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Performance Analysis of Motorbike Engine Using Bioethanol Gasoline Blends

Yasir Hussain[1], Sajjad Miran[1], Nazam Siddique[2], Samar ul Hasnain[1], Hafiz Ahmad Bilal[2], Waseem Arif[1]
[1]Department of Mechanical Engineering, University of Gujrat, Pakistan
[1]Department of Electrical Engineering, University of Gujrat, Pakistan.
[2]Govt. Swedish Pakistani College of Technology, Gujrat, Pakistan
***Correspondence:** sajjad.miran@uog.edu.pk.

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The increasing demand for sustainable energy and reduced reliance on fossil fuels has driven the exploration of alternative fuel options. This study aims to evaluate the performance of a motorcycle engine using bioethanol-gasoline blends. Simulations were conducted using AVL Boost software. By applying AVL Boost in innovative ways, the research provides new insights into improving the performance of motorcycle engines powered by bioethanol-gasoline blends, contributing to more eco-friendly transportation. A numerical model of a single-cylinder engine was developed, and various fuel blends were tested to assess performance characteristics at engine speeds ranging from 1000 to 4000 RPM. Single-cylinder spark ignition engines are commonly used in many types of motorcycles. The results showed that the E20 blend achieved a 4% increase in power and improved performance characteristics during tests on engines running on lower ethanol blends.

Keywords: Biofuels, Bioethanol, AVL Boost, Numerical Investigation, Engine Performance.

Introduction:

The rising daily demand for energy has encouraged researchers to explore alternative, non-fossil vehicle fuels. With fossil fuel reserves depleting, finding widely accepted alternatives has become increasingly urgent. Biofuels, derived from renewable resources, have emerged as a promising substitute for conventional fossil fuels due to their limited availability [1][2]. Recognized as a sustainable energy source, biofuels play a crucial role in the renewable energy sector [3][4]. Among biofuels, alcohol is particularly significant [5]. Bioethanol, in particular, stands out as a potential alternative fuel for gasoline engines because it shares several key physical and chemical properties with gasoline, as shown in Table 2 [6][7]. Compared to conventional gasoline, bioethanol-gasoline blends have been found to significantly lower carbon monoxide (CO), hydrocarbon (HC), and particulate matter (PM) emissions while offering mixed effects on nitrogen oxides (NOx) and carbon dioxide (CO_2) emissions. This research uses a one-dimensional simulation model developed with AVL Boost [8] to analyze the performance characteristics of a single-cylinder spark ignition gasoline motorcycle engine fueled by gasoline-bioethanol blends. Several parameters affecting engine performance are examined, including power, torque, fuel consumption, and efficiency. The objective is to assess how the selected fuel blends—E0, E20, and E40—impact engine performance at different speeds: 1000, 2000, 3000, and 4000 RPM. Ethanol-gasoline blends with ethanol content of 50% or higher (E50+) have demonstrated significant potential for improving engine performance and reducing emissions. Research has shown that E50 blends can enhance brake thermal efficiency, with studies indicating that a compression ratio of 9.1 results in maximum power output, while a higher compression ratio of 9.7 leads to minimal fuel consumption. Additionally, E50 blends have been found to increase brake torque and power in spark-ignition (SI) engines, making them a viable alternative to conventional fuels.

In terms of emissions, E50 blends have been associated with significant reductions in carbon monoxide (CO) and hydrocarbon (HC) emissions compared to pure gasoline. Furthermore, nitrogen oxide (NOx) emissions also decrease when using E50 blends, contributing to a cleaner and more sustainable combustion process. These improvements are largely attributed to ethanol's higher oxygen content, which facilitates more complete combustion.

However, certain operational considerations must be taken into account when using E50 blends. Due to ethanol's lower energy density compared to gasoline, fuel consumption may increase slightly. Nonetheless, this effect can be offset by the overall gains in thermal efficiency. Another critical factor is material compatibility, as higher ethanol concentrations can affect engine components, necessitating further research into long-term durability. Future studies on E50+ blends should focus on optimizing engine parameters, assessing material compatibility, and conducting real-world driving condition evaluations to fully leverage the benefits of higher ethanol content fuels.

