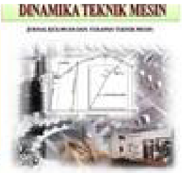
Dinamika Teknik Mesin 16(1) (2026) 62-69

Dinamika Teknik Mesin
Jurnal Keilmuan dan Terapan Teknik Mesin
http://dinamika.unram.ac.id/index.php/DTM/index



The effect of electric turbulent flow pressure in the intake system on diesel engine emissions and performance

D.A. Muntaha*, A. Sanata, M.F.R. Hentihu, N. Ilminnafik, S.N.H. Syuhri
Mechanical Engineering Department, Engineering Faculty, Universitas Jember, Jl. Kalimantan No. 37, Kampus Tegalboto, Kecamatan Sumbersari, Kabupaten Jember, Jawa Timur. HP: 085138882213
*E-mail: akbardigyo4@gmail.com

ARTICLE INFO

Article History:
Received 03-02-2026
Accepted 14-03-2026
Available online 01-04-2026

Keywords:
Diesel engine
Intake system
Pressure electric turbulent flow
Engine performance
Fuel consumption
Soot emissions

ABSTRACT

Current diesel engine technology development is directed at improving performance and fuel efficiency in line with the demands of exhaust emission control. One potential approach to achieve this goal is intake system engineering through airflow conditioning. This study aims to experimentally investigate the effect of applying pressure electric turbulent flow (PETF) to the intake system on the characteristics of the intake airflow, engine performance, fuel consumption, and exhaust emissions of a standard 2300 cc diesel engine. Testing was conducted by comparing engine conditions without PETF and with PETF at several engine speed levels under steady-state operating conditions. The parameters described include intake air pressure and temperature, torque, effective power, Brake Specific Fuel Consumption (BSFC), and soot opacity as an indicator of particulate emissions. The results show that the application of PETF increases intake air pressure and improves intake flow characteristics, which results in increased torque and effective power, especially at low to medium speeds. In addition, the use of PETF results in a decrease in BSFC and soot opacity values compared to the condition without the device, indicating increased combustion efficiency and reduced particulate formation. Overall, these results indicate that pressure electric turbulent flow has the potential to be an applicable approach to improve the performance, fuel efficiency, and emission control of standard production diesel engines without requiring internal engine modifications.

Dinamika Teknik Mesin, Vol. 15, No. 1, April 2025, ***p. ISSN:*** **2088-088X,** ***e. ISSN:*** **2502-1729**

1. INTRODUCTION

Diesel engines are widely recognized in the industrial and automotive sectors due to their superior thermal efficiency, structural robustness through high compression ratios, and fuel economy, Reitz et al., (2020). Unlike gasoline engines, the diesel combustion cycle relies on high temperatures and pressures from compressed pure air without an external ignition system (Dec 2009; Wen et al. 2025). However, global demands for reduced exhaust emissions, particularly NOx and particulates, have driven the development of modern diesel engine

https://doi.org/10.29303/dtm.v16i1.1254

technology to achieve a balance between high performance and environmental sustainability (Johnson, 2016; Firdausah et al, 2025).

Despite offering superior thermal efficiency, diesel engines still face serious challenges in the form of relatively high particulate emissions, noise, and mechanical vibration compared to spark-ignition engines (Patel et al. 2016; Torregrosa et al. 2011). In Indonesia, the transition to Euro 5 emission standards forces the development of technologies that are able to balance between pollution reduction and operational efficiency (Ramlan et al., 2016; Setiawan et al, 2021). One effective method is through engineering the intake system to improve air supply and the quality of the air-fuel mixing before injection.

Although the use of conventional turbochargers can significantly increase the intake air supply, the limited dynamic response due to the turbo lag phenomenon remains a major obstacle, especially under low load and speed conditions, Baek et al, (2021). To overcome this problem, various studies have begun to develop electrically actuated boosting systems that allow for instantaneous air pressure increases and are more adaptive to engine operating conditions (Ricard et al, 2011; Alshammari et al , 2019; Suciu et al., 2024; Wagino et al., 2024). However, this approach generally still focuses on increasing intake air pressure, without specifically controlling the flow characteristics and air turbulence structure that play an important role in the combustion process.

