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Design and Experimental Investigation of Forward Curved, Backward Curved and Radial Blade Impellers of Centrifugal Blower

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ABSTRACT

The centrifugal blowers have been widely investigated because of their extensive applications in ventilation and processing at industries. The performance of the centrifugal blowers mainly depends on the design parameters of the impeller blades used. In industries, various design parameters are assigned to each type of blade in order to obtain maximum efficiency from each blade. But the effective use of blower can be obtained from the impeller blades with same material and same design parameters. This paper deals with the design and experimental investigation of the centrifugal blower impellers with same design parameters in order to optimize the performance of centrifugal blower.

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INTRODUCTION

A blower is a machine giving compression ratio between 1.07 and 2.5 and is not water cooled as the added expense of the cooling system is not justified in the view of the relatively slight gain in efficiency at these pressures. Centrifugal blower is a rotodynamic type unit. A blower used to remove gases from a system is known as exhauster. If the pressure at the inlet is above atmospheric pressure the blower is termed as a booster or a circulator. Blowers are used as exhausters in coke ovens and as boosters to transfer coke oven gas from reservoir to point of use. Blowers are also used for cleaning castings, motor windings, operating pneumatic tools, scavenging dead gases out and introducing fresh charge into the cylinders of large diesel engines. They are also used as super charges in aeroplane engines. The centrifugal blowers provide air for ventilation and other industrial processing requirements. Blowers generate pressure to move air against a resistance caused by ducts, dampers or other components. They use the kinetic energy of the impeller blades to increase the pressure of the supplied air. Hence their efficiency depends on the design of impeller blades. In current scenario, industries assign different design parameters and materials to each blade in order to obtain maximum performance from each blade. The need is an effective design for the impeller blades with same design parameters that gives an improved performance. An attempt was made to analyse the performance of all types of impeller blades. There are three types of blades generally used for the construction of centrigufugal blowers, which are discussed in detail.

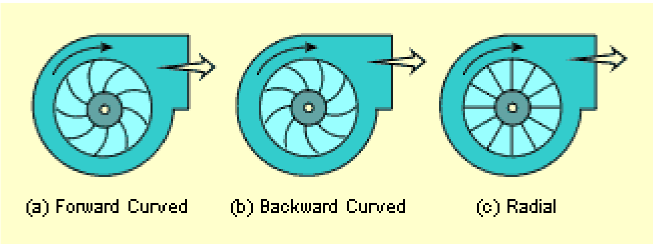

Fig. 1: Impeller blades of a blower.

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Blowers can achieve much higher pressures than fans, as high as 1.20 kg/cm^2. They are also used to produce negative pressures for industrial vacuum systems. The centrifugal blower and the positive displacement blower are two main types of blowers, which are described below. Centrifugal blowers look more like centrifugal pumps than fans. The impeller is typically gear-driven and rotates as fast as 15,000 rpm. In multi-stage blowers, air is accelerated as it passes through each impeller. In single-stage blower, air does not take many turns, and hence it is more efficient. Centrifugal blowers typically operate against pressures of 0.35 to 0.70 kg/cm^2 , but can achieve higher pressures. One characteristic is that airflow tends to drop drastically as system pressure increases, which can be a disadvantage in material conveying systems that depend on a steady air volume. Because of this, they are most often used in applications that are not prone to clogging.

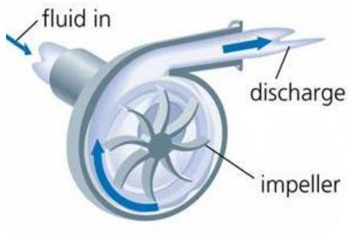

Fig. 2: Direction of air flow in blower.

The flow pattern of the air inside a blower is shown in Fig. 2.

