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Experimental and Performance Analysis of Axial Jet Fan with Diffuser Angle 5°

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Abstract

This study presents an experimental performance analysis of an axial jet fan with a converging nozzle and a 5° angle of diffuser, designed for basement car parking ventilation. The objective is to improve airflow quality and fan efficiency. The axial jet fan design parameters are computed with theoretical calculations and simulated computational fluid dynamics (CFD) the airflow characteristics and pressure distribution. The results were validated through experimental testing conducted in a fabricated tunnel. Parameters such as axial velocity, pressure distribution, and carbon monoxide (CO) concentration were measured at different fan speeds. The results indicate that the designed nozzle improves inlet airflow and diffuser pressure recovery, leading to improved fan efficiency. Additionally, CO concentration was significantly reduced over time, demonstrating effective ventilation performance. The study confirms that integrating nozzle–fan–diffuser components enhance operational efficiency of axial jet fan.

A. Introduction

Jet fans are to maintain air quality, and ensuring safety in basement parking requires effective ventilation to remove harmful pollutants like carbon monoxide (CO) and vehicle exhaust.

According to O. P. Garrick (2015), applied velocity triangle theory and axial fan similarity laws to evaluate fan performance in confined spaces. The results indicated that blade angle, hub-to-tip ratio, and specific speed are crucial parameters governing efficiency [3].

Manikandapirapu P. K. (2012), jet fans play a critical role in controlling smoke and pollutants by inducing longitudinal airflow, which reduces the need for large duct systems. The study highlighted that fan placement and nozzle geometry significantly affect airflow. CFD simulations have become a dominant tool in evaluating jet fan performance under various operating conditions. A computational fluid dynamics (CFD) analysis is used to evaluate jet fan efficiency that inlet nozzles can improve velocity distribution while reducing turbulence at the fan entry [4].

According to FläktComp (2026) [5], axial jet fans are designed to move large volumes of air through a nozzle at low pressure, ensuring efficient air circulation in large enclosed spaces such as tunnels and underground car parks.

Therefore, the addition of nozzle before the fan and diffuser after the fan has received considerable attention in the literature. Previous studies have mainly focused on the design parameters of axial jet fan with the theoretical and numerical analysis of airflow, pressure distribution, and efficiency [6].

This research focuses on experimental performance analysis of an axial jet fan equipped with a converging nozzle at the inlet and a 5° diffuser at the outlet.

B. Research Method

The axial jet fan with the inlet nozzle and outlet diffuser was designed and numerically analyzed to predict performance characteristics. For the experimental test, the axial jet fan was fabricated with an inlet nozzle and a 5° outlet diffuser angle. And then the testing tunnel was constructed in accordance with Japanese Industry standards (JIS) that to provided simulation of airflow conditions. The axial jet fan was installed within the experimental setup, where parameters such as airflow, pressure distribution, and ventilation performance like carbon monoxide concentration, were measured. The theoretical results were compared with experimental and numerical analysis results to improve the accuracy and reliability of the performance evaluation.

1. The Specification Data of Axial Jet Fan

The axial jet fan was designed with the importance geometric parameters such as blade tip and hub diameters, blade length, chord length, thickness, blade angles, number of blades, and rotational speed for fan performance. In addition, the dimensions of the inlet nozzle and outlet diffuser angle of 5° are also shown in Table 1. These specifications data were selected previous studies to achieve efficient airflow performance [6].

Table 1. Design Specification Data of the Axial Jet Fan

Parameter	Value	Unit
Blade Tip Diameter	0.457	m
Blade Hub Diameter	0.138	m
Blade Length	0.16	m
Blade Chord Length	0.191	m
Blade Thickness,	0.010	m
Blade Inlet Angle	58.933	degree
Blade Outlet Angle	46.463	degree
Number of Blades	3	-
Rotational Speed	2500	rpm
Nozzle Inlet Diameters	0.608	m
Nozzle Outlet Diameters	0.482	m
Nozzle Length	0.039	m
Nozzle Angle	45	degree
Diffuser Inlet Diameters	0.482	m
Diffuser Outlet Diameters	0.539	m
Diffuser Length	0.478	m
Diffuser Angle	5	degree

2. Numerical Analysis of an Axial Jet Fan

The numerical analysis of an axial jet fan begins with creating geometry and domain with design data of the axial jet fan, followed by generating mesh. After that, boundary conditions are set up and model is solved with CFX solver manager. Finally, the numerical analysis results are obtained from geometry creation into the fluid flow (CFX), followed by mesh generation and the CFX setup, solution and results stages. The geometry setup of axial jet fan presents the following Figure 1.