Recent experimental and numerical studies have shown that increasing the intensity of airflow turbulence in the intake system plays a significant role in improving the quality of the air–fuel mixing in the cylinder, so that combustion is more homogeneous and the formation of fuel-rich zones that become soot precursors can be suppressed (Alias et al. 2025; Hamid et al. 2020; Wang et al. 2020). In contrast to performance improvement strategies that only focus on increasing the intake air pressure, turbulence-based intake flow engineering directly affects the in-cylinder flow structure and subsequent combustion characteristics (Kaplan, 2019; Demir et al., 2022). However, experimental studies specifically investigating the effect of electrically induced turbulent flow combined with increased pressure on the intake system of standard production diesel engines are still very limited in the open literature.

Therefore, this study aims to experimentally evaluate the effect of applying a pressure electric turbulent flow device to the intake system of a standard 2300 cc diesel engine without any internal engine modifications, so that it is relevant to real applications and practical implementation. The focus of the study is directed at analyzing changes in intake air flow characteristics, engine performance including effective torque and power, specific fuel consumption, and exhaust emissions measured through soot opacity levels. The results of this study are expected to provide an experimental contribution in understanding the potential and limitations of the electric actuation-based intake flow turbulence approach as an alternative to improve diesel engine performance and emission control.

2. RESEARCH METHODS

This experimental study was conducted using a standard 2300 cc diesel engine operated without any internal engine modifications. The objective of the test was to evaluate the effect of applying pressure electric turbulent flow (PETF) to the intake system on intake airflow characteristics, engine performance, fuel consumption, and exhaust emissions. To ensure that the observed characteristic changes were due to the influence of the PETF, the test was conducted by comparing two intake system configurations: one without a PETF as the baseline condition and one with a PETF installed in the intake duct.

A schematic of the experimental setup and the position of the measuring instruments are shown in Figure 1. The PETF device was installed in the intake duct before air enters the engine, while intake airflow parameters were measured using an anemometer and thermocouple placed downstream of the device. Engine performance was evaluated by measuring torque and effective power using a dynamometer, fuel consumption was measured directly using a volumetric method with a measuring cylinder, and exhaust emissions were analyzed based on soot opacity using a smoke opacity meter installed in the exhaust duct.

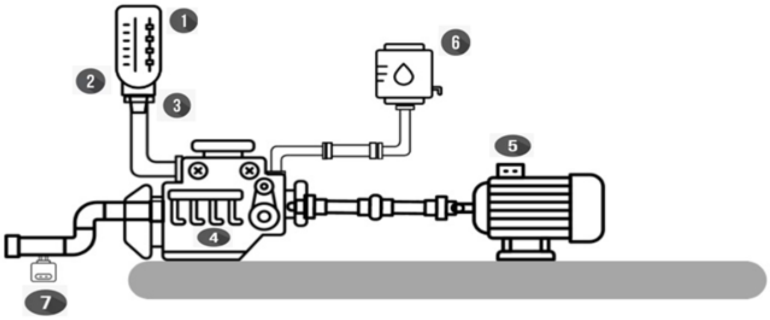


Figure 1. Research Scheme: 1. Pressure electric turbulent flow, 2. Anemometer, 3. Thermocouple, 4. Diesel engine, 5. Dynamometer, 6. Measuring cup or burette, 7. Smoke opacity meter

The pressure electric turbulent flow device used in this study is an airflow drive unit based on a three-phase, sensorless, Hall-free brushless electric motor controlled by a 50 A electronic speed controller (ESC) with a 12 V DC power supply. This device has a maximum electrical power of approximately 300 W and a maximum operating current of up to 24 A. Geometrically, the device is approximately 10 cm long with inlet and outlet diameters of 7 cm and 7.6 cm, respectively, thus matching the dimensions of the intake duct of the diesel engine being tested. The motor's maximum rotational speed reaches approximately 52,000 rpm, which allows for increased airflow momentum and the generation of turbulence in the intake duct. In this study, the PETF is not intended to replace a conventional turbocharger but rather is used as a flow conditioning device to increase the dynamic pressure and turbulence intensity of the intake airflow.

All tests were conducted using commercial B30 diesel fuel, a blend of fossil diesel fuel with fatty acid methyl ester (FAME) up to 30% v/v. The fuel used met the relevant ASTM standard specifications, with key characteristics including a minimum cetane number of 51, a density at 15°C in the range of 815–880 kg/m³, and a kinematic viscosity at 40°C between 2.0–5.0 mm²/s. All tests used the same fuel batch to minimize the influence of variations in fuel properties on the experimental results.

