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Research Paper :

Performance evaluation of centrifugal flow mist blowers in laboratory

D.D. TEKALE, A.R. MANTRI AND S.C. KAWADE

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See end of the article for authors' affiliations

Correspondence to:
D.D. TEKALE
Department of Agricultural Engineering, Maharashtra Agricultural University, PARBHANI (M.S.) INDIA

ABSTRACT

Experiments were conducted in laboratory to study the performance of three centrifugal flow mist blowers based on air velocity, air discharge, efficiency and power requirement. These blowers B_1, B_2 and B_3 gave more air velocity, air discharge and efficiency at 2450, 2000 and 1600 rpm, respectively and power required to run these blowers was 28.4 kW, 19.9 kW and 4.4 kW, respectively. The suitable tractors to operate these blowers in the field were 45 hp, 35 hp and 18 hp, respectively.

Key words : Performance evaluation, Centrifugal, Mist blower

It is difficult to spray the pesticide uniformly and efficiently throughout the tree and vines by conventional method of spraying. Air carrier sprayer provides good coverage consuming very less water, time and labour, hence suitable for spraying. The sprayers which uses air as a carrier for spraying chemicals are called as "Mist Blowers". It employs a blower to deliver an air blast of sufficient discharge and velocity. Spray fluid is introduced into this air blast in the form of fine droplets.

Centrifugal and axial flow blowers are used in air carrier spraying system. The centrifugal flow blowers are suitable for small height plants, where as axial flow blowers are suitable for large height plants. Axial blowers gives large air discharge at lower pressures and centrifugal blower gives lower air discharge at greater pressure.

The effectiveness of an air blast sprayer depends upon its ability to displace the air in all parts of the tree with spray-laden air from the machine. Also, the performance of an air carrier sprayer depends upon air flow rate and its velocity, liquid flow rate and its pressure, forward travel speed of sprayer as well as prevailing atmospheric conditions like wind velocity, humidity and temperature.

Experiments were conducted in laboratory to study the performance of three centrifugal flow mist blowers based on air velocity, air discharge, efficiency and power requirement.

METHODOLOGY

The performance evaluation of three blowers namely, B_1, B_2 and B_3 was evaluated in laboratory at different speeds. Constructional details of these blowers are given in Table 1. The optimum speeds of operation of the blowers were determined from these tests.

Experimental design for laboratory Testing

Independent variables

No of blowers:	3
Speeds of rotation:	5
Test section points:	20

Measurements of atmospheric variables:

a. Temperature b. Humidity

Dependent variables:

Static pressure, Dynamic pressure, Air velocity, Air discharge, Blower efficiencies, Power input and Power output.

The laboratory test set-up consisted of blower assembly, frame to support the blower, wind tunnel assembly, prime mover, transmission assembly, pressure, measuring instruments, power measuring instruments, speed measuring instruments, and temperature measuring instruments.

The frame was fabricated by joining the two Mild Steel angles of size 50 x 50 x 5 mm and bolted to heavy Mild Steel plate to resist the vibration while in operation. This Mild Steel plate has number of holes and blower was fitted to these Mild Steel plates by means of nuts and bolts. The wind tunnel assembly was constructed according to AMCA (1985) specifications. It consists of transition section, flow straightner and the tunnel. The details of wind tunnel assembly for different blowers are given in Table 2. The blower was driven by different induction motors by means of chain and sprockets. The details of motors used are given in Table 3.

The static, dynamic and total pressure of the air that was blown by the blower was determined by standard pitot tube in conjunction with U tube manometer and pitot

Table 1: Details of blowers

Sr. No.	Particulars/Blower	B_1	B_2	B_3
1	Impeller			
	Impeller type	Double sides	Double sides	Double sides
	Outer diameter, mm	500	419.1	406.4
	Inlet diameter, mm	400	355.6	336.5
	Impeller width, mm	200	230	244.4
2	Blades			
	Blade type	Forward curved	Forward curved	Forward curved
	Number of blades	108	72	48
	Inlet blade angle	13.5	22	20
	Outlet blade angle	160	155	157
3	Casing			
	Type	Circular	Volute	Volute
	Number of outlets	8	2	2
	Inlet diameter, mm	162	390	430
	Outlet diameter, mm	162	965 x 65	760 x 90

