Comparative Analysis of Gasoline and Biofuel Impacts on the Performance, Emissions, and Wear of Motorcycle Engines Over Long-term Operating Conditions

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ABSTRACT

In this study, experimental methods were employed to evaluate the impact of E10 fuel, a renewable fuel source, on the engine performance and wear of key engine components, such as pistons, cylinders, and piston rings. Two 100cc motorbike engines, running on RON 92 and E10 gasoline, were tested over a cycle equivalent to 20,000 km. The results indicated that for RON 92 engines, the average power loss was 5.48%, while for E10 engines, it was 6.08%. Fuel consumption increased, with RON 92 vehicles showing an average rise of 6.55%, compared to 7.27% for E10 biofuel motorbikes. In terms of emissions, vehicles running on RON 92 experienced a 3.83% increase in HC, a 4.17% in NOx, a 3.7% increase in CO_2, and a 3.17% rise in CO. For motorbikes using E10 biofuel, HC increased by 3.85%, NOx by 4%, CO_2 by 5.16%, and CO by 4.02%. The wear of critical engine components was 0.02% higher when using E10 compared to RON 92. Future research should focus on investigating different ethanol concentrations, fuel-injection engine types, or hybrid drive systems.

Keywords-biofuel; wear; emission; E10; motorcycle engines

I. INTRODUCTION

Renewable energy, especially bioenergy, is becoming an essential solution to mitigating environmental pollution and reducing fossil energy shortages [1]. Ethanol, as the major contributing alcohol related to these issues, plays a vital role [2]. For countries, such as United States, Brazil, and Europe, biofuel E10 has been widely used in boosting the economy through decreased petroleum consumption and ensuring sustainable development. In Vietnam, E10 usage is gradually becoming popular, especially in large cities.

Research on biofuels has become progressively popular. For example, authors in [3] utilized biodiesel derived from algae, and tested it in an engine cylinder as a mixture of diesel/n-pentane. Algae-based biodiesel is inherently superior to other types of biodiesel, but its direct blend with diesel can negatively affect engine performance. The addition of suitable additives significantly enhances combustion efficiency. Notably, while CO_2 and NO_x emissions slightly increase, pollutants, such as HC, CO, and O_2, are significantly reduced compared to pure biodiesel mixtures. Ethanol produced from wheat hydrolysate, as investigated in [4], is also highly regarded for its detailed insights into the effects of environmental factors on growth, tolerance, and ethanol properties. Blending 20% bioethanol with a diesel/biodiesel mixture improves engine efficiency to 33%, compared to 27% without bioethanol. In [5], a comparison of combustion and emissions in a three-component fueled SI engine was conducted using oxyhydrogen/ethanol/gasoline under different fuel injection modes. The results for ethanol were notably positive, demonstrated improved combustion states, better stratification, and reduced emissions compared to the gasoline direct injection. For the same ethanol fuel blend, different combustion modes yielded varying outcomes. Authors in [6] highlighted the importance of ethanol blending in fuels. As the ethanol content in the fuel increased, the Particle Number (PN) generally decreased. However, the results were less favorable when the engine operated under high load conditions. By adjusting the ethanol content, cylinder pressure and emissions became more predictable. Authors in [7] explored various fuel supply methods, including blending, dual-mode, and dedicated-mode approaches. The aim of their study was to assess the impact of alcohol fuels on combustion efficiency and emissions. Their findings emphasized that the specific properties of alcohol fuels require tailored operating setups to enhance and optimize their advantages. While many studies have focused on the effects of alcohol on the combustion process, authors in [8] used experimental methods, to evaluate the changes in performance and emissions (HC, CO, CO2, NO_x) when using different types and concentrations of alcohol blended with gasoline. A key highlight of this study is the comprehensive comparison of various alcohol types, that is, not only ethanol, but also methanol, propanol, and butanol, analyzed in detail. The findings provided a broad perspective on the suitability of different alcohol fuels for Spark Ignition (SI) engines, offering a visual overview of their effects on engine operation. Another significant contribution came from authors in [9], who examined the role of alcohol fuels in SI engines. The study underscored the importance of alcohol in enhancing engine performance and anti-knock characteristics through a dual-fuel strategy. Compared to regular gasoline, a 30% reduction in emissions was recorded. The emission patterns were strongly influenced by the fueling strategy and operating conditions. Moreover, due to the lower carbon content of alcohol fuels, CO_2 emissions were reduced by approximately 10%. Additional studies also investigated the broader impacts of alcohol fuels on engine power and emissions.

