Experimental Analysis Of Unsteadiness At Inlet Of Ducted Axial Fan Due To Stall And Surge

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Abstract

This paper deals with the effect of stall and surge phenomenon on the nature of flow pattern and velocity profile. . The fluid flow through an axial ducted fan set up is of scientific and industrial significance. The experiment is conducted with hot wire anemometer at three different planes. . Using these velocity difference fluctuation plots are drawn and studied, for steady state, viscous fluid flow.

Keywords

Velocity profile, fluctuation profile, Hot wire anemometer, surge

1. Introduction

For centuries, the behaviour of fluid flows has captured the attention of some of history's most esteemed minds. Steady, incompressible, turbulent flow through a circular duct has been studied experimentally. Stall is found in dynamic compressors, particularly axial compressors, as used in jet engines and turbochargers for reciprocating engines Compressor stalls result in a loss of compressor performance, which can vary in severity from a momentary engine power drop (occurring so quickly it is barely registered on engine instruments) to a complete loss of compression (compressor surge) necessitating a reduction in the fuel flow to the engine.. Unsteady flow phenomena such as periodic rotating stall, which is one of the most serious instabilities at part load can lead to reduction of efficiency stall, more commonly known as compressor surge; or pressure surge, is a complete breakdown in compression resulting in a reversal of flow and the violent expulsion of previously compressed air out through the engine intake, due to the compressor's inability to continue Working against the already-compressed air behind it. During "Surging" the compressor shows cyclic flow and back-flow of the compressed medium resulting into High vibrations. The breakdown of flow due to persistent surging may lead to heavy damage. A certain amount of surge is normal during start-up, when engine rpm is too low to keep air going in one direction, and is more likely to happen if rpm drops too quickly or if excess backpressure builds up as a result of the exhaust nozzle closing too far for a given rpm.

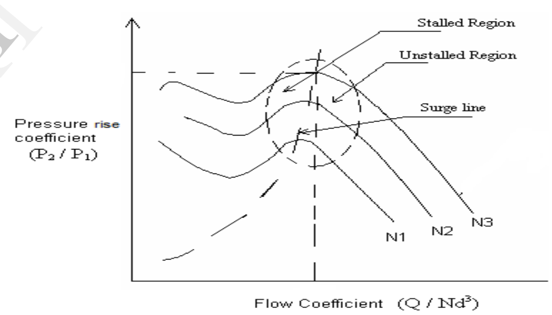


Fig: 1 Graphical representation of axial fan performance curve.

2. EXPERIMENTAL SET UP AND INSTRUMENTATION

Fig: 2 Axial ducted fan set up

Fig:3 Automatic throttle controller

Fig4: Bell mouth inlet

A 2 HP Variable frequency 3-phase induction electrical drive is coupled to the electrical motor to derive variable speed ranges. Schematic representation of ducted fan in fig: 2

The flow enters to the duct throw bell mouth inlet which provides the high, smooth and undisturbed flow motor is positioned in a casing of diameter 370mm and length of 450mm and it is at distance of 1550mm from bell mouth inlet. Assemble of throttle is placed at the outlet of ducted fan setup. It regulates the flow.

Fig5: Hot wire anemometer

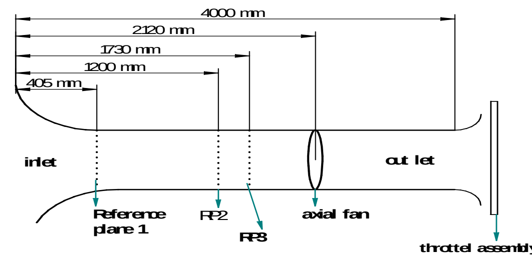


Fig6: Schematic Representation of Axial Ducted Fan Set Up

1. RESULTS AND DISCUSSION

In axial ducted fan set up air is flowing in axial direction. Measurement of velocity of flow is made in radial direction of duct at specified planes 1, 2 and3 as shown in figure6. These planes are at distance of 405 mm, 1200 mm, and 1730 mm respectively from inlet of bell- mouth then difference in velocities between two planes (that is plane 2,1 and planes 3,2) is calculated, measurements are made for two conditions, one is 7 cm throttle opening (i.e., normal condition there is no disturbance for flow) and other one is for 3 cm throttle opening,(where sudden drastic reduction in flow velocity is observed). For different speeds of rotor like 2400 rpm, 3000 rpm and 3600 rpm, and for these values fluctuation plot are drawn and studied through the comparison of plots.

