Aerodynamic Analysis and Comparison between Axial Fan of Five and Seven Blades

Mehrab Hasan
Mechanical and Energy Engineering Department
University of North Texas

Abstract

In this study, numerical simulations were conducted on a specific model of axial fan, which has a wide range of applications in the industry. The simplified geometry of the fan was generated using SOLIDWORKS and then it was imported to ANSYS for aerodynamic analysis. Static Pressure on fan blades were calculated for different air flow velocities ranging from 2.5 to 7.5 ms-1 velocity. It was revealed that with the increase of air flow velocity, the static pressure increases on fan blades.

KEYWORDS: Axial Fan, CFD, ANSYS, Static Pressure

Introduction

Axial fan is widely used in many engineering applications industrywide. They are being used for industrial applications and air conditioning. Although they are incapable of developing high pressure, at relatively low air pressure they can handle a significant volume of air.

Candaş et al. [1]performed a CFD analysis of an industrial model fan and used LES and k-ε turbulence models for numerical modeling. The study was performed using both stationary and rotational domain. 720 rpm and 1080 rpm were considered rotational speeds. A relation between volumetric flow rate (m3/s) and pressure rise was established for analysis.

Previously, Hemant Kumawat [2] in his study, analyzed and simulated results for fans having seven to eleven blades and he plotted static pressure, and temperature contour for those fans. He finally determined that fan with eleven blades had the highest efficiency at air velocity of 22 m/s. Also, Thumbe et al. [3] conducted an analysis of axial fan having six blades. Jain and Deshpande analyzed the airflow distribution from a radial axial flow fan and considered 1680 rpm and 25.26 kg/s as the input conditions for their analysis. The static pressure contour plots were almost similar to this study.

In this present study, analysis of five and seven blade axial fan was performed for RS 1442047 model. Static pressure and streamline velocity were analyzed for variable velocity conditions.

Geometry and CFD Model

The geometry was created from the dimensions provided by the catalogue of RS PRO DC Axial Fan[4]. The frame is rectangular in shape, and it is 50x50x10 mm in dimension. For mesh cell number constraints in ANSYS student version software, a simplified geometry of the fan was created. Then it was imported into ANSYS and modeled. To observe the physical properties, a domain was created using enclosure module. The enclosure was 40 mm in x and y directions, 30 mm in positive z direction and 200 mm in negative z directions. These dimensions were chosen for better observation. As per the product datasheet, the angular velocity for the fan was determined at 4600 rpm and all the simulations were conducted at this motion.

