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Optimizing the Exhaust System to Improve Air Quality in Vehicle Service Repair Shops

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ABSTRACT

Air pollution from vehicle emissions, including NO_2, SO_2, O_3, TSP, and CO, negatively impacts workers' health and reduces work efficiency and productivity. This study aims to (1) develop an exhaust system at the Nissan Mlati ATPM workshop, and (2) determine the effectiveness of the exhaust system. The process of optimizing the exhaust system to improve air quality in the vehicle service repair stall was carried out through a comprehensive design and development project, including design and development phases and tool use. Then, metric volume (theoretical), actual use, and performance efficiency calculations were used. The results of the study show that optimizing the exhaust system at the Nissan Mlati ATPM workshop has been proven effective in increasing airflow capacity, maintaining air quality, and improving performance efficiency. This system can reduce the concentrations of pollutants such as Carbon Monoxide (CO) and Total Suspended Particulate (TSP) and increase workshop productivity without requiring structural design changes. The overall percentage results show a 51.03% increase in value after exhaust system optimization. This exhaust system not only improves air quality but also increases work productivity, which is crucial in the automotive industry's competition.

1. Introduction

Transportation plays a vital role in modern life, especially in supporting community mobility. Motor vehicles are the dominant means of transportation used in various regions, including Indonesia. However, the annual increase in the number of motor vehicles has environmental consequences, particularly worsening air pollution. According to data released by the Central Statistics Agency [1] in 2023, the number of motor vehicles in Indonesia reached 157,080,504 units. This figure shows an increase of around 7,191,056 units compared to the previous year, indicating significant growth. In the Special Region of Yogyakarta (DIY), the number of registered motor vehicles reached 3,238,203 units, with an estimated annual growth of 4% for cars and 6% for motorcycles [2]. This increase in the number of vehicles certainly has implications for air quality in the region, especially in urban areas with high motor vehicle activity. There are two types of combustion in motor vehicle fuel: complete and incomplete. These two processes have different impacts on the environment.

Complete combustion occurs when hydrocarbon compounds (C_xHy) react with oxygen (O_2) in sufficient quantities, producing carbon dioxide (CO_2) and water vapor (H_2O) as the main products. A common chemical reaction that illustrates this process is C_8H_{18} + 12.5 O2 • 8 CO_2 + 9 H_2O, which shows that octane (C_8H_{18}), one of the main components of gasoline, undergoes complete combustion with higher energy output. This process also does not produce harmful substances such as carbon monoxide (CO) or unburned hydrocarbons. However, in practice, complete combustion is difficult to achieve in vehicle engines due to various constraints, such as an ideal air-fuel ratio and limitations in combustion system efficiency.

Air pollution is caused by various types of harmful gases emitted by vehicles, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), particulate matter (TSP), and carbon monoxide (CO). Based on research conducted by [3]. Motor vehicle emissions are known to contribute to nearly 100% of carbon monoxide (CO) levels, 100% of lead (Pb) levels, 70-89% of hydrocarbon (HC) levels, and 34-73% of nitrogen oxide (NOX) levels in the atmosphere. This situation is even more alarming when looking at data from IQAir.

According to IQAir data, Indonesia ranked 14th out of 134 countries with the worst air quality in 2023, with an average PM2.5 concentration of 37.13 µg/m³. This figure exceeds 7.4 times the annual PM2.5 (particles measuring 2.5 micrometers) guideline value recommended by the World Health Organization (WHO). In addition, real-time data from IQAir shows that several cities in Indonesia have high levels of air pollution. For example, on February 27, 2025, the city of Medan in North Sumatra recorded an Air Quality Index (AQI) of 163, which is categorized as "Unhealthy."

Measurements of motor vehicle emissions were conducted by [4] in the Sleman region, with a total of 528 vehicles tested, including 125 official vehicles and 403 public vehicles. The test results showed that 20% of government vehicles and 15% of public vehicles did not meet the Emission Quality Standards (BME). Overall, 84 vehicles, or 16% of the total tested, did not meet emission standards. Gasoline-fueled vehicles did not show significant changes in their level of compliance with emission standards.

Exhaust emission testing on Nissan D22 or Nissan Navara diesel engines using pure diesel fuel conducted by [5] showed that carbon monoxide (CO) emissions were in the range of 14% vol at 1000 rpm. It decreased to 12 vol at 3000 rpm. Carbon dioxide (CO_2) emissions increased from 6% vol to 14% vol, reflecting a more complete combustion process as engine speed increased. Oxygen (O_2) concentration was also recorded as higher at 8% vol, indicating excess air in the combustion process.