Table 1 gives the readings of velocity gradient at plane 1 and 2 and its difference, for 7cm and 3cm opening at runner speed 2400 rpm.

The measurements are made using hot wire anemometer and from these readings profile plots are drawn as profile plot 1 indicate that the fluctuation range is more for 3cm throttle opening than 7cm. It indicates the backflow at 3 cm and. at 3 cm there is drastic reduction in velocity of flow, it indicates stall. But Maximum fluctuation range between plane 1 and 2 is remaining almost same for 7cm and 3 cm throttle opening.

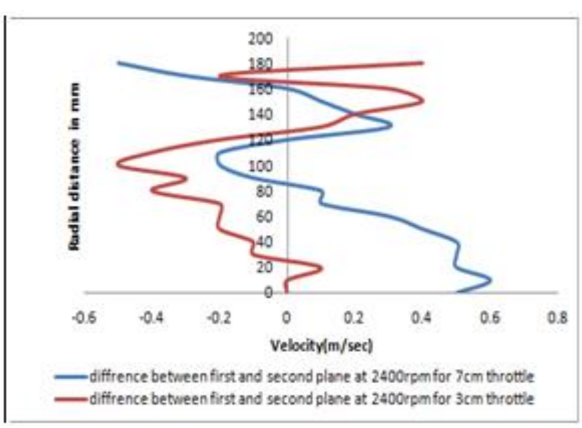
Table.2 and its respective profile plot 2 indicate the fluctuation of velocity between 2nd and 3rd plane, for normal condition as well for stall region at runner speed 2400 rpm. It shows that in both the condition (i.e. at 7 cm and 3 cm throttle opening).
Flow is developing through these fluctuation curves it is clear that, at low speed throttling is not affecting the flow much. (As it moves nearer to the fan flow is improved at 3 cm throttle opening)

Table1. Indicates velocity at plane 1 and 2 and its Difference of velocity for 1st and 2nd plane at inlet of axial ducted fan for 7cm and 3cm throttle opening at 2400 rpm

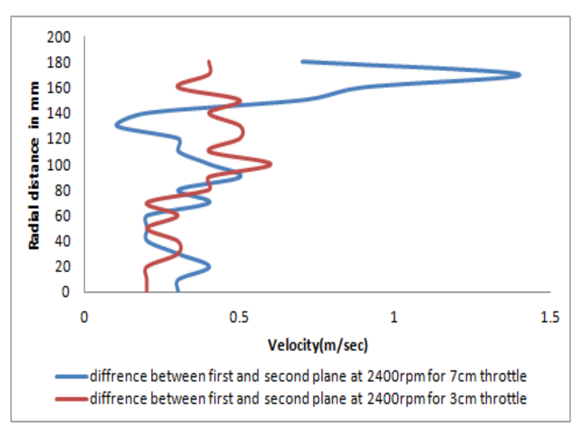
Velocity at different planes in m/sec for 2400rpm						
	Throttle 7cm open			Throttle 3cm open		
Probe distance (mm)	1st plane	2nd plane	Diff Ernce Of 1st And 2nd plane	1st plane	2nd plane	Diff Ernce Of 1st And 2nd plane
0	14.5	15	0.5	8.5	8.5	0
10	14.4	15	0.6	8.5	8.5	0
20	14.4	14.9	0.5	8.4	8.5	0.1
30	14.4	14.9	0.5	8.5	8.4	-0.1
40	14.4	14.9	0.5	8.5	8.4	-0.1
50	14.4	14.8	0.4	8.6	8.4	-0.2
60	14.4	14.7	0.3	8.5	8.3	-0.2
70	14.4	14.5	0.1	8.5	8.3	-0.2
80	14.4	14.5	0.1	8.5	8.1	-0.4
90	14.4	14.3	-0.1	8.4	8.1	-0.3
100	14.4	14.2	-0.2	8.4	7.9	-0.5
110	14.4	14.2	-0.2	8.3	7.9	-0.4
120	14.1	14.1	00	8	7.8	-0.2
130	13.8	14.1	0.3	7.7	7.8	0.1
140	13.6	13.8	0.2	7.6	7.8	0.2
150	13.1	13.2	0.1	7.3	7.7	0.4
160	12.8	12.8	00	7.2	7.5	0.3
170	12.5	12.2	-0.3	7	6.8	-0.2
180	12	11.5	-0.5	6	6.4	0.4