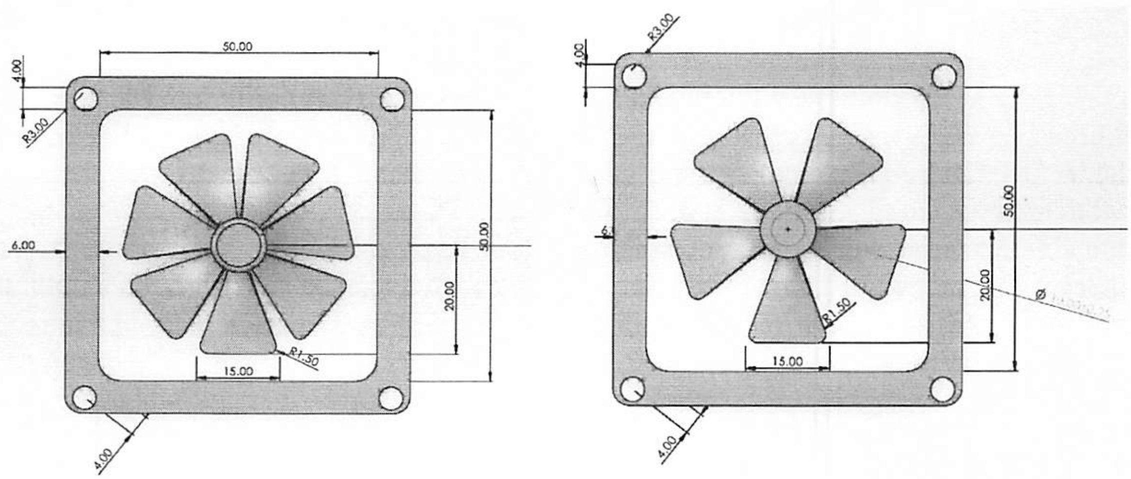

Figure 1.CAD Geometry of the Five Blade and Seven Blade Fans

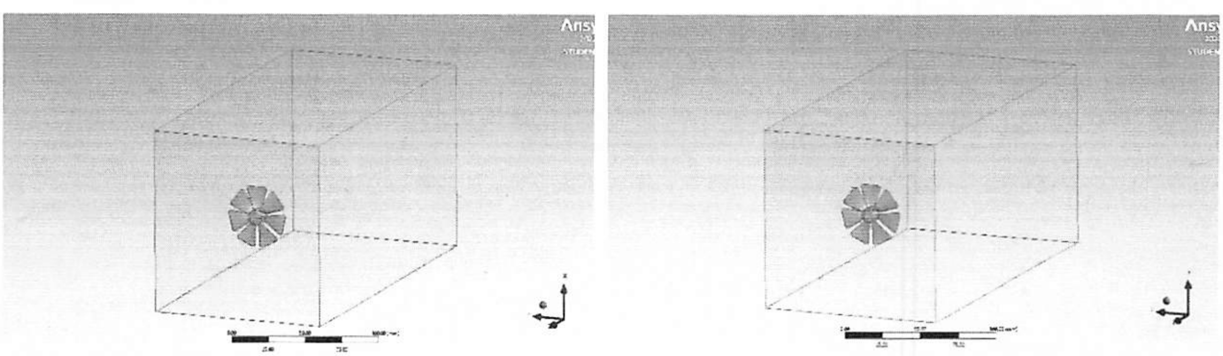

Figure 2. Geometry in ANSYS

Simulation Conditions

A pressure based transient simulation method was adopted for this study. For model, k- ε model was selected. The model was selected as realizable. For near wall treatment, scalable wall function was used. For Solution, SIMPLE algorithm and second order upwind method were used. SIMPLE algorithm is an iterative procedure, and it starts with an initial guess value and continues to run until converged.

Domain Size and Mesh

For mesh, three named selections were created as inlet, outlet and wall. Element size was selected as 0.001m and program-controlled element was chosen. Due to mesh cell number limitations, much smaller mesh element size could not be selected. For both seven blade and five blade fans, same setup was used. Quality of mesh was selected as smooth. Mesh element number for five blade fan was 293334 and for seven blade fan it was 319240.

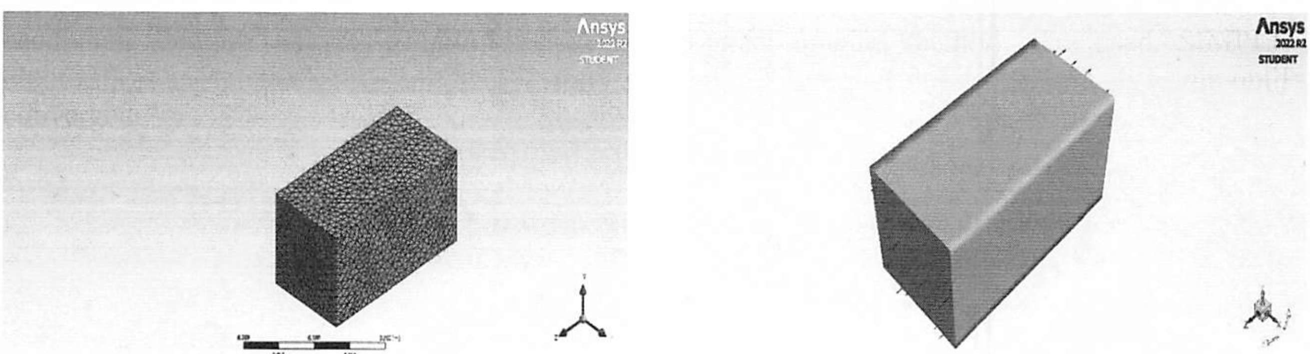

Figure 3. Surface mesh and Volume mesh

Governing Equations and Discretization Schemes

Continuity Equation

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{V}) = 0 \quad (1)$$

Momentum Equation

$$\rho \frac{D\vec{V}}{Dt} = -\nabla p + \nabla \cdot \bar{\bar{\tau}} + \rho \vec{f} \quad (2)$$

Energy Conservation Equation

$$\rho\left[\frac{\partial h}{\partial t} + \nabla \cdot (h\vec{V})\right] = -\frac{Dp}{Dt} + \nabla \cdot (k\,\nabla T) + \phi \tag{3}$$

$$\phi = (\bar{\bar{\tau}} \cdot \nabla)\vec{V} = \tau_{ij}\frac{\partial V_i}{\partial x_j} \tag{4}$$

The governing equations stated above were solved for convergence using SIMPLE algorithm in ANSYS solution module. These equations are applicable for both compressible and incompressible fluids. They are presented in conservative form.