Prior to data collection, the diesel engine was tuned to ensure standard operating conditions and then warmed up to a stable operating temperature. The experiment was designed to evaluate the influence of pressure electric turbulent flow on intake airflow characteristics under steady-state engine operation. For each engine speed, data on intake air pressure and temperature, torque, effective power, fuel consumption, and soot opacity were taken three times. The values used in the analysis were averaged from these measurements to ensure repeatability and reliability.

The test data were analyzed quantitatively to evaluate the effect of PETF application on intake flow characteristics, engine performance, specific fuel consumption (BSF), and exhaust emissions. The BSFC value was calculated based on the ratio of fuel consumption rate to effective engine power. Comparisons were made between configurations with and without PETF at each engine speed level to identify trends and changes in diesel engine performance characteristics.

3. RESULTS AND DISCUSSION

3.1 Intake air pressure and temperature characteristics

The test results show that the application of the pressure electric turbulent flow device to the intake system consistently increases the intake air pressure across the entire engine speed range tested compared to the condition without the device. At low speed (1000 rpm), the intake air pressure increases from 0.441 kPa at baseline conditions to 0.707 kPa when the device is applied. This pressure increase trend continues at medium and high speeds, with a relatively significant pressure difference at 1500 rpm and 2000 rpm. At the highest speed tested (2500 rpm), the intake air pressure remains higher in the configuration with the pressure electric turbulent flow than in the condition without the device, although the difference is relatively small. On average, the application of this device increases the intake air pressure from 1.765 kPa to 2.094 kPa.

The increase in intake air pressure indicates that the pressure electric turbulent flow device not only functions as a turbulence generator but also contributes to increasing the availability of air mass entering the cylinder. This effect becomes particularly significant at low to mid-range revs, where conventional intake systems generally have limitations in maintaining a stable air supply. With increased intake air pressure, the

https://doi.org/10.29303/dtm.v16i1.1254

density of the air drawn into the cylinder tends to be higher, potentially improving the air-fuel ratio and supporting a more stable combustion process. The phenomenon of increasing air density and mass due to modification of intake flow characteristics has also been reported in previous studies which show that intake flow pressure and structure play a significant role in diesel engine volumetric efficiency and combustion quality (Wang et al. 2019).

In addition to pressure changes, the application of pressure electric turbulent flow also affects the intake air temperature. Data shows that the intake air temperature in the condition with the device is always higher than the baseline condition at all engine speeds. At 1000 rpm, the intake air temperature increased from 38.4 °C to 41.5 °C, while at 2000 rpm it increased from 38.6 °C to 43.4 °C. The highest temperature was recorded at 2500 rpm with a value of 44.7 °C in the condition with the device, compared to 42.0 °C in the condition without the device. On average, the intake air temperature increased from 39.37 °C to 44.05 °C due to the application of the pressure electric turbulent flow device.

This increase in intake air temperature can be attributed to two main mechanisms: the electrical actuation of the device and increased turbulence in the airflow within the intake duct. Higher turbulence increases the dissipation of kinetic energy into thermal energy, thereby increasing the intake air temperature. The interaction mechanisms between flow turbulence, air–fuel mixing, and combustion characteristics have been widely discussed in the literature, which confirms that turbulence intensity has a central role in the combustion dynamics of diesel engines (Tong et al. 2025). Although increased temperature tends to decrease air density, this effect appears to be offset in this study by increased intake air pressure, resulting in a net increase in the total air mass entering the cylinder.

Overall, these results demonstrate that the pressure-electric turbulent flow device is capable of modifying the intake airflow characteristics through a combination of increased pressure and flow turbulence. This modification creates more stable and controlled intake conditions, particularly at low to mid-range revs. These changes in intake characteristics are crucial for understanding engine performance and exhaust emission characteristics, which will be discussed in the following subsection.