Literature Review:

XinweiShu *et al* (2009) showed how the performance can be improved by properly reshaping its blade profileusing a developed multipoint optimisation approach. The superior performance of the optimised impeller blade is demonstrated by comparing the performance improvement with that of the original blade. They conducted test on the forward blade. Li Chunx *et al* (2009) studied that the efficiency of the backward blade is greater than that of radial and forward blades. They also found that radial and forward blades have the same power characteristics.Singh O. P. *et al* (2011) investigated the effect of geometric parameters of centrifugal blower with forward and backward curved blades. The results showed that the blower with different blades would show same performance under high pressure co-efficient. Li Chunx *et al* (2009) have stated that the efficiency of backward blade is greater than that of the other blades. Pham Ngoc Son *et al* (2011) conducted performance test on centrifugal blower and they studied the effects of bell mouth geometries on the flow rate of centrifugal blowers. Zhang Bin *et al* (2011) performed a test on low specific speed centrifugal blower and optimized the blade design. Jie Jina Ying Fan *et al* (2012) made design and analysis on Hydraulic model of the ultra - low Specific-speed centrifugal pump using software. M.H. Shojaeefard *et al* (2012) numerically studied the effects of some geometric characteristics of a centrifugal pump impeller that pumps a viscous fluid. Singh O. P. *et al* (2012) have found that efficiency of all blades remains the same. Chen-Kang Huang *et al* conducted performance analysis and optimized design of backward curved airfoil centrifugal blowers and they optimized the backward curved blade. Sun-Sheng Yang *et al* conducted performance on centrifugal blower theoretically, numerically and experimentally. Choon-Man Jang *et al* (2013) analysed the effect of design variables on the performance of centrifugal blowers. They found that the casing height of the design variable is more sensitive on the function of efficiency compared to that of casing width.

Specifications of the Blower:

The specifications of the blower used for investigation is given in table 1.

Table 1: Specifications of the blower.

Description	
Impeller diameter	500 mm
Power	7.5 HP (AC 3 phase)
Inlet diameter	200 mm
Delivery size	125 mm*80 mm
Energy meter constant	1600 imp/kW-hr
Motor	SCIM

Design of Blades:

The design of available (forward) blade was measured manually. From the obtained values, the velocity triangle of forward blade was drawn, from which corresponding velocities were obtained. By using the calculated values and corresponding inlet and outlet velocity triangles, the dimension of other blades have been found. The backward and radial blades are fabricated to the dimensions obtained from the design procedure. The dimensions are summarised in table 2.

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Table 2: Parameters of Impeller Blades.

Design parameters	Forward blade	Backward blade	Radial blade
Outside Diameter	500 mm	500 mm	500 mm
Number of blades	14	14	14
Blade thickness	3 mm	3 mm	3 mm
Blade width at inner rim	47 mm	47 mm	47 mm
Blade width at outer rim	18 mm	18 mm	18 mm
Inlet vane angle	38^0	26^0	8^0
Outlet vane angle	52^0	64^0	90^0
Axial length	130 mm	130 mm	130 mm
Material	Medium Carbon Steel	Medium Carbon Steel	Medium Carbon Steel

Experimental Investigation:

The manual experiments have been conducted on the blades in order to determine their performance. Each blade was tested 3-4 times for the consistency purposes and the results were interpreted. The procedure for experimental testing is explained below. First, the delivery valve was fully closed (full load). The blower was allowed to run at rated speed. Then, the manometer deflection which indicates the difference between delivery and suction pressure was noted down along with the manometer deflection from the venturimeter connected in order to measure the flow rate. The time taken for 20 impulses of energy meter and energy meter constant was noted. After each load, the delivery valve was opened by two revolutions and the similar procedure was followed until no load condition (fully open). The readings were noted and their performance was determined.

Comparison of Performance of Blades:

From the calculated values of performance parameters of all the blades, their characteristics were compared, which are shown in Fig.s 3 to 5.

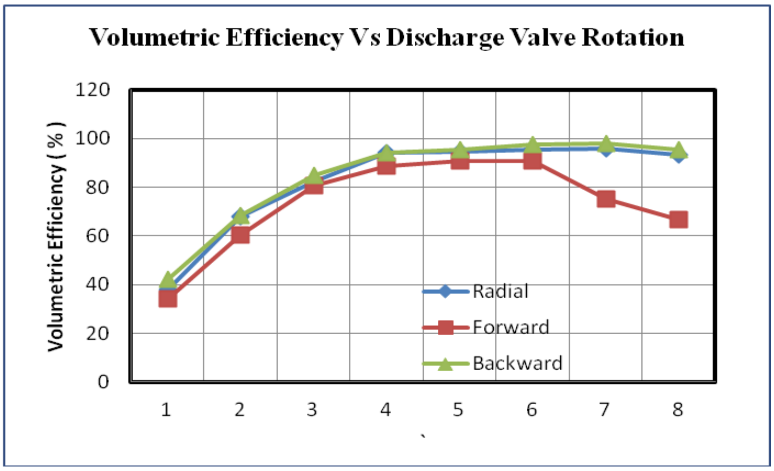

Fig. 3: Volumetric Efficiency Vs Discharge Valve Rotation of all blades.