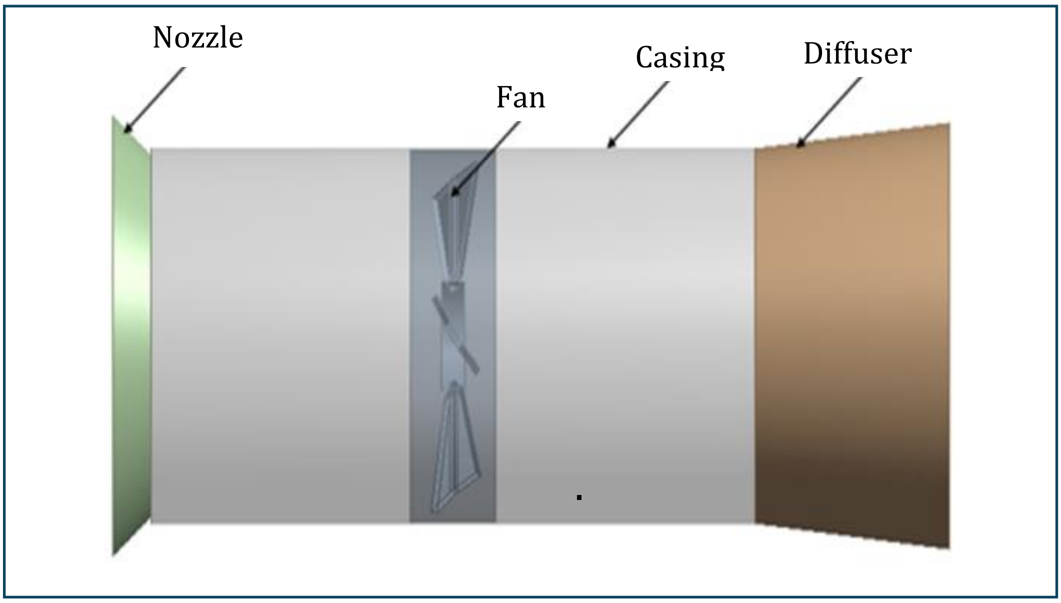

Figure 1. Geometry of Axial Jet Fan

3. Constriction of Axial Jet Fan

The axial jet fan was constructed with three bladed fans as shown in Figure 2.

Figure 2. Axial Jet Fan with Three Bladed Fan

4. Design Consideration of Tunnel

The tunnel, constructed according to JIS standards as shown in Figure 3, was used to test airflow conditions and evaluate the performance of the axial jet fan intended for basement car parking ventilation.