Table2. Indicates velocity at plane 2 and 3 and its Difference of velocity for 2nd and 3rd plane at inlet of axial ducted fan for 7cm and 3cm throttle opening at 2400 rpm

Velocity at different planes in m/sec for 2400rpm						
	Throttle 7cm open			Throttle 3cm open		
Probe distance (mm)	2nd plane	3rd plane	Diff Ernce Of 2nd and 3rd plane	2nd plane	3rd Plane	Diff Ernce Of 2nd and 3rd plane
0	15	15.3	0.3	8.5	8.7	0.2
10	15	15.3	0.3	8.5	8.7	0.2
20	14.9	15.3	0.4	8.5	8.7	0.2
30	14.9	15.2	0.3	8.4	8.7	0.3
40	14.9	15.1	0.2	8.4	8.7	0.3
50	14.8	15	0.2	8.4	8.6	0.2
60	14.7	14.9	0.2	8.3	8.6	0.3
70	14.5	14.9	0.4	8.3	8.5	0.2
80	14.5	14.8	0.3	8.1	8.5	0.4
90	14.3	14.8	0.5	8.1	8.5	0.4
100	14.2	14.6	0.4	7.9	8.5	0.6
110	14.2	14.5	0.3	7.9	8.3	0.4
120	14.1	14.4	0.3	7.8	8.3	0.5
130	14.1	14.2	0.1	7.8	8.3	0.5
140	13.8	14	0.2	7.8	8.2	0.4
150	13.2	13.9	0.7	7.7	8.2	0.5
160	12.8	13.7	0.9	7.5	7.8	0.3
170	12.2	13.6	1.4	6.8	7.2	0.4
180	11.5	12.2	0.7	6.4	6.8	0.4



Profile plot 1, Fluctuation curve bet between 1st and 2nd plane for normal and stall condition at 2400 rpm



Profile plot 2, Fluctuation curve bet between 2nd and 3rd plane for normal and stall condition at 2400 rpm

Table3. Indicates velocity at plane 1 and 2 and its Difference of velocity for 1^{st} and 2^{nd} plane at inlet of axial ducted fan for 7cm and 3cm throttle opening at 3000 rpm

