International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-09, Issue-03, June 2023

Experimental Analysis of Centrifugal Blower with Backward, Forward and Radial Curved Vane of Impeller

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Abstract. This paper deals, an experimental analysis for the performance prediction of the centrifugal blower, the various performance parameters are investigated for wide operating speeds and various conditions of valve position. The test rig is equipped to measure suction and delivery pressure heads at inlet and outlet of each component to determine the total pressure head and discharge. The model results show good agreements with experimental results. The results show the blower efficiency for different impellers at given conditions, and it reveals that blower with backward vane is very efficient compared with forward vane, also the diffuser losses increase by increasing mass flow rate while that of volute decreases.

Keywords: Centrifugal Impeller, Venturi Head, Suction Head, Delivery Head, Efficiency.

I. INTRODUCTION

Centrifugal compressors have broad applications in the aerospace, automotive, ventilation and aviation industry, especially when continuous high pressure stream in low flow rate is of interest. Impeller, diffuser and volute casing are the main components of most centrifugal compressors. The impeller helps in directing the air flow and a casing helps to direct the flow of air out toward the edge. The performance of a centrifugal blower mainly depends on the vanes of that impeller. In order to improve component design, a good understanding of the compressor characteristics in-design and off-design conditions is of great importance. Although 3D models are developed for flow field investigation, 1D models which can predict compressor characteristics with low running time and acceptable accuracy is of interest. First attempts of centrifugal compressor modeling lead to recognition of centrifugal compressor loss sources. These sources can be categorized to compressor inlet loss, incidence loss, skin friction loss, clearance loss, recirculation loss, disc friction loss, blade loading loss, diffuser loss and volute loss [1]. Stanitz Developed a 1D loss prediction model for vane less diffuser radial and mixed flow compressors [2]. Galvas introduced a one dimensional model to predict a compressor behavior in off- design condition considering surge and chock region [3]. Conrad et al. proposed a model for a vane-less diffuser centrifugal compressor and investigated all impeller losses by details [4]. Aungier predicted aerodynamics characteristics of an impeller in mean streamline and showed that results are matched with experimental results for turbocharger application with pressure ratio up to 3.5[5]. Daily and Nece investigated impeller disc friction loss and proposed an analytical method for loss prediction and validated the results with experiments. Jansen introduced an analytical method in order to predict velocity profile at impeller outlet. Also Johnson developed a model for predicting losses in vane-less diffuser [8]. After these main and basic attempts, many numerical models were developed in order to predict each compressor component losses using experimental verification. Whitfield and Baines summed up these literatures and introduced a general method to model a centrifugal compressor for characteristic predicting [9]. Different measurement instruments are employed to obtain

 DOI : 10.35291/2454-9150.2023.0137

ISSN : 2454-9150 Vol-09, Issue-03, June 2023

the compressor characteristic curves and also total pressure loss in impeller, vane-less diffuser and volute. Based on experimental validation the best combination of models are selected and used in model. Contribution of each component in efficiency reduction of compressor for different mass flow rates and rotational speed is reported. In this analysis, an experimental study has been carried out to study the performance of centrifugal blower for different types of vanes.

II. EXPERIMENTAL SETUP

2.1. Specifications of Constant Air Blower Test Rig:

This specification covers the general requirements for manufacture, inspection, testing, guarantee and safe door delivery of Centrifugal Air Blower with following specification:

Figure. 1 Constant Air Blower Test Rig

TABLE 1. Experimental Setup Specifications

S. no	Description	Values
1	Type	Centrifugal
2	Medium	Air
3	Capacity	2000 CFM
4	Static pressure	200mm WG @ 20°C
5	Operating Temperature	40°C
6	Sound level	Max. 85db from 1.5m dist.
7	Fan Speed	2880 RPM

To conduct a test on the given blower using forward vanes, backward vanes and radial vanes and determine the blower efficiency at 25%, 50 %, 75% & 100% valve opening position.

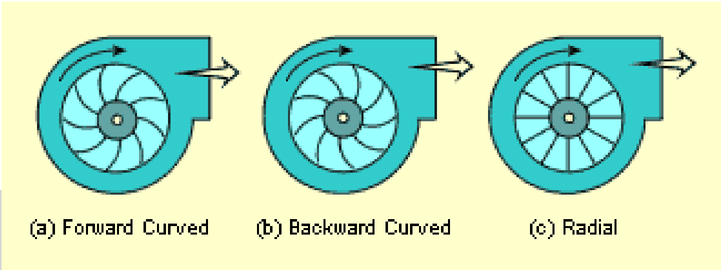

Figure 2 Centrifugal Fan blades

Initially fill the mercury in the Manometer provided for the venturimeter, the levels must be equal, if not remove air blocks. Then Fill water in the manometer provided for pitot tubes, provided on the suction and delivery side. Close the cock connected to the inner pipe of the Pitot tube and leave this column of the manometer open to the atmosphere. Open the cock connecting the static pressure end of the Pitot tube. Close the delivery control valve and start the unit. Note the time taken for 5 revolution of energy meter reading.