PT Wahana Sumber Baru Yogya (Nissan-Datsun Mlati) is an automotive company located at Jalan Magelang KM.10, Mlati, Sleman, Special Region of Yogyakarta. This company plays an important role in the motor vehicle industry by providing key services, namely the sale of Nissan, Datsun, KIA, Citroën, and AION vehicles; vehicle servicing; and the sale and ordering of original spare parts. However, the workshop's operational activities at this company have the potential to contribute to air pollution through exhaust emissions from vehicles being repaired and from the workshop itself.

Based on observations and interviews conducted at the Nissan Mlati ATPM workshop, several issues related to working conditions were identified. Several mechanics complained of frequent vision problems from exposure to thick exhaust fumes. This was evident from the workshop's air exhaust system not functioning optimally. These observations also revealed problems with the ventilation system, including narrowing of the ventilation holes due to dirt buildup and damage to the exhaust fan. As a result, smoke from vehicle engines can settle in the room, especially in areas with suboptimal ventilation.

The accumulation of pollutants indoors not only harms workers' health but also reduces work efficiency and productivity. Vehicles that have undergone combustion chamber cleaning require mechanics to leave the workshop area to revise the engine, as this process produces white smoke. This activity impacts work effectiveness and efficiency, as mechanics must move to a different location each time they perform this procedure. If this activity is carried out in the workshop, the smoke produced can pose health risks to mechanics and other workers.

Therefore, efforts are needed to improve the air management system by optimizing ventilation, regularly maintaining air exhaust devices, and adopting more effective filtration technology to enhance air quality in the workshop environment. These measures are expected to reduce the negative impact on workers' health and minimize discomfort for customers.

In addition, regular maintenance of the exhaust system has been proven to reduce exhaust emissions by up to 25% and improve vehicle fuel efficiency [6]. However, at the Nissan Mlati ATPM workshop, a more effective exhaust system still faces several challenges, including limited infrastructure and a lack of accurate air quality data within the workshop. The exhaust system was damaged in the fan and electrical circuit, including burnt 3-phase capacitors and insulators.

This study aims to fill this gap by conducting an air quality analysis at the Nissan Mlati ATPM workshop to obtain actual data on indoor pollutant concentrations and assess the effectiveness of the ventilation system in use. More accurate data from this study is expected to serve as a basis for recommendations to improve the exhaust or blower system. In addition, this study aims to educate the public and repair shops about the importance of controlling exhaust emissions to create a healthier, more environmentally friendly work environment. The findings from this study are expected to make a significant contribution to improving the quality of the working environment in repair shops and to supporting emission-reduction policies in the automotive industry.

2. Methodology

The method used in this study was development research, using the Design and Development Research stages [7]. Product or tool development yielded comprehensive, practical results in accordance with field conditions. This study focuses on optimizing the exhaust system in workshops exposed to pollution due to work activities, especially during the vehicle combustion chamber cleaning process. To achieve an effective and efficient system, direct testing of the object under study and measurement of variables that reflect the success of exhaust system optimization are required. This study sets two main focuses: air as the object and air quality as the research variable, both systematically observed.

The object of this study is the air inside the workshop. Air pollution in workshops can take the form of micron-sized particles (PM2.5 and PM10), exhaust gases such as carbon monoxide (CO) and nitrogen oxides (NOx), and volatile organic compounds (VOCs). Long-term exposure to these substances can cause various health problems for workers, including respiratory disorders, eye irritation, and even the risk of chronic diseases.

The main variable in this study is Air Quality, which serves as a related variable. Air quality is used as a benchmark to assess the extent to which an optimized exhaust system can improve the working environment in a workshop. Since this study focuses on the development of ventilation systems, air quality measurements are an important aspect in evaluating the effectiveness of the designed product, both in terms of technical aspects and its impact on health and work productivity.

Particulate concentration measurements were conducted using a MiniVolt Air Sampler, which detects dust or smoke particles in micrograms per cubic meter (µg/m^3). These particulates originate from incomplete combustion and can cause respiratory problems at high concentrations. Meanwhile, an Impinger is used to measure the content of hazardous gases such as carbon monoxide (CO), nitrogen dioxide (NO_2), and hydrocarbon compounds (HC) in parts per million (ppm) or milligrams per cubic meter (mg/m^3), which are important indicators of toxic air pollution [8, 9].