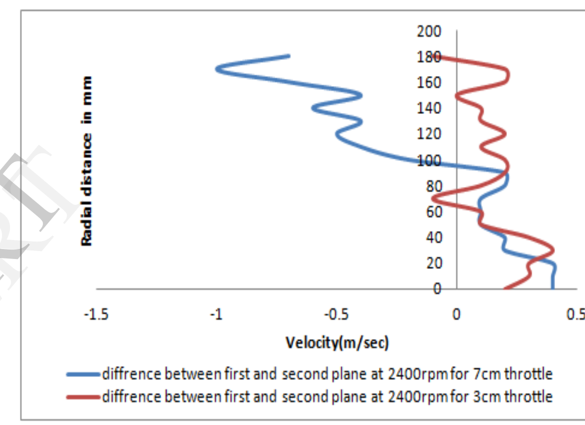
Velocity at different planes in m/sec for 3000rpm						
	Throttle 7cm open			Throttle 3cm open		
Probe distance (mm)	1^{st} plane	2^{nd} plane	Diff Emce Of 1^{st} And 2^{nd} plane	1^{st} plane	2^{nd} plane	Diff Ernce Of 1^{st} And 2^{nd} plane
0	18.4	18.8	0.4	10.9	11	0.2
10	18.3	18.7	0.4	10.7	11	0.3
20	18.3	18.7	0.4	10.7	11	0.3
30	18.3	18.5	0.2	10.6	11	0.4
40	18.3	18.5	0.2	10.7	11	0.3
50	18.3	18.4	0.1	10.7	10.8	0.1
60	18.3	18.4	0.1	10.7	10.8	0.1
70	18.3	18.2	0.1	10.6	10.5	-0.1
80	18.3	18.1	0.2	10.4	10.5	0.1
90	18.3	18.1	0.2	10.2	10.4	0.2
100	18.2	18	-0.2	10	10.2	0.2
110	18.2	17.8	-0.4	9.9	10	0.1
120	18.2	17.7	-0.5	9.8	10	0.2
130	17.9	17.5	-0.4	9.7	9.8	0.1
140	17.4	16.8	-0.6	9.6	9.7	0.1
150	16.9	16.5	-0.4	9.5	9.5	00
160	16.7	16	-0.7	9.3	9.5	0.2
170	16.2	15.2	-1.0	9.1	9.3	0.2
180	15	14.3	-0.7	8.4	8.3	-0.1

Table4. Indicates velocity at plane 2 and 3 and its Difference of velocity for 2^{nd} and 3^{rd} plane at inlet of axial ducted fan for 7cm and 3cm throttle opening at 3000 rpm

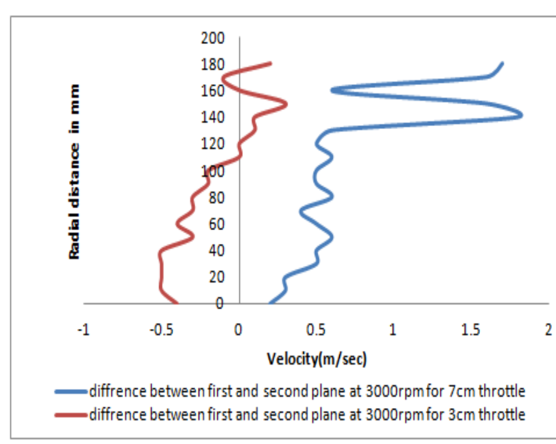
Velocity at different planes in m/sec for 3000rpm						
	Throttle 7cm open			Throttle 3cm open		
Probe distance (mm)	2^{nd} plane	3^{rd} plane	Diff Emce Of 2^{nd} and 3^{rd} plane	2^{nd} plane	3^{rd} Plane	Diff Ernce Of 2^{nd} and 3^{rd} plane
0	18.8	19	0.2	11	10.6	-0.4
10	18.7	19	0.3	11	10.5	-0.5
20	18.7	19	0.3	11	10.5	-0.5
30	18.5	19	0.5	11	10.5	-0.5
40	18.5	19	0.5	11	10.5	-0.5
50	18.4	19	0.6	10.8	10.5	-0.3
60	18.4	18.9	0.5	10.8	10.4	-0.4
70	18.2	18.8	0.4	10.5	10.2	-0.3
80	18.1	18.7	0.6	10.5	10.2	-0.3
90	18.1	18.6	0.5	10.4	10.2	-0.2
100	18	18.5	0.5	10.2	10	-0.2
110	17.8	18.4	0.6	10	10	00
120	17.7	18.2	0.5	10	10	00
130	17.5	18.1	0.6	9.8	9.9	0.1
140	16.8	17.9	1.8	9.7	9.8	0.1
150	16.5	17.8	1.6	9.5	9.8	0.3
160	16	17.6	0.6	9.5	9.5	00
170	15.2	16.8	1.6	9.3	9.2	-0.1
180	14.3	16	1.7	8.3	8.5	0.2