Forward vane:

S. no	Valve Position	Motor R.P.M	Venturi Head (M)		Delivery Head (M)		Suction Head (M)		Time for 5 Rev. (Sec)
			h1	*h2*	*h1*	*h2*	*h1*	*h2*	
1	25	2792	0.211	0.186	0.245	0.195	0.245	0.243	16
2	50	2790	0.217	0.179	0.275	0.246	0.246	0.243	15
3	75	2862	0.232	0.174	0.284	0.156	0.244	0.243	11
4	100	2870	0.254	0.172	0.285	0.158	0.243	0.242	10

Radial vane:

S. no	Valve Position	Motor R.P.M	Venturi Head (M)		Delivery Head (M)		Suction Head (M)		Time for 5 Rev. (Sec)
			h1	h2	h1	h 2	h 1	h 2	
1	25	2914	0.19	0.175	0.208	0.165	0.187	0.183	20
2	50	2910	0.20	0.165	0.24	0.135	0.19	0.183	18
3	75	2904	0.205	0.16	0.25	0.123	0.19	0.18	17.6
4	100	2900	0.255	0.16	0.253	0.123	0.19	0.18	17.5

DOI : 10.35291/2454-9150.2023.0137

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Backward vane:

S. no	Valve Position	Motor R.P.M	Venturi Head (M)		Delivery Head (M)		Suction Head (M)		Time for 5 Rev. (Sec)
			h1	h2	h1	h2	h1	h2	
1	25	2984	0.112	0.11	0.83	0.73	0.89	0.87	45.68
2	50	2988	0.115	0.108	0.87	0.69	0.89	0.87	32.48
3	75	2994	0.119	0.10	0.89	0.68	0.89	0.87	30.40
4	100	2998	0.12	0.10	0.91	0.65	0.89	0.88	27.18

III . CALCULATIONS

a) Delivery Head ($\boldsymbol{h_d}$) = ($\boldsymbol{h_1}$ - $\boldsymbol{h_2}$) * (ρ_w / ρ_a - 1)

b) Suction Head ($\boldsymbol{h_s}$) = ($\boldsymbol{h_1}$ - $\boldsymbol{h_2}$) * (ρ_w / ρ_a - 1)

c) H = $\boldsymbol{h_s} + \boldsymbol{h_d}$

Let, Q = $a_1 a_2 (\sqrt{2gh}) \sqrt{a_1}\,^2 - a_2\,^2$

$\because$ $a_1 = \pi /4 * d^{\,2} = \pi /4 * (0.1)^{\,2} = 0.078m^2$ $\because$ $a_2 = \pi / 4 * d^{\,2} = \pi /4 * (0.06)^{\,2} = 0.0028m^2$

h = ($\boldsymbol{h_1} - \boldsymbol{h_2}$) venturi * [$\rho_{hg} / \rho_a$ - 1]

d) Q = 0.21$m3$/sec

e) Power Output (Po) = ρ_a * Q * g * H

f) Power Input (P_i) = 3600 * n / ϵ * t , in Watts

g) Blower Efficiency (η_{blower}) = (Po Pi) * 100

Forward vanes:

S.No	Valve position (%)	Delivery head in (m)	Suction head in (m)	Total Head in (m)	P_i	P_o	η_{blower}
1	25	41.61	1.66	43.27	4687.5	106.96	2.28
2	50	24.13	2.49	26.53	5000	185.229	3.7
3	75	106.53	0.83	107.36	6810	404.4	5.93
4	100	105.70	0.83	106.53	7500	464	6.18