Table 2 : Details of wind tunnel used for the blowers

Sr. No.	Particulars/Blower	B_1	B_2	B_3
1.	Diameter of wind tunnel, mm	1655	265	265
2.	Length of wind tunnel, mm	1830	2650	2650
3.	Slope of transition section, %	-	7	7
4.	Length of transition section, mm	-	2550	2550
5.	Distance of test section from end of transition section, mm	-	2420	2420
6.	Total length between outlet and test section , mm	1805	4970	4970
7.	Distance between flow straightner and test section, mm	1030	1500	1500
8.	Width of flow straightner, mm	75	130	130
9.	Thickness of fins of flow straightner, mm	7.5	13	13
10.	Spacing of fins of flow straightner, mm	20	20	20

Table 3: Details of prime mover used for the blowers

Sr. No.	Details of electric motor/Blower	B_1	B_2	B_3
1.	Type	Squirrel cage induction motor	Squirrel cage induction motor	Squirrel cage induction motor
2.	Rated speed, rpm	1465	1465	1430
3.	Rated voltage, V	141	414	400
4.	Phase/cycle	3/50	3/50	3/50
5.	Rated current, A	52.8	52.8	22
6.	Type of starter	Star-delta	Star-delta	Star-delta
7.	Efficiency, %	90.9	90.9	77.5
8.	Rated hp	40	40	15

static tube with spherical head. The Pitot tube was inserted into the tunnel through the holes drilled on tunnel surface. Velocity and static pressure were measured at various traverse points. Then average of the readings was considered for calculating these pressures.

For measuring the power consumption by the blower, a voltmeter and ammeter were used. Voltmeter and ammeter were connected to the line supplying power in parallel and series, respectively after the starter. Tachometer was used to measure the speed of the impeller shaft in revolutions per minute. A dry bulb temperature was measured by dry bulb thermometer and humidity in the air was measured by hygrometer.

Laboratory test procedure:

The wind tunnel was fixed to the blower. It was operated at the desired speed of rotation. The various observations taken at the time of experiment included dry bulb temperature, relative humidity, static and dynamic head, current and the voltage.

Determination of static, dynamic and total pressure at test section:

When the two limbs of the manometer are connected to the pitot tube the difference in water column in the two limbs gives the dynamic head. When the static end of the pitot tube is connected to one end of the manometer and the other limb is kept open to the atmosphere, the difference in the water level of U tube limbs gives the static head. These heads were converted in terms of pressure unit by using the property that one-cm rise in water column corresponds to the 98.1 N/cm^2 of pressure.

Thus, static pressure (P_s) = static head x 98.1

Dynamic pressure (P_d) = dynamic head x 98.1

Then the total pressure was computed by adding theses two pressures.

RESULTS AND DISCUSSION

Three centrifugal blowers namely B_1, B_2 and B_3 were tested separately in the laboratory at different speeds such as Blower B_1 from 2050 to 2450, blower B_2 from 2000 to 2400 and blower B_3 from 1600 to 2000 rpm. The various observations at the time of testing and various computed values of performance parameters are presented in Table 4.

Laboratory performance of blower B_1:

It was observed that the static pressure at all speeds at test section and blower exit was less as compared to dynamic pressure because air was at low pressure and had high velocity (Table 4). The dynamic pressure increases with the increase in speed linearly due to increase in the outlet peripheral velocity. Velocity is function of impeller speed. The dynamic pressure at test section and blower exit was same due to the same cross sectional area of outlet and wind tunnel.

The total pressure output at blower test section varied from 629.03 N/m^2 at 2050 rpm to 911.74 N/m^2 at 2450 rpm and total pressure output at blower exit varied from 972.65 N/m^2 at 2050 rpm to 1385.976 N/m^2 at 2450 rpm. This shows that the total pressure at blower exit was more than the total pressure at the test section because of various losses in the wind tunnel.

Velocity and air discharge varied from 32.69 m/sec and 5.59 m^3/sec at 2050 rpm to 38.90 m/sec and 6.65 m^3/sec at 2450 rpm, respectively. It indicated that as the speed of rotation of the impeller increased the velocity and discharge also increased. The increase in the velocity of air may be due to its increase in peripheral velocity of the impeller. The air velocity and discharge were same at test section and blower exit because of the same cross sectional area at test section and blower exit.

Power input to the blower varied from 21.02 kW at 2050 rpm to 27.83 kW at 2450 rpm. If the different power losses are considered, this blower can be operated by tractor of 45 hp and above.