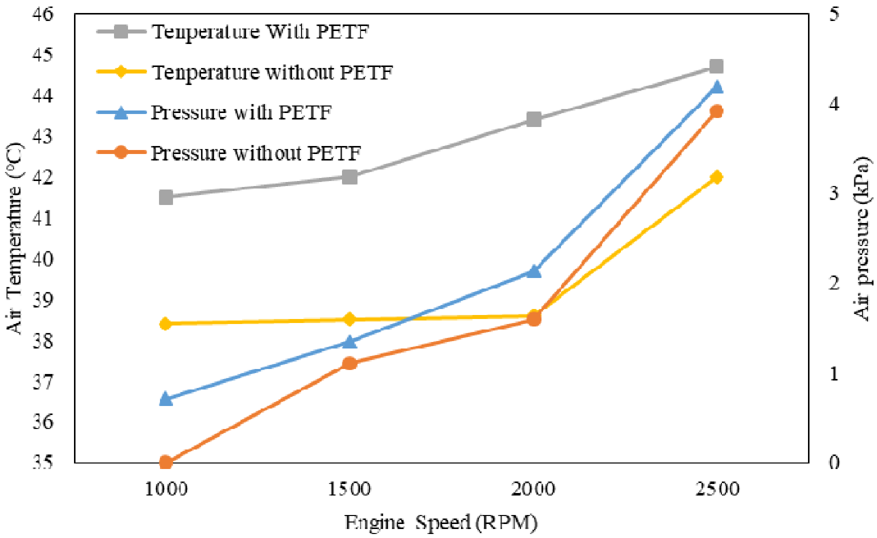


Figure 2. Variation of intake air pressure and temperature against engine speed in configurations with and without pressure electric turbulent flow.

3.2 Engine performance (torque and effective power)

Test results show that the application of a pressure electric turbulent flow (PETF) device to the intake system provides consistent improvements to diesel engine performance, both in terms of effective power and torque, across the entire engine speed range tested. Compared to the condition without the device, the engine equipped with PETF produced higher power at all speed levels, with the most significant difference occurring at low to mid-range speeds.

At 1000 rpm, engine power increased from 2.932 kW without PETF to 3.636 kW with PETF. This power increase trend continued at 1500 rpm and 2000 rpm, where engine power with PETF reached 5.512 kW and 7.425 kW, respectively, higher than without PETF. At the highest tested rpm (2500 rpm), engine power continued to increase, although the difference was relatively smaller. This pattern indicates that PETF effectiveness is most dominant at low to medium rpm, while at high rpm the engine begins to approach volumetric limitations.

https://doi.org/10.29303/dtm.v16i1.1254

Performance improvements are also reflected in the engine torque characteristics. Data shows that engine torque with PETF is consistently higher than without PETF at all engine speeds. At 1000 rpm, torque increases from 15.04 Nm to 19.00 Nm. The torque value is relatively stable in the 1500–2000 rpm range with a value of around 19 Nm in the condition with PETF, while the torque in the condition without PETF is around 16 Nm. At 2500 rpm, the torque with PETF decreases slightly to 18.05 Nm, but remains higher than the condition without PETF.

Mechanistically, these increases in torque and power are closely related to the results in Section 4.1, where the application of a PETF increases intake air pressure and improves intake flow characteristics. Higher intake air pressure increases the mass of air entering the cylinder, while more intense flow turbulence improves air-fuel mixing. The combination of these two effects results in more effective combustion, characterized by increased combustion pressure during the expansion stroke, which directly increases engine torque. This finding is consistent with previous studies which reported that increasing the pressure and air flow conditions in the intake can increase volumetric efficiency as well as the mean effective pressure, which ultimately has an impact on increasing the power and torque of a diesel engine (Wang et al. 2019).

These results demonstrate that the application of pressure-electric turbulent flow can significantly improve the performance of a standard production diesel engine, particularly at low to mid-range revs, without requiring internal engine modifications. These characteristics make PETF a potentially relatively simple and applicable performance improvement solution, especially for diesel engine operating conditions that frequently operate in this rev range.