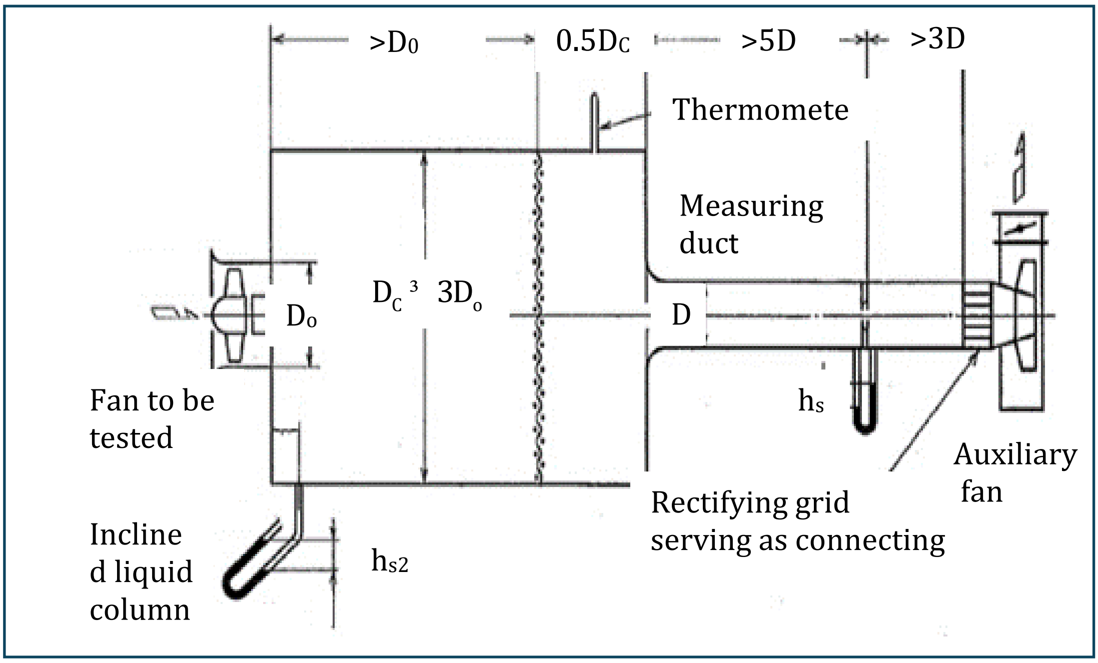

Figure 3. Tunnel according to JIS

As presented in Figure 4, the tunnel was constructed using plywood board, hollow and foam lining. After measuring the hollow, they were welded and joined with plywood and foam lining to ensure structural stability and airtight conditions.

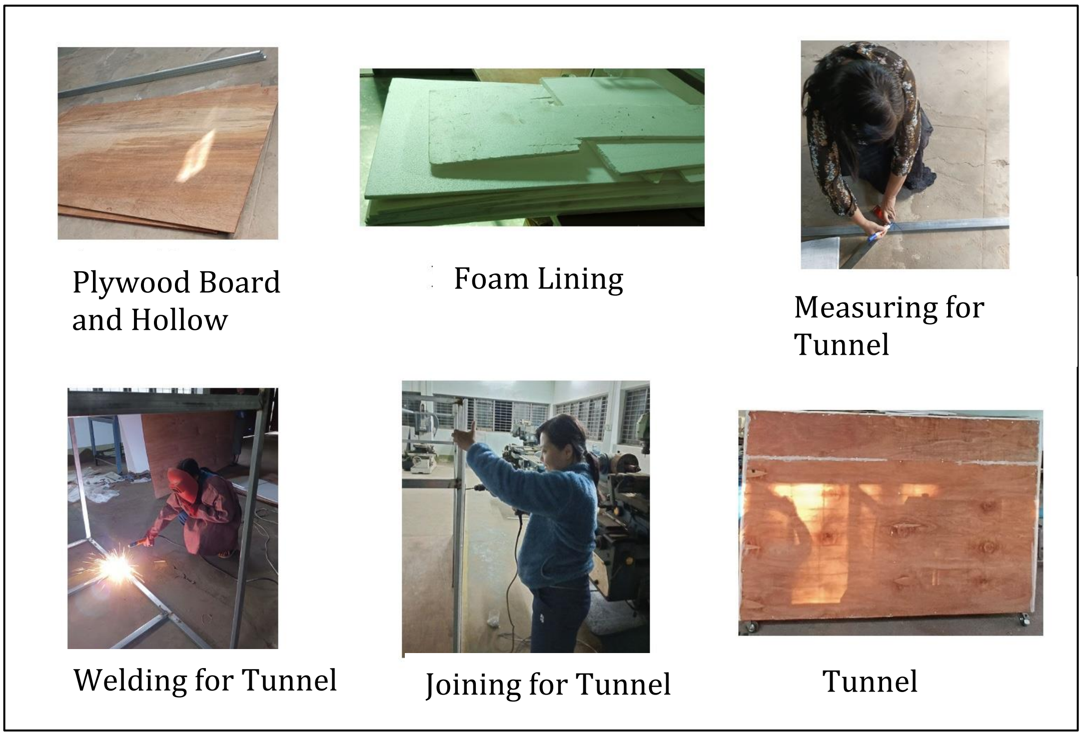

Figure 4. Tunnel Construction for Performance Testing

The assembly of an axial jet fan shown in Figure 5 was connected to the test the tunnel, equipped with a carbon monoxide (CO) generation system and axillary fan for performance testing.