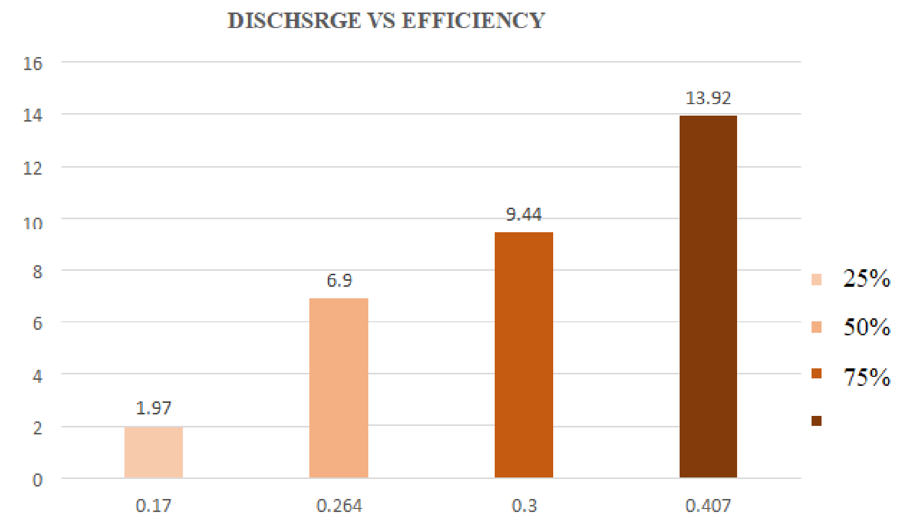

Figure 3. Discharge Vs Efficiency for Forward Vanes

We can see from the above graph “Discharge vs Efficiency” There is increase in efficiency and discharge from position to position at different valve position.

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RADIAL VANES:

S.no	Valve position (%)	Delivery head in (m)	Suction head in (m)	Total Head in (m)	P_i	P_o	η_{blower}
1	25	35.79	3.329	39.119	3750	74.14	1.97
2	50	87.39	5.82	93.215	4166.66	282.6	6.9
3	75	105.7	8.32	114.2	4261.36	402.67	9.44
4	100	105.56	8.12	113.68	4285.71	596.68	13.92

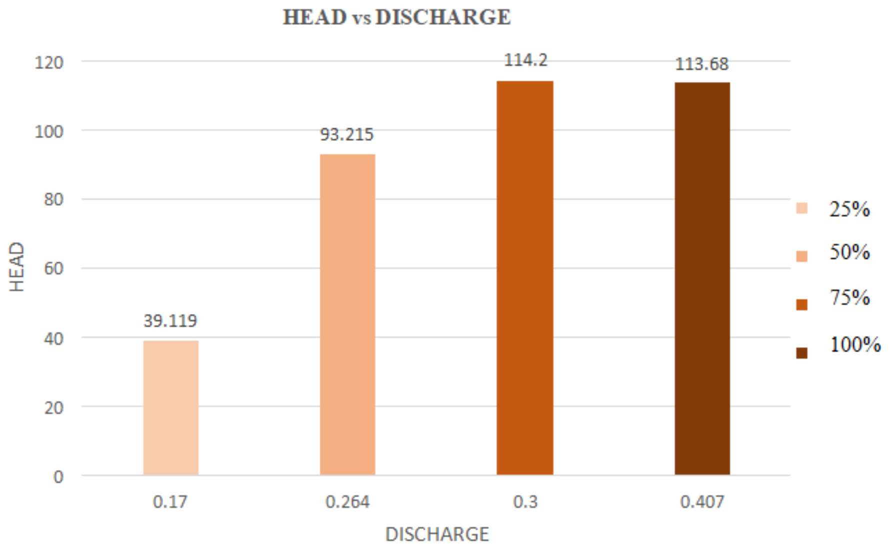

Figure 4. Discharge Vs Efficiency for Radial Vanes

As we can see from the above graph "head vs Discharge" Discharge is gradually increases and head is fluctuating at different valve position.

BACKWARD VANES:

S.No	Valve position (%)	Delivery head in (m)	Suction head in (m)	Total Head in (m)	P_i	P_o	η_{blower}
1	25	83.23	16.64	99.87	1641.85	74.97	4.56
2	50	116.52	16.64	133.16	2309.1	186.53	8.07
3	75	174.79	16.6	191.39	2467.10	410.05	16.62
4	100	216.4	8.23	224.9	2759.3	492	17.83

