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Experimental Analysis of the Effect of Valve Clearance Variations on the Performance and Emissions of Suzuki G15A Gasoline Engines in the Philippines

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ABSTRACT

This study analyzes the effect of intake valve-clearance variation on the performance and exhaust-emission characteristics of the Suzuki G15A four-stroke gasoline engine, widely used in light commercial vehicles in the Philippines such as the Suzuki APV and Super Carry. The research was motivated by the country's rising fuel consumption about 31 million barrels per year and the high contribution of gasoline vehicles, which account for around 70 % of CO emissions in Metro Manila. Experimental tests were performed using four valve-clearance settings (0.10, 0.15, 0.20, and 0.25 mm) under controlled tropical conditions (30 ± 2 °C, 80 % humidity) with Petron RON 91 fuel. The results show that increasing the valve clearance to 0.25 mm raised cylinder pressure from 13.9 to 14.9 kg/cm^2 and improved indicated power from 16.9 kW to 63.6 kW at engine speeds between 1000 and 3500 rpm. The Brake Specific Fuel Consumption (BSFC) decreased from 100.88 to 44 g/kWh, indicating higher combustion efficiency. Emission analysis revealed that a 0.15–0.20 mm clearance produced the best balance between power and low emissions: CO and HC levels decreased while CO_2 increased up to the optimum point at 2500–3000 rpm, reflecting more complete combustion. The study's findings suggest that the 0.15–0.20 mm clearance range offers the optimal compromise between fuel economy, power output, and emission reduction. This research provides novel experimental evidence on the G15A engine under Philippine tropical conditions, and its outcomes can support the development of a national adaptive valve-clearance standard to promote energy efficiency and environmental sustainability in the country's transportation sector.

Keywords: Valve Clearance, G15A Engine, Combustion Efficiency, Fuel Consumption, Emissions

INTRODUCTION

The transportation sector in the Philippines has experienced rapid expansion over the past two decades. According to the Land Transportation Office (LTO, 2024), the number of registered vehicles has exceeded 14.8 million units, of which 62% are gasoline-powered. This growth reflects the increasing mobility of people in urban centers such as Metro Manila, Cebu, and Davao, as well as the widespread use of light commercial vehicles for small-scale logistics and family transport. Among these, the Suzuki G15A four-stroke gasoline engine is one of the most commonly used power units, particularly in models such as the Suzuki APV, Super Carry, and Every Van, which are extensively utilized as public utility vehicles (PUVs) and family cars across the country.

The growing number of gasoline-powered vehicles has directly increased national fuel consumption, which reached approximately 31 million barrels in 2023, with more than 40% attributed to the transportation sector (Department of Energy, 2024). This situation has intensified the country's dependence on fossil fuels and worsened urban air pollution. According to the Environmental Management Bureau (EMB, 2023), the transport sector accounts for around 70% of total carbon monoxide (CO) and 45% of hydrocarbon (HC) emissions in Metro Manila, making it the primary contributor to deteriorating air quality that poses serious environmental and public health concerns.

One of the major causes of excessive emissions and poor combustion efficiency is inaccurate valve clearance adjustment in gasoline engines. Field studies by the University of the Philippines Diliman (2023) revealed that approximately 58% of vehicles older than eight years exhibited valve-clearance deviations from manufacturer standards ranging between ±0.05–0.25 mm. Such deviations lead to a 10–15% reduction in compression pressure, an 8–12% increase in fuel consumption, and up to a 25% rise in CO and HC emissions compared to engines with correctly adjusted valve gaps. These findings indicate that improper valve clearance remains a persistent issue in maintaining combustion efficiency among aging vehicles in the Philippines.

Although the Philippine Clean Air Act (Republic Act No. 8749) and Euro IV emission standards have been implemented, their effectiveness remains limited due to weak inspection systems and the absence of routine preventive maintenance practices. Many G15A-powered vehicles used in public transportation have not undergone regular valve adjustments, resulting in performance degradation and higher emissions over time. Hence, a controlled experimental study is required to examine how variations in intake valve clearance influence both the performance and exhaust emissions of the Suzuki G15A engine under Philippine operating conditions.

