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THE FUEL SYSTEM MODIFICATION TO STRENGTHEN ACHIEVEMENT AND THE PROSPECT OF UTILIZING GASOLINE ETHANOL BLENDED WITH WATER INJECTION

Wawan Purwanto[1]*, Tung-Kwan Liu[2], Hasan Maksum[3], Hendra Dani Saputra[4], Ahmad Arif[5], Muhammad Yasep Setiawan[6], M. Nasir[7]
Automotive Department, Universitas Negeri Padang, West Sumatera, Indonesia[1,3,4,5,6,7]
Mechanical Engineering and Technology Department, National Kaohsiung University of Science and Technology, Kaohsiung, Taiwan[2]
Wawan5527@ft.unp.ac.id

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**Corresponding Author*

ABSTRACT
The purpose of this research is a fuel system conversion from a carburetor to an electronic fuel injection (EFI), implementing renewable fuel varieties to save fossil fuels using gasoline-ethanol combined with water injection. Beneficial as an offer for Indonesian motorcycle environmental friendliness in terms of exhaust emissions. The goal of this study is to improve engine performance and accommodate technology for the deployment of ethanol gasoline implementations. In this study, the direct experimental method on the experimental vehicle was applied. The experiment was conducted using fuel with a ration octane number (RON) of 92, gasoline-ethanol was executed up to E25 then applied water injection (Wi). The results show that converting a conventional carburetor to EFI and additional water injection increases engine performance of 33.9%, mileage of 172%, and reduces exhaust emissions below the Indonesian government's emission standards.
Keywords : *Carburetor, Electronic Fuel Injection, Emission, Modification, Performance*.

1. Introduction

The population of motorized vehicles in Indonesia with carburetor technology reaches more than 1 million vehicles (BPS, 2023). The largest population is found in rural areas and plantations, with the main use as a vehicle for transporting goods. In addition, the creativity of the Indonesian people in modifying old vehicles into unique vehicles, subsequently becoming a lifestyle complement, and having high economic value when traded (Sidoarjo et al., 2021). Behind of the advantages, there are situations that are dangerous for the environment, where modified vehicles are generally old vehicles and still use conventional carburetor technology. The effect is an increase in pollution in urban areas of Indonesia (Pirmana et al., 2020). Furthermore, all vehicles with carburetor technology are highly dependent on fossil fuels. (Ismail et al., 2022) concluded that the implementation of large fossil fuels increases the effect of greenhouse gases and leads to global warming (Pirmana et al., 2020).

The quantity of air and fuel mixture, as well as the combustion process in the combustion chamber, influence the performance of an engine with spark ignition. The total of each air and fuel mixture is controlled by the throttle mechanism opening in carburetor equipment (Khoa, 2020). Thus, (Kunwer et al., 2022), (Ellyanie et al., 2023), and (Aydogan et al., 2017) determined that this approach uses conventional air and fuel combining, as fuel moves from the carburetor float chamber through the orifice and into the idle tube. Moreover, mix with inactive air bleed. Following that, the blend passes through the idle discharge holes and enters the intake manifold in bursts. When the throttle valve is opened, air will enter the intake manifold through the carburetor opening. The hole expels a mixture of air and fuel because of the intake manifold's vacuum. (Hoang et al., 2019) added in the carburetor flume, there is a narrow section defined as the Venturi. According to the principle of Bernouli's theory, the venture accelerates the flow and creates a difference in pressure, as well as a vacuum in the section, enabling the air and fuel fluxes to mix uniformly. All mechanisms of air and fuel blending in the carburetor are manual (Hoang, 2020b). Consequently, the lambda produced by the combustion system is not suitable for the engine's operating conditions, resulting in an increase in exhaust gas emissions (Sakai & Rothamer, 2022).

EFI on spark ignition engines allows mixing of air and fuel accurately and according to engine conditions (Kaya, 2022; B. Li et al., 2024). Fuel is sprayed into the intake manifold based on input from sensors processed by the ECU (Zhou et al., 2022). Previous studies applying carburetor technology to EFI such as (Purwanto et al., 2023) the results describe that changing carburetor technology to EFI effect increasing engine torque and power from the engine (Lin et al., 2024; Obhuo et al., 2023), confirmed that EFI technology can reduce emissions in motorized vehicles compared to carburetors. Behind all that, scrimp studies have been found that reveal the overall characteristics ranging from power, torque, emission, and specific fuel consumption (SFC).

