Works 2015 software. Further modification such as modeling of inlet duct, outlet duct and passages were done in Design Modular of ANSYS Fluent. Rotating zone and stationary zone were solved by Multiple Frames of Reference in rotating reference frame and stationary reference frame respectively. A rotating reference frame was set to impeller wheel with rotational speed and other parts were referred as stationary frame. In meshing process, tetrahedral elements were selected for the elements of rotating impeller and hex elements were defined for the inlet duct, outlet duct and casing of centrifugal blower. Meshing size of element was taken as 5 mm.

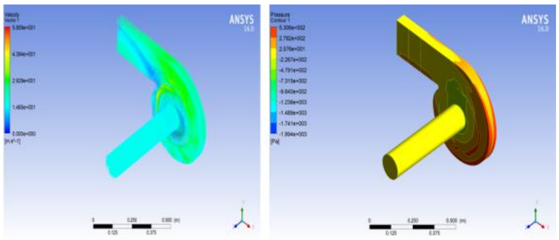
The flow of air inside centrifugal blower is generally turbulent flow. Hence to solve 3D Navier-Stokes equations standard k-epsilon model was selected. Here k represents turbulent kinetic energy and epsilon denotes turbulent dissipation. Inlets, outlets and impeller of original and modified centrifugal blowers were taken as boundary conditions. The atmospheric pressure was defined as the inlet boundary condition at the entrance of the inlet duct. Also outlet boundary condition was set as atmospheric pressure at the exit of outlet duct. Rotational motion was given to impeller and considered as moving wall. Sufficient iterations were given until solution was converged.

When solution is converged, numerical results were obtained in vector plots, counter plots and streamlines. Velocity vector and pressure counter plots for centrifugal blowers 0, A and B are shown in Fig. 2 to Fig. 4 respectively.



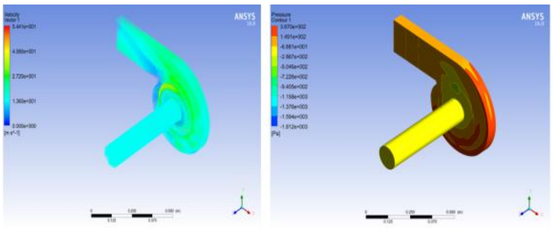
Velocity Counter Pressure Counter

Fig.2. CFD result of centrifugal blower O



Velocity Counter Pressure Counter

Fig.3. CFD result of centrifugal blower A_1



Velocity Counter Pressure Counter

Fig.4. CFD result of centrifugal blower B_1

IV. EXPERIMENTATION

A standard test setup for the experimental analysis of centrifugal blower according to IS: 4894-1987 was developed. Experimentation was carried out on original and modified centrifugal blowers. Photograph of experimental setup of blower is shown in Fig. 8. An electric motor of 0.5 HP with three phase was used to drive the centrifugal blower. The input of four way inlet and one way outlet valve was connected to inlet duct and also output of this valve was connected to one limb of the manometer. Three U-tube manometer was used to measure flow rate and pressure at set-points on inlet duct and outlet duct which are connected through four side tapping's. First at the entrance of the inlet duct to measure static pressure which later used to calculate flow rate as, second at exit side of inlet duct, for the measurement of average static pressures and third at the outlet of the blower to calculate outlet total pressure. Dimmer-stat was used to vary voltage associated to which different speed can be achieved. The input power of current and voltage was measured by analogue ammeter and voltmeter as shown in Fig.5.

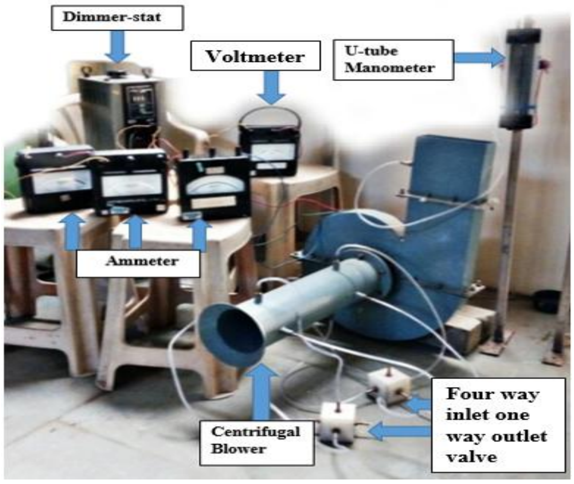


Fig.5. Photograph of the experimental setup

V. RESULT AND DISCUSSION

The modifications done in impeller of centrifugal blower have affected performance parameters like flow rate, totalpressure, shaft power, blower efficiency. Variations of numerical results of operating parameters at different operating speed of modified centrifugal blowers and original centrifugal blower shown in Fig.6 to Fig.9.