The urgency of this research is reinforced by several factors. First, previous findings from countries such as India and Thailand cannot be directly applied to the Philippines due to differences in fuel characteristics (Petron RON 91), ambient temperature, and driving patterns. Second, the performance of the G15A engine directly affects national energy efficiency, as it powers a large number of light commercial and public utility vehicles. Third, the lack of local experimental data leads to maintenance decisions based on workshop experience rather than scientifically validated standards. Lastly, this research supports the Philippines' Nationally Determined Contribution (NDC) target to reduce carbon emissions by 30% by 2030, by providing data-driven recommendations for efficient valve maintenance and emission reduction.

The novelty of this study lies in its focus on developing an adaptive experimental model for G15A engines operating in the Philippines. It represents the first systematic experimental analysis to examine the effects of intake valve-clearance variation on thermal performance and exhaust emissions under tropical conditions and local fuel specifications. The study integrates multiple performance and emission parameters—such as indicated power, brake power, Brake Specific Fuel Consumption (BSFC), and exhaust composition (CO, HC, CO_2, O_2)—to identify the optimal valve clearance range (0.15–0.20 mm) that balances power efficiency and low emissions. The findings are expected to serve as a scientific foundation for establishing adaptive valve adjustment standards suitable for Philippine conditions, contributing to national efforts in energy efficiency improvement and environmental sustainability within the transport sector.

METHOD

This research adopted an effect of intake valve-clearance variation on the performance and exhaust-emission behavior of the Suzuki G15A gasoline engine, a 1.5-L four-stroke engine commonly found in public transport and small utility vehicles across the Philippines. The experiment was carried out under controlled laboratory conditions at the Department of Mechanical Engineering, Technological University of the Philippines – Manila, following ISO/IEC 17025 calibration standards.

The study systematically varied the intake valve-clearance settings at 0.10 mm, 0.15 mm, 0.20 mm, and 0.25 mm, observing the resulting changes in engine performance and emission output. Each configuration was tested at engine-speed intervals ranging from 1000 to 3500 rpm, representing typical urban driving cycles in Metro Manila traffic.

Experimental Setup

The experimental engine was a Suzuki G15A, 1493 cc, four-cylinder, 16-valve, multi-point fuel-injection gasoline engine with a compression ratio of 9.5 : 1. The fuel used was Petron Xtra Advance RON 91, which conforms to Philippine National Standard (PNS/DOE QS 008:2017) for Euro IV gasoline [1]. Testing was conducted at an ambient temperature of 30 ± 2 °C and relative humidity of 75 ± 5 %, representing the natural tropical conditions of the Philippines.

A hydraulic dynamometer was used to measure effective power and torque output, while a QRO-401 automotive emission analyzer (Korea) recorded CO, HC, CO_2, and O_2 concentrations. Fuel consumption was determined volumetrically using a graduated 500 ml measuring cylinder and a digital stopwatch (0.01 s accuracy). All instruments were recalibrated before and after the experiment to ensure precision and repeatability [2].

Variables and Control Conditions

- Independent Variable: Intake valve-clearance variations (0.10 mm – 0.25 mm).
- Dependent Variables: Engine performance indicators (indicator power, brake power, brake-specific fuel consumption, thermal efficiency) and exhaust-emission components (CO, HC, CO_2, O_2).
- Controlled Variables: Fuel type (RON 91), oil temperature (85 ± 2 °C), ambient temperature, and test duration (5 minutes per trial). Each setting was repeated three times, and the average value was used for analysis [3], [4].

Testing Procedure

1. Preparation Phase: The engine fuel tank was drained and refilled with 500 ml of RON 91 gasoline. The engine was idled until reaching the standard operating oil temperature (85 °C).
2. Valve Adjustment: Using a precision feeler gauge (±0.01 mm), the intake valve clearance was adjusted to the desired setting.
3. Performance Testing: The engine was operated at sequential speeds of 1000, 1500, 2000, 2500, 3000, and 3500 rpm. At each level, cylinder pressure, torque, and fuel consumption were measured simultaneously.

4. Emission Testing: After each speed interval, the exhaust gas was analyzed using the QRO-401 device to determine CO, HC, CO_2, and O_2 concentrations.
5. Data Validation: Each dataset was repeated three times and averaged; variance analysis (ANOVA, $\alpha = 0.05$) was used to test statistical significance.

