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Performance Analysis of Centrifugal Fan by CFD

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Abstract- Our research paper is based on performance improvement of centrifugal fan. Centrifugal fans are consuming very high energy and require frequent maintenance. The Fan having low capacity, Low Static Pressure, Low Static efficiency during the performance testing by manufacturer. We will carried out analysis for existing design of the fan by ANSYS and modify the design of the impeller.

Keywords- *Centrifugal Fan casing, Impeller and Inlet &Outlet section etc.*

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1. INTRODUCTION

A centrifugal fan is a mechanical device for moving air or other gases. They convert the kinetic energy of the impeller for increment of the pressure of the air or gas which is moves against the resistance caused by casing, dampers and other components. Centrifugal fans increase air velocity radially, by changing the direction (typically by 90°) of the airflow.

Centrifugal fans are continuous displacement devices or constant volume devices, at a constant speed, a centrifugal fan will flow at a constant rate volume of air rather than a constant mass. This means that the air velocity of the system is fixed even though the mass flow rate through the fan is not.

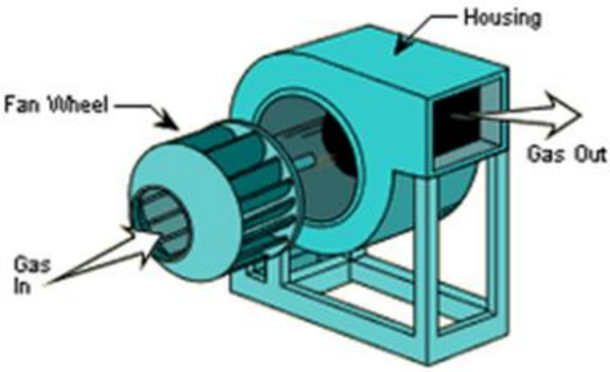

Figure 1 Centrifugal Fan

Main component of a centrifugal fan are:

1. Fan casing
2. Impeller
3. Inlet and outlet Vents
4. Drive shaft
5. Drive mechanism

Other parts used are bearings, couplings, impeller locking device, fan discharge casing, shaft seal plates etc.

2. MACHINE SPECIFICATIONS

Sl No.	Description	
1	Fan Make	Suvidha Air Engineers
2	Type of Fan	Centrifugal Fan DWDI
3	Fan Model/Size	SB-550
4	Blade Type	Backward Inclined/20 Nos/62.0°
5	Impeller Diameter	Ø 470 mm
6	Capacity (M³/Hr) /CFM	13803/8124
7	Static Pressure (mm WC)	50 at 50°C
8	Total Pressure (mm WC)	85 at 50°C
9	Fan Design Temperature	50°C
10	Type Drive/Arrangement	V Belt/ #3
11	Fan Speed (RPM)	1165
12	Critical Speed	2018

	(RPM)	
13	Fan Power (KW)	2.84 at 50°C/ 3.13 at 20°C
14	Motor Rating (KW/Pole)	5.5/4
15	Motor Speed (RPM)	1450
16	**Material of Construction**	
16.1	Fan Casing	2 mm IS 1079 Gr 0
16.2	Impeller Blade	2.5 mm IS 1079 Gr 0
16.3	Impeller Back Plate	5 mm IS 2062 Gr E 250
16.4	Impeller Shroud	2.5 mm IS 1079 Gr 0
16.5	Shaft Dia @ Bearing in mm	Ø 50
16.6	Bearing No	22211 EK
17	Fan Static Efficiency (%)	66.04
18	Fan Total Efficiency (%)	71.16
19	GD² Value (Kg M²) at fan speed	6.78
20	Outlet Velocity (M/sec)	36.92
21	Noise Level	85 dBA @ 1 Mtr distance
22	Balancing of Impeller (Static & Dynamic)	ISO 1940 Gr 6.3
23	Static Weight Kgs.	415
24	Dynamic Weight Kgs.	665

3. DESIGN CALCULATIONS

The input parameters for the design of backward curved inclined blade centrifugal fan are summarized below.

Flow Capacity Q = 3.83 m3/s
Static Pressure = 490.32 N/m2
Inlet Diameter of impeller D1= 0.428 m
Outlet Diameter of impeller D2= 0.470 m
Impeller Speed N = 1165 rpm
Air Density = 1.09486 kg/m3
Number of blades z = 10
Suction Temperature Ts = 50 °C = 323 K
Atmospheric Pressure Patm = 1.01325 x 105 Pa
Atmospheric Temperature Tatm = 50° C = 323° K

These parameters are kept ideal for existing design methodology defined here in.