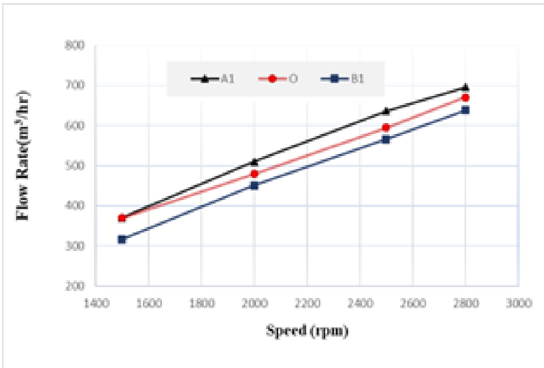


Fig.6. Variation in flow rate at different operating speed for three blowers

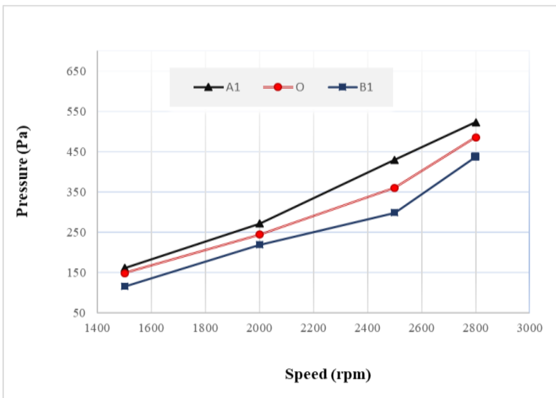


Fig.7. Variation in pressure at different operating speed for three blowers

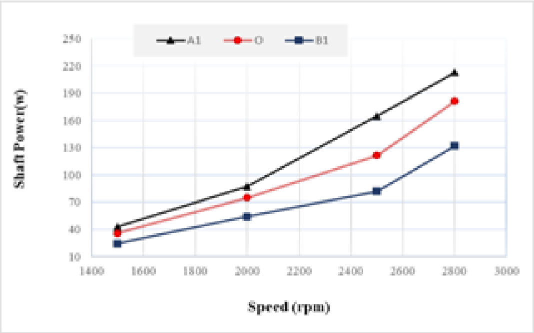


Fig.8. Variation in shaft power at different operating speed for three blowers

Fig.6 to Fig.8 shows that flow rate, pressure and shaft power is maximum for blower A i.e. for 5% increment in impeller diameters. Flow rate, pressure, shaft power occurred to be minimum in modified centrifugal blower B i.e. for 5% decrement in impeller diameters while for original blower all three parameters are is in between blower A and B for different speed rates.

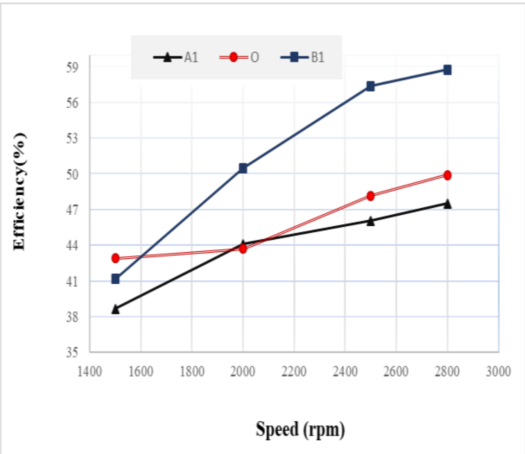


Fig.9. Variation in efficiency at different operating speed for three blowers

Fig.9 shows that the efficiency is maximum for blower B i.e. for 5% decrement in impeller diameters and it occurred to be minimum in modified centrifugal blower A_1 i.e. for 5% decrement in impeller diameters while for original blower is in between blower A and B for different speed rates.

Comparision of numerical and experimental results of original and modified centrifugal blowers at 2800 rpm for flow rate, total pressure, blower efficiency and discharge head are shown in Fig. 10 to Fig. 13 respectively.