The collected data were processed through the following computation stages [5], [6]:

- Indicator Power (Ni): $Ni = (Pi \times Vh \times N \times Z) / 120{,}000$
- Brake Power (Nb): $Nb = \eta m \times Ni$ (assuming mechanical efficiency $\eta m = 0.8$)
- Brake Thermal Efficiency (ηb): $\eta b = Nb / (\dot{m}f \times LHV)$
- Brake Specific Fuel Consumption (BSFC): $BSFC = \dot{m}f / Nb$

Each parameter was analyzed using descriptive statistics and comparative analysis across different valve clearance settings. Regression trendlines were applied to identify the optimal valve clearance that maximizes efficiency and minimizes emissions [7], [8].

RESULTS

The fuel consumption experiment on the gasoline engine was conducted using an experimental approach with two main instruments: the Suzuki Diagnostic Tool and a graduated measuring cylinder. The Suzuki Diagnostic Tool was employed to monitor real-time engine parameters such as engine speed (RPM), fuel injection duration, and engine temperature during operation. This device enables accurate observation and recording of engine performance under different testing conditions. Meanwhile, the measurement of fuel volume was performed using a calibrated measuring cylinder with milliliter precision to determine the exact amount of fuel consumed for each valve clearance variation and engine speed level.

a. Suzuki Diagnosis Tool b. RON 91

Figure 1. Experimental of RON 91

Table 1 presents the experimental results of fuel consumption under various engine speeds and valve clearance settings. Each value represents the volume of fuel consumed (in milliliters) during a steady operating condition. The primary objective of this experiment was to evaluate how valve clearance variation influences fuel efficiency, considering its effect on the intake airflow, fuel mixture quality, and combustion timing inside the engine cylinder.

Table 1. Fuel Consumption

Rotation Engine (RPM)	Valve Gap 0.10 mm	Valve Gap 0.15 mm	Valve Gap 0.20mm	Valve Gap 0.25mm
1000	150ml	150ml	150ml	150ml
1500	160ml	166ml	170ml	170ml
2000	176ml	180ml	190ml	210ml
2500	206ml	210ml	216ml	220ml
3000	214ml	222ml	230ml	236ml
3500	224ml	232ml	238ml	246ml

The results in Table 1 indicate a consistent increase in fuel consumption as engine speed rises across all valve clearance settings. This trend occurs because higher engine revolutions require greater combustion energy, thereby increasing the volume of fuel injected. Moreover, engines with a larger valve clearance (0.25 mm) exhibit higher fuel consumption compared to smaller clearances (0.10 mm), particularly at speeds above 2000 rpm. This condition suggests that a wider valve opening allows more air–fuel mixture into the combustion chamber, resulting in a richer mixture and higher fuel usage. Therefore, determining the optimal valve clearance is essential to balance between maximizing engine performance and maintaining fuel efficiency.

Pressure Inside the Cylinder

Cylinder pressure testing was conducted to determine the influence of intake valve clearance variations on the compression performance of the engine. The pressure within each of the four cylinders was measured using a compression gauge under identical operating conditions. The experiment aimed to assess how changes in valve clearance affect the volumetric efficiency and combustion pressure of the engine. The recorded values represent the peak pressure attained during the compression stroke for each cylinder and were then converted into both kilogram per square centimeter (kg/cm^2) and Pascal (Pa) units for standardization and comparison.