 DOI : 10.35291/2454-9150.2023.0137

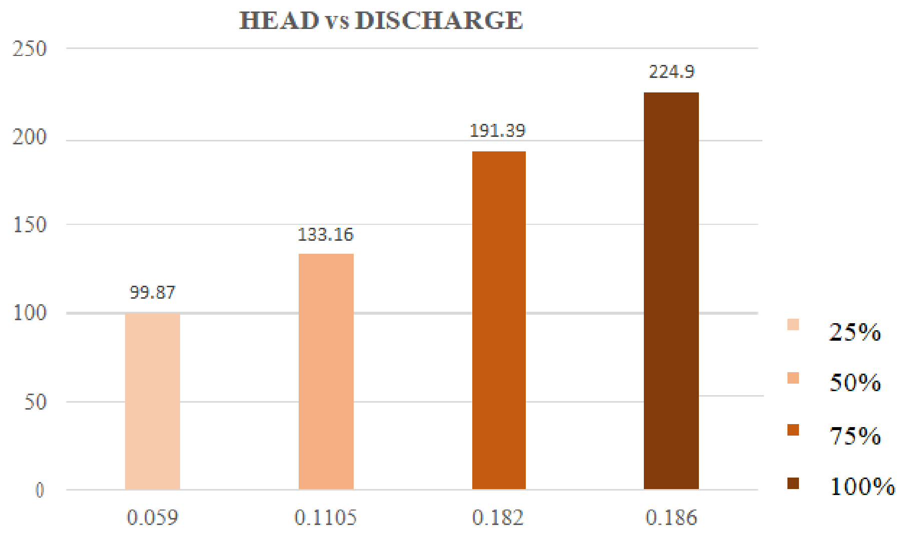

Figure 5 Discharge Vs Efficiency for Backward Vanes

We can see from the above graph "head vs Discharge" Discharge is gradually increases and head is fluctuating at different valve position.

Analysis of different vanes at different valve position:

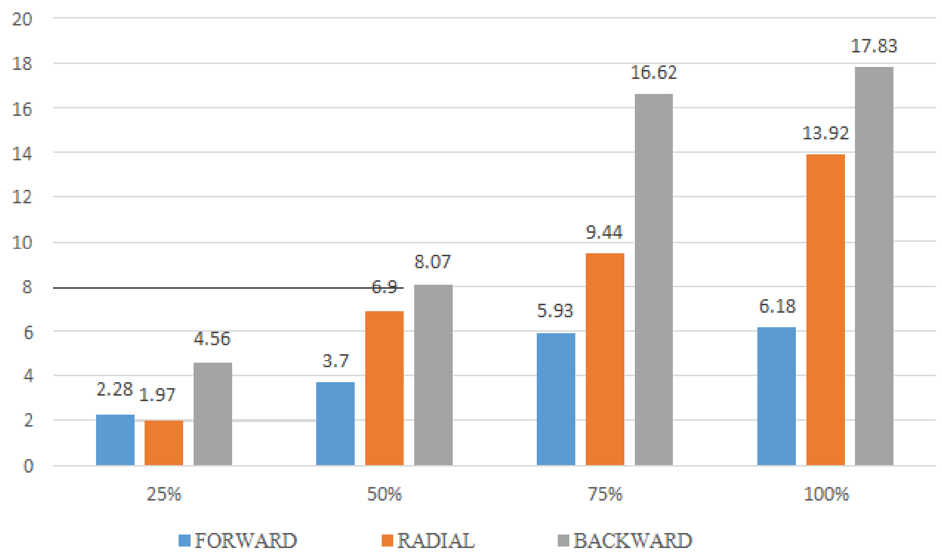

Figure 6. Discharge Vs Efficiency comparison graph for Forward, Backward and Radial Vanes

IV. RESULT AND DISCUSSION

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 utilized 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.

The blades attached to the interior of impeller drastically affect by efficiency on the blower. The straight blades imparts the equal forces out as rotational while the backward curved blades reduce the rotational force on the fluid so the reason backward curved vanes are most efficient.

The overall efficiency of centrifugal blower is the product of three individual efficiencies such as mechanical, volumetric and hydraulic.

- The mechanical and volumetric losses are largest factor in impeller of a blower.
- Factors affecting deviation from attainable efficiency are surface roughness, internal clearance, mechanical losses such as related to bearing, lip seals, mechanical seals and packing, high suction specific speed, impeller losses.

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- Install fixed blades to straighten the airflow to help to reduce your energy loss from 5 to 15%.

V. CONCLUSION

The performance of a centrifugal blower mainly depends upon the design parameters of the impeller blades. The efficiency of the 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 the most efficient impeller to be used because of its ease to manufacture and higher efficiency.

- In forward curved vane have large volume discharge and pressure rise for the demand of high power however the curved vanes are unstable for off design operation conditions.
- Radial curved vanes are preferred for dust- laden fluids due to their shape solid particles are not stuck and deposits on the blades surface.
- Backward curved vanes are very efficient and dropping power characteristics makes them suitable for better off design performance.
- In theoretical analysis in forward vane efficiency 30-60%.
- In theoretical analysis in radial curved vane efficiency 30-70%
- In theoretical analysis in backward vane efficiency 30-80%.

Due to mechanical losses, hydraulic losses, electrical losses, damping vibrations, slight deflections in blades.

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 DOI : 10.35291/2454-9150.2023.0137