Accurate, relevant data-acquisition techniques are used to support the development of air management systems in workshops. Quantitative data collection methods are used with a direct observation approach. Various measuring instruments are used to measure important parameters, such as air particle concentration, pollutant gas content, air flow velocity, and the physical dimensions of the workshop room. Measurements are carried out in accordance with Indonesian National Standard (SNI) 7119:2017 to ensure accuracy and compliance with national ambient air quality standards. Each tool has a specific function that supports objective and measurable data collection in accordance with standards.

Calibration of measuring instruments is a crucial aspect in maintaining the accuracy and traceability of measurement results against national and international standards. According to the Calibration Certificate issued by Greenlab Indonesia, the calibration was conducted on February 27, 2024. The calibration process was carried out in accordance with applicable standard procedures, using reference equipment that has been verified and meets international standards. This calibration covered various measuring instruments, including the MiniVol Air Sampler, Impinger, and Handheld Anemometer, to ensure they are in optimal condition and capable of providing consistent, scientifically accountable results. In general, the research stages and activities are described in detail in the diagram below.

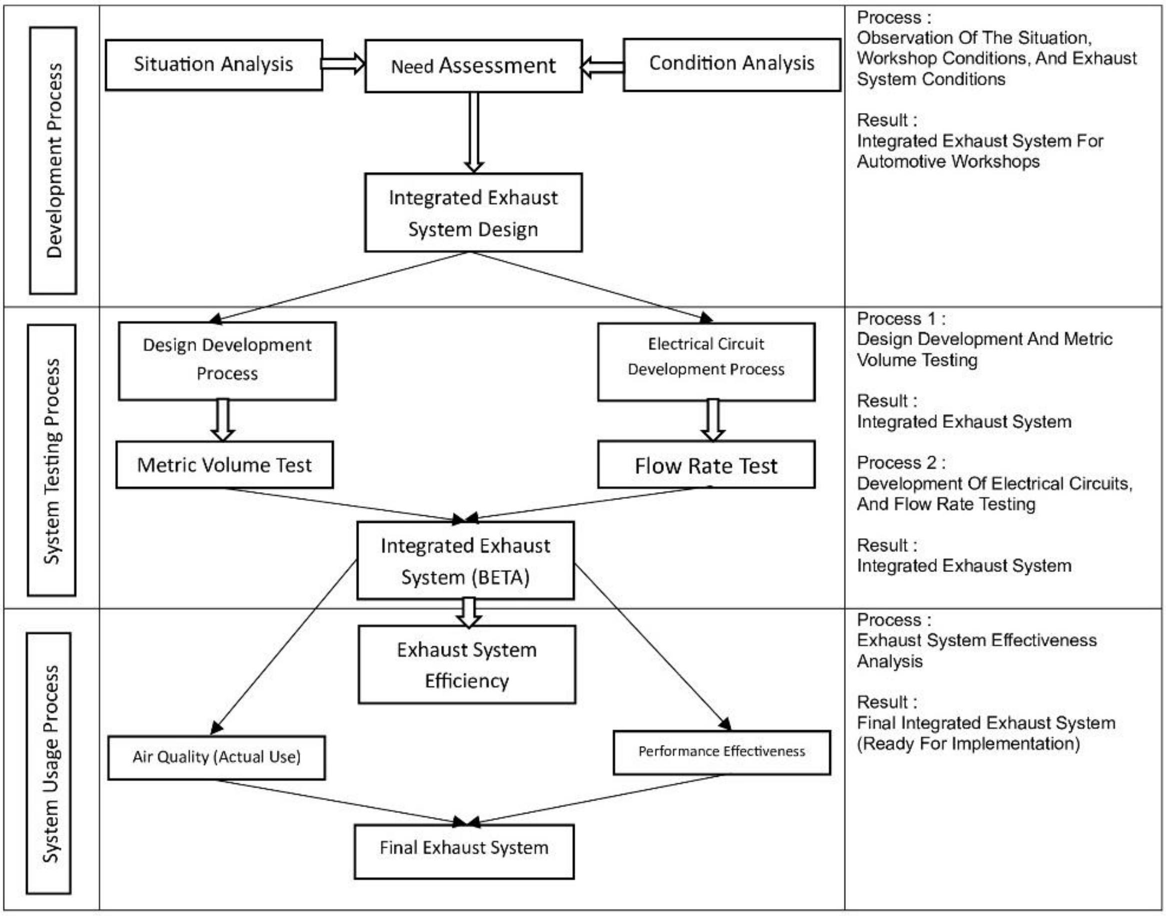

Figure 1. Research Process

3. Result and Discussion

3.1 Result

3.1.1 Pre-Product Development Stage

The pre-product development stage in this study aims to identify major problems in the exhaust system before the repair and optimization process is carried out. Activities in this stage include observing blockages in the exhaust system pipes, observing damage to the exhaust system's electrical circuitry, and measuring air quality before repairing the exhaust system. This pre-product development stage is an important foundation for designing targeted repair strategies, so that the resulting solutions are truly effective in improving the performance of the exhaust system and air quality in the surrounding environment.