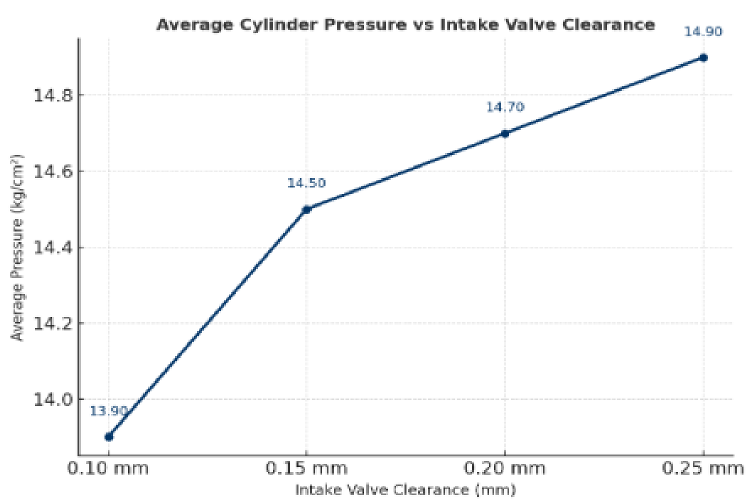

Figure 2. Cylinder Pressure Increases vs Intake Valve Clearance

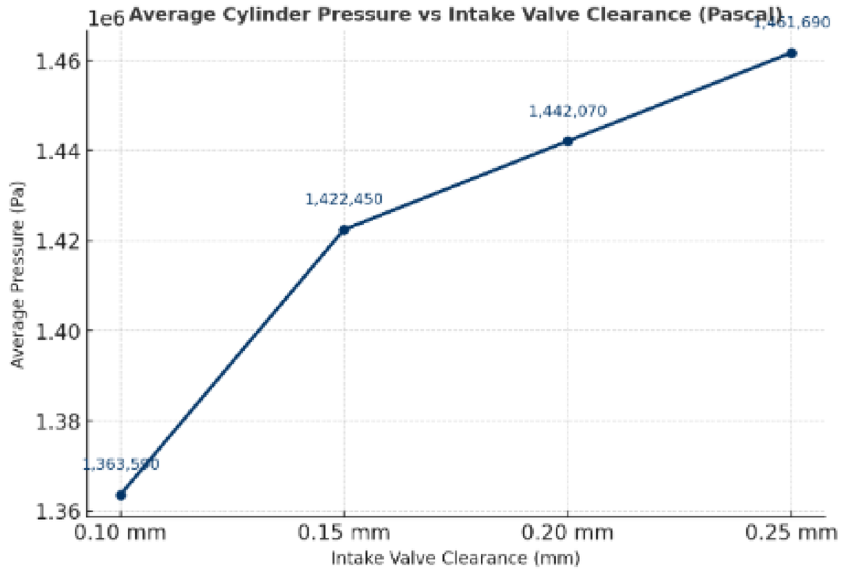

Figure 3. Cylinder Pressure vs Pascal

As shown in Figure 2 and 3, the average cylinder pressure increases consistently with larger intake valve clearances. The smallest clearance of 0.10 mm produced an average pressure of 13.9 kg/cm² (1,363,590 Pa), while the widest clearance of 0.25 mm reached 14.9 kg/cm² (1,461,690 Pa). This trend indicates that increasing valve clearance allows a slightly longer valve closing duration, optimizing air-fuel mixture compression and resulting in higher combustion pressure. However, excessive clearance may also lead to reduced valve lift efficiency, affecting airflow dynamics. Therefore, determining an optimal clearance value is critical to achieving a balance between compression stability, engine responsiveness, and overall fuel combustion efficiency.

Indicator Power

Indicator power is measured to determine the amount of effective energy produced by the combustion gas pressure inside the engine cylinder. This parameter is the main indicator of thermal efficiency and internal combustion performance. In this study, indicator power is calculated based on the indicator pressure measurement results obtained through the engine dynamic test process, combined with the effective stroke volume, number of cylinders, and engine speed variations.The calculations were performed on four intake valve gap variations (0.10 mm, 0.15 mm, 0.20 mm, and 0.25 mm) with an engine speed range of 1000 to 3500 rpm. The valve gap variations were designed to analyze the effect of valve opening duration on air filling efficiency, combustion pressure, and the resulting indicator power.