This knowledge could contribute to the development of improved engines and higher-quality vehicular fuels. There is growing awareness of biofuels, such as bioethanol, as a means to reduce environmental impacts and dependence on fossil fuels [9]. As the automotive industry searches for more sustainable alternatives, understanding how bioethanol fuel blends affect engine performance becomes both essential and challenging [10]. Studying the impact of bioethanol-gasoline blends offers valuable insights that can guide the design of engines optimized for these alternative fuels. By incorporating bioethanol, the reliance on limited fossil fuel reserves can be reduced [11].

This report provides several recommendations to help the automotive industry transition toward more eco-friendly and sustainable energy sources. However, biofuel blending comes with certain challenges. While some blends are compatible with existing engines, others are not [12]. Therefore, it is crucial to determine which ethanol-gasoline blend is best suited for single-cylinder spark ignition engines to achieve optimal performance. Ultimately, understanding the performance characteristics of biofuels and their compatibility with gasoline is key to successful engine integration.

Objectives of the Study:

The main objectives of this study on the performance analysis of a motorbike engine using bioethanol-gasoline blends are as follows:

- Analyze the impact of ethanol-gasoline blends (E0, E20, E40) on power, torque, fuel consumption, and efficiency using AVL Boost simulations.
- Utilize AVL Boost software to create and validate a simulation model for a single-cylinder motorcycle engine.
- Investigate ethanol's potential to enhance engine performance and reduce reliance on fossil fuels.
- Identify the most efficient ethanol-gasoline ratio for improved engine performance while maintaining fuel economy.

Material and Methods:

This study uses the AVL Boost simulation tool to develop a simulation model for a single-cylinder motorcycle engine. The model is validated using experimental data to ensure its accuracy and alignment with current experimental findings [13]. After validation, the motorcycle engine model, based on the HONDA CD 70 with a 72cc single-cylinder spark ignition engine, is simulated on AVL Boost to analyze performance characteristics, including exhaust gas temperature data for each ethanol-gasoline blend at engine speeds of 1000, 2000, 3000, and 4000 RPM.

AVL Boost is specifically designed for engine simulations, enabling the analysis of changes in fuel compositions, engine configurations, and related components. It provides highly accurate predictions for both intake and exhaust parameters. In modern engineering, simulations are highly valued due to their ability to save time and costs compared to physical experiments, while also optimizing experimental designs.

This simulation investigates motorcycle engine performance using bioethanol-gasoline blends at different speeds. In Pakistan, 70cc motorcycles are widely used and primarily run on gasoline. These bikes typically use single-cylinder spark ignition engines equipped with carburetor-based fuel systems, which ensure the precise delivery of air and fuel to the combustion chamber for optimal engine performance.

The engine parameters used in this study are sourced from the HONDA CD 70 technical specification manual, an authoritative and reliable reference for accurate data. The study's methodology is illustrated in the flow diagram shown in Figure 1, while the parameters used to develop the simulation model are summarized in Table 1.

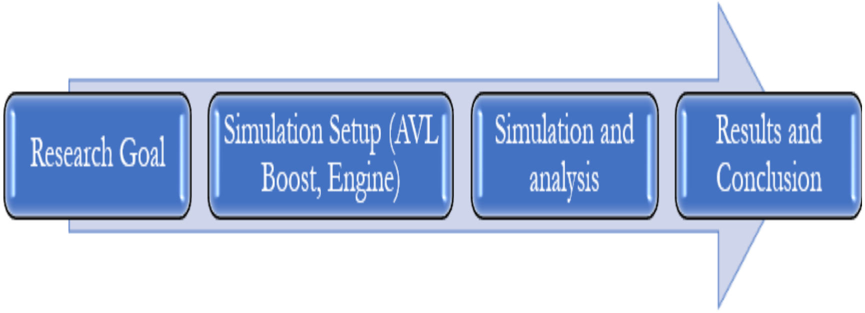

Figure 1. Flow Diagram of Methodology

Table 1: Single Cylinder Four Stroke Engine Parameters

Parameters	Specification	Unit
Engine	S I Engine 4 Stroke Air Cooled	
Make & Model	HONDA CD 70 2024	
Number of Cylinders	1	
Bore	47	mm
Stroke	41.4	mm
Connecting Rod	91	mm
Displacement Vale	72	cm3
BMEP Controlled	3	Bar
Compression Ratio	9.3: 1	
Aspiration Type	Natural	
Cooling System	Air Cooled	