The Nissan Mlati ATPM workshop is a high-activity vehicle service center that produces significant exhaust emissions, especially during testing and post-service engine revving. Initial observations indicate that indoor air quality in the workshop is suboptimal, as evidenced by mechanics' complaints of vision impairment and discomfort from exposure to thick smoke. This condition is exacerbated by damage to the ventilation system, such as broken fans, faulty capacitors, and clogged ventilation holes. The accumulation of pollutants hurts health and work productivity. Therefore, the pre-development stage focused on evaluating the ventilation system and collecting pollutant concentration data to formulate appropriate improvement measures to create a healthier work environment that supports mechanical performance.

Conditions at the Nissan Mlati ATPM workshop pose serious air-quality challenges due to an exhaust system that is not functioning optimally. Technical problems such as clogged ventilation holes from dirt buildup, damaged electrical capacitors, and broken fans block airflow, allowing vehicle exhaust to settle in the work area. As a result, mechanics experience health problems such as shortness of breath and vision impairment and must run vehicles outside the workshop to avoid exposure to exhaust fumes, which actually reduces work efficiency. In addition, emission test results show that some vehicles do not meet standards, exacerbating air pollution in the workshop. Therefore, an in-depth analysis of pollutant concentrations, such as CO and NOx, and a comprehensive evaluation of the ventilation system are needed to design solutions that create a healthy working environment while improving operational efficiency. The following is the design before and after the exhaust system optimization.

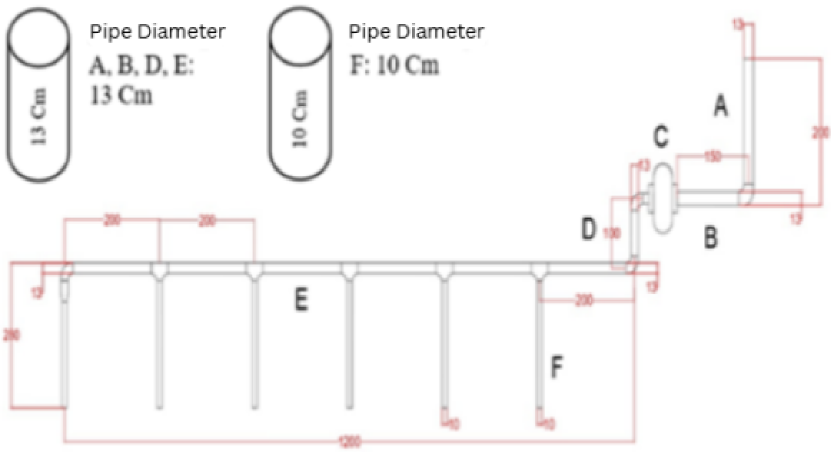

Figure 2. Design Before Exhaust System Optimization

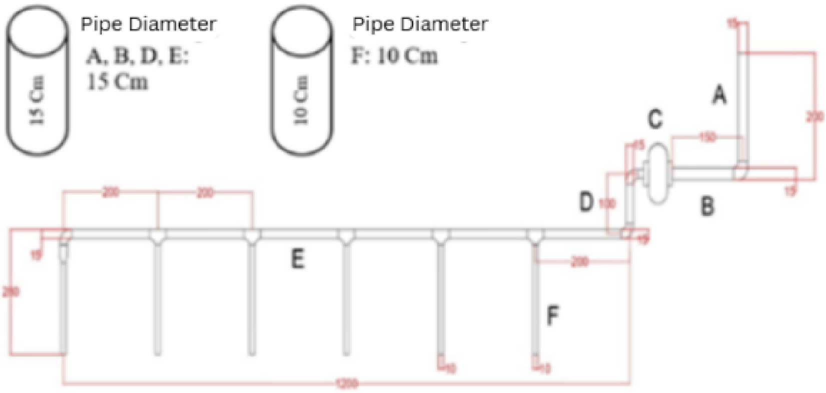

Figure 3. Design After Exhaust System Optimization

3.1.2 Product Development Stage

The product development stage in this study focused on optimizing the exhaust system without changing the main structural design. This process involved three main steps: modifying the pipe diameter to increase airflow capacity, repairing the electrical circuit due to damage to the capacitor and 3-phase insulator switch, and adjusting the control system to ensure more reliable, efficient system performance.