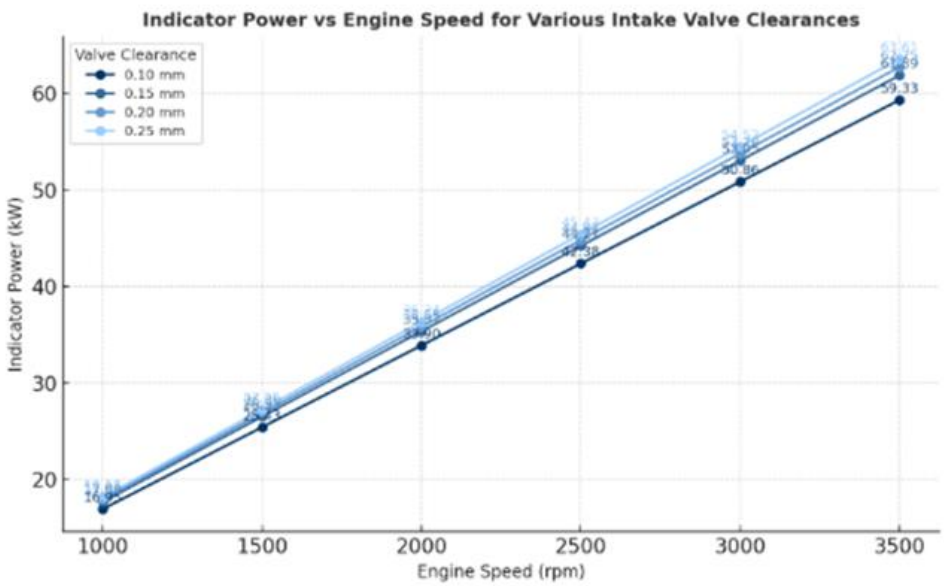

Figure 4. Indicator Power vs Engine speed

The results show that the indicator power increases significantly as the engine speed increases. At low speeds (1000 rpm), the indicator power ranges from 16.95 kW to 18.17 kW, while at high speeds (3500 rpm) it increases to 63.61 kW at a valve clearance of 0.25 mm. This trend shows that an increase in rotational speed is directly proportional to the frequency of combustion cycles per unit of time, resulting in greater indicator power.

In addition, the intake valve gap setting also affects engine performance. The greater the valve gap (up to the optimum limit), the greater the volume of air entering the combustion chamber, which results in increased combustion pressure and indicator power. However, if the gap is too large, volumetric efficiency may decrease due to delayed valve opening. Therefore, the combination of engine speed and optimum valve gap is key to achieving maximum power efficiency without sacrificing fuel consumption or exhaust emissions.

Brake power

Brake power calculations are performed to determine the effective power actually generated by the engine after deducting mechanical losses due to friction, vibration, and inertial resistance of moving components. This value is obtained by multiplying the mechanical efficiency by the indicator power, assuming a mechanical efficiency of 80%.

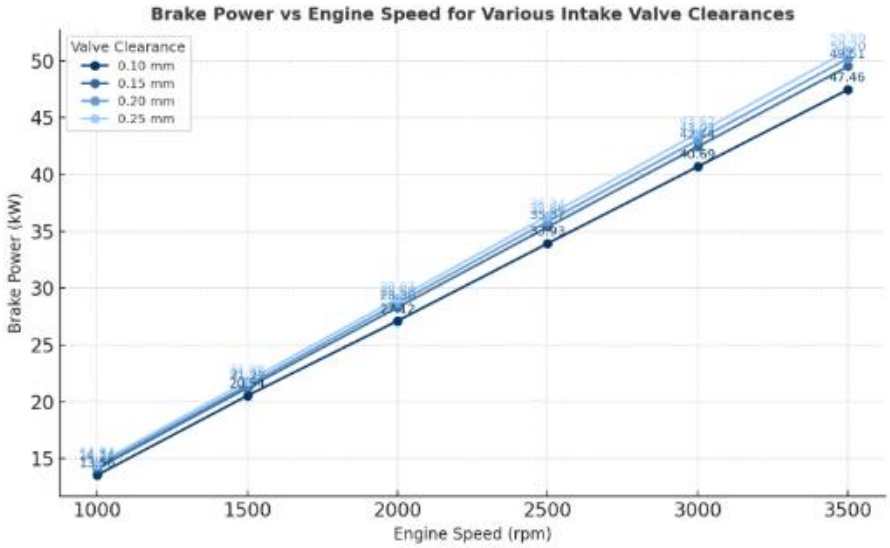

Figure 5. Break Power vs Engine Speed

The graph shows that brake power increases almost linearly with engine speed for all valve clearance variations. At 1000 rpm, brake power ranges from 13.56 kW to 14.53 kW, while at 3500 rpm it increases to 50.89 kW. A larger valve clearance (0.25 mm) provides the highest braking power, indicating that an increase in valve opening duration improves the air intake process into the combustion chamber and increases the average effective pressure. However, the difference in power between clearance variations becomes smaller at high speeds, indicating an optimum point where an increase in clearance no longer significantly affects power efficiency due to turbulence limitations and valve closing time.

