



Design and Analysis of Impeller for Centrifugal Blower using Solid Works

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Abstract: In this paper, backward-curved impeller was simulated and compared with theoretical result by using SolidWorks Software. Flow Analysis is also based on the computational fluid dynamic and can obtain the results for the estimation of the outlet flow velocity components, pressure distribution and temperature distribution for impeller. SolidWorks is used to build 3D geometry for analysis using SolidWorks Flow Simulation. The impeller design calculation consists of shaft diameter, hub diameter, vane inlet diameter, and inlet width, inlet vane angle, outside diameter and outlet width. The inlet and outlet velocities are considered. The impeller inlet width and outlet width are designed 43 mm and 22 mm. Impeller inlet vane angle is calculated 34° and outlet vane angle is 50°. Impeller inlet diameter and outlet diameter are 260 mm and 600 mm. The number of vane is 12. Centrifugal blower is very useful in many industries and farm machinery operations because this one is very simple and easiest way to support air supply for these applications.

Keywords: Centrifugal Blower, Backward-Curved Blade, Design Of Impeller, Analysis Of Impeller, Solidworks Software.

Nomenclature:

A_1	Impeller inlet area (mm ²)
A_2	Impeller outlet area (mm ²)
b_1	Blade width at impeller inlet (mm)
b_2	Blade width at impeller outlet (mm)
D_0	Eye diameter (mm)
D_1	Impeller inlet diameter (mm)
D_2	Impeller outlet diameter (mm)
D_s	Shaft diameter (mm)
D_H	Hub diameter (mm)
g	Gravitational constant (m/sec ²)
H_{ad}	Total adiabatic head (m)
P	Input power (kW)
P_0	Pressure at impeller eye (Pa)
P_2	Pressure at impeller outlet (Pa)
Q	Capacity (m ³ /sec)
R	Gas constant of air (J/kg K)
S_s	Allowable shear stress (MPa)
T_a	Temperature of inlet (K)
T_0	Temperature of gas through the eye (K)
T_2	Temperature of gas through the impeller outlet (K)
u_1	Inlet peripheral velocity (m/sec)
V_1	Absolute inlet velocity (m/sec)
V_2	Absolute outlet velocity (m/sec)
V_{r_1}	Radial component of absolute inlet velocity (m/sec)
V_{u_1}	Tangential component of inlet velocity (m/sec)
Z	Number of impeller vanes (-)
ϵ_p	overall pressure ratio (-)

ϵ_1	Inlet vane thickness factor (-)
ϵ_2	Outlet vane thickness factor (-)
β_1	Vane inlet angle (-°)
β_2	Vane outlet angle (-°)
η_o	Overall efficiency (%)
ρ_a	Air density (kg/m ³)

I. INTRODUCTION

Centrifugal blowers are widely used in different industrial applications, which are proficient of as long as restrained to high-pressure rise and flow rates. Centrifugal blowers are mainly two main parts, namely, the casing and the impeller. The impeller is often considered an integral part of the suction motor since its housings and the motor are assembled as a unit. The impeller, driven by the blower shaft adds the velocity component to the fluid by centrifugally casting the fluid away from the impeller vane tips. The key idea here is that the energy created is kinetic energy. The amount of energy given to the fluid corresponds to the velocity at the edge or vane tip of the impeller. Addison (1995) established that the faster the impeller revolves or the bigger the impeller is, the higher will be the velocity of the fluid at the vane tip and the greater the energy imparted to the fluid [8].

The principle involved in the design of a blower is similar in virtually every important aspect as that of a centrifugal pump except for the fact that the term “centrifugal pump” is often associated with liquid as its working fluid while the blower is meant to work on air (Edward, H.S. 1995). The effects of centrifugal force acting upon the spinning air within the impeller create the suction. As the impeller rotates,

the spinning air moves outward away from the hub, creating a partial vacuum which causes more air to flow into the impeller [9]. Air enters the impeller axially through the inlet nozzle which provides slight acceleration to the air before its entry to the impeller. The action of the impeller swings the air from a smaller to a larger radius and delivers the air at a high pressure and velocity to the casing. The centrifugal energy also contributes to the stage pressure rise. The flow from the impeller blades is collected by a spirally-shaped casing known as scroll or volute. It delivers the air to the exit of the blower. The scroll casing can further increase the static pressure of air [4]. The outlet passage after the scroll can also take the form of a conical diffuser is as shown in figure (1).