The engine specifications include a bore of 47 mm, a stroke length of 41.4 mm, a compression ratio of 9.3, and a connecting rod length of 91 mm. The single-cylinder spark ignition motorcycle engine model was developed and calibrated using AVL Boost. The physical and thermal properties of gasoline and bioethanol are provided in Table 2.

Table 2: Properties of Gasoline and Bioethanol

Fuel Properties	Gasoline	Bioethanol
Molecular formula	$C_8H_{15.6}$	C_2H_6O
Density at 15 °C (kg/m3)	720 – 775	792
Boiling point at 1.013 bar (°C)	25 – 210	78.4
Research Octane number (RON)	85	89.7
Motor Octane Number (MON)	95	108.6
Heat of vaporization (kJ/kg)	289	854
Energy density (MJ/kg)	45	26
Composition C/H/O (%mass)	87.4/12.6/0	52.18/13.04/34.7
Molecular weight (kg/km)	98	46.070

The system boundary (SB1) was set with a temperature of 23.85°C and a pressure of 1 bar. For the system boundary (SB2), the maximum temperature was set at 126.85°C, also at a pressure of 1 bar, with a maximum air-fuel ratio of 13. The engine models, using AVL Boost's Classic Species Setup, were tested with both gasoline and ethanol. This setup helps simulate combustion behavior and analyze the processes occurring during combustion, allowing a detailed investigation of engine performance features.

The engine model characteristics, including the Vibe 2 Zone combustion model, were developed based on experimental data on gasoline performance. Previous studies with similar engine geometries provided vibration parameters used for ethanol fuel simulations. During these investigations, ignition and combustion timing for various gasoline-ethanol blends were kept constant.

The process of examining engine characteristics and applying bioethanol-gasoline blends involves several steps. The initial step includes gathering relevant engine data and specifications, followed by testing bioethanol-gasoline blends using the AVL Boost simulation model. In this model, gasoline has a molar mass of 111.20875 kg/mol and a stoichiometric air-fuel ratio of 14.600477%. Ethanol, in comparison, has a molar mass of 46.06952 kg/mol and a stoichiometric air-fuel ratio of 8.998616%.

The indicated engine work [13], calculated using governing equations, can be used to derive the engine power equation, as illustrated in the following equation.

$$\boldsymbol{Wi = PmiVH = \int_0^{720} \frac{PdV}{1000}} \qquad (1)$$

$$\boldsymbol{Ni} = \frac{\boldsymbol{Wi \times n}}{\mathbf{60 \times 2}} \quad (2)$$

In the equation, **Wi** represents the Indicated Engine Power, measured in kilojoules (kJ), and **Pmi** denotes the Mean Indicated Pressure, measured in pascals (Pa). **VH** is the Cylinder Displacement, expressed in cubic meters (m^3), while **P** and **V** refer to the In-Cylinder Pressure (Pa) and Cylinder Volume (m^3), respectively. Additionally, **Ni** represents the Indicated Engine Power in kilowatts (kW), and **n** stands for the engine speed, measured in revolutions per minute (RPM). The given indicated power calculates torque;

$$\boldsymbol{Mi} = \frac{\mathbf{60}}{\boldsymbol{2\pi n}} \boldsymbol{Ni} \quad (3)$$

In this context, Ni refers to the Indicated Engine Power, measured in kilowatts (kW), while n represents the Engine Speed, measured in revolutions per minute (RPM).

AVL Boost simulations have become an essential tool for research focused on improving engine efficiency while reducing both the time and cost associated with engine model development. The software provides a wide range of programs related to Internal Combustion Engines (ICE). While much of the existing research is centered on spark ignition (SI) and compression ignition (CI) engines, some studies have expanded beyond these areas.