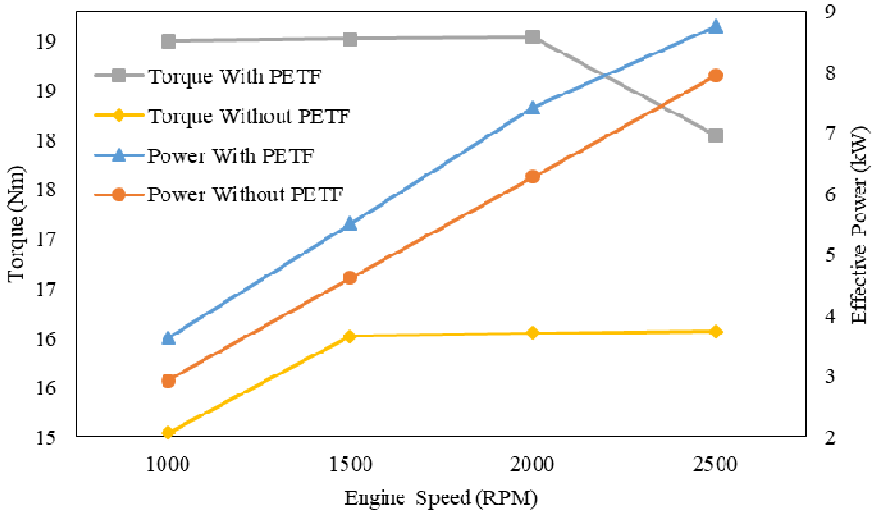


Figure 3. Variation of effective power and torque against engine speed in configurations with and without pressure electric turbulent flow.

3.3 Specific fuel consumption

Fuel consumption test results show that the application of a pressure electric turbulent flow (PETF) device to the intake system provides a consistent reduction in fuel consumption across the entire engine speed range compared to the un-PETF system. At 1,000 rpm, fuel consumption with the PETF was recorded at 3.98 g/s, lower than the 4.77 g/s for the un-PETF system. This downward trend in fuel consumption continued at mid- and high-speed speeds, with the difference becoming more pronounced at 1,500 rpm and 2,000 rpm.

At 2,000 rpm, fuel consumption with the PETF was recorded at 2.40 g/s, compared to 3.12 g/s for the un-PETF system. This difference indicates that the increase in engine performance achieved by the PETF was not accompanied by increased fuel consumption, but rather by improved fuel efficiency. At the highest tested speed (2,500 rpm), fuel consumption with the PETF remained lower than the un-PETF system, at 1.36 g/s and 1.96 g/s, respectively. On average, the application of PETF reduced fuel consumption from 3.44 g/s to 2.68 g/s.

This reduction in fuel consumption is closely correlated with the improvement in intake airflow characteristics discussed in Section 3.1, as well as the increase in torque and effective power in Section 3.2. Increasing intake air pressure and the intensity of intake turbulence improves the quality of the air-fuel mixture, resulting in a more homogeneous combustion process and more effective conversion of the fuel's chemical energy into mechanical work. With more efficient combustion, the fuel requirement for producing the same or higher power is reduced. Theoretically, increasing air mass and improving volumetric efficiency will increase effective thermal efficiency and reduce brake specific fuel consumption, as explained in the basic literature on internal combustion engines (Heywood. 1988).

At high rpm, the difference in fuel consumption between the two configurations tends to narrow, indicating that under these conditions the engine is approaching its volumetric and thermal efficiency limitations. Nevertheless, the configuration with PETF still demonstrates an efficiency advantage over the baseline condition. Overall, these results confirm that the application of pressure-electric turbulent flow not only improves the performance of standard production diesel engines but also provides significant benefits in terms of fuel economy, particularly at low to mid-range rpm, which are prevalent in real-world operation.

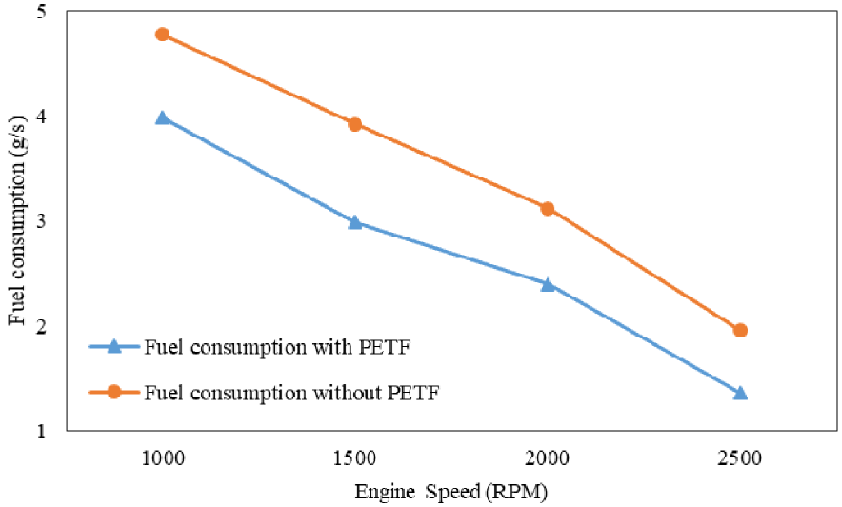


Figure 4. Variation of Fuel Consumption against engine speed in configurations with and without pressure electric turbulent flow.