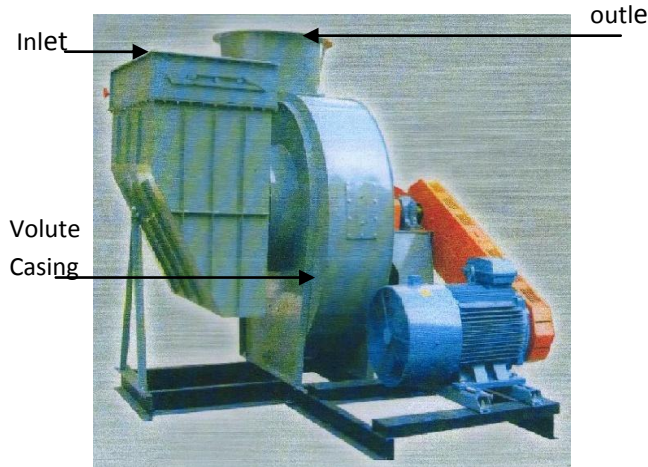


Figure1. Assembly of Centrifugal Blower [10]

Impeller is the most important part of the blower components because of the fact that its performance inadvertently determines the blower's performance. An impeller is essentially a disk shaped structure with vanes that create the actual suction in a blower. The impeller is always placed directly onto the shaft of the electric motor so that it spins at a very high speed. The effects of centrifugal force acting upon the spinning air within the impeller create the suction [3].

II. DESIGN OF BACKWARD-CURVED IMPELLER

A. Design of Impeller

The blower design is analyzed single stage centrifugal blower. Input data for design calculations are taken from Shwe Nan Taw Wheat Mill Factory in Mandalay industrial zone, used for separate the wheat and the defect for wheat mill factory. The details of an impeller specification are provided in table 1.

Table1. Specification of impeller

Specification of impeller	
Parameter	Dimension
Air flow rate, Q	1.2 m ³ /s
Rotational speed, N	3800rpm
Inlet air pressure, P _a	101.353 kPa
Inlet air temperature, T _a	30°C
Discharge air pressure, P _d	11kPa
Gravitational acceleration, g	9.81m/s ²
Air constant, R	287 J/kgK

The design of centrifugal blower involves a large number of interdependent variables so there are several possible designs for the same duty. To calculate the power input, flow rate and total adiabatic head must be known. As a result, to provide a certain amount of power to the air a larger amount of power must be provided to the blower shaft. This power is called brake horsepower. The power input to the blower is determined from the relationship

$$P = \frac{\rho_a g Q H_{ad}}{\eta_o} \quad (1)$$

Total adiabatic head is:

$$H_{ad} = \frac{1}{g} \times \frac{RT_a}{0.283} (\epsilon_p^{0.283} - 1) \quad (2)$$

The shaft diameter at the hub section is:

$$D_s^3 = \frac{16}{\pi S_s} \times \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (3)$$

The impeller inlet diameter is:

$$D_1 = 1.1 D_0 \quad (4)$$

Inlet vane angle of impeller is:

$$\tan \beta_1 = \frac{V}{u_1} \quad (5)$$

Impeller inlet width is:

$$b_1 = \frac{A_1}{\pi D_1 \epsilon_1} \quad (6)$$

The outlet diameter of impeller is:

$$D_2 = \frac{60 \sqrt{H_{ad} g}}{\pi N \sqrt{K}} \quad (7)$$

Blade number is:

$$Z = 6.5 \times \frac{D_2 + D_1}{D_2 - D_1} \sin \frac{\beta_1 + \beta_2}{2} \quad (8)$$

The impeller outlet width is :

$$b_2 = \frac{A_2}{\pi D_2 \epsilon_2} \quad (9)$$

Impeller outlet pressure is:

$$P_2 = \epsilon_p \times P_0 \quad (10)$$

Impeller outlet temperature is:

$$T_2 = T_0 \times \epsilon_p^{0.283} \quad (11)$$

Absolute velocity is:

$$V_2' = \sqrt{V_{t2}^2 + V_{u2}^2} \quad (12)$$

The require parameters to draw the impeller blade is calculated by the following equation. Figure (2) shows 2D drawing of impeller and velocity vector diagram of impeller wheel in a backward-curved blower is shown in figure (3). The final design of 3D impeller model is as shown in figure (4) below.