The final step is to measure air quality after repairs to assess the system's effectiveness in accordance with Permenaker No. 5 of 2018. The results of these measurements indicate the system's success in improving air quality and work comfort. These three stages are expected to yield an optimal, efficient exhaust system that can be implemented without major changes to the existing structure.

After evaluation and repair, the exhaust system at the Nissan Mlati ATPM workshop retained its main structural design, with a focus on functional improvements to maximize performance. The improvements included thoroughly cleaning the exhaust ducts of dust, dirt, and lint that were clogging them, as well as replacing the main connecting pipe with a capacity of 35.34 liters to restore air flow efficiency. Additionally, the damaged fan was replaced with a new, more efficient and durable unit. At the same time, the burnt capacitor was also replaced with a new component according to system specifications, all carried out in accordance with industry technical and electrical standards.

Figure 4. Image After Exhaust System Optimization

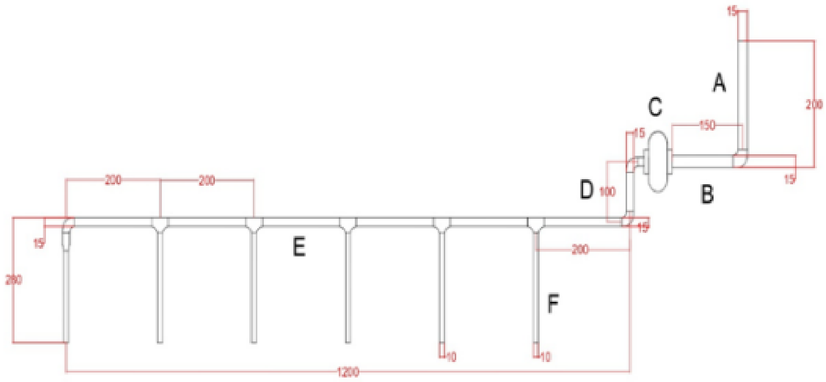

Figure 5. Exhaust System Design after Optimization

The exhaust system has been optimized through several technical improvements that remain consistent with the original design. Optimization was carried out by replacing burnt capacitors with new capacitors with specifications suitable for the fan motor load. The 3-phase isolator switch, which had been damaged by overcurrent, was also replaced. To ensure system reliability, electrical connections on the control panel were checked and reinforced to prevent potential current surges caused by loose contacts. All these repairs were also accompanied by a re-check of the current protection system and safety adjustments to ensure optimal protection under maximum load conditions.

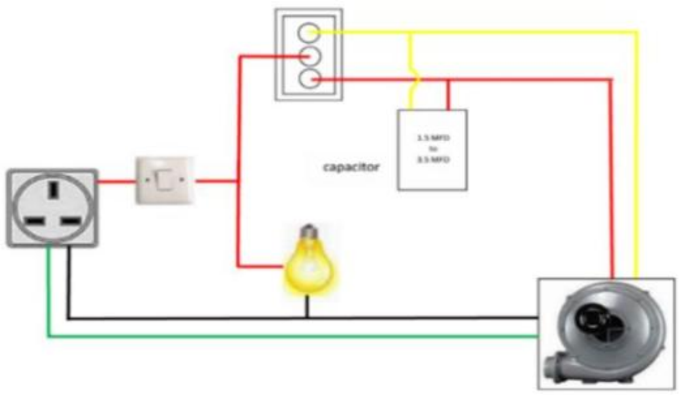

Figure 6. Electrical Circuitry of the Exhaust System After Optimization

The exhaust system at the Nissan Mlati ATPM workshop is now functioning optimally again after functional repairs: 6-inch pipe, 130 W/ 220 V motor rotating at 2,500 RPM, and a capacity of 720 CMH in a unit measuring 40 × 40 × 27 cm and weighing 5.25 kg, it efficiently vents exhaust gases again thanks to the replacement of the main pipe, fan, and capacitor according to specifications; Three-phase voltage distribution is stable without the need to change the basic structure, resulting in a longer system lifespan and daily operations that continue to meet occupational safety and health (OSH) standards.

