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Experimental Study for Reducing Vehicle Harmful Emissions and Enhancing Vehicle Performance: Injector Cleaning Case Studies

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Abstract: Climate change is a critical worldwide concern, marked by increasing temperatures, severe weather phenomena, and substantial disturbances to ecosystems and human societies. More than 60% of vehicles are equipped with gasoline internal combustion engines. Consequently, minimizing harmful exhaust gas emissions such as carbon monoxide (CO), nitrogen oxides (NOx), and hydrocarbons (HC) is a crucial consideration in gasoline fuel combustion. A gasoline injector cleaner has been designed and implemented to simulate the real-time conditions for the injectors in the gasoline multiport injection system. This research examines the impact of injector cleaning on exhaust emissions and vehicle performance using chassis dynamometer tests involving five case study vehicles. The results indicate a significant improvement in vehicle brake power, ranging from a 3% to a 43% increase. Moreover, there is a significant reduction in harmful gases, especially CO gases, due to complete combustion inside the cylinder as a result of uniform spraying and atomization of fuel.

Keywords: Exhaust engine emissions, gasoline injector cleaner, engine performance test, gasoline injector cleaner

1. Introduction

The automobile sector has continually led in technology adoption, principally due to the implementation of pollution laws, which notably contributed to the extensive widespread of electronic engine management systems (Rizzoni et al., 2009). Consequently, technical advancement resulted in the implementation of On-Board Diagnostics (OBD) systems in vehicles, which have now become a common feature in most Electronic Control Units (Aris et al., 2007). Nowadays, Artificial intelligence (AI) has introduced substantial innovations in the automobile sector, including pollution control and predictive maintenance, which enhance real-time diagnostics and decision-making, which is an expensive tool and needs a huge infrastructure (Heroual et al., 2023; Udoh et al., 2024). As reported by statista.com (February 2025), in the latter half of 2023, Egypt had approximately 9.9 million licensed petrol vehicles, significantly influencing the nation's fuel consumption and emissions profile. As the automotive sector expands and gasoline-powered cars persist, controlling harmful emissions, which have a considerable impact on air pollution and greenhouse gas emissions, is essential.

The conventional methods for analyzing and quantifying automotive emissions generally encompass two approaches: laboratory testing and field testing. Such testing is often highly complicated and costly. They often need substantial financial investment in the equipment used. The data-collecting procedure in vehicle emissions testing is essential for assessing the quantity and kind of pollutants released by vehicles in simulated real-world driving scenarios. Sensor-based emission measuring systems provide a viable option for the real-time monitoring and evaluation of vehicle emissions. Kurniawan et al (2023) studied an economical sensor system for quantifying CO, NOx, CO2, and temperature for internal combustion engine exhaust emissions. The analysis revealed a significant difference between the sensor outcomes and the field results due to the restricted reading range of the inexpensive sensor.

Port SAE J2715 guidelines cover port fuel injection (PFI) and gasoline direct injection (GDI) engine sprays (SAE International Surface Vehicle Recommended Practice, 2007). This recommended practice document provides background, test techniques, and data reduction strategies for most automobile fuel spray characterization measures. Moreover, it includes non-spray injector performance measures, such as flow curve measurement and leakage testing. In

**Corresponding author: helzomor@aast.edu* recent years, fuel consumption and CO2 emissions have gathered considerable attention from the public, environmental groups, and consumer organizations.

Carbon dioxide emissions from passenger vehicles are measured during the vehicle certification process, referred to as the New European Driving Cycle (NEDC) test. Vehicle fuel consumption is indirectly calculated from the recorded emissions of carbon dioxide (CO2), hydrocarbons (HC), and carbon monoxide (CO) during certification testing, considering the carbon mass balance in the exhaust gases (Kaisan et al., 2023). Contemporary automobiles that comply with Euro norms (Euro 5 and 6) have controlled amounts of CO and HC emissions, accounting for around 1% of fuel use. Also, in the Euro norms, CO2 emissions might be considered in proportion to the fuel utilized during vehicle operation.

The gasoline injector cleaning device for (PFI) systems enhances engine performance, reduces exhaust emissions, and improves fuel efficiency (Hung et al., 2008; Duarte et al., 2016). It can remove the deposits and accumulations that may accumulate on the fuel injectors over time by pumping special cleaning materials into the injectors under different operating conditions (Zhang et al., 2010). Also the gasoline injector cleaning device can measure precise fuel flow and distribution for each injector, which helps effectively diagnose and repair any injector problems.