Let consider the tangential velocity component 10% more than axial velocity component for greater suction of flow.

$$U_1 = 1.1\ V_1$$

$$Discharge, Q = \frac{\pi}{4} \times {D_1}^2 \times V_1$$

$$V_1 = \frac{4\ Q}{\pi \times\ D_1^2}$$

$$U_1 = \frac{\pi\ D_1 N}{60} = 1.1 V_1$$

$$\therefore\ \frac{\pi\ D_1 N}{60} = 1.1\ \times\ 4 \frac{Q}{\pi \times\ D_1^2}$$

$$\therefore\ Q = \frac{\pi^2 \times D_1^3 \times N}{60 \times 1.1 \times 4}$$

$$\therefore\ Q = 3.41 \frac{m^3}{s}\ = 7220\ ft^3/m$$

So, it is clear that the required capacity is less than existing from the fundamental calculation as per the given speed of the fan and inlet diameter.

Now, for the required flow discharge the speed of the fan is

$$\frac{CFM_{new}}{CFM_{old}} = \frac{RPM_{new}}{RPM_{old}}$$

$$\therefore \frac{8124}{7220} = \frac{RPM_{new}}{1165}$$

$$RPM_{new} = 1310.86 \approx 1311$$

$$\therefore \frac{\pi\ D_1 N}{60} = 1.1\ \times\ 4\frac{Q}{\pi \times D_1^2}$$

$$\therefore D_1^3 = \frac{1.1 \times 4 \times Q \times 60}{\pi^2 \times N}$$

$$\therefore D_1 = 0.427m$$

$$\therefore V_1 = 26.62\ m/s$$

So, That Inlet tip Velocity

$$U_1 = \frac{\pi\ D_1 N}{60} = 1.1 V_1$$

$$\therefore U_1 = 29.29\ m/s$$

$$\therefore V_1 = 26.62\ m/s$$

$$V_{r1} = \sqrt{U_1^2 + V_1^2} = 39.57\ m/s$$

Impeller inlet blade angle:

$$tan\beta_1 = \frac{V_1}{U_1} = \frac{26.62}{29.29}$$

$$\beta_1 = 42.26°$$

Impeller width at inlet:

Here Z=10 and blade thickness t=2.5 mm

$$Q = [\pi D_1 - Zt] \times b_1 \times V_1$$

$$b_1 = 0.109\ m = 109\ mm$$

Impeller outlet parameters:

$$\text{The Fan power} = Q \times Total\ Pressure$$

$$= 3.83 \times 833$$

$$= 3190.39\ W$$

Considering 10% extra to accommodate flow recirculation and impeller exit hydraulic losses

So,.

$$1.1 \times The\ Fan\ Power = 3509.429\ W$$

$$Power, P = \dot{m} \times W_s$$

$$Sepcific\ Workdone, W_s = 837.56\ W/(kg/s)$$

$$Eulerpower = \dot{m}\ V_{w2}\ U_2$$

$$Taking, V_{w2} = 0.8\ U_2$$

$$3509.429 = 1.09486\ \times 3.83\ \times 0.8\ U_2 \times U_2$$

$$U_2 = 32.35\ m/s$$

$$V_{w2} = 0.8\ \times 32.35 = 25.88\ m/s$$

$$\text{And}, U_2 = \frac{\pi\ D_2 N}{60}$$

$$D_2 = 0.471\ m$$

Taking width of blade at inlet=outlet blade width

$$\therefore b_1 = b_2$$

$$Q = (\pi D_2 - Zt)\ \times b_2\ \times V_{f2}$$

$$V_{f2} = 24.16\ m/s$$

$$W_2 = 0.2\ U_2 = 6.47\ m/s$$

$$V_{r2} = \sqrt{W_{u2}^2 + V_{f2}^2}$$

$$V_{r2} = 25.01\ m/s$$

$$V_2 = \sqrt{V_{w2}^2 + V_{f2}^2}$$

$$V_2 = 35.40\ m/s$$

$$tan\ \alpha_2 = \frac{V_{f2}}{V_{w2}} = \frac{24.16}{25.88} = 0.9335$$

$$\alpha_2 = 43.03°$$

Comparison as per fundamental calculation			
Parameters		Existing Impeller Design	New Impeller Design
Impeller Inlet Diameter	D_1	428 mm	427mm
Speed of Fan	N	1165 rpm	1311
Peripheral Inlet velocity	U_1	26.09 m/s	29.29 m/s
Relative Inlet Velocity	V_{r1}	35.26 m/s	39.57 m/s
Inlet Flow Velocity	V_{f1}	23.72 m/s	26.62 m/s
Absolute Inlet Velocity	V_1	23.72 m/s	26.62 m/s
Width of Inlet Blade	b_1	250mm	109mm
Inlet Air Angle	α_1	90°	90°
Inlet Blade Angle	β_1	42.27°	42.26°
Impeller Outlet Diameter	D_2	470mm	471mm
Peripheral Outlet velocity	U_2	28.65 m/s	32.35 m/s
Swirl Outlet Velocity	V_{w2}	22.92 m/s	25.88 m/s
Relative Outlet Velocity	V_{r2}	12 m/s	25.01 m/s
Outlet Flow Velocity	V_{f2}	10.55 m/s	24.16 m/s
Absolute Outlet Velocity	V_2	25.23 m/s	35.40 m/s
Width of Outlet Blade	b_2	250 mm	109 mm
Outlet Air Angle	α_2	24.70°	43.03°
Outlet Blade Angle	β_2	61.49°	75.00°