Table.3 and its respective profile plot 3 indicate the fluctuation of velocity between 1st and 2^{nd} plane, for normal condition as well for stall region at runner speed 3000 rpm. It shows that between plane 1^{st} and 2^{nd} fluctuation is more under normal condition. And fluctuation is less for stall condition.

Table.4 and its respective profile plot 4 indicate the fluctuation of velocity between 2^{nd} and 3^{rd} plane, for normal condition as well for stall region at runner speed 3000 rpm. It shows that at normal condition flow is developing. For stall region the flow is suffering due to high fluctuation, retardation and reverse flow etc. it is found that as speed increases there is retardation in the flow, it is because of reverse flow (formation of vertices) flow separation etc.



Profile plot 3, Fluctuation curve bet between 1^{st} and 2^{nd} plane for normal and stall condition at 3000 rpm



Profile plot 4. Fluctuation curve bet between 2^{nd} and 3^{rd} plane for normal and stall condition at 3000 rpm

Table 5. Indicates velocity at plane 1 and 2 and its Difference of velocity for 1st and 2nd plane at inlet of axial ducted fan for 7cm and 3cm throttle opening at 3600 rpm

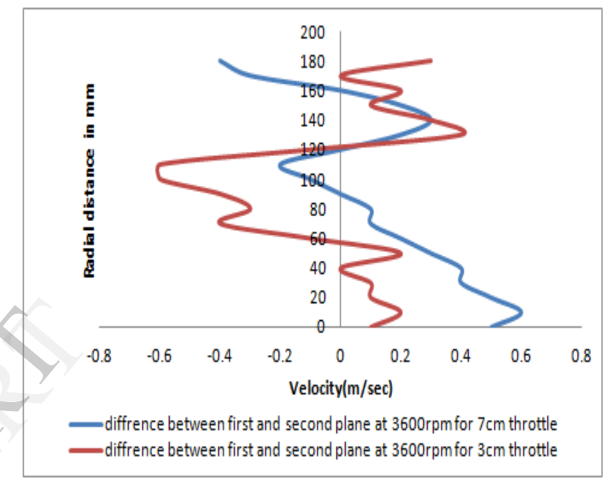
Velocity at different planes in m/sec for 3600rpm						
	Throttle 7cm open			Throttle 3cm open		
Probe distance (mm)	1st plane	2nd plane	Difference Of 1st And 2nd plane	1st plane	2nd plane	Differnce Of 1st And 2nd plane
0	20.2	20.7	0.5	12.9	13	0.1
10	20.1	20.7	0.6	12.8	13	0.2
20	20.1	20.6	0.5	12.8	12.9	0.1
30	20.1	20.5	0.4	12.8	12.9	0.1
40	20.1	20.5	0.4	12.8	12.8	00
50	20.1	20.4	0.3	12.7	12.9	0.2
60	20.1	20.3	0.2	12.8	12.7	-0.1
70	20.1	20.2	0.1	12.8	12.4	-0.4
80	20	20.1	0.1	12.7	12.4	-0.3
90	20	20	00	12.7	12.3	-0.4
100	20	19.9	-0.1	12.7	12.1	-0.6
110	20	19.8	-0.2	12.7	12.1	-0.6
120	19.7	19.7	00	12.1	12	-0.1
130	19.4	19.6	0.2	11.6	12	0.4
140	19.2	19.5	0.3	11.4	11.7	0.3
150	19	19.2	0.2	11.1	11.2	0.1
160	18.7	18.7	00	11	11.2	0.2
170	18.4	18.1	-0.3	10.6	10.6	00
180	17.8	17.4	-0.4	9.8	10.1	0.3

Table6. Indicates velocity at plane 2 and 3 and its Difference of velocity for 2nd and 3rd plane at inlet of axial ducted fan for 7cm and 3cm throttle opening at 3600 rpm.