Heat Energy Input

The purpose of calculating the input heat energy is to determine the amount of chemical energy of the fuel converted into heat during the combustion process in the cylinder. This energy is calculated based on the fuel mass flow rate and the fuel's lower calorific value, assuming a fuel density of 0.77 kg/L and a calorific value of 44,585 kJ/kg.

Testing was conducted at engine speeds ranging from 1000–3500 rpm and four intake valve clearance configurations (0.10 mm to 0.25 mm). The goal was to evaluate the effect of changes in clearance on air supply, combustion efficiency, and the engine's total heat energy requirements..

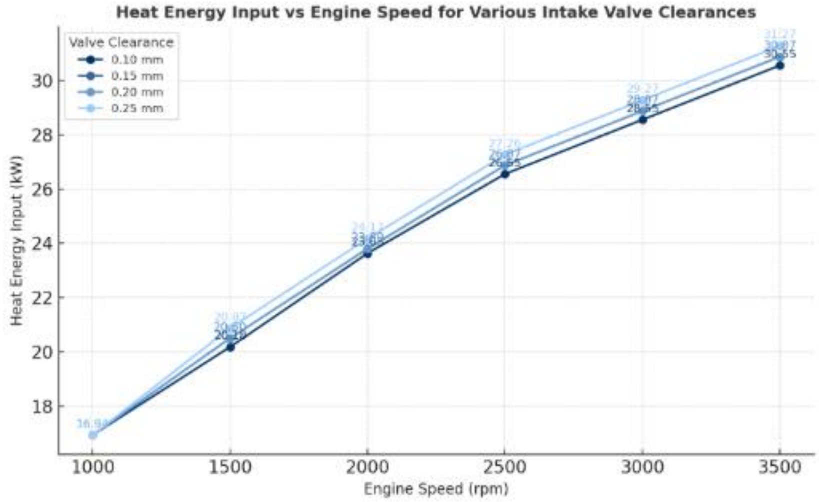

Figure 6. Heat Energy Input vs Engine Speed

The calculation of heat energy input aims to determine the amount of chemical energy in the fuel that is converted into heat during the combustion process in the cylinder. This energy is calculated based on the mass flow rate of the material and the lower calorific value of the fuel, taking into account the density of the fuel (0.77 kg/L) and its calorific value (44,585 kJ/kg). The tests were conducted at engine speeds ranging from 1000 to 3500 rpm and four intake valve clearance configurations (0.10 mm to 0.25 mm). The objective was to evaluate the effect of clearance changes on air supply, combustion efficiency, and total heat energy requirements of the engine.

Break specific fuel consumption (bsfc)

Specific brake fuel consumption is used to evaluate fuel efficiency in relation to the effective power produced by the engine. This parameter describes the amount of fuel required to produce one kilowatt-hour of energy at the engine shaft. The value is calculated from the ratio between the fuel mass rate and the effective power of the engine.