4. CFD Analysis of centrifugal fan.

Basic Steps for CFD Analysis

(1) Preprocessing: defining the problem

Import the geometric model in the ansys and the geometry is checked for any free edges, copy surfaces, and little gaps/filets. Crossing point and globules so it doesn't trade off the outline result.

(i) define element type and material/geometric properties,

(ii) Mesh lines/areas/ volumes as required. The amount of detail required will depend on the dimensionality of the analysis, i.e., 1D, 2D, ax symmetric, and 3D.

(2) Solution: assigning cellzone condition , boudry conditions, solution model, solution initialization etc.

Here, it is necessary to specify the inlet conditions (velocity or pressure), rotational speed provide to roattional frame of the fan and finally solve the resulting set of equations.

(3) Post processing: further processing and viewing of the results

In this stage one may wish to see verious plot of the outlet of the fan,

(i) Velocity stream lines,

(ii) Velocity contours,

(iii) Pressure contours

Meshing and Its Quality

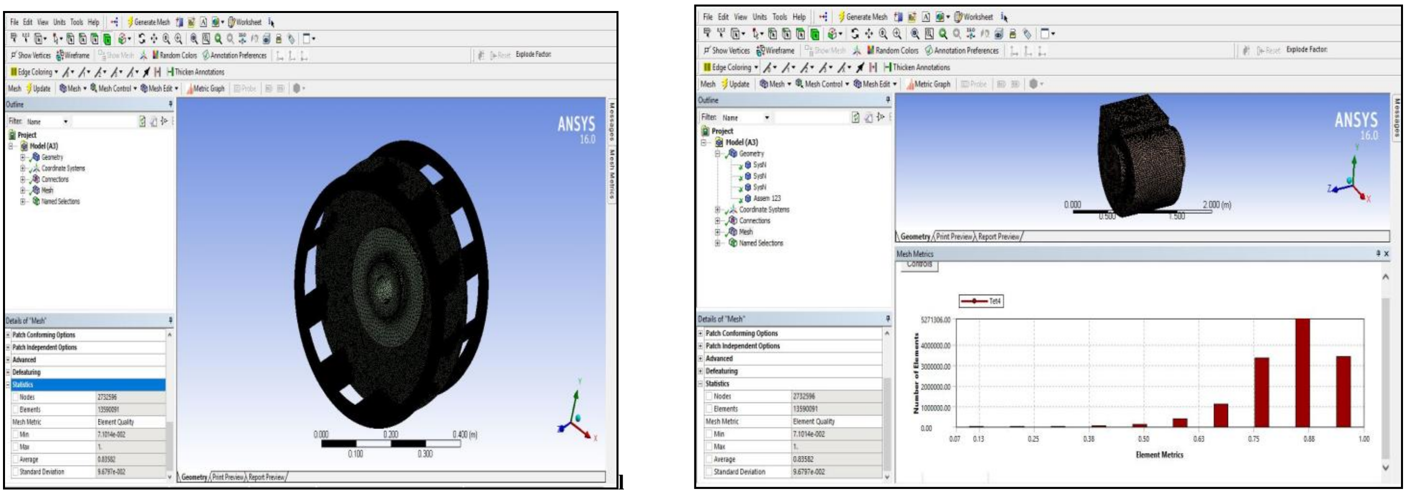

Figure 2 Meshing Quality of fan

5. Comparison between Existing Design and Modified design:

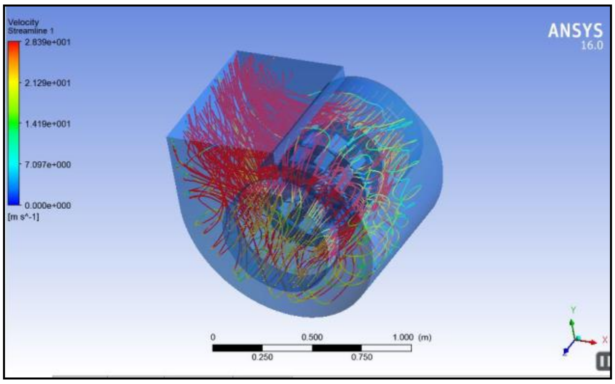

Figure 3 Velocity stream lines of existing design