2. Experimental Work

An experimental test facility for gasoline fuel injector cleaners has been designed and implemented specially for this work at the New Cairo Technological University. It consists of three main subsystems: frame chassis, fuel system, and electronic system, including ultrasonic cleaner. The frame chassis can withstand external vertical.

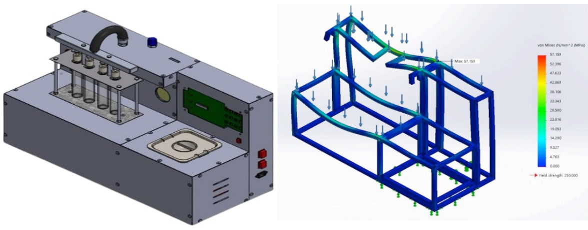

Figure 1. Proposed design for the gasoline injector cleaner (left) stress analysis for the frame design (right).

Loads up to 880 N with a minimum safety factor of 4.2, as shown in Figure 1. The frame design considers keeping the electrical systems as far away from the fuel system using sheet metal separators. The primary components of the fuel system include a five Liters tank, a pump capable of generating a maximum pressure of 10 bar, a fuel filter, a fuel rail with connectors, solenoid valves, a pressure regulator, glass measuring tubes, a cleaning fluid drain valve, and a pressure gauge, as illustrated in Figure 2.

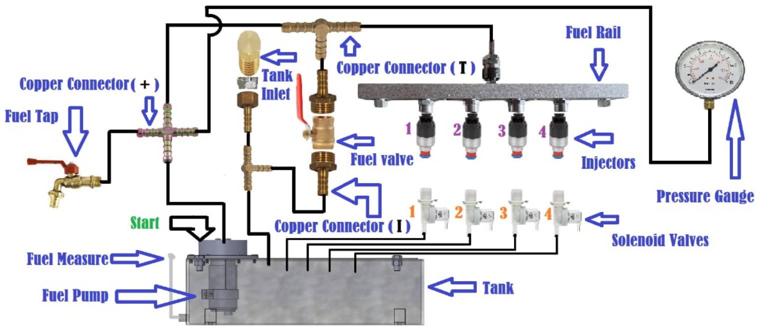

Figure 2. Fuel system layout diagram.

The primary components of the electrical system are a 200-watt ultrasonic bath, injector pulse signal cables, a 300-watt power supply, a control board, a 12V fuel pump, relays, and a protected class valve solenoid, as seen in Figure 3. Ultrasonic technology employs cavitation bubbles generated by high-frequency (20-40 kHz) sound waves to agitate a liquid. These bubbles are so tiny that they can penetrate minute gaps, deposits, and blind holes that are impossible to reach by hand scrubbing using conventional parts washers. The injector cleaner fluid is an alkaline detergent such as Sonic Power Degreaser for aggressive cleaning.

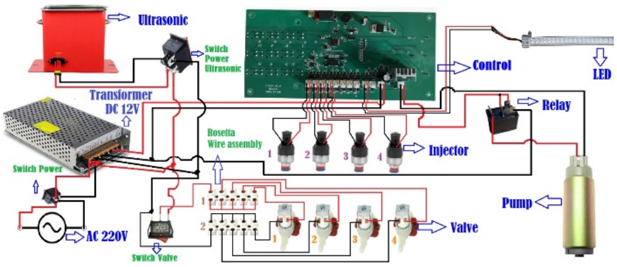

Figure 3. Electrical System layout diagram.

The proposed design possesses numerous advantageous attributes: compact dimensions (length 700 mm x width 300 mm x height 450 mm), a lightweight structure (29 kg), safety features by separating the fuel system from the electronic systems, ergonomic arrangement of buttons and measuring test tubes, and expedited maintenance facilitated by removable back doors, as illustrated in Figure 4.

Figure 4: Real pictorial view for the gasoline injector cleaner device (left) rear view (right).

3. Case Studies

Five case studies have been evaluated before and after the injector cleaning using the above-mentioned device, as shown in Table 1. Two types of tests have been performed to evaluate the effect of cleaning the injectors:

3.1 Exhaust Gas Emission Analyser

The AGS-688 gas analyzer is used to determine the different gas concentrations in the exhaust gases of vehicles with spark ignition engines. This tool withdraws the exhaust gas from the tailpipe through the proper probe supplied with the device to measure the following harmful gases (CO, CO2, HC, O2, NOx, Lambda).