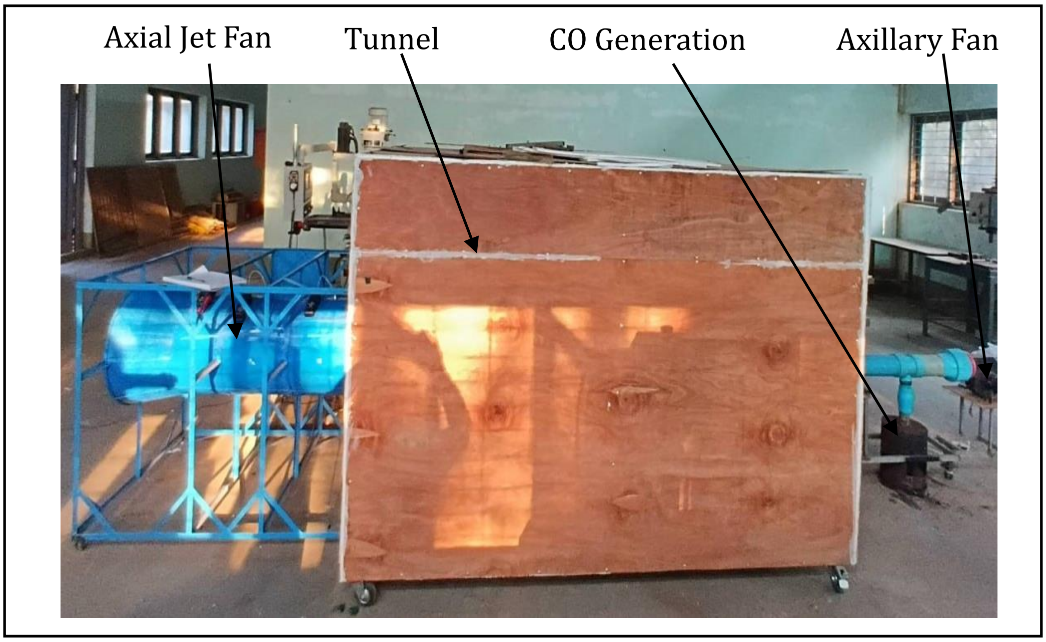

Figure 5. Assembly of Axial Jet Fan for Performance Testing

The Figure 6 shows the experimental setup for performance testing the axial jet fan. Pressure at the fan inlet, fan outlet, and diffuser was measured during the experiment.

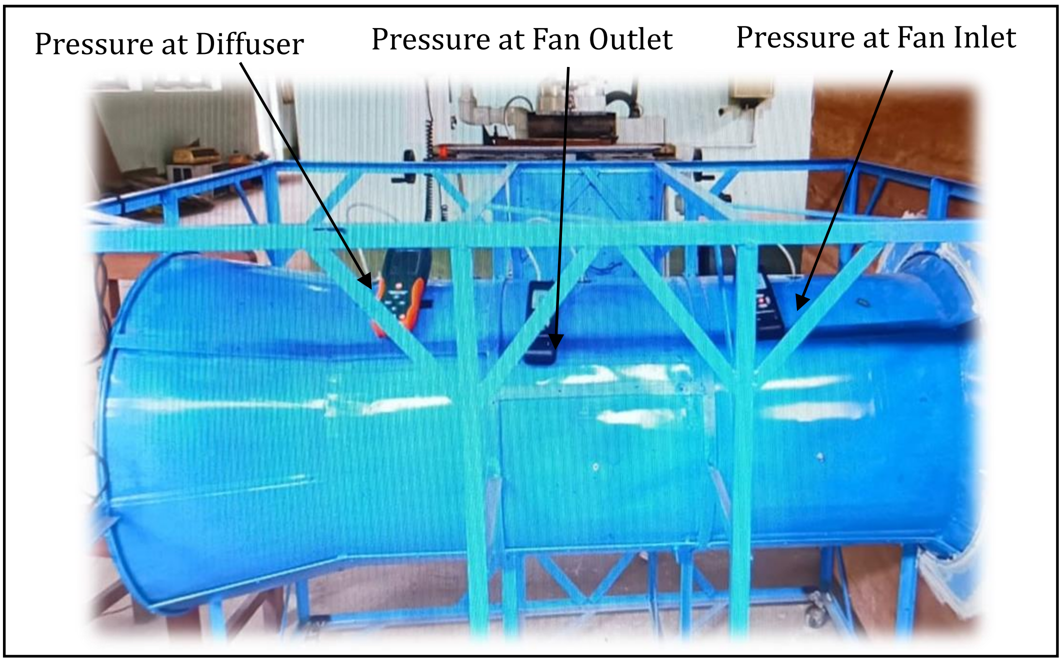

Figure 6. Performance Testing of Axial Jet Fan

The experiment was conducted by varying the fan speed to evaluate the performance testing of the axial jet fan. Parameters such as fan speed, pressure at the fan inlet, fan outlet, and diffuser, axial velocity, were measured as shown in Figure 7.