$$\rho = \frac{R_b^2 - R_a^2}{2 \times (R_b \cos \beta_b - R_a \cos \beta_a)} \quad (13)$$

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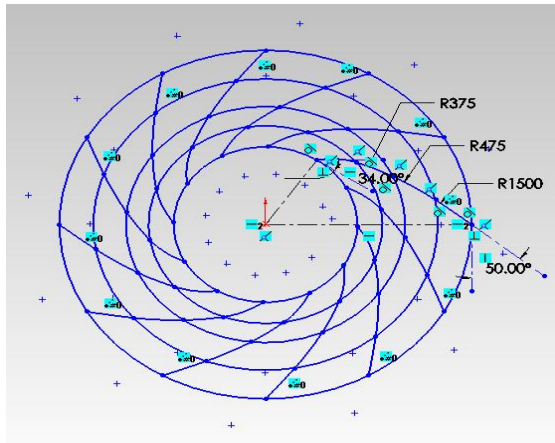


Figure2. 2D Drawing of Impeller.

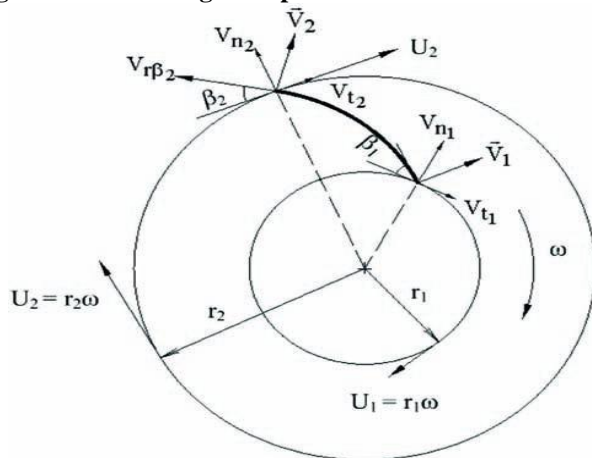


Figure3. Velocity Vector Diagram of Impeller Wheel in a Backward-Curved Blower [1].

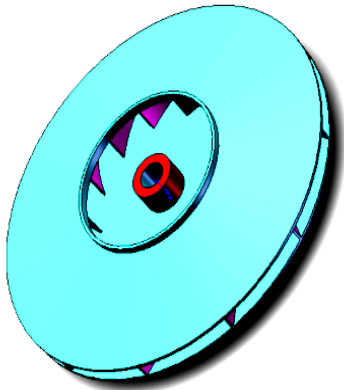


Figure4. 3D Drawing of Backward-Curved Impeller.

III. FLOW ANALYSIS OF IMPELLER

Generally, there are three steps to perform the flow simulation analysis in the SolidWorks Flow Simulation software. First step is assigning about the computational domain, boundary conditions and rotational region for the analysis. Second step is assigning the goal for flow simulation analysis and final step is run the simulation for the results.

A. First Step

The first step for the simulation is the assigning of computational domain, boundary conditions and rotational region. Computational domain is the overall boundary box for the computation to solve the design and as shown in figure(5). Boundary condition for inlet and outlet is for calculating the impeller outlet velocity, pressure and temperature distribution during the blower rotating. In this paper, inlet flow rate is $1.2 \text{ m}^3/\text{sec}$ and outlet pressure is environment. The impeller rotating speed is 3800 rpm for the simulation.

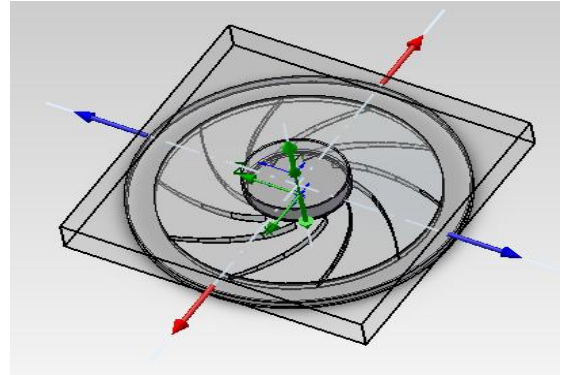


Figure5. Computational Domain.

After assigning the computational domain, the boundary conditions for the inlet and outlet of centrifugal impeller are assigned as shown in figure (6).