Boundary Conditions

As the fan has a specific angular velocity and different air flow velocity were applied, these criteria were put into consideration for boundary conditions. In the cell zones, mesh motion was applied to fan body and as per the product data sheet angular velocity of 4600 rpm was applied. For inlet boundary, air flow velocity ranging from 2.5 to 7.5 ms^{-1} was applied for different cases. For outlet boundary, the gauge pressure was kept at zero pascal. Also, the wall zones were kept stationary. Temperature for the whole geometry was kept at 300k as initial condition.

Results and Discussions

As for the inlet boundary condition, three different air flow velocity were applied, and results were analyzed accordingly. A side-by-side comparison was done for both the blades in different inlet velocity. Static pressure limit was checked for all the cases and maximum velocity was determined.

Velocity 2.5 m/s

For air flow velocity 2.5 m/s, both the fans experienced static pressure below the allowable limit. For five blade fans, the maximum static pressure was 5.58 Pa while for seven blade fan, it was higher, 5.97 Pa.

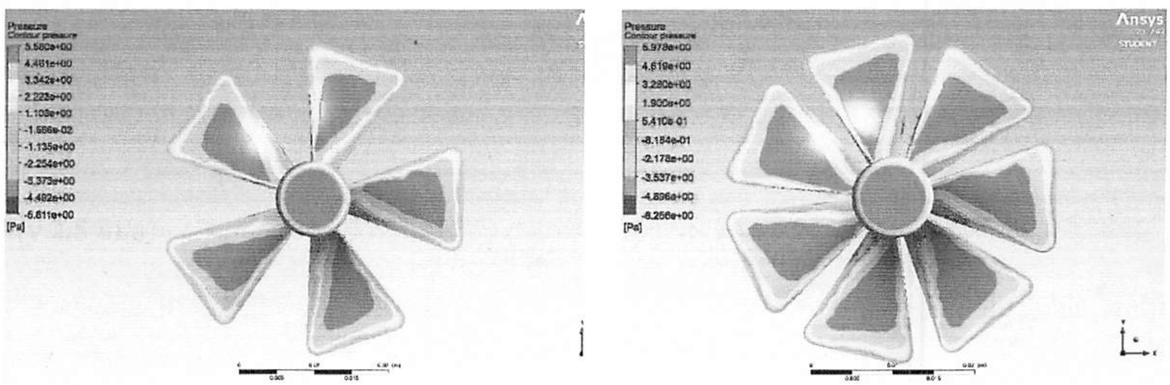

Figure 4. Static Pressure Contour at 2.5 m/s velocity

The maximum velocity for five blade fan is 3.679 ms-1 while it is 3.784 for the seven blade fan.