After repairs to the exhaust system, air quality measurements were taken again in the area surrounding the workshop to determine current emissions and air pollution levels. These measurements aim to evaluate the effectiveness of the repairs and compare the results with data before the repairs. In addition, these measurements are used to ensure that the optimized exhaust system maintains the quality of the working environment air in accordance with the standards set by Permenaker No. 5 of 2018.

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LABORATORY TEST RESULT
HASIL PENGUJIAN LABORATORIUM
No. Report: 622.1284/LHU-GIG/III/2025

CUSTOMER / *Nama Pelanggan* : MAHASISWA UNIVERSITAS NEGERI YOGYAKARTA - Mr HERNANDA IQBAL

SAMPLE DESCRIPTION / *Deskripsi Sampel* : INDUSTRIAL HYGIENE (WORKSHOP BENGKEL (SESUDAH EXHAUST DINYALAKAN))

LABORATORY SAMPLE ID / *Nomor Sampel Lab* : IH-02

TIME OF RECIEPT / *Waktu Penerimaan Sampel* : 20 FEBRUARY 2025

COORDINATE / *Koordinat* : S 7° 46'10.632" E 110° 30'12.637"

TIME OF ANALYSIS / *Waktu Analisis* : 20 FEBRUARY - 05 MARCH 2025

SAMPLED BY / *Pengambil Sampel* : GREENLAB TECHNICAL TEAM (SYUHADA)

GOVERNMENT STANDART / *Baku Mutu* : PERATURAN MENTERI KETENAGAKERJAAN REPUBLIK INDONESIA NOMOR 5 TAHUN 2018 TENTANG KESELAMATAN DAN KESEHATAN KERJA LINGKUNGAN KERJA

No	PARAMETERS *Parameter*	UNIT *Satuan*	RESULT *Hasil*	STD. (MAX) *Baku Mutu*	TEST METHOD *Metode Uji*	CAL. RESULT OF MUE* *Hasil Perhitungan Estimasi Ketidakpastian Pengukuran*
1	Sulfur Dioksida (SO_2)	mg/m³	0.011	0.25	GSP. W-LAB-TS.089	0.001
2	Karbon Monoksida (CO)(*)	ppm	14,3	-	GSP W-LAB-TL.031	-
3	Nitrogen Dioksida (NO_2)(*)	BDS	0.006	0.2	SNI 7119-2 tahun 2017	0.0002
4	Oksidan (O_3)(*)	BDS	0.006	0.08	SNI 7119-8 tahun 2017	0.0002
5	Debu (TSP)	mg/m³	13.3	-	SNI 7119-3 tahun 2017	-

INFORMATION / *Keterangan* :
- *MUE : Measurement Uncertainty Estimation*
- (*) : *Parameter Belum Terakreditasi*
- "-" : *< Limit Deteksi*

SAMPLING METHOD / *Metode Pengambilan Sampel* : SNI 7230 tahun 2009

METEOROLOGICAL CONDITION		
1	Temperature	31,6 °C
2	Tekanan Udara	745.5 mmHg
3	Kelembaban	57,3 %RH
4	Kecepatan Angin	0,1 m/s
5	Arah Angin	Selatan ke Utara
6	Cuaca	Cerah

Yogyakarta, 05 March 2025

Ulin Nu Rohmi, A.Md. Si
Technical Manager

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Figure 7. Air Quality Measurement Results After System Optimization

After repairing the exhaust system by cleaning the ducts, replacing the fan, and replacing the capacitor, laboratory test results showed a significant improvement in air quality. CO concentration dropped from 16.4 ppm to 14.3 ppm and TSP from 18.1 mg/m³ to 13.3 mg/m³. Other pollutant parameters, such as SO_2, NO_2, and O_3, also remained well below the thresholds set by Permenaker No. 5 of 2018. This proves that repairs without structural design changes can effectively restore exhaust function, creating a healthier and safer working environment.

3.1.3 Product Effectiveness Testing Stage

Metric volume testing (theoretical) was conducted to determine changes in system performance before and after the optimization process. Most parameters, such as stall volume, total workshop volume, and metric volume per minute for the east stall and the entire workshop, remained unchanged. This shows that optimization focused more on improving flow efficiency than on changing room volume. For certain variables, such as connecting pipes, the flow volume increased significantly after optimization. This data forms the basis for further analysis of the success of optimization in improving the performance of the flow distribution system in the workshop.