3.2 Vehicle Chassis Dynamometer Performance

The Mustang Chassis Dynamometer MD100:2WD has been used to measure power and load capabilities, allowing vehicles to simulate actual road conditions while stationary. The Dynamometer consists of a drive roll set, a power absorbing unit (PAU), a load cell, and a speed encoder. It has a peak capacity of 300 horsepower and a maximum speed of 160 km/hr.

Table 1. The vehicles used in this evaluation

Name	Model	Manufacture Year	Kilometers
Veh_1	DAEWOO NUBIRA	2006	202,000 Km
Veh_2	KIA PRIDE	2009	172,000 Km
Veh_3	BYD F3	2021	102,000 Km
Veh_4	NISSAN SUNNY	2014	140,000 Km
Veh_5	NISSAN SUNNY	2013	152,000 Km

The gasoline injector cleaner may execute many cleaning modes for inspecting, measuring, and cleaning the injectors as follows:

I) Uniformity/Spray-ability Assessment

The uniformity test determines if the flow of each injector complies with standards under similar operating conditions. The spray ability test primarily assesses spraying performance by examining variations in injector bore and instances of clogging. Three distinct operating conditions simulate engine speed: the Idle-Speed test, characterized by an engine speed of 750 rpm, lasts 4 minutes; the Middle-Speed test, defined by an engine speed of 2400 rpm, lasts 75 seconds; and the High-Speed test, marked by an engine speed of 6000 rpm, lasts 30 seconds, as shown in Figure 5.

II) Ultrasonic Cleaning

The ultrasonic injector cleaner uses the penetrability of the impacting high-frequency wave to offer intense cleaning on injector surfaces, allowing trapped carbon deposits to be removed from the injectors.

III) Leakage Test.

The leakage test evaluates the sealing integrity of the injector needle valve at actual working pressure and identifies any leaking from the injector.

Figure 5. Sample of injector testing and measuring amount of fuel at idle speed before cleaning for Veh_4 2014 (left) injector after cleaning using the injector cleaner (right).

4. Results and Discussion

The engine performance and exhaust emission tests were done on five vehicles equipped with in-line four-cylinder, spark ignition multi-port injection engines. Each vehicle undergoes testing before and after injector cleaning to assess its impact. The vehicles were firmly affixed to the chassis dynamometer, employing mechanical friction for braking. Throughout all the tests, the engine and chassis dynamometer parameters were monitored and regulated in real-time. Considering that the driver's accelerator pedal action may significantly affect cylinder combustion, it was secured during the test. The vehicle performance test for veh_3, as shown in Figure 6, indicates that the maximum braking power before injector cleaning was 51 hp at 5060 rpm, corresponding to 47% of overall engine performance with respect to the manufacturer datasheet. Post-cleaning, the maximum brake power increased to 73 hp at 5200 rpm, reflecting 67% overall engine performance. Thus, the vehicle's overall performance was enhanced by 43% as a result of injector cleaning.

The observed improvement in engine performance can be attributed to the restoration of proper fuel injector function. Prior to cleaning, injector fouling likely caused poor fuel atomization and uneven air–fuel mixture distribution, resulting in incomplete combustion and reduced power output. After cleaning, the injectors were able to deliver a finer and more uniform fuel spray, promoting more efficient combustion within the cylinder. This enhanced combustion process not only increases engine power but also improves fuel efficiency. Furthermore, more complete combustion is expected to reduce the formation of harmful exhaust emissions, particularly carbon monoxide (CO) and unburned hydrocarbons (HC). These findings highlight the importance of regular injector maintenance in optimizing engine performance and reducing environmental impact.

In addition to improving peak engine performance, injector cleaning may also contribute to more stable engine operation across different speed ranges. Cleaner injectors ensure consistent fuel delivery, which reduces engine vibration, improves throttle response, and enhances overall drivability. This stability is particularly important under varying load conditions, where precise air–fuel ratio control is required to maintain optimal combustion. Moreover, the improvement in combustion quality can lead to long-term benefits such as reduced engine wear and lower maintenance costs. Therefore, routine injector maintenance should be considered an essential practice not only for restoring lost engine performance but also for ensuring durability, operational stability, and environmental sustainability.