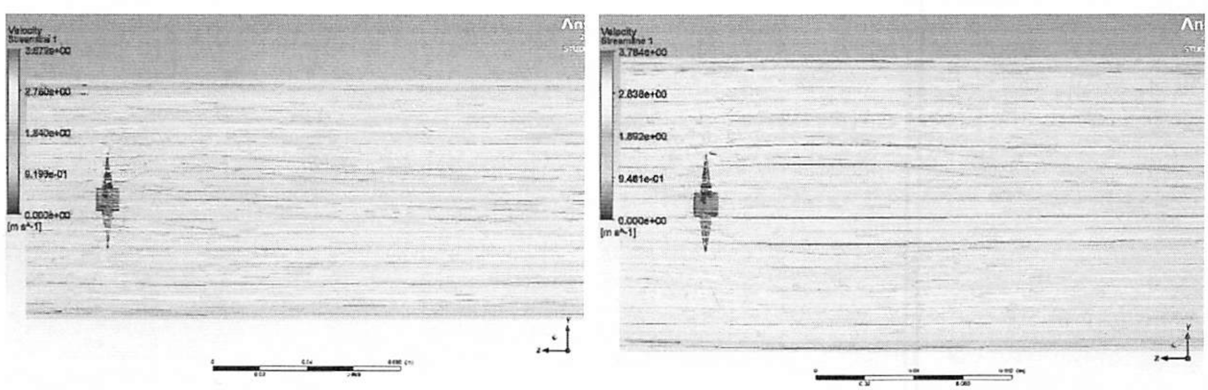

Figure 5. Velocity Streamline at 2.5 m/s velocity

Velocity 5 m/s

In this case, air flow velocity for inlet was 5 m/s. The static pressure increased for both fans, but it did not exceed the allowable static pressure limit. While the maximum static pressure for five blade fan was 21.98 Pa, it was 23.77 Pa for seven blade fan.

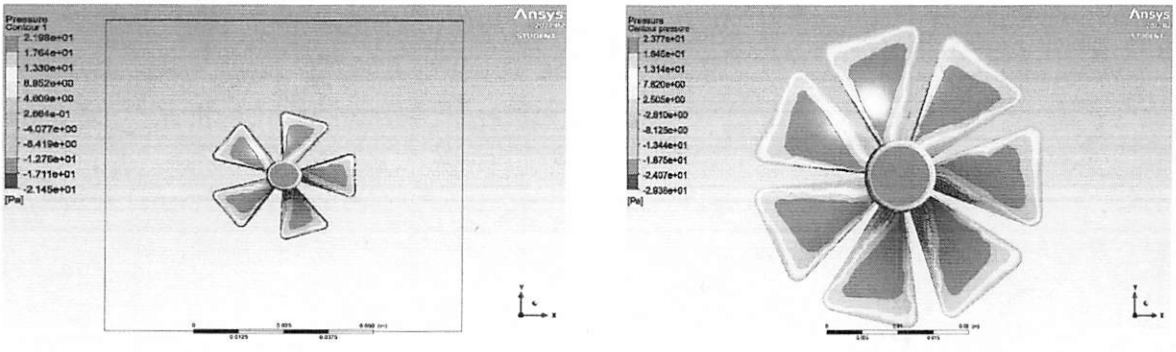

Figure 6. Static Pressure Contour at 5 m/s velocity

In case velocity, the maximum velocity magnitude increased by almost 50% for both the fans. The maximum velocity for seven blade fan was 7.653 m/s while it was 7.241 m/s for five blade fan.

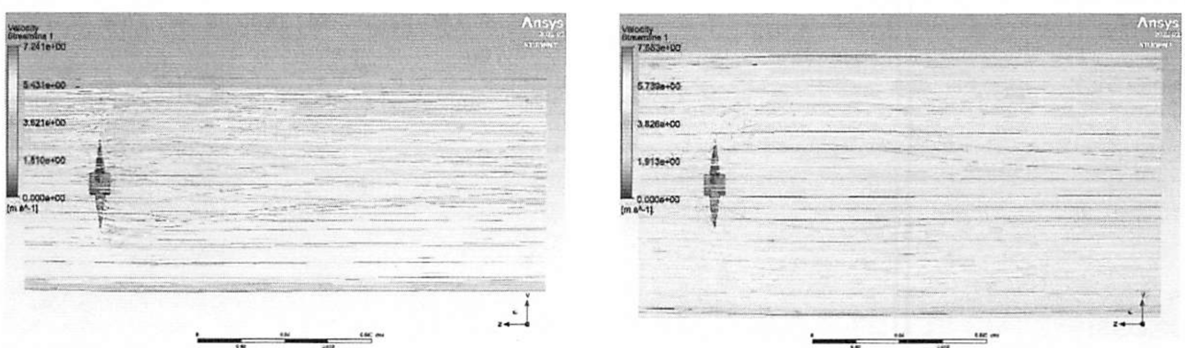

Figure 7. Velocity Streamline at 5 m/s velocity

Velocity 7.5 m/s

The static pressure exceeded the limit for air flow inlet velocity 7.5 m/s. Therefore, airflow over 5 m/s velocity would cause deterioration to fan working condition. Here, the maximum static pressure for five blade fan was 48.91 Pa and 53.65 Pa for seven blade fan.