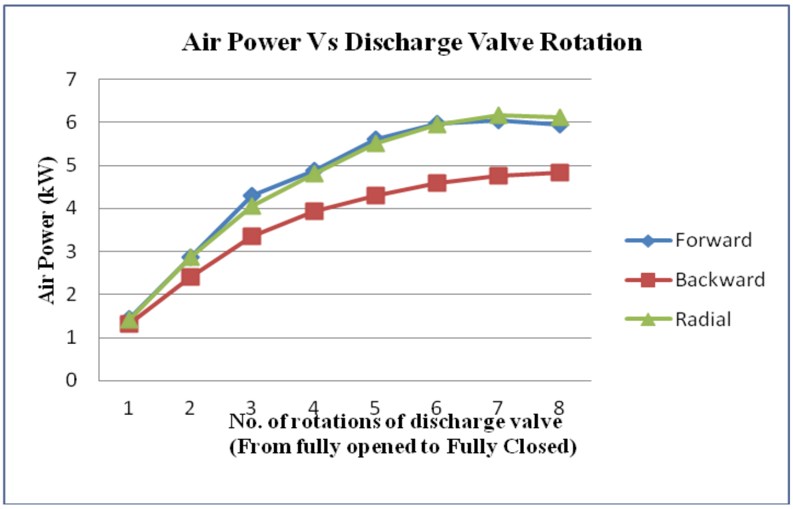

Fig. 4: Air Power Vs Discharge Valve Rotation of all blades.

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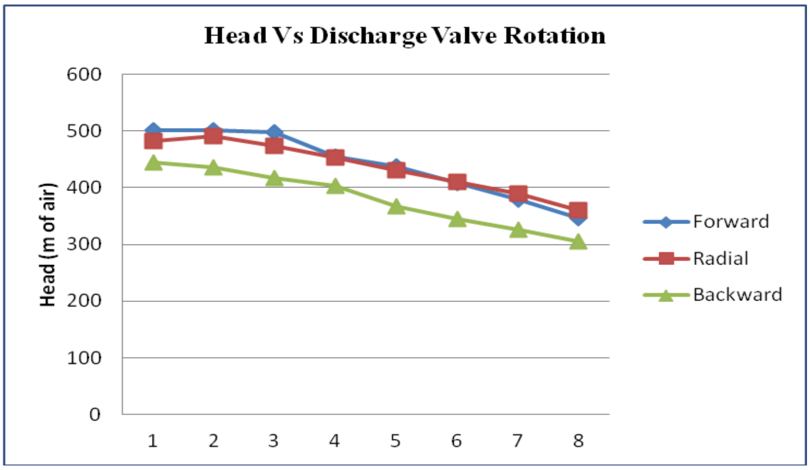

Fig. 5: Head Vs Discharge Valve Rotation of all blades.

RESULTS AND DISCUSSIONS

The following results were made from the curves obtained. The efficiency of the backward and radial blade were found to be increasing gradually with decrease in load and then remained constant on reaching the optimum value. The efficiency of the forward blade was increasing up to its maximum value and suddenly dropped with further decrease in load. The maximum efficiency was obtained from the backward blade at 1/8thload. The air power of all three blades was found to be increasing with decrease in load and maximum air power was utilised by radial blade at 1/8th load. The head developed by the blower decreases with the decrease in load. The head developed does not vary from blade to blade.

Conclusion:

The performance of centrifugal blower mainly depends upon the design parameters of the impeller blades. The efficiency of backward blade was found to be greater than that of the other blades. The efficiency and air power of the blower was found to vary inversely with the load while the head developed varied directly with the load applied. The forward blades exhibited abnormal efficiency characteristics at lower loads. This shows that the forward blades cannot be used at lower loads. At medium loads, the backward blade is most efficient impeller to be used because of its ease to manufacture and higher efficiency.

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