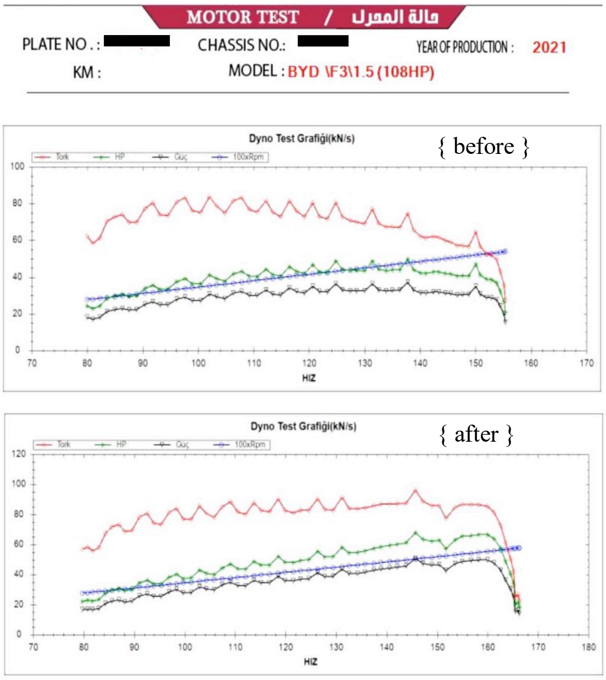

Figure 6. Sample of vehicle dynamometer performance test before and after cleaning the gasoline fuel injectors for veh_3

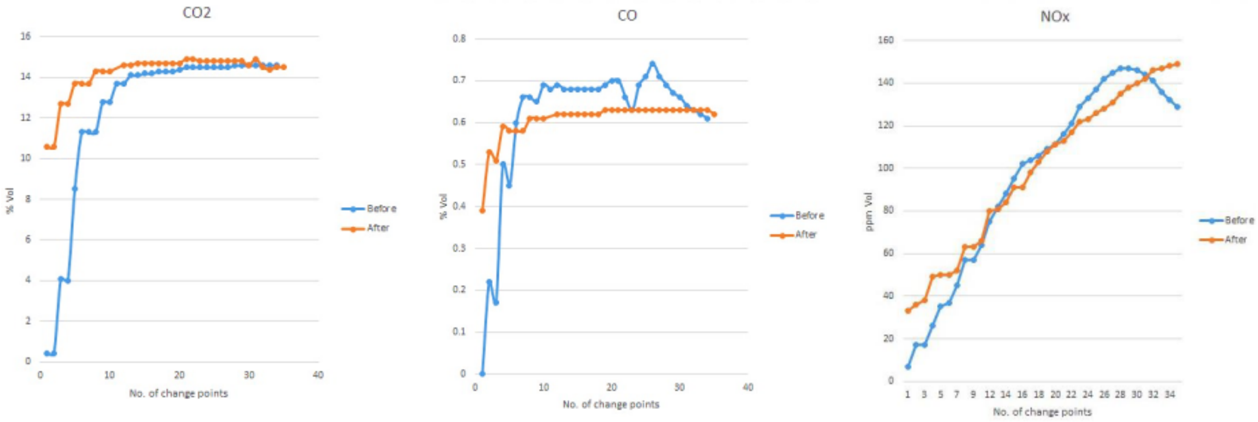

Figure 7. Sample of exhaust gas analysis at medium speed 2500 rpm for veh_4.

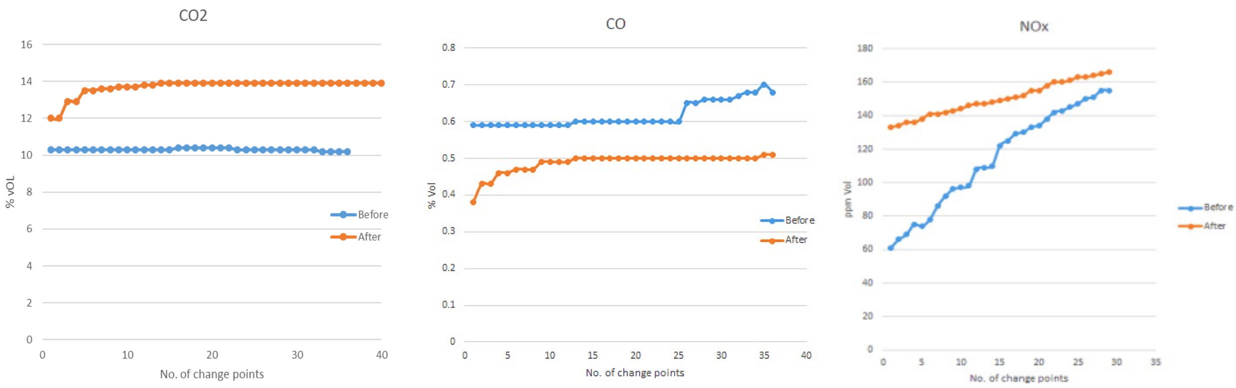

Figure 8. Sample of exhaust gas analysis at high speed 4000 rpm for veh_2.