Biofuels also exhibit a notable impact on the durability and wear of engine components. In [10], the effects of ethanol fuel on lubricating oil and engine part wear were examined. The results revealed that the high oxygen content in ethanol fuel accelerated the oxidation process of lubricating oil, leading to a reduction in its viscosity. When comparing the effects of ethanol and gasoline on engine cylinder wear, it was found that ethanol fuel caused greater wear at the bottom dead center of the cylinder.

From the above studies, there is limited data available on motorcycles, making it difficult to fully evaluate the feasibility and practical benefits of E10 fuel. In Southeast Asian countries, especially Vietnam, motorcycles remain the primary mode of transportation. In 2024, 77 million registered motorcycles were recorded in Vietnam [11], highlighting their continuous dominance in daily transportation. Given this significant number, studying the effects of biofuels on motorcycle engines is crucial. To address these gaps, this study aims to enhance and expand the understanding of E10 fuel's impact on motorcycle engines. The key contribution of this research is the detailed evaluation of changes and differences between motorcycle engines using E10 gasoline and those using RON 92 gasoline by testing over a distance of 20,000 km.

II. METHODOLOGY

A. Experimental Method and Fuel

The experiment was conducted following a unified procedure for two vehicles of the same type, manufacturer, and size, using two types of fuel: E10 biofuel and RON 92 market gasoline. The test vehicles included two 100cc motorcycles, with the basic parameters presented in Table I. Before testing, the engines of both vehicles were overhauled: pistons, piston rings, filters, and spark plugs were replaced, carburetors were flushed, and other necessary maintenance was performed to ensure that both motorbikes were in the same initial conditions. Some of the main properties of these fuels are presented in Table II.

TABLE I. ENGINE SPECIFICATION

Engine	Gasoline engine
Engine type	4-stroke, single cylinder, 2 valves, air-cooled
Cylinder capacity	97.1 cc
Piston diameter and stroke	50 mm x 49.5 mm
Compression ratio	9:1
Maximum capacity	4.41 kW (7000 rpm)
Maximum torque	6.03 Nm (5000 rpm)

TABLE II. FUEL PROPERTIES

Properties	RON 92	E10
Density at 20 ^{0}C	0.73	0.74
Octane number (-)	92.4	94.4
Reid vapor pressure (kPa)	60.46	70.46
Low calorific value, Q_H (MJ/kg)	42.7	42.0
A/F ratio (kg/kg)	14.3	13.8

B. Testing Procedure

The testing procedure was carried out by two motorbikes operating on two different fuels: RON 92 gasoline and E10 biofuel. Each vehicle was run for a total distance of approximately 20,000 km. During the durability test, the engine lubricating oil was replaced every 50 hours of operation, equivalent to approximately 3,600 km of road use. All tests were performed using a CD20 test bench over a 2-hour period, in accordance with the European test cycle ECE-R40. The evaluation included two measurement modes:

- Static Mode: The vehicle was tested in both the 3rd and 4th gears with the throttle fully open. In the 3rd gear, the speed ranged from 20-40 km/h while in the 4th gear, it varied from 30-70 km/h.
- Dynamic Mode: This mode was conducted according to the ECE-R40 European standard test cycle, as displayed in Figures 1 and 2, to assess the fuel consumption and emission components.