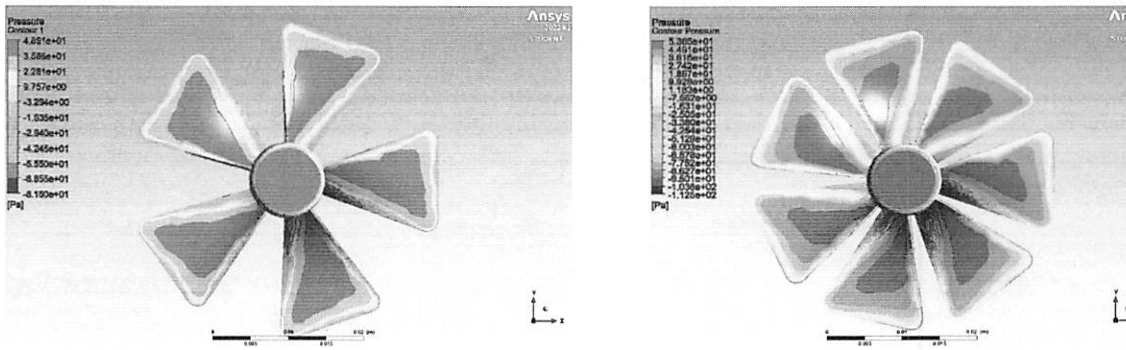

Figure 8. Static Pressure Contour at 7.5 m/s velocity

The maximum velocity magnitude was 13.27 m/s for five blade fan, which is higher than the seven blade fan at 13.15 m/s. Although the velocity was not significantly higher, it was an exception from the previous cases.

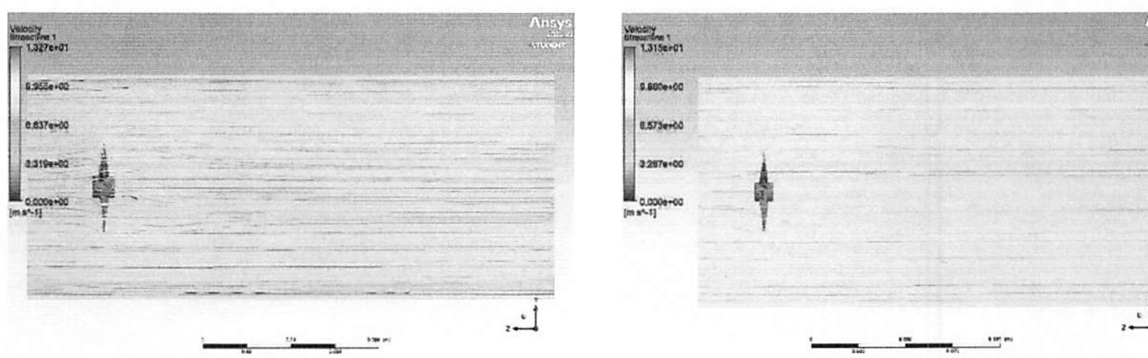

Figure 9. Velocity Streamline at 7.5 m/s velocity

Discussion

From all the cases some common characteristics were observed. The static pressure was close to zero or lower than zero along the blade edges. But in the mid part of the blade and close to vicinity of the center, pressure increased, and maximum pressure was observed there. It happened in all the cases. The maximum static pressure was observed from inlet to the front portion of the blades while the negative pressure zone was observed mostly in the backside of the blades.

In case of velocity streamline plots, maximum velocity flow was observed close to fan blades. But as the distance from fan body increased, the velocity of flow began to decrease and turned into a uniform flow. It was applicable for all the cases.

Conclusion

From the above study, following concluding remarks can be obtained-

- With the increase, inlet flow velocity, static pressure increased for both the fans. The maximum allowable static pressure was 23.77 Pa, which was for seven blade fan at 5 m/s inlet air flow velocity. But at 7.5 m/s velocity static pressure was significantly higher than the allowable maximum static pressure of 24.909 Pa for both the fans.
- For all the cases, static pressure of seven blade fan was higher compared to the five-blade fan. But the difference was not that significant. As the fans were operating at a remarkably high angular velocity and the dimension of the fans and domain were small, that's why the static pressure difference was not significant.
- Maximum velocity was always higher for seven blade fan than the five blade fan. But, for 7.5 m/s inlet air flow velocity five blade fan experienced the higher velocity. The difference between maximum velocity magnitudes were not significant, due to smaller domain and high operating angular velocity of the fans.

References

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