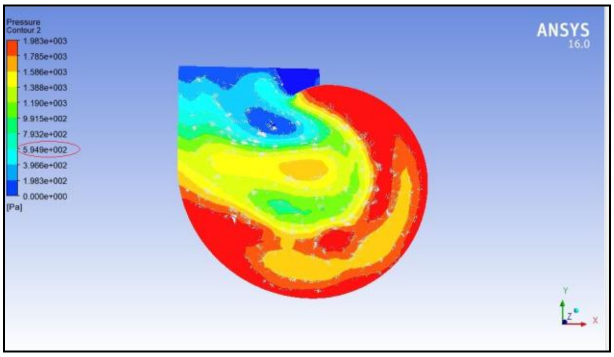

Figure 7 Pressure Contour of existing design

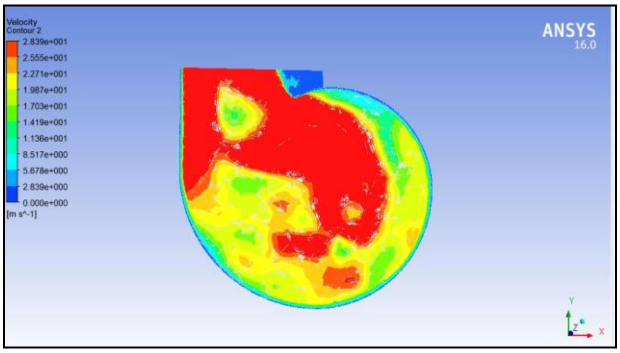

Figure 5 Velocity Contour of existing design

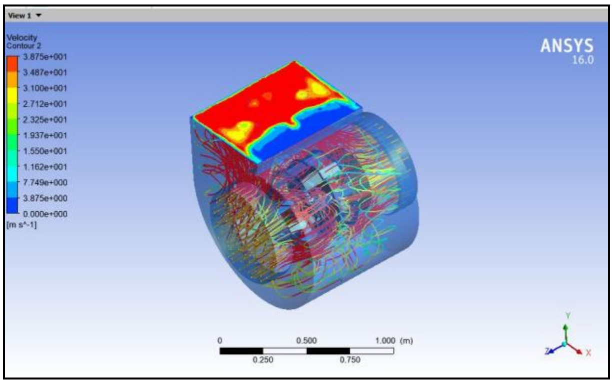

Figure 4 Velocity stream lines of modified design

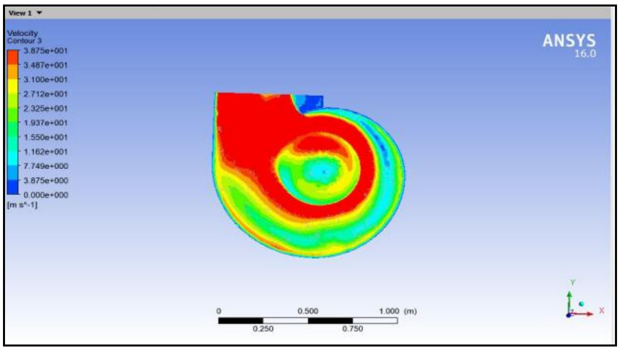

Figure 6 Velocity Contour of modified design

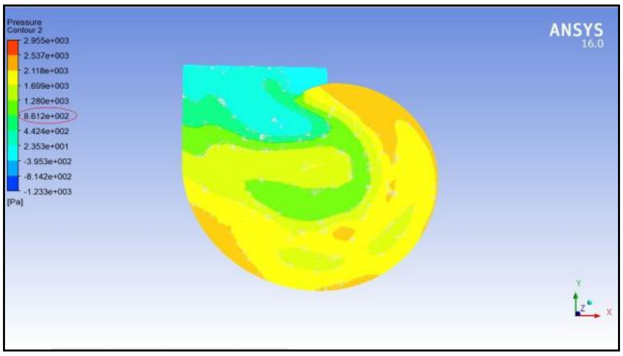

Figure 8 Pressure Contour of modified design

6. Comparison of Centrifugal Fan Outlet

Existing Design Analytical outlet velocity	Modified Design Analytical outlet velocity	Existing Design Fluent Analysis outlet velocity	Modified Design Fluent Analysis outlet velocity
25.23m/s	35.40 m/s	28.39 m/s	38.75 m/s

7. CONCLUSION

We have compared the existing design and modified design outlet velocity of the fan. After the modified the design by changing the speed of the impeller at 1311rpm and width of the blade 109mm by fundamental calculations it is understandable from the results that the maximum velocity for the flow by CFD simulation is 38.75 m/s and 35.40 m/s with the fundamental calculation value. Thus the results are clear enough for comparison with new design and finding out what effects will be there among both the impeller designs.

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