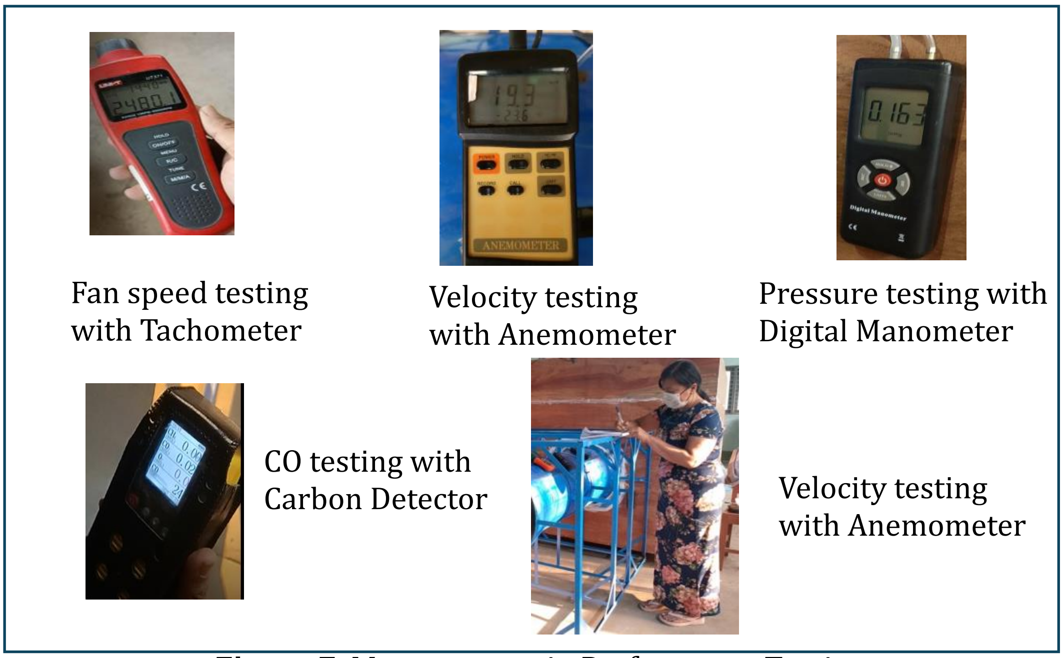

Figure 7. Measurement in Performance Testing

C. Result and Discussion

The pressure data at the fan inlet, measured using a manometer at different fan speeds, are presented in Table 2. The pressure distribution at the fan inlet is shown in Figure 8.

Table 2. Pressure Data at the Fan Inlet

Fan rotational speed (rpm)	P_s (Pa)
1189	101358.86
1427	101321.61
1783	101321.61
2480	101355.48
2741	101284.36

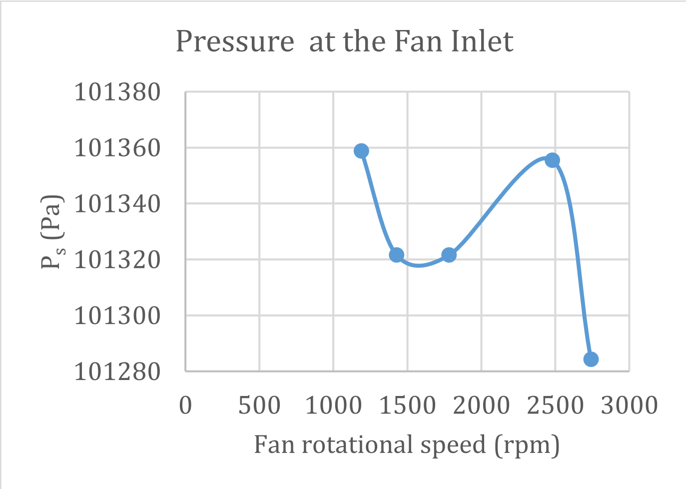

Figure 8. Pressure distribution curve at the fan inlet

The pressure data at the fan outlet are shown in Table 3, measured using a manometer at different fan speeds, The pressure distribution at the fan inlet is shown in Figure 9.