The exhaust gas emission test was conducted for each vehicle at three distinct engine speeds (idle, medium, and high) to monitor harmful gases in real-time conditions. Figures 7 and 8 show sample findings from the exhaust gas emission test conducted at medium and high speeds. A comparison of the pre-and post-injector cleaning for veh_4 at medium speed reveals that the CO_2 % by volume increases after cleaning, but the CO percentage falls. This phenomenon is attributed to the complete combustion resulting from the uniformity of the injector spraying and good mixing of air and fuel inside the combustion chamber. Conversely, the nitrogen oxide (NOx) concentration in parts per million (PPM) exhibits a slight reduction after cleaning the injector.

The exhaust gas emission test at high-speed for veh_2 confirms that the volume % of CO_2 increases post-cleaning, whereas the volume percentage of CO drops. In this instance, the NOx particles per million (PPM) exhibit a slight increase after the injector cleaning, suggesting a rise in temperature within the combustion chamber. Table 2 presents the emission values for Veh_1 at various engine speeds. The trend of CO_2 emissions rises with rising engine speed, and injector cleaning influences CO_2 emission by increasing the percentage post-cleaning. The reduction in CO emission percentage following injector cleaning indicates an improvement in the combustion of the mixture, approaching the stoichiometric ratio. Reducing NOx and Hydrocarbons (HC) after injector cleaning is a notable benefit compared to pre-cleaning levels.

Table 2. The Average Results of emissions test for veh_1 at different vehicle speeds.

Veh_1 at idle Speed					
Tested Gas	CO	CO2	HC	O2	NOx
Before	0.77	13	97	1.09	108
After	0.67	14.1	75	1.12	90
% of change	-13.0%	8.5%	-22.7%	2.8%	-16.7%
Veh_1 at medium speed					
Tested Gas	CO	CO2	HC	O2	NOx
Before	0.64	15.5	72	0.89	277
After	0.54	17.2	60	1.07	260
% of change	-15.6%	11.0%	-16.7%	20.2%	-6.1%
Veh_1 at high speed					
Tested Gas	CO	CO2	HC	O2	NOx
Before	0.87	32.2	121	1.05	600
After	0.56	39.6	81	0.96	470
% of change	-35.6%	23.0%	-33.1%	-8.6%	-21.7%

The effect of CO_2 gas emission for all tested vehicles before and after cleaning the injectors is presented in Figure 9 at medium speed. The results show that improvement in CO_2 gas ranged from (5.7%- 11%) due to reducing the CO gases in the combustion chamber as a result of improvement in the atomization of fuel, as shown in Figure 9. Moreover, the brake horsepower recorded from the chassis dynamometer for the tested vehicles (veh_2, veh_3, veh_4) shows enhanced vehicle power ranging from 3% to 43% as a result of cleaning the fuel injectors, as shown in Figure 10. The notable enhancement in engine horsepower for veh_3 resulted from the discovery of a clog in two injectors during the pre-cleaning phase of the injector dynamometer test.

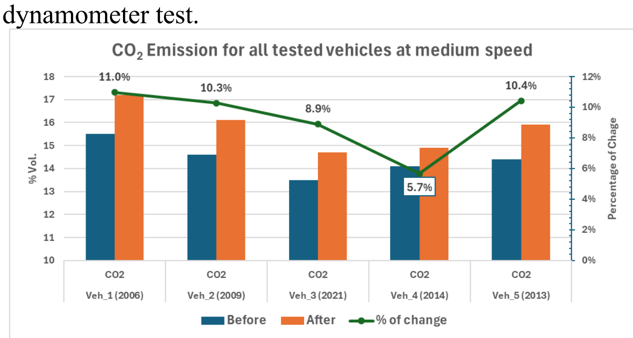

Figure 9. CO_2 gas emission for all tested vehicles at medium speed and percentage of improvements.