3.4 Exhaust gas emissions (soot opacity)

Exhaust emission testing results indicate that the application of a pressure electric turbulent flow (PETF) device to the intake system significantly impacts soot opacity levels at various engine speeds. At low to mid-range speeds, the PETF configuration consistently produces lower opacity values than the PETF-free configuration. At 1,000 rpm, soot opacity decreased from 22.03% without the PETF to 19.8% with the PETF. A more pronounced downward trend was observed at 1,500 rpm and 2,000 rpm, where soot opacity decreased from 32.5% to 23.08% and from 49.2% to 38.0%, respectively.

This decrease in soot opacity at low to mid-range speeds indicates that the PETF can improve combustion quality by enhancing intake airflow characteristics. Increasing intake air pressure and the intensity of intake flow turbulence improves in-cylinder oxygen distribution, resulting in more homogeneous combustion and effectively suppressing the formation of local fuel-rich zones—the primary precursors of soot formation. These results align with the improved combustion efficiency reflected in the reduction in BSFC discussed in Section 3.3.

At high rpm (2500 rpm), soot opacity values in the PETF configuration were slightly higher than those without PETF. This phenomenon can be attributed to the increased fuel injection rate and limited mixing time at high rpm, making the effect of increased intake turbulence less dominant than the diffusion combustion characteristics under these conditions. Furthermore, the higher intake air temperature at high rpm may also contribute to changes in soot formation dynamics. Previous CFD-based numerical studies have also reported that increasing the swirl ratio does not always result in a linear decrease in soot emissions, as changes in flow structure and spray–airflow interactions can elicit different combustion responses under certain operating conditions. This suggests that there is an optimum turbulence value that depends on engine conditions and operating parameters (Gupta and Vashi 2025).

However, these differences at high speeds do not negate the general trend that PETF is effective in reducing soot emissions in the operating speed range most frequently used in real applications. Overall, these results demonstrate that the application of pressure-electric turbulent flow has the potential to be an effective approach to suppressing particulate emissions in standard production diesel engines, particularly at low- to medium-speed operating conditions. The combination of increased intake air pressure and intake flow turbulence has been shown to improve combustion quality and reduce soot formation without requiring internal engine modifications or additional after-treatment systems.

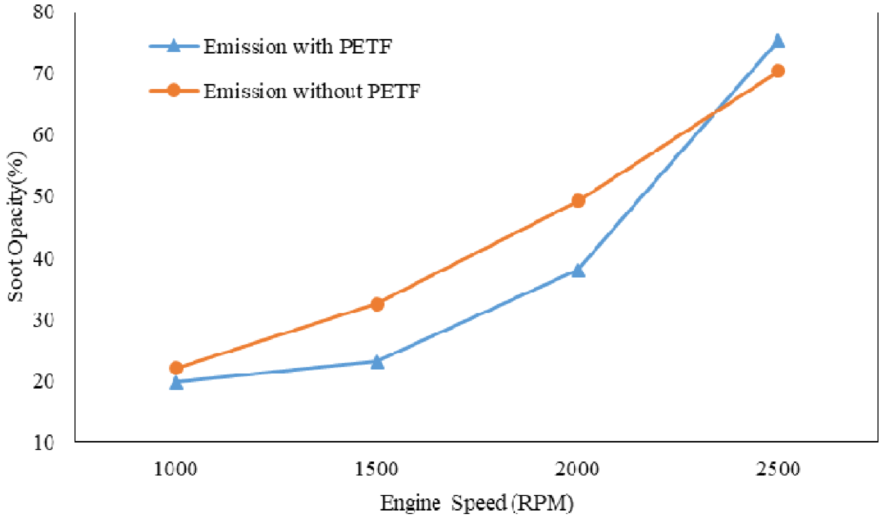


Figure 5. Variation of soot opacity with engine speed in configurations with and without pressure electric turbulent flow

4. CONCLUSION

This study experimentally evaluates the effect of applying pressure electric turbulent flow to the intake system of a standard production 2300 cc diesel engine. The results show that this device is able to improve the characteristics of the intake air flow, which results in increased torque and effective power, decreased specific fuel consumption, and reduced soot emissions in the low to mid-range rev range. These performance and efficiency improvements were achieved without any internal engine modifications, thus demonstrating the potential of pressure electric turbulent flow as an applicable and relevant approach for improving the performance and controlling emissions of standard production diesel engines.