AVL Boost enables users to perform fully computational analyses and integrate experimental data with simulation results. Its versatility in handling various fuel types allows researchers to perform advanced calculations, including simulations involving alternative fuels. Fuel blends can be configured using the Classic Species Setup within the Boost gas properties tool, enabling users to adjust fuel blend ratios. The software calculates gas properties for each cell at every time step, ensuring accuracy. The fuel blends, defined by fraction ratios in the Boost gas properties tool, are listed in Table 3.

Table 2: Gasoline and Ethanol blending ratio

Blend	Gasoline%	Ethanol%
E0	100	0
E20	80	20
E40	60	40

Result and Discussion:

Validation of the Model:

The experimental study data was validated by comparing it with exhaust gas temperature data collected from the current experimental engine test. At 4000 RPM, the maximum recorded exhaust gas temperature reached 510°C. The observed error in exhaust gas temperature was highest at 2% for elevated temperatures, with an average error of 10%, as shown in Figure 2.

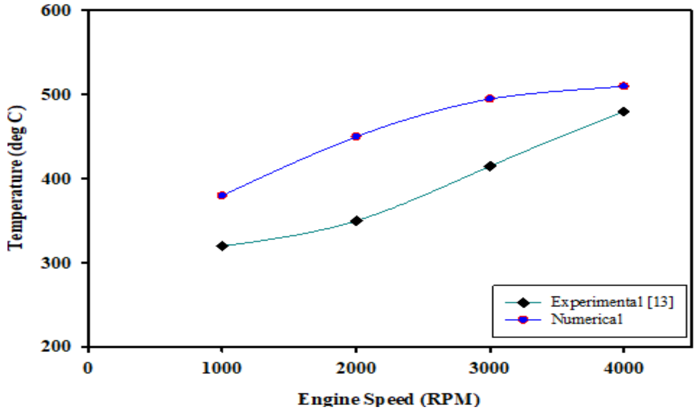

Figure 2: Engine Speed (RPM) vs Exhaust Gas Temperature

The maximum torque of 3.21 Nm was observed at 2000 RPM, representing a 16.52% increase compared to E100. At 4000 RPM, the torque performance is shown in Figure 3.

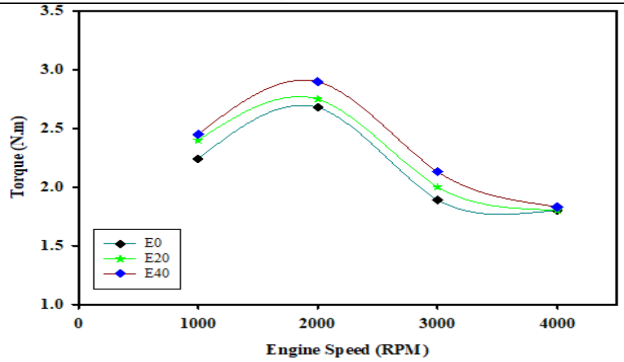

Figure 3: Engine Speed (RPM) vs Engine Torque

The engine's observed power output for gasoline and ethanol blends, measured in horsepower, is illustrated in Figure 4. The results indicate that power increases with higher ethanol content in the blends. However, at a lower speed of 1000 RPM, only the E20 blend shows a significant 52.31% increase in power compared to gasoline, making it a promising choice. This is due to ethanol's higher volatility, which allows it to expand and combust more efficiently in the E20 blend, thereby producing maximum power at 1000 RPM. Additionally, at lower RPM, the extended combustion time enhances power generation. The superior performance of the E20 blend at low speeds is attributed to its optimal volatility, which leads to highly efficient combustion.