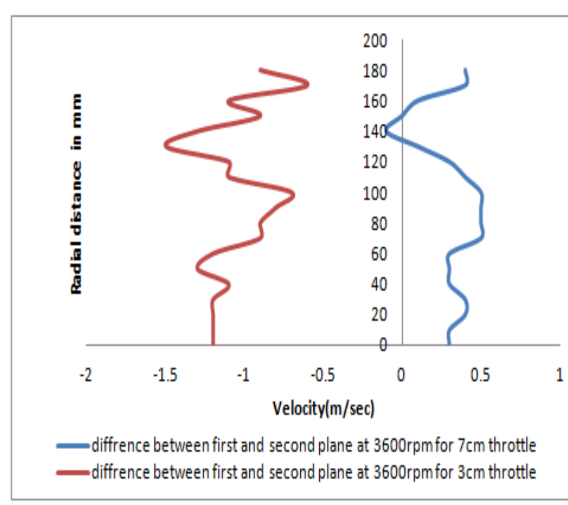
Velocity at different planes in m/sec for 3600rpm						
	Throttle 7cm open			Throttle 3cm open		
Probe distance (mm)	2nd plane	3rd plane	Difference Of 2nd and 3rd plane	2nd plane	3rd Plane	Differnce Of 2nd and 3rd plane
0	20.7	21	0.3	13	11.8	-1.2
10	20.7	21	0.3	13	11.8	-1.2
20	20.6	21	0.4	12.9	11.7	-1.2
30	20.5	20.9	0.4	12.9	11.7	-1.2
40	20.5	20.8	0.3	12.8	11.7	-1.1
50	20.4	20.7	0.3	12.9	11.6	-1.3
60	20.3	20.6	0.3	12.7	11.5	-1.2
70	20.2	20.6	0.5	12.4	11.5	-0.9
80	20.1	20.5	0.5	12.4	11.5	-0.9
90	20	20.5	0.5	12.3	11.5	-0.8
100	19.9	20.4	0.5	12.1	11.4	-0.7
110	19.8	20.2	0.4	12.1	11	-1.1
120	19.7	20	0.3	12	10.9	-1.1
130	19.6	19.7	0.1	12	10.5	-1.5
140	19.5	19.4	-0.1	11.7	10.4	-1.3
150	19.2	19.2	00	11.2	10.3	-0.9
160	18.7	18.8	0.1	11.2	10.1	-1.1
170	18.1	18.5	0.4	10.6	10	-0.6
180	17.4	17	0.4	10.1	9.2	-0.9

At rotor speed of 3600 rpm for both the condition flow is developing between the plane 1 and 2, but plot drawn for stall condition is under retardation it is due to the flow separation, back flow etc,

And between 2nd and 3rd plane it is found that at normal condition flow is developing. At stall condition flow is severely affected by stall. Flow is under high retardation. It indicates flow is highly reversal.



Profile plot 5. Fluctuation curve bet between 1st and 2nd plane for normal and stall condition at 3600 rpm



Profile plot 6. Fluctuation curve for 2nd and 3rd plane for normal and stall condition at 3600 rpm

4. CONCLUSIONS

It was observed that the velocity and flow rate in axial ducted fan setup decreases with decrease in throttle distance. At low speed for given condition of duct stall is not much affecting the flow. As runner speed increases stall effect is more on flow. At stall as speed increases fluctuation in the flow is increasing with increasing adverse pressure gradient, flow is retarding since reversal flow and flow separation. Due to this velocity profile is drastically effected at inlet of an axial ducted fan.

NOMENCLATURE

D=diameter of duct in m

V = Velocity in m/s

N = speed of the blades in rpm

Q = Flow discharge in m3/s

d = Diameter of the blade in m

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