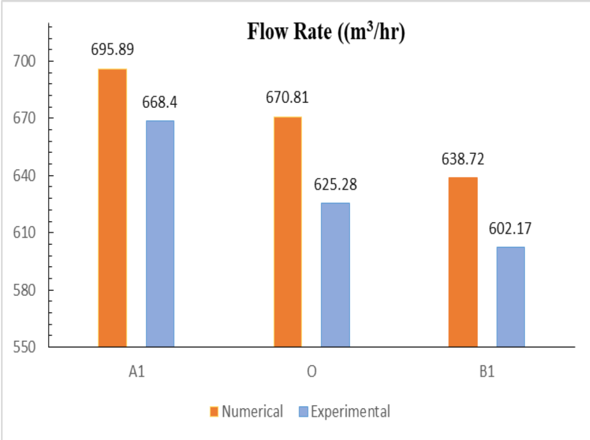


Fig. 10. Numerical and experimental results for flow rate

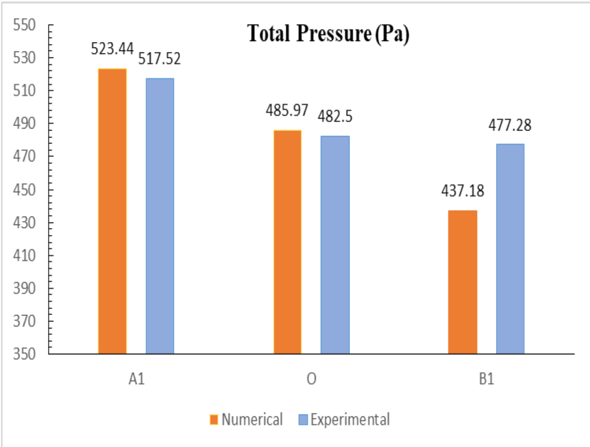


Fig. 11. Numerical and experimental results for total pressure

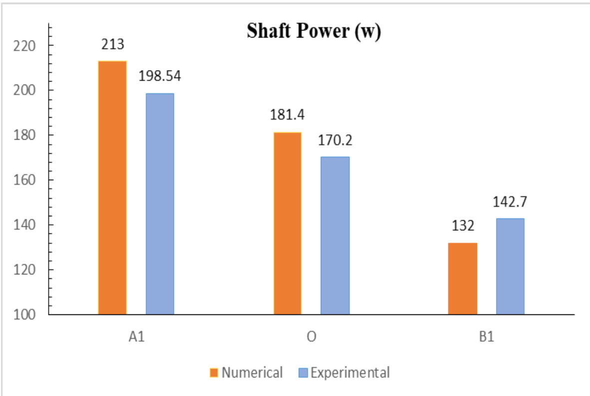


Fig. 12. Numerical and experimental results for shaft power

The operating parameters of centrifugal blower i.e flow rate, pressure and shaft power increses when impeller inlet and outlet diameters areincresed and decresed when it is decresed. Incement and decrement in impeller diameters are directly proportional to these operating parameters of centrifugal blower.

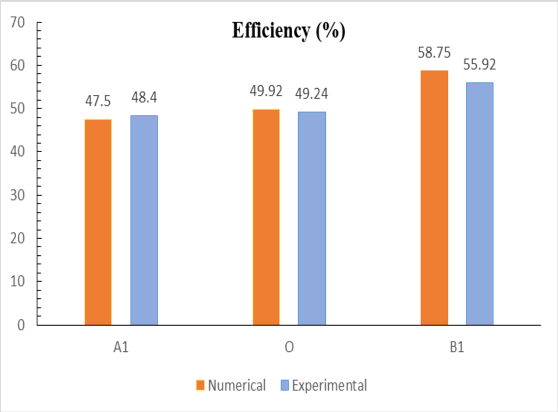


Fig. 13. Numerical and experimental results for efficiency

The efficiency increses when impeller inlet and outlet diameters are decresed and dectreases when diameters are increased. Incement and decrement in impeller diameters are inversaly proportional to the efficiency of centrifugal blower.

Comparison of numerical results with experimental results is done for validation purpose from Table 2 toTable 4.

Table 2. Comparison of numerical and experimental results of original blower O

Performance parameters	**Numerical**	**Experimental**	**Deviation in results**
Flow Rate (m^3/hr)	670.8174	625.2876	7.28 %
Total Pressure (Pa)	485.9755	482.5043	0.719 %
Blower Efficiency (%)	49.92	49.24	1.38 %

Table 3. Comparison of numerical and experimental results of modified centrifugal blower A_1

Performance parameters	**Numerical**	**Experimental**	**Deviation in results**
Flow Rate (m^3/hr)	695.8976	668.4029	4.11 %
Total Pressure (Pa)	523.4438	517.5276	1.14 %
Blower Efficiency (%)	47.5	48.4	1.85 %

Table 4. Comparison of numerical and experimental results of modified centrifugal blower B_1

Performance parameters	**Numerical**	**Experimental**	**Deviation in results**
Flow Rate (m^3/hr)	638.7260	602.1725	6.07 %
Total Pressure (Pa)	437.1868	440.1850	0.68 %
Blower Efficiency (%)	58.75	55.92	5.06 %

The deviations occurred between numerical results and experimental results are within 8 %, hence it is found that numerical results have good agreement with experimental results. Hence it confirms validity.

VI. CONCLUSION

This study was conducted to analyse the peformace of centrifugal blower for different impeller diameters. The performance parameters flow rate, total pressure, shaft power increased by 3.73 %, 7.71 %, 17.42 % when impeller diametrs are incresed by 5 % and they are decreased by 5.02 %, 11.15%, 37.42 % when impeller diameters are decreased by 5 % . The flow distributed is less uniform in volute which causes volute loss leadind to lower efficiency when impeller diameters are incresed so efficiency is decreased by 5 % when diameters are incresed and efficiency increased by 15.02 % when diameters are decreased as compared to original centrifugal blower .The pressure distribution for small impeller blower is more uniform in the volute part than the bigger impeller blower and the area of high pressure region in the volute is larger for small impeller blower. Large impeller blower gives more pressure fluctuation than small impeller blower and velocity distribution inside the inlet diameter is uniform having small rate while in casing area velocity distribution is not uniform having higher rate.

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