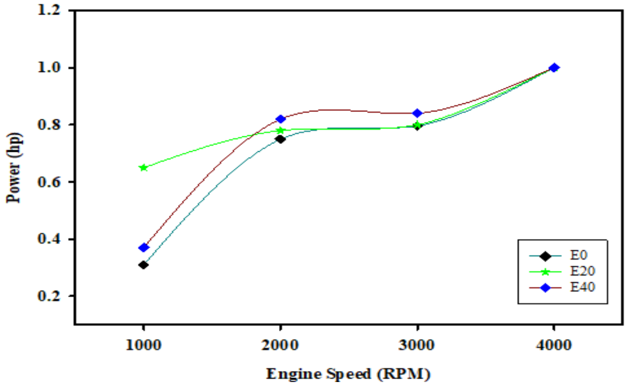

Figure 4: Engine Speed (RPM) vs Engine Power

Fuel consumption, measured in kilograms per hour (kg/h), represents the rate at which an engine uses fuel, expressed as the mass consumed over time, as shown in Figure 5. Ethanol contains 33% less energy per gallon compared to gasoline due to its higher octane rating. Additionally, ethanol's faster vaporization contributes to increased fuel consumption.

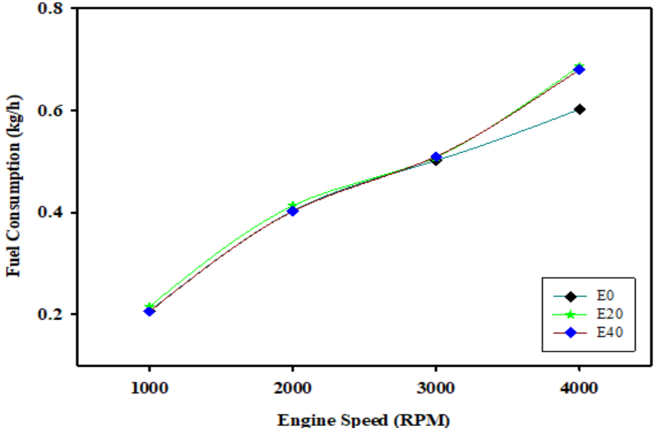

Figure 5: Engine Speed (RPM) vs Engine Fuel Consumption (Kg/h)

For small engines (< 100 cc), fuel efficiency varies between 25% and 35%, with engine load and friction conditions influencing the indicated efficiency. For E40, the maximum indicated efficiency is observed at 4000 RPM, as shown in Figure 6. Ethanol improves engine efficiency due to its higher-octane rating, which reduces engine knock and enhances compression ratios. While pure gasoline achieves maximum efficiency of around 15%, ethanol blends demonstrate a 10% to 15% improvement over gasoline at various RPMs.

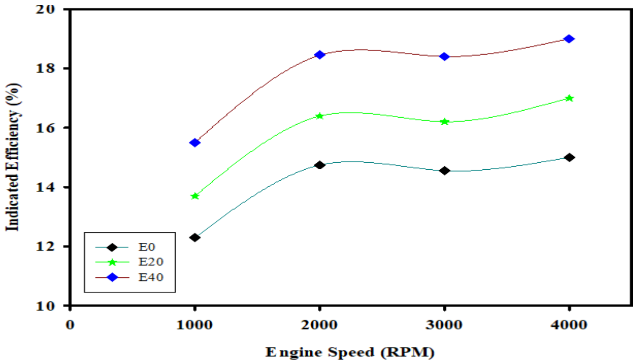

Figure 6 Engine Speed (RPM) vs Engine Indicated Efficiency

The effect of bioethanol-gasoline blends on engine mechanical efficiency at varying RPM is illustrated in Figure 7.

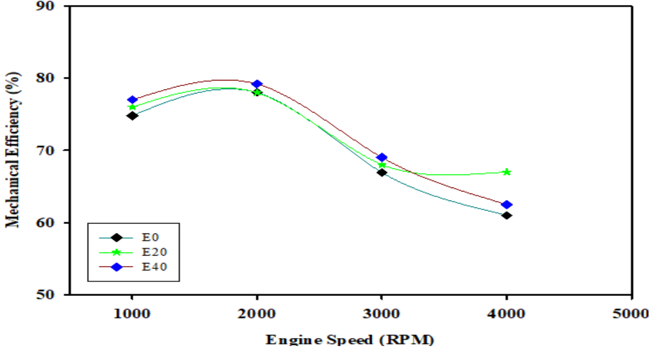

Figure 7 Engine Speed (RPM) vs Engine Mechanical Efficiency

At 2000 RPM, the engine demonstrates its highest mechanical efficiency, highlighting the optimal operating speed for the tested blends. However, as the RPM increases beyond this point, a decline in mechanical efficiency is observed due to increased frictional losses and reduced combustion time. Notably, at higher speeds (3000-4000 RPM), the E20 blend maintains a slight advantage in mechanical efficiency, particularly at 4000 RPM, where it shows a marginal but measurable difference. Other blends, including E0 and E40, exhibit only minor variations in efficiency at these higher RPM levels. This suggests that E20 offers a balance of efficient combustion and mechanical output, making it more suitable for high-speed operations compared to other blends.