Table 3. Pressure Data at the Fan Outlet

Fan rotational speed (rpm)	P_s (Pa)
1189	101426.59
1427	101321.61
1783	101321.61
2480	101338.54
2741	101304.68

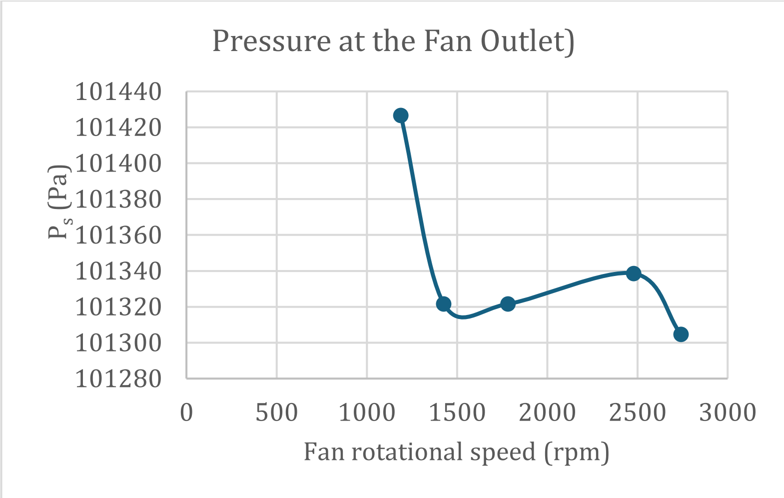

Figure 9. Pressure distribution curve at the fan outlet

The pressure data at diffuser are presented in Table 4. The pressure distribution at the diffuser is shown in Figure 10. The rotational speed of the fan is also directly proportional to the flow rate. An increase in fan rotational speed results in a corresponding increase in the flow rate and consequently the decreasing of the pressure at the diffuser.

Table 4. Pressure Data at Diffuser

Fan rotational speed (rpm)	**P_s (Pa)**
1189	101494.31
1427	101460.56
1783	101426.69
2480	101392.73
2741	101325.00

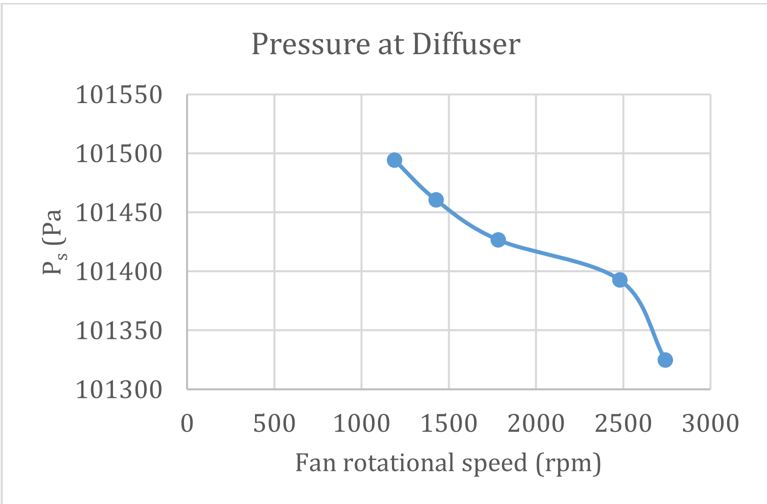

Figure 10. Pressure distribution at Diffuser

The pressure changes with volumetric flow rate (Q) and axial velocity (V_a) under different speed control settings, as shown in Table 5. The relationship between pressure and flow rate is illustrated in Figure 12.

Table 5. Result Data Pressure and Volume Flow Rate

Fan rotational speed (rpm)	Speed Control	V_a (m/s)	Q (m^3/s)	P_s (Pa)
1189	50	16.5	2.71	101426.59
1427	60	19.3	3.17	101321.61
1783	70	23.5	3.85	101321.61
2480	90	26.2	4.30	101338.54
2741	100	27.5	4.97	101304.68