Applied air quality testing was conducted to evaluate the impact of the optimization process on the working environment, particularly the exhaust system and air pollutant levels in the workshop area. A comparison of test results between pre- and post-optimization conditions was conducted. After optimization, the exhaust system's speed and flow rate were measured correctly, indicating that the ventilation system was beginning to function effectively. In addition, the concentrations of several air pollutants, such as sulfur dioxide (SO2), carbon monoxide (NO2), and total suspended particulates (TSP), decreased, indicating an improvement in air quality. This is an early indicator that the optimization has had a positive impact on improving the health and comfort of the working environment.

Performance effectiveness testing was conducted to assess the extent of productivity improvements after optimizing the exhaust system in the workshop area. Based on the table below, a comparison was made between the conditions before and after optimization by measuring working time, hours worked per day, and the number of cars serviced.

Table 1. Performance Effectiveness Testing

No	Before Optimization		After Optimization	
	Combustion chamber cleaning unit	Time	Combustion chamber cleaning unit	Time
1	Nissan Navara	2 hours 15 minutes	Nissan March	1 hour 30 minutes
2	Nissan Livina	1 hours 50 minutes	Nissan Kicks	1 hour 30 minutes
3	Nissan Terra	2 hours 10 minutes	Nissan Juke	1 hour 40 minutes
4	Nissan X-Trail	2 hours 20 minutes	Nissan Serena	1 hour 50 minutes
5	Nissan March	1 hour 40 minutes	Nissan Livina	1 hour 20 minutes

Table 2. Performance Effectiveness Test Results

Condition	Processing Time	Working hours/day	Number Of Cars That Can Be Serviced
Before Exhaust Optimization	2 hours 3 minutes	8 hours	4 cars
After Exhaust Optimization	1 hour 34 minutes	4 hours	6 cars

The test results showed a significant difference: the processing time per vehicle unit decreased, and the number of cars serviced in a day increased. This data indicates that system optimization not only improves efficiency but also positively affects the workshop's overall service capacity.

3.2 Discussion

3.2.1 How to Optimize the Exhaust System at the Nissan Mlati ATPM Workshop?

Optimization of the exhaust system at the Nissan Mlati ATPM workshop was carried out in several stages, from problem identification to the repair of damaged components, such as broken fans and clogged ducts. The main objective of this process was to reduce the negative impact of exhaust gases on mechanics' health, such as shortness of breath and blurred vision. The optimization focuses on increasing airflow capacity and smoothness without altering the system's overall structural design. One important step is to increase the main pipe radius from 6.5 cm to 7.5 cm, increasing the pipe volume from 26.54 liters to 35.34 liters and resulting in smoother, more efficient air circulation.

The airflow rate was increased to 12 m^3/minute in the eastern area and 24 m^3/minute for the entire workshop, while maintaining air circulation time within the ideal standard. Although the airflow time increased slightly, the system's efficiency was maintained. This process aligns with the research by Roihan Muhammad Iqbal [10], which emphasizes the importance of functional design in exhaust systems, and with the research by Orisha Yuhan [11], which highlights the importance of regular maintenance and air distribution design. By adding a direct exhaust path from the vehicle to the exhaust system without altering the pipe dimensions at each stall, this workshop has successfully improved air efficiency significantly while meeting Occupational Safety and Health (OSH) standards.

Initially, the electrical exhaust system at the Nissan Mlati ATPM workshop sustained significant damage, including burned capacitors and 3-phase insulator switches. This problem indicated inadequate current protection due to voltage instability and excessive load. During the optimization process, repairs focused on replacing key components, namely capacitors and 3-phase isolator switches, with new versions that are compatible with the blower motor load. In addition, electrical connections on the control panel were checked and reinforced to prevent current surges caused by loose contacts, which could damage the system.

This optimization was carried out with reference to the technical specifications of the 130 Watt exhaust blower motor, 220 Volt voltage, 2500-RPM speed, 720-CMH airflow capacity, and a 6-inch-diameter pipe, ensuring the selection of new components was right on target. As a result, the voltage distribution became more stable, and the blower motor operated within its design capacity. This improvement significantly increases efficiency, extends the system's lifespan, and ensures workshop operations remain compliant with standards (K3). This comprehensive approach aligns with the findings of Comoglio [10], who emphasizes the importance of measuring environmental parameters as the basis for comprehensive improvements in workshop systems.

3.2.2 How effective is the optimized exhaust system at the Nissan Mlati ATPM workshop?

Metric volume testing on the exhaust system of the Nissan Mlati ATPM workshop is a crucial step in assessing the effectiveness of air circulation and the quality of the working environment. The test results show that after optimization, the volume of the main connecting pipe increased to 35.34 liters, and the volume of each pipe in the stall remained at 21.99 liters. The air volume for the six eastern stalls was recorded at 1,008 m³ and for the entire workshop at 2,184 m³. With flow capacities of 12 m³/minute and 24 m³/minute, respectively, this system efficiently removes vehicle exhaust gases and maintains air quality in the workspace.