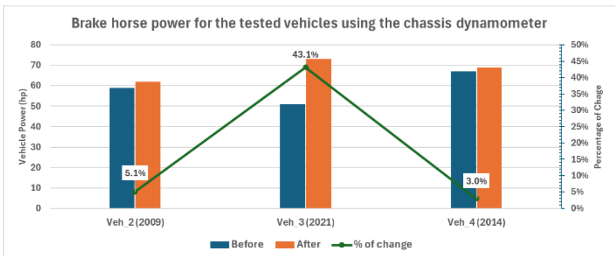

Figure 10. The brake horse power for the available tested vehicles.

5. Conclusion

A diverse range of research has been conducted on fuel injection systems and its emission control systems. Nonetheless, there is significant potential for innovation and inventive thought. This research aimed to design and develop a multi-port fuel injector cleaning device that was more cost-effective than existing devices. This research examined five vehicle case studies to investigate the impact of injector cleaning on vehicle performance and exhaust pollution levels of spark ignition engines as follows:

a. Experimental vehicle performance tests using chassis dynamometer for pre and post-injector cleaning revealed that a noticeable enhancement in vehicle output horsepower ranged between (3% - 43%) and veh_3 is the most favorable among all samples.

b. Furthermore, carbon monoxide (CO) and hydrocarbon (HC) emissions decrease after the injectors have been cleaned while increasing the CO_2 emissions for all vehicle samples at different engine speeds. Regarding the NO_x emissions at veh_1, there is a significant reduction from 600 to 470 ppm at medium engine speed.

Finally, Cleaning the gasoline injector enhances fuel atomization and mixing efficiency inside the combustion chamber. We encourage all vehicle manufacturers to include the injector cleaning within the routine preventative maintenance for all vehicles.

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Conflict of Interest

The authors declare no conflicts of interest

References

Aris, I., Zakaria, M. F., Abdullah, S. M., & Sidek, R. M. (2007). Development of obd-ii driver information system. International Journal of Engineering and Technology, 4(2), 253-259.

Duarte, G. O., Gonçalves, G. A., & Farias, T. L. (2016). Analysis of fuel consumption and pollutant emissions of regulated and alternative driving cycles based on real-world measurements. Transportation Research Part D: Transport and Environment, 44, 43-54. https://doi.org/10.1016/j.trd.2016.02.009

Heroual, L., Berkane, M. L., & Bouzerzour, N. E. H. (2023). Towards an AI-Based Approach for Adaptive Emission Control and Sensor Diagnostics: A gasoline engine case study. In TACC (pp. 43-54).

Hung, D. L., Harrington, D. L., Gandhi, A. H., Markle, L. E., Parrish, S. E., Shakal, J. S., ... & Kramer, J. L. (2008). Gasoline fuel injector spray measurement and characterization-a new SAE J2715 recommended practice. SAE International Journal of Fuels and Lubricants, 1(2008-01-1068), 534-548. https://doi.org/10.4271/2008-01-1068

Kaisan, M. U., Kachalla, M., Ibrahim, I. U., & Narayan, S. (2023). Comparison of camphor and fuel injector cleaner effects on the performance and emission levels of gasoline engines. Journal of Engineering Research, 11(2), 48-56. https://doi.org/10.36909/jer.15017

Kurniawan, M., Ardiles, S. A., Adiwidya, A. S., Ummi, A. Z., Halinda, M. F. A., Okthaviany, I. C. A. G., ... & Chandra, I. (2023). Measurement of Motor Vehicle Emissions Based on Low-Cost Sensors. JMECS (Journal of Measurements, Electronics, Communications, and Systems), 10(2), 67-76.

Rizzoni, G., Onori, S., & Rubagotti, M. (2009). Diagnosis and prognosis of automotive systems: motivations, history and some results. IFAC Proceedings Volumes, 42(8), 191-202. https://doi.org/10.3182/20090630-4-ES-2003.00032

SAE International Surface Vehicle Recommended Practice. (2007). Gasoline Fuel Injector Spray Measurement and Characterization. SAE standard J2715.

Udoh, J., Lu, J., & Xu, Q. (2024). Application of machine learning to predict CO2 emissions in light-duty vehicles. Sensors, 24(24), 8219. https://doi.org/10.3390/s24248219

Zhang, W., Zhang, Z., Ma, X., Awad, O. I., Li, Y., Shuai, S., & Xu, H. (2020). Impact of injector tip deposits on gasoline direct injection engine combustion, fuel economy and emissions. Applied Energy, 262, 114538. https://doi.org/10.1016/j.apenergy.2020.114538