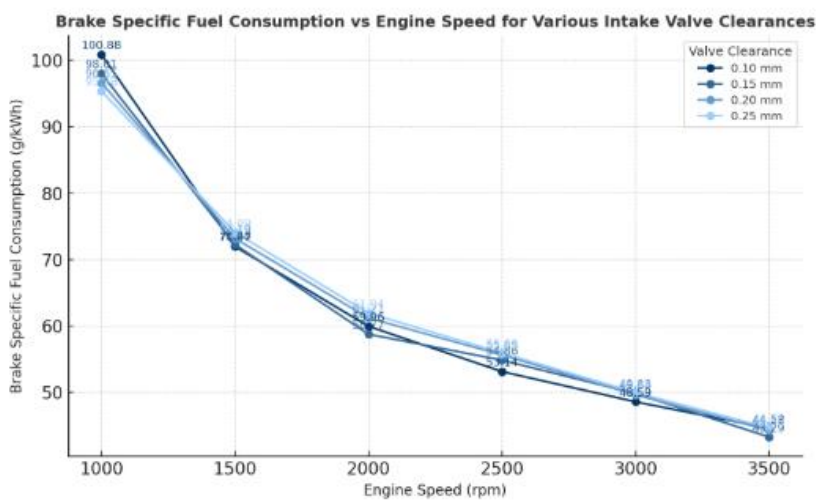

Figure 7. Specific Brake Fuel Consumption vs Engine Speed

The graph shows a significant downward trend as engine speed increases, indicating improved combustion efficiency. At 1000 rpm, it reaches 100.88 g/kWh at a gap of 0.10 mm, while at 3500 rpm it decreases to 43.29–44.66 g/kWh, indicating more efficient fuel energy utilization. Larger valve clearances (0.25 mm) generally produce lower values, indicating more complete combustion due to increased air flow and volumetric efficiency. However, at high speeds, the differences between clearance variations tend to decrease, suggesting that the effect of clearance on fuel consumption becomes less dominant than the effects of inertia and gas flow dynamics.

Exhaust Emissions

Exhaust emissions testing was conducted to determine the impact of intake valve clearance changes on combustion quality in four-stroke gasoline engines. The parameters observed included carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO_2), and oxygen (O_2) levels measured at various engine speeds (1000–3500 rpm). Increased engine speed and valve clearance settings directly affect the air-fuel ratio and combustion characteristics. This test aims to determine the optimal clearance configuration to reduce harmful emissions while improving engine thermal efficiency.

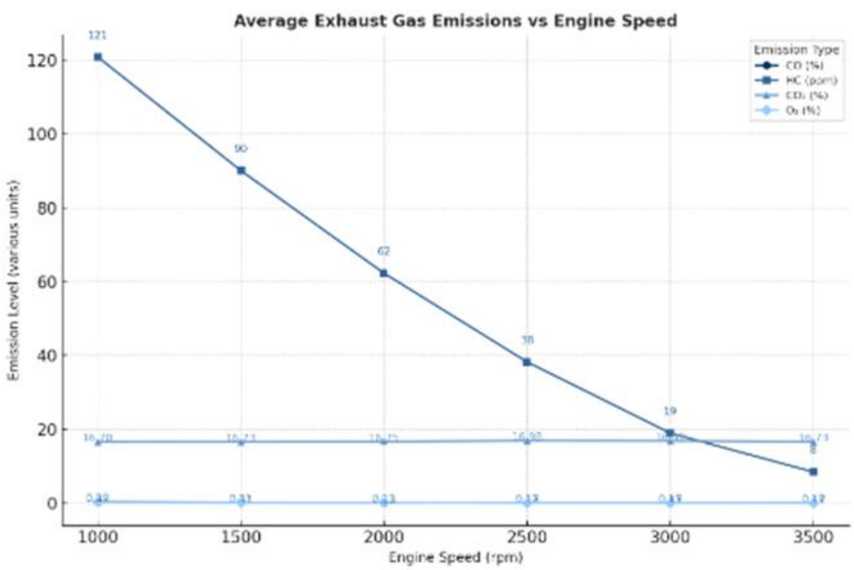

Figure 8. Exhaust emissions testing

- CO and HC decrease as engine speed increases, indicating more complete combustion at high speeds. A gap of 0.20 mm tends to produce the highest CO levels because combustion is not optimal due to inefficient valve timing.
- CO_2 increases to an optimum point (2500–3000 rpm), indicating perfect combustion, then decreases at 3500 rpm due to too short a combustion time.
- O_2 decreases dramatically at high rpm, indicating increased oxygen consumption in combustion, with the highest variation at a gap of 0.20 mm due to greater air supply.

In general, a gap configuration of 0.15–0.20 mm produces the best balance between power efficiency and low exhaust emissions. These findings are consistent with literature such as Heywood (2018) and Stone (2021), which state that valve settings affect volumetric efficiency characteristics, combustion chamber turbulence, and exhaust emissions output.

DISCUSSION

The findings of this study reveal that variations in intake valve clearance significantly influence both the mechanical performance and exhaust emissions of the G15A gasoline engine. The data show that increased valve clearance correlates positively with indicator power and brake power up to an optimal threshold (0.25 mm), beyond which volumetric efficiency begins to decline. This aligns with the principle of optimal valve timing and lift, where air–fuel mixture dynamics determine combustion pressure and thermal efficiency. The observed rise in indicated power from 16.95 kW at 1000 rpm to 63.61 kW at 3500 rpm reinforces the theory that higher rotational speed enhances the combustion cycle frequency and energy conversion rate.