5. REFERENCES

Alias, M.S.M., Hairuddin, A.A., Hassan, M.K., Rezali, K.A.M., A review of swirl air intake effect on the performance of a compression ignition engine. Jurnal Kejuruteraan, 37(3), 2025.

Alshammari, M., Alshammari, F., Pesyridis, A., Electric boosting and energy recovery systems for engine downsizing. Energies, 12(24), 2019.

Baek, S., Lee, h., Lee, k., Fuel efficiency and exhaust characteristics of turbocharged diesel engine equipped with an electric supercharger, Energy, 214, 2021.

Chandra, S.I., Indarto., Deendarlianto, Quantitative analysis of automobile sector in indonesian automotive roadmap for achieving national oil and co2 emission reduction targets by 2030, Energy Policy, 150, 2021.

Dec, J.E., Advanced compression-ignition engines - understanding the in-cylinder processes. Proceedings of the Combustion Institute, 32 (2), 2009.

Demir, Ü., Çetinkaya, O., Türkmen, A.C., Çelik, D.D.C., Experimental investigation of intake manifold design effect on diesel engine performance. International Journal of Automotive Science and Technology, 6(2), 2022.

Firdausah, R.E., Ilminnafik, N., Asrofi, M., Performance of a single cylinder diesel engine fueled by 40 % biodiesel blend with excess air system, Journal of Mechanical Engineering, Science, and Innovation' 5(1). 2025.

Gupta, R.M., Vashi, O., Computational fluid dynamics analysis of combustion characteristics in a direct-injection engine with varying swirl ratios and hydrogen addition, Engineering Research Express, 7(3), 2025.

Hamid, M.F., Numerical investigation of fluid flow and in-cylinder air flow characteristics for higher viscosity fuel applications, Processes, 8(4), 2020.

Heywood, J.B., Internal combustion engine fundamentals, In McGraw-Hill Education, McGraw-Hill Education, 960 1988.

Johnson, T., Vehicular emissions in review, SAE International Journal of Engines 9(2), 2016.

Kaplan, M., Influence of swirl, tumble and squish flows on combustion characteristics and emissions in internal combustion engine-review, International Journal of Automotive Engineering and Technologies, 8(2), 2019.

Patel, Chetankumar, Spray characterization, combustion, noise and vibrations investigations of jatropha biodiesel fuelled genset engine, Fuel 185, 2016.

Ramlan, N.A, Performance and emissions of light-duty diesel vehicle fuelled with non-surfactant low grade diesel emulsion compared with a high grade diesel in malaysia, Energy Conversion and Management, 130, 2016.

Reitz, R.D, The future of the internal combustion engine, International Journal of Engine Research, 21(1), 2020.

Ricardo, M.B., Apostolos, P., Yang, M.Y., Overview of boosting options for future downsized engines, Science China Technological Sciences, 54(2) 2011.

Suciu, C.C., Igret, S.V., Vetres, I., Ionel, I., Review of the integration of hybrid electric turbochargers for mass-produced road vehicles, Energies 17(6), 2024.

Tong, Z, Wu, H., Shi, Z., Myagkov, L., A review on the influence of in-cylinder turbulence type on combustion characteristics of high power-density diesel engine, Journal of Traffic and Transportation Engineering (English Edition), 12(5), 2025.

Torregrosa, A. J., Broatch, A., Novella, R., Mónico., L.F., Suitability analysis of advanced diesel combustion concepts for emissions and noise control, Energy, 36(2)., 2011.

Wagino, W, Implementation of an electric turbocharger on a single-cylinder spark ignition engine in an effort to use ethanol gasoline e40, TEM Journal, 13(1), 2024.

Wang, G, Experimental and numerical study on the influence of intake swirl on fuel spray and in-cylinder combustion characteristics on large bore diesel engine, Fuel, 237, 2019.

Wang, G., Yu, W., Li, X., Yang, R., Influence of fuel injection and intake port on combustion characteristics of controllable intake swirl diesel engine, Fuel, 262, 2020.

Wen, H., Li, J., Li, J., Xu, L., Effect of intake air conditions on combustion and emission performance of ammonia-diesel dual fuel engine, Journal of the Energy Institute, 118, 2025.