The ECE-R40 test cycle included a total test duration of 1,210 sec, covering a total test distance of 6 km. Sampling was conducted over 430 sec and an effective driving distance of 4 km. The maximum speed was limited to 50 km/h.

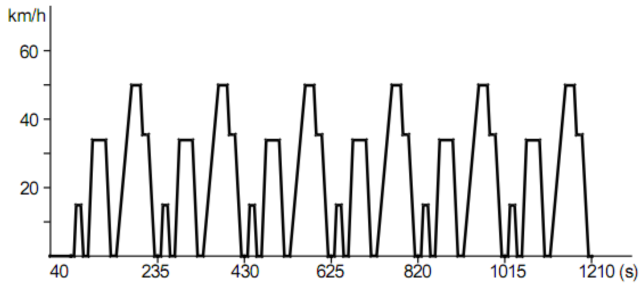

Fig. 1. The European Standard Test Cycle ECE-R40.

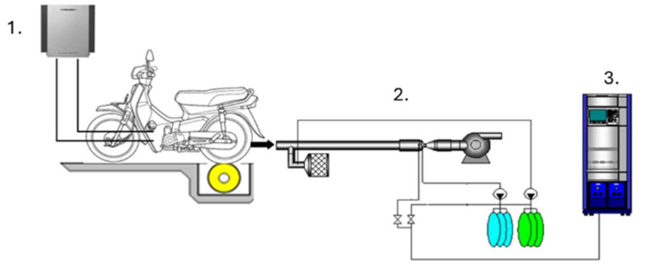

Fig. 2. The European Standard Test Cycle ECE-R40. 1. AVL 733S fuel comsumption measuring device, 2. CVS sampling system, 3. Emission analyzer.

III. RESULTS AND DISCUSSION

The power of two motorbikes running on RON 92 gasoline and E10 biofuel was evaluated Before Endurance Running (BRD) and After Endurance Running (ARD) (20,000 km distance). Figure 3 presents the power results of both vehicles at low and medium speeds (3^{rd} gear) under 100% load. After 20,000 km, both vehicles indicated a reduction in power from approximately 4-7%. The largest power reduction was observed in the E10 biofuel motorbike with a 6.70% decrease at a speed of 20 km/h. In the RON 92 gasoline motorbike, the greatest decrease was detected at a speed of 25 km/h (5.70%). This difference in power reduction can be attributed to their calorific values. Specifically, the E10 calorific value is approximately one-third lower than that of RON 92, directly affecting engine power. Additionally, the latent heat of vaporization of ethanol (361 Btu/lb) is significantly higher than that of gasoline (140 Btu/lb). As a result, under the same conditions, biofuel evaporation caused a greater temperature drop than gasoline, leading to a higher intake air density. Consequently, more air enters the engine, requiring more fuel when using E10.

As for fuel consumption, Figure 4 illustrates its changes in THE 3^{rd} gear before and after running 20,000 km. The findings demonstrated that the fuel consumption rate of both motorbikes increased after the endurance run. However, the rate of increase was higher in the E10 biofuel compared to RON 92 gasoline. The average increase in fuel consumption rate was 6.55% for the RON 92 powered vehicle, and 7.27% for the E10 biofuel type vehicle.

The degree of power loss can be further analyzed by assessing the tightness of the engine's combustion chamber both before and after the endurance run. This condition is indicated by the non-explosive compression pressure. Table III displays the measurement results for both motorbikes.

The compression pressure measured after the endurance run was lower for the engine running on E10 biofuel compared to the one using RON 92 gasoline. This suggests that the combustion chamber tightness in the E10 biofuel after 20,000 km was worse than in the RON 92 gasoline. However, the difference between these two values was minimal (1-2%), which explains why the decrease in power after the endurance run was higher for the E10 fuel vehicle.