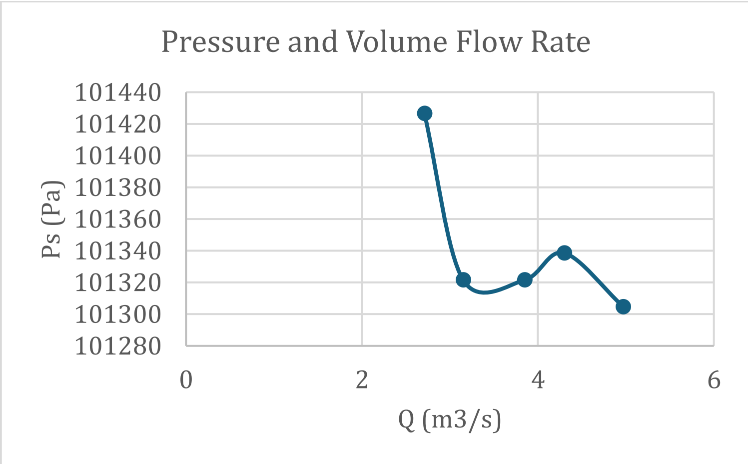

Figure 12. Pressure and Volume Flow Rate

The numerical, theoretical, and experimental results for the axial jet fan parameters are shown in Table 6. The percentage deviations show the differences between the theoretical and measured values. Figure 13 shows these comparisons of the fan performance.

Table 6. Efficiency Comparison Axial Jet Fan Parameters

Parameter	Numerical Result	Theoretical Result	Experimental Result	Unit	Theoretical & Numerical Percent Deviation (%)	Theoretical & Experimental Percent Deviation (%)
Pressure Drop across Fan, Δp_{fan}	582	562	552	Pa	3.436	1.778
Flow Rate, Q	4.849	4.508	4.3	m^3/s	7.032	4.614
Axial Velocity	30.079	29.984	26.2	m/s	0.385	12.620
Rotational Speed	2500	2500	2480	rpm	0	0.800
Efficiency, η_{fan}	65.201	63.485	57.776	%	2.631	8.993

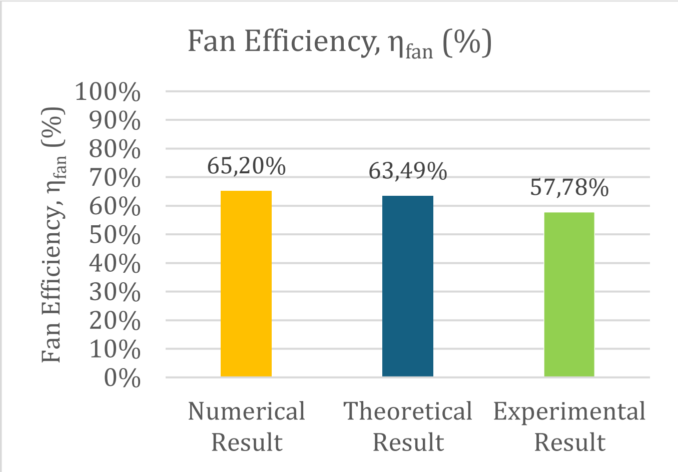

Figure 13. Efficiency for Axial Jet Fan

CO Concentration

The CO concentration levels are presented in the result Table 7 at one-minute intervals. The data shows a very high initial concentration parts per million (PPM) of 1780 ppm at 0 minutes, which rapidly decreases to 48 ppm after 1 minute and continues to drop gradually to 24 ppm by 5 minutes. It indicates effective ventilation performance in removing carbon monoxide from the parking area.

Table 7. CO Concentration per Time Interval

Minutes	CO Concentration (PPM)
0	1780
1	48
2	33
3	35
4	30
5	24

D. Conclusion

The experimental analyses showed pressure from 101355.48 Pa at the inlet to 101338.54 Pa at the outlet, while the diffuser reached 101392.73 Pa, indicating effective pressure recovery. The flow rate increased from 2.71 to 4.97 m^3/s, improve airflow rates at various speed. The pressure and flow rates relationship followed a typical axial fan characteristic curve. The fan efficiency is approximately 57.78% in experimental results, with acceptable percent deviations from theoretical predictions. The carbon monoxide (CO) concentration was significantly reduced from 1780 ppm to 24 ppm, achieving approximately 98.65 % reduction, that demonstrating efficient pollutant removal. Overall, the results confirm that the axial jet fan with a converging nozzle and 5° diffuser provides efficient airflow, stable pressure distribution, and effective ventilation for basement car parking.

E. Acknowledgment

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