The efficiency was calculated from the power input and power output values of the blower. The efficiency of blower varied from 25.86 per cent at 2050 rpm to 33.11 per cent at 2450 rpm. It indicates that the efficiency of blower increases as speed increases. Higher efficiency of the blower was at 2450 rpm. So, the best at 2450 rpm operating speed of the blower in the field operation was. At this speed velocity, air discharge and the efficiency of the blower were found to be 38.90 m/sec, 6.65 m^3/sec and 33.11 per cent, respectively.

Laboratory performance of blower B_2:

Static pressure at test section was less than at blower exit, whereas dynamic pressure at blower test section was more than that at blower exit. It indicates that static pressure increases with increase in area (Table 4).

Total pressure at test section was less than that at blower exit section. It was due to frictional losses from blower exit to test section *i.e.* in wind tunnel. The data also indicated that the air velocity and discharge increased as speed of rotation increased linearly. The air velocity at test section was more than at blower exit because of difference in cross sectional area at test section and blower exit. But discharge was same irrespective of cross sectional area.

The power input to the blower varies from 19.57 kW at 2000 rpm to 34.87 kW at 2400 rpm. If the power losses were considered, this blower was operated by 50 or more hp tractor. It was found from data that blower output and input power increased linearly with increase in rotational speed.

The maximum blower efficiency (22 per cent) was found at 2000 rpm. Hence, the blower should be run at a speed of 2000 rpm. Therefore, this blower was operated in the field at 2000 rpm. Where air velocity, air discharge and efficiency of the blower were found to be 29.93 m/

Table 4: Performance evaluation of blowers

Sr. No.	Parameters	B_1					B_2					B_3				
		Speed, rpm														
		2050	2150	2250	2350	2450	2000	2100	2200	2300	2400	1600	1700	1800	1900	2000
A	**Observations**															
1.	Mean dynamic head, cm of water column	6.30	6.82	7.23	7.99	9.1	6.91	7.83	8.4	8.93	10.11	1.61	1.67	2.08	2.22	2.43
2.	Mean static head, cm of water column	0.11	0.13	0.14	0.16	0.19	0.78	0.79	0.83	0.84	0.75	0.18	0.20	0.25	0.33	0.37
3.	Input current, A	40.0	41.5	42.0	46.5	51.5	38.5	45.5	52.2	59.3	66.0	14.0	15.0	19.3	20.4	21.4
4.	Input voltage, V	400	395	385	395	385	395	395	340	376	380	395	400	395	400	400
5.	Average air temperature, ^0C	32	31	29	33	26	28	30	29	29	30	28	28	28	29	29
6.	Relative humidity, per cent	34	33	41	31	37	49	61	51	48	68	34	35	34	36	36
7.	Power factor, 0	0.86	0.87	0.88	0.90	0.92	0.84	0.86	0.88	0.89	0.91	0.52	0.55	0.71	0.75	0.78
B	**Computed values at test section**															
1.	Mean dynamic pressure, N/m^2	618	669	709	783	892	678	774	824	873	990	166	167	206	225	245
2.	Mean static pressure, N/m^2	11	12	14	15	19	76	78	82	83	93	18	21	24	33	37
3.	Total pressure, N/m^2	629	681	723	798	911	754	852	906	956	1083	184	188	230	258	282
4.	Air velocity, m/s	33.6	33.9	34.8	36.8	38.9	34.1	36.5	37.5	38.6	41.3	16.9	16.8	16.7	19.7	20.5
5.	Air discharge, m^3/s	5.59	5.81	5.96	6.30	6.65	3.62	3.88	3.99	4.11	4.39	1.80	1.80	1.99	2.09	2.17
C	**Computed values at blower exit**															
1.	Mean dynamic pressure, N/m^2	618	669	709	784	893	523	599	637	675	766	108	108	134	147	159
2.	Mean static pressure, N/m^2	355	381	401	444	493	667	745	793	834	921	197	201	244	271	295
3.	Total pressure, N/m^2	973	1050	1110	1228	1386	1190	1344	1430	1509	1687	305	309	377	418	458
4.	Air velocity, m/s	32.7	33.9	34.9	36.9	38.9	29.9	32.0	33.0	34.0	36.2	13.6	13.6	15.1	15.9	16.5
D	**Motor**															
1.	Input power, kW	23.8	24.7	24.5	28.6	31.6	22.2	26.9	31.3	34.5	39.3	4.99	5.72	9.35	10.5	11.6
2.	Output power, kW	21.5	22.2	22.1	25.8	28.4	19.9	24.2	28.1	31.1	35.6	4.48	5.15	8.42	9.52	10.46
E	**Blower**															
1.	Input power, kW	21.0	21.8	21.6	25.3	27.8	19.6	23.8	27.6	30.5	34.9	4.39	5.04	8.25	9.33	10.25
	Output power, kW	5.44	6.10	6.62	7.74	9.22	4.31	5.23	5.70	6.19	7.38	0.55	0.56	0.76	0.88	0.98
	Blower efficiency, %	25.86	27.98	30.64	30.60	33.11	22.0	21.98	20.67	20.30	21.19	12.43	10.96	9.11	9.35	9.64