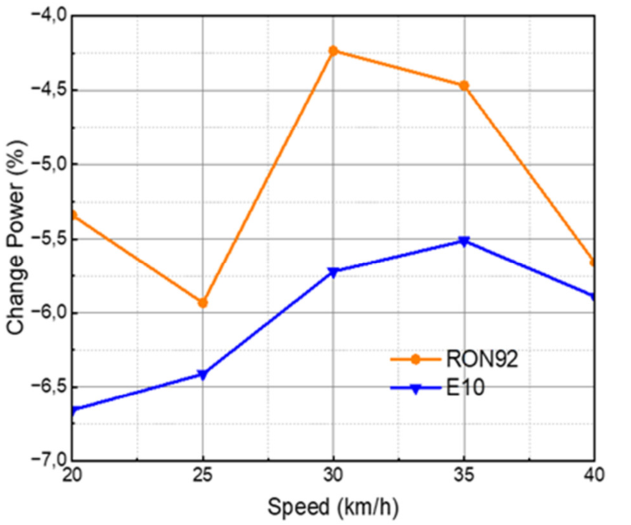

Fig. 3. Change in power after long-term use of RON 92 gasoline and E10 biofuel.

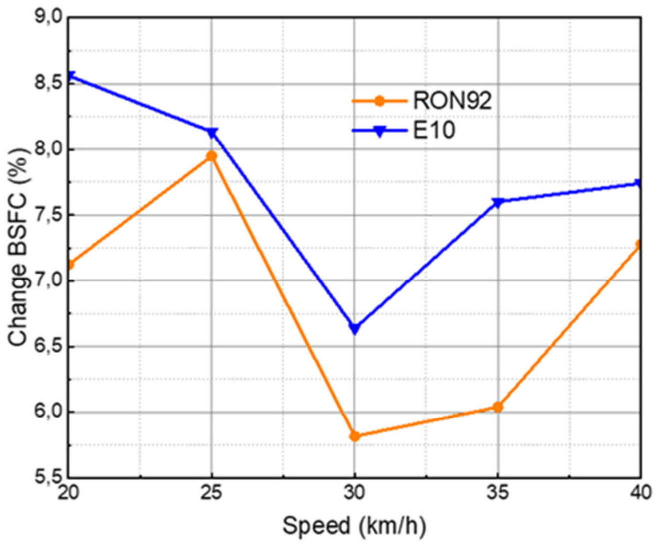

Fig. 4. Change in fuel consumption after long-term use of RON 92 gasoline and E10 biofuel.

TABLE III. COMPRESSION PRESSURE MEASURED BEFORE AND AFTER ENDURANCE RUNNING

Speed (km/h)	Compression pressure (bar)			
	Engine using E10		Engine using RON 92	
	BRD	ARD	BRD	ARD
5	11.5	11.3	11.5	11.4
10	11.8	11.6	11.8	11.7
15	12.3	12.1	12.3	12.2

The difference in percentages comparing the two vehicle types was minimal and this could be due to the increased wear between the piston, piston rings, and cylinder parts in the engine running on E10 fuel, which may have had a greater impact on the combustion process. Additionally, after a prolonged period of operation on E10 fuel, both vehicles exhibited increased fuel consumption, contributing to higher emissions. Specifically, the fuel consumption of the E10 biofuel vehicle increased from 2.51 l/100 km to 2.655 l/100 km, equivalent to a 5.78% rise. The change in emission levels observed before and after running on E10 biofuel aligns with the previously noted decrease in engine power and the increase in fuel consumption. Furthermore, using E10 biofuel resulted in higher CO_2 emissions compared to RON 92 gasoline, indicating that fuel consumption with E10 was also higher. This conclusion is consistent with the findings from the earlier analysis of fuel consumption using E10 biofuel.

The wear of key engine components before and after long-term operation for vehicles using RON 92 gasoline and E10 biofuel is illustrated in Figure 6. The results revealed the following changes: the horizontal diameter increased by 0.273 mm, and the vertical diameter by 0.260 mm. For the engine running on E10 biofuel, the cylinder diameter measurements demonstrated a rise of 0.280 mm in the horizontal direction and 0.283 mm in the vertical direction. These observations indicated that, after the 20,000 km durability test, the largest increase in cylinder diameter occurred in the vertical direction of the E10 biofuel engine, which is equivalent to a 0.561% increase compared to the pre-test size. In comparison, the largest increase for the RON 92 gasoline engine happened in the horizontal direction.