Discussion:

The findings from this study demonstrate that bioethanol-gasoline blends significantly influence the performance characteristics of a motorcycle engine. The AVL Boost simulation results indicate that the E20 blend provides the most balanced improvement in power output, torque, and efficiency, making it a promising alternative to pure gasoline for small-displacement engines.

One of the key observations is the increase in engine power and torque with ethanol addition, particularly at low-to-mid engine speeds (1000-3000 RPM). The E20 blend shows a 4% improvement in power compared to E0, which aligns with previous research findings that highlight the efficiency of low-ethanol blends in spark ignition (SI) engines. The increased performance is attributed to ethanol's higher oxygen content, leading to better combustion and reduced knocking tendencies. However, at higher RPMs (4000+), efficiency gains plateau or slightly decline, possibly due to ethanol's lower energy density (26 MJ/kg vs. 45 MJ/kg for gasoline), which increases fuel consumption.

While the simulation results are promising, real-world experimental validations are necessary to confirm these findings. Previous studies using dynamometer testing on ethanol-gasoline blends have reported similar trends, with E20-E40 providing optimal trade-offs between performance and fuel economy. However, higher ethanol concentrations (E50-E85) require modifications in fuel injection systems, which are not addressed in this study. Future research should explore real-time road tests to validate AVL Boost predictions.

The increase in fuel consumption with ethanol addition is a critical concern, as ethanol has a lower energy density than gasoline. As shown in Figure 5, fuel consumption increases as ethanol content rises beyond E20. This is consistent with previous research, which found that ethanol's higher volatility leads to increased evaporation losses and fuel consumption. However, its higher-octane number (RON 89.7) and heat of vaporization (854 kJ/kg) contribute to smoother combustion and reduced engine knocking, making it beneficial in modern engines designed for alternative fuels.

Although this study does not analyze emissions, previous research indicates that ethanol blends can significantly reduce CO and HC emissions due to improved combustion efficiency. However, NOx emissions may increase due to higher combustion temperatures. Future studies should incorporate exhaust gas analysis to assess the environmental impact of bioethanol adoption in motorcycle engines.

Several challenges and opportunities exist for further research in this domain. Experimental validation through dynamometer-based testing would provide greater accuracy in performance assessments. Investigating the impact of higher ethanol blends such as E50 and E85, along with analyzing combustion characteristics like heat release rates, flame propagation, and ignition delays, would enhance the understanding of ethanol's effects on engine operation. Examining potential engine modifications required for higher ethanol concentrations and assessing the economic viability of ethanol fuel adoption in developing countries would further strengthen the case for bioethanol as an alternative fuel.

This study confirms that bioethanol-gasoline blends, particularly E20, improve motorcycle engine performance while maintaining fuel economy at lower RPMs. However, challenges remain in fuel consumption, emissions trade-offs, and compatibility with existing engine systems. With further research, ethanol-blended fuels could serve as a viable transition towards sustainable and cleaner transportation fuels.

Conclusion:

This study aims to examine the performance of engines using ethanol-gasoline blends. The results show that engine performance can be improved by using bioethanol-gasoline mixtures. Increasing the ethanol content slightly boosts the power of motorcycle engines as engine speed increases. The E20 blend showed a minor improvement in power output. More research is needed to explore the potential of ethanol-gasoline blends in motorcycle engines. Future studies could focus on developing Flexible Fuel Vehicles (FFVs) that can efficiently use these blends and help reduce dependence on fossil fuels. Adding hydrogen to the blends may further enhance engine performance and lower carbon emissions.

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Conflict of interest: The authors declare no conflict of interest regarding this publication.

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