sec, 3.62 m^3/sec and 22 per cent, respectively. The power requirement was 19.57 kW. It was operated by 35-hp tractor.

Laboratory performance of blower B_3:

The data in the Table 4 indicates that static pressure at test section was less than that at blower exit. Whereas dynamic pressure at blower test section was more than at blower exit. Total pressure at test section was less than the total pressure at blower exit. This shows that the performance trend of blower B_3 and blower B_2 are similar. The data showed the trend of linearly increasing velocity and discharge with increasing speed.

Power input to the blower varies from 4.39 kW at 1600 rpm to 10.25 kW at 2000 rpm. Hence, if the power losses were considered this blower was operated by 18 hp tractor. Also relationship shows power output and input to blower increases linearly with increase in rotational speed.

The maximum blower efficiency was found at 1600 rpm *i.e.* 12.43 per cent. Further increase in speed resulted in decreased efficiency. Hence, this blower was operated in the field at 1600 rpm, where air velocity, air discharge and efficiency of the blower were found to be 13.60 m/sec, 1.80 m^3/sec and 12.43 per cent, respectively and input power was 4.39 kW.

Performance Comparison of Blowers B_1, B_2 and B_3 :

The performance of blowers B_1, B_2 and B_3 was compared on the basis of power requirement, air discharge, air velocity and efficiency. The blower B_1 gave more velocity, air discharge and efficiency at 2450 rpm speed of impeller. The corresponding values were 38.90 m/sec, 6.65 m^3/sec and 33.11 per cent, respectively. Whereas power required to run the blower was 28 kW which required 45 or more hp tractor to operate it in the field. This blower is designed for cotton crop by the manufacturer.

The blower B_2 gave more velocity, air discharge and efficiency at 2000 rpm of impeller. Corresponding values were 29.93 m/sec, 3.62 m^3/sec and 22 per cent, respectively. Whereas power required to run this blower was 19.57 kW which required 35 hp tractor to operate it in the field. This blower was recommended for orchard crop by the manufacturer.

The blower B_3 gave more velocity, air discharge and efficiency at the impeller speed of 1600 rpm. Corresponding values were 13.6 m/sec, 1.8 m/sec and 12.43 per cent, respectively. Whereas power required to run the blower was 4.39 kW for which 18 hp tractor can be used to operate it in the field. This blower is suitable for spraying grape crop, where limitation of size is a governing factor.

Conclusion:

The study indicates that static pressure and dynamic pressure increases linearly with the increase in the rotational speed.

– The maximum blower efficiency was observed in blower B_1 (33.11 per cent) as compared to blower B_2 (12 per cent) and B_3 (12.43 per cent).

– The blowers B_1, B_2 and B_3 were operated best in the field at 2450, 2000 and 1600 rpm speed of impeller and required 28.83, 19.57 and 4.39 kW power, respectively.

– The maximum air discharge was observed in blower B_1 (6.65 m3/sec) as compared to the discharge of blower B_2 (3.62 m3/sec) and blower B_3 (1.8 m3 /sec).

– The blower B_1, B_2 and B_3 needed tractors of 45, 35 and 18 hp, respectively.

– The maximum air velocity was observed in blower B_1 (38.9 m/sec) as compared to blower B_2 (29.93 m/sec) and B_3 (16.51 m/sec).

Authors' affiliations:

A.R. MANTRI AND S.C. KAWADE, Department of Agricultural Engineering, Maharashtra Agricultural University, PARBHANI (M.S.) INDIA

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