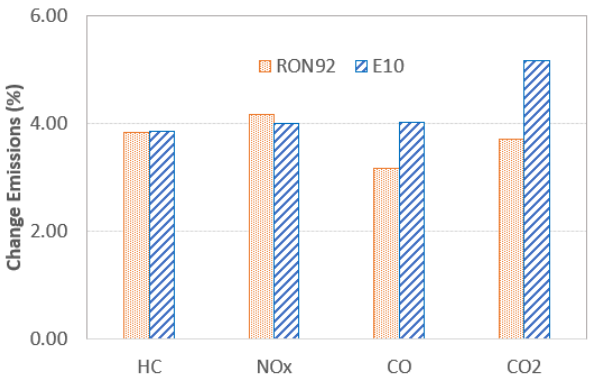

Fig. 5. Emissions before and after long-term operation of motorcycles.

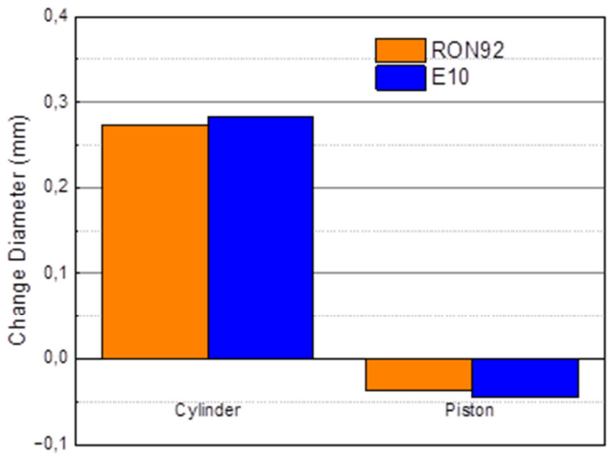

Fig. 6. Summary of changes in piston and cylinder dimensions before and after endurance testing.

The measurements of piston size before and after the endurance run for two vehicles running on E10 biofuel and RON92 gasoline exhibited minimal differences. The average piston diameter reduction for the RO N92 engine was 0.037 mm (equivalent to a 0.075% decrease compared to its pre-test size), while for the E10 engine, the reduction was 0.045 mm (equivalent to a 0.090% decrease). Piston ring wear was assessed based on the loss in mass of the piston rings. The test results indicated no changes in the size or weight of the piston rings after the endurance run. Both vehicles, running on E10 biofuel and RON 92 gasoline, exhibited identical results in this regard.

IV. CONCLUSION

This study provided one of the first comprehensive evaluations of E10 biofuel's long-term effects on small-displacement motorcycle engines. While prior research has largely focused on combustion performance and emissions of ethanol blends in modern automotive engines, this work uniquely investigated not only performance and emissions, but also mechanical wear over an extended distance of 20,000 km in real-world motorcycle operating conditions.

Compared to RON92 gasoline, E10 biofuel resulted in:

- A slightly higher average power loss (6.08% vs. 5.48%), attributed to its lower calorific value.
- A marginal increase in fuel consumption (7.27% vs. 6.55%).
- A minimal yet measurable increase in engine component wear (cylinder diameter wear difference of 0.02%, piston wear difference of 0.015%).
- A moderate rise in emissions, particularly CO and CO_2, consistent with the increased fuel consumption.

These findings demonstrate that although E10 exhibited slight improvements in performance and durability, the differences remain within acceptable operational thresholds, confirming its potential as an alternative fuel for widespread motorcycle use. Future research may extend this work by investigating different ethanol concentrations, fuel-injection engine types, or hybrid drive systems, to further explore the balance between performance, emissions, and durability in real-world biofuel applications.

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