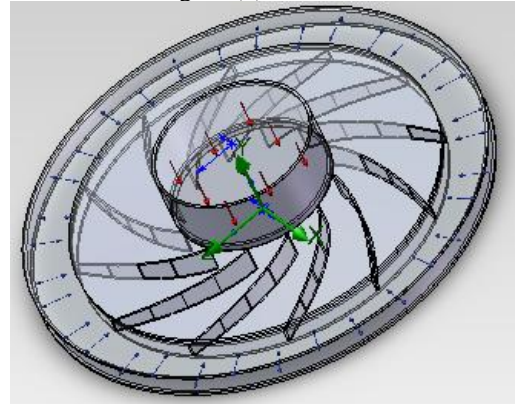


Figure6. Boundary Conditions.

B. Second Step

The second step is to choose the simulation goal. In the centrifugal blower, the goal for simulation is chosen the surface goal. After that the volume flow rate is chosen for the results of velocity flow, pressure flow and temperature distribution around the impeller blades.

C. Final Step for the Simulation Results

Final step for the flow simulation analysis in SolidWorks is running the design by using the boundary conditions. The simulation results for the velocity flows, pressure distributions and temperature distributions results are obtained and these simulation results are as shown in figures (7-9) below.

IV. THEORETICAL RESULTS AND SIMULATION RESULTS

According to the equation (1) to (12), the design results for the impeller are obtained as shown in table (2).

Table 2. Design Result Data of Impeller

Parameter	Dimensions
Impeller inlet diameter	260 mm
Impeller outlet diameter	600 mm
Shaft diameter	42 mm
Inlet vane angle	34°
Outlet vane angle	50°
Impeller inlet width	43 mm
Impeller outlet width	22 mm
Number of blades	12

According to the running simulation, the results for the minimum and maximum pressure, temperature, velocity components are obtained as shown in table (3) and (4).

Table 3. Simulation Results

Name	Minimum	Maximum
Pressure [Pa]	92166.36	101641.65
Temperature [K]	292.28	305.56
Velocity [m/s]	0	141.167
X - Component of Velocity [m/s]	-528.033	127.733
Y - Component of Velocity [m/s]	-127.518	128.074
Z - Component of Velocity [m/s]	-110.722	133.411

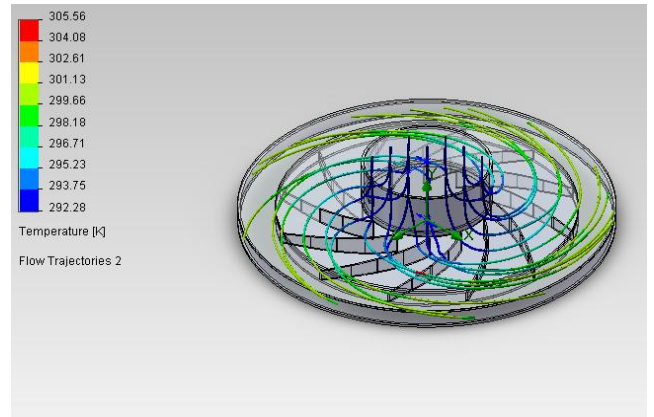


Figure9. Temperature Distribution of the Impeller.

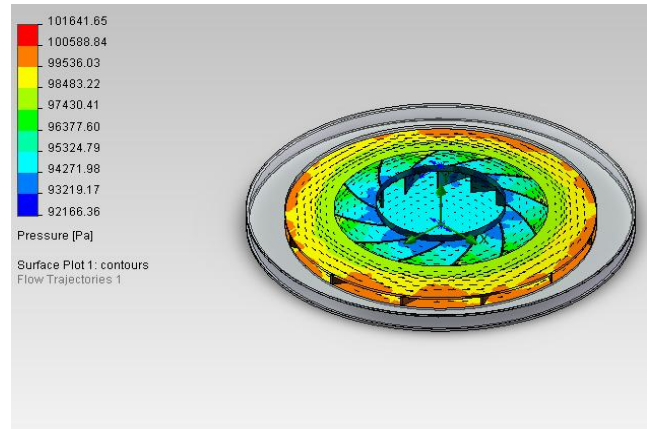


Figure 10. Contour of Pressure on Surface Plot.