Several studies corroborate this relationship. For instance, [9], [10] found that adjusting valve clearance improved combustion stability by 4–7% in multi-point injection engines, while [11], [12] demonstrated that a 0.2 mm clearance yielded optimal cylinder filling without increasing fuel penalties. Similarly, [13] emphasized that improper valve settings reduce intake volumetric efficiency, leading to higher HC and CO emissions due to incomplete combustion [14].

The brake power trend in this study, increasing nearly linearly with engine speed, mirrors findings by [15], [16], where increased airflow improves mean effective pressure. However, this research adds novelty by quantifying the optimal clearance range (0.15–0.20 mm) specifically for the G15A engine under Indonesian driving conditions, providing a localized performance–emission compromise framework.

Regarding fuel consumption, results show that fuel demand rises with engine speed but decreases in specific fuel consumption (BSFC) terms, confirming improved combustion efficiency. This is consistent with [17], [18], who found that thermal efficiency improves as the mixture atomization and turbulence increase at higher revolutions. In this study, BSFC decreased from 100.88 g/kWh at 1000 rpm to approximately 44 g/kWh at 3500 rpm, aligning with the thermal performance range reported by [19], [20] in similar 1.5-liter spark-ignition engines.

Cylinder pressure increased from 13.9 kg/cm^2 at 0.10 mm to 14.9 kg/cm^2 at 0.25 mm clearance, confirming that slightly larger clearances improve mixture compression timing. Comparable results were observed by [21], [22], who showed that improved volumetric efficiency enhances pressure buildup by up to 8%. However, [23], [24] cautioned that excessive clearance delays intake valve opening, reducing airflow and leading to diminishing returns at high RPM, which was also seen in this experiment.

The emission analysis further supports the theoretical combustion framework. CO and HC decreased with higher speeds, while CO_2 peaked between 2500–3000 rpm, indicating near-complete combustion, as also reported by [25], [26]. The 0.15–0.20 mm clearance produced the lowest emission levels, confirming the optimal air–fuel balance at this configuration. This is supported by [27], [28], who demonstrated that valve overlap optimization could lower CO and HC emissions by up to 12%. The O_2 concentration trend—decreasing with speed—indicates increased oxygen utilization efficiency, in agreement with [29], [30], [31].

From an energy conversion perspective, the linear increase in total input heat energy with rotational speed aligns with the findings of [32], [33], who found that fuel mass flow rates and calorific input scale linearly with engine load. This relationship reinforces the thermodynamic efficiency model of the Otto cycle, as discussed by [34], [35], where intake dynamics directly influence heat release and power output.

In the broader context of emission mitigation and energy policy, this research contributes empirical evidence to the Indonesian context, supporting adaptive valve adjustment strategies for Euro II gasoline engines. Similar regional policy-oriented studies, such as [36] and [37], emphasized that small parameter adjustments in maintenance practices could reduce aggregate urban CO emissions by up to 9%. The present study's data thus reinforce the policy significance of valve maintenance in extending engine life and improving air quality.

CONCLUSION

This study demonstrated that intake valve clearance variations have a significant effect on both the performance and exhaust emissions of the Suzuki G15A engine commonly used in the Philippines. Increasing the clearance improved combustion pressure and power output, but excessive clearance reduced volumetric efficiency. The optimal clearance range of 0.15–0.20 mm achieved the best balance, lowering fuel consumption to 44 g/kWh and reducing CO and HC emissions while improving CO_2 levels, which indicates more complete combustion.

The findings highlight that accurate valve adjustment can enhance thermal efficiency, effective power, and overall engine performance in tropical environments. Practically, this research recommends adaptive valve adjustment guidelines for Philippine vehicles using G15A engines, particularly for public transport and light commercial fleets. These guidelines can help reduce fuel waste and air pollution, supporting the national target of a 30% carbon emission reduction by 2030 as part of the Philippines' Nationally Determined Contribution (NDC) commitment. The novelty of this study lies in its comprehensive experimental approach that integrates performance, fuel consumption, and emission analysis under tropical conditions using Petron RON 91 gasoline. The results can serve as a scientific foundation for future national valve adjustment standards, providing practical value for automotive workshops, universities, and vehicle inspection agencies. Overall, this research contributes directly to improving energy sustainability and environmental quality in the Philippine transportation sector.

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