The calculation of a fast airflow time of 0.002945 minutes for the eastern area and 0.0014725 minutes overall indicates the speed of the system's response in removing dirty air. This not only improves circulation but also reduces air resistance in the pipes. This optimization complies with ASHRAE (2003) and SNI 03-6572-2001 standards [11], which regulate artificial ventilation requirements based on room volume and pollution levels. Therefore, the optimized exhaust system is technically feasible and has created a healthier, more comfortable working environment for mechanics.

Testing the effectiveness of the exhaust system through actual use provides a realistic picture of its performance in workshop operating conditions. By simulating vehicle service activities, this test enables a comprehensive evaluation of the system's ability to manage exhaust gas and particulate emissions. Laboratory results show a significant decrease in carbon monoxide (CO) concentration from 16.4 ppm to 14.3 ppm, which remains well below the safe limit of 25 ppm set by Permenaker No. 5 of 2018. Additionally, the Total Suspended Particulate (TSP) level also decreased from 18.1 mg/m³ to 13.3 mg/m³, indicating a noticeable improvement in air quality. Other parameters, such as SO_2,

NO_2, and O_3, remained within safe limits, reinforcing that the system is operating optimally overall.

The application of this approach demonstrates that simple optimizations, such as replacing capacitors and 3-phase isolator switches, as well as adjusting pipe sizes, can have a significant impact without requiring major changes to the system structure. Air flow efficiency has increased, pipe resistance has decreased, and electrical stability supports consistent system performance. Overall, in terms of effectiveness and air quality, the optimized exhaust system is considered suitable for implementation because it not only meets technical and regulatory standards but also has been proven to improve workplace comfort and health significantly.

Optimizing the exhaust system at the Nissan Mlati ATPM workshop not only improves air quality but also significantly increases operational efficiency and work productivity. Before optimization, the average service time per vehicle was 2 hours, meaning that only four vehicles could be serviced in an 8-hour workday. Poor air quality caused health and comfort issues for mechanics, slowing down their work pace. After the exhaust system was improved, the processing time dropped to 1 hour and 30 minutes per vehicle, allowing up to 6 vehicles to be completed per day. This represents a 51.03% increase in productivity without additional working hours.

This improvement not only reflects time efficiency, but also a significant improvement in work comfort. Cleaner air contributes to concentration and physical endurance, thus directly impacting work effectiveness. These results reinforce those of Orisha Yuhan [12], who found that the effectiveness of air pollution control systems depends heavily on adequate maintenance and exhaust infrastructure. Thus, the optimization of the exhaust system in this workshop has proven feasible to implement, as it provides dual benefits: improved operational performance and worker health protection.

4. Conclusion

Based on the results of research and optimization of the exhaust system at the Nissan Mlati ATPM Workshop, it can be concluded that the optimized product, namely "an integrated exhaust system for automotive workshops," has been proven to improve air quality in the work environment significantly. The optimization of the system was carried out through several important stages, including:

1) Replacing the main connecting pipe from 6.5 cm to 7.5 cm increased the volume from 26.54 to 35.34 liters, and cleaning the pipe channels ensured smooth airflow. Replacement of fans and capacitors that can support motor performance and repair of the electrical system without changing the main structural design.
2) The results of this system optimization show a significant reduction in pollutant levels, such as carbon monoxide (CO), which decreased from 16.4 ppm to 14.3 ppm, and total suspended particulates (TSP), which decreased from 18.1 mg/m3 to 13.3 mg/m3. This reduction in pollutant levels is significant, given the negative impact that air pollution can have on worker health and the quality of the working environment.
3) The optimized exhaust system has had a positive impact on operational performance. Vehicle processing time has been reduced from 2 hours and 3 minutes to 1 hour and 34 minutes, enabling the workshop to increase the number of vehicles serviced from 4 to 6 per day. This optimization has resulted in a 51.03% increase. The exhaust system not only improves air quality but also increases work productivity, which is crucial in the competitive automotive industry.

4) The exhaust system product developed in this study is deemed suitable for implementation in supporting occupational safety and health (OSH) and workshop operational efficiency. The implementation of this system is expected to serve as a model for other workshops in creating a healthier, more productive work environment, as well as to contribute positively to worker safety and operational sustainability.

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