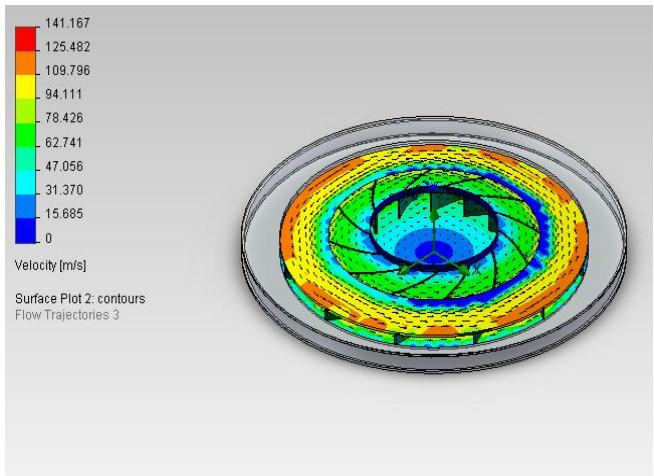


Figure11. Contour of Velocity on Surface Plot.

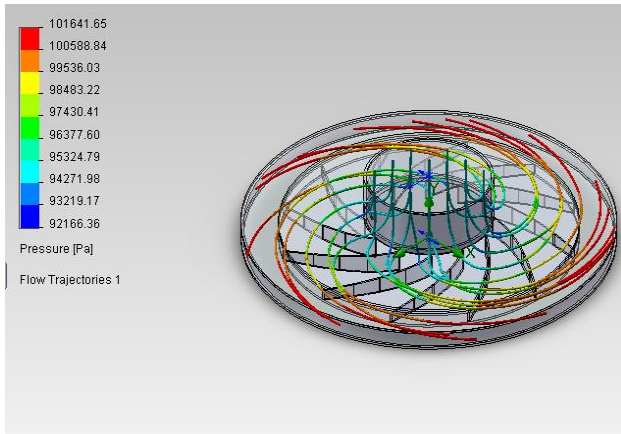


Figure7. Pressure Distribution of the Impeller.

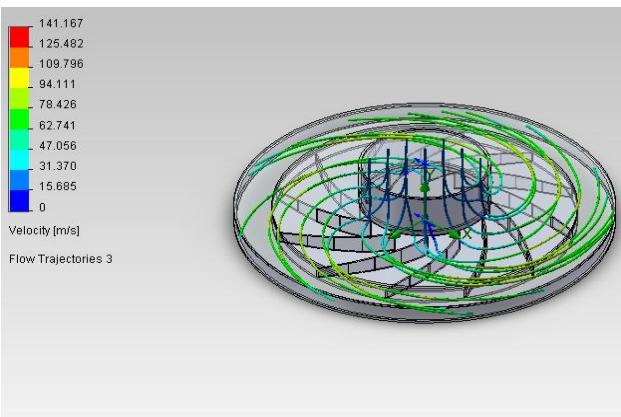


Figure 8. Velocity Distribution of the Impeller.

Figure 7 shows that the pressure distribution increases gradually along stream wise direction within impeller passage and has higher pressure in pressure side than suction side of the impeller blade. At figure 8 shows, the velocity distribution in impeller's inlet is the lowest, and it increase gradually along streamwise direction in the impeller. Figure 9 shows that the temperature distribution at the inlet is lowest, the outlet temperature near 301.13K is very close to the theoretical outlet temperature. Pressure contour and velocity contour are plotted as shown in figures (10-11).

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Table 4. Comparison between Numerical and Theoretical Results

Name	Theoretical Results	Numerical Results	Percentage error
Pressure	108.23 kPa	101.642 kPa	6%
Velocity	76.22 m/s	94.111 m/s	19%
Temperature	309.21 k	301.13 k	3%

V. DISCUSSIONS & CONCLUSION

In this paper, impeller design, shaft design and casing design were calculated and run the simulation in SolidWorks Flow Simulation Analysis. Inlet and outlet diameter and number of blades were designed. According to the theoretical design calculation results and simulation results, the pressure distribution in this impeller design is 108.23 kPa at the output of impeller by theoretically and 101.642 kPa by numerically from simulation output results. And then, theoretical output velocity is about 76.22 m/s and 94.111 m/s in numerical simulation for impeller design. Moreover, the calculated result for temperature distribution is 309.21 K and 301.13 K at simulation result. So, the percentage error of the calculated results and simulation results for this centrifugal blower are 6% in pressure, 19% in velocity and 3% in temperature distribution respectively. Pressure and velocity distribution inside impeller of the centrifugal blower has direct influence due to change of flow rate. Similar computational simulation models can also be used for analyzing the pressure and velocity of the blower.

VI. REFERENCES

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