Previous research has shown that adding ethanol to gasoline can enhance engine performance and lower pollutants (Kunwer et al., 2022; Mourad & Mahmoud, 2019). Furthermore, (Mohammed, 2021; Mohammed Shahinsha et al., 2023) experimented with varying the gasoline ethanol ratio from E5 to E15, and the findings revealed an increase in effective power and specific fuel usage (SFC). CO and HC emissions decreased, while NOx emissions increased. Adding to this research (Ismail et al., 2022; B. Li et al., 2024) by combining calculation methods and experimental investigation of ethanol blended on engine performance and exhaust emissions, the results indicate that there is no significant loss in performance between gasoline and gasoline blended, but CO and NOx decrease with a slight increase in HC, which relates to a reduced cylinder temperature. As part of their ongoing attempts to minimize emissions, HC, and (A. Li et al., 2020; Woo & Lee, 2023) did more research by injecting water into gasoline ethanol blends. (Zhao et al., 2023) explains that when E15 is used, there is a little drop in power, SFC, and effective efficiency. Water injection with a 20% mist can boost engine torque while decreasing SFC. While E15 had the greatest drop in HC at various degrees of water injection. Overall, (Mohammed Shahinsha et al., 2023) decided that the E15 had the best water injection in terms of engine performance and exhaust pollutants. Under various conditions, (Hoang, 2020a; Suresh & Porpatham, 2023) found that the best water injection was in the E10 mixture, both in terms of engine performance and CO, NOx, and HC.

This research focuses on converting a standard fuel system to an EFI system to acquire comprehensive features of the use of gasoline ethanol blended, then application of water injection on small-scale engine. Through this modification, we can effectively define and control the research process. The description of the results of this study has an essential contribution to, firstly for motorcycle modifiers in Indonesia, where in addition to modifying the body, it is also better to modify the fuel system. Use it as an effort to reduce air pollution. Second, referring to research (Iodice et al., 2018; Verma et al., 2022) that gasoline-ethanol possible to reduce exhaust emissions and improve engine performance (Setiyo, 2021; Setiyo et al., 2018), the potential application of gasoline ethanol more than E25 requires special engine modifications also for implementing water injection to lessen reliance on fossil fuels. So, the results of this study also contribute to being an alternative in special engine modifications in the application of gasoline ethanol with water injection on gasoline ethanol blended E25.

2. Combustion modeling in single cylinder spark ignition engine

The burning process in engines powered by spark ignition is preceded by a flick of sparks from the spark plug. At the start of combustion, the flame is a finely formed spark with a size of about 1 mm and a reasonably circular shape in the next step degree. During this time, it is additionally referred to as beginning combustion. The interaction of the flame and the turbulent flow form of the air and fuel masses produces an extremely intense flame after the next degree (Ismail et al., 2022; B. Li et al., 2024). The combustion velocity is equal to the turbulence velocity of the flame during this interval. This is known as the advanced combustion phase. During the compression process, the combustion chamber contains an arrangement of air, fuel vapor, and combustion gases. If the entire mass of the system is assumed to be constant during the compression process. As a result, the following equations can identify the First Law of Thermodynamics and ideal gas, combustion time, pressure, and temperature in the compression technique, as shown in (1) – (3).

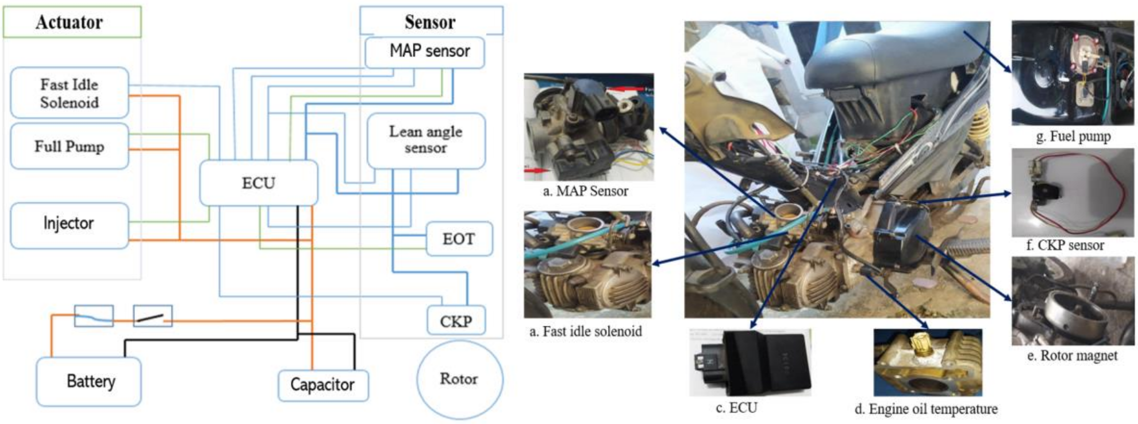
$$\dot{T}_u = \left(\frac{B}{A}\right)_u \left[-\frac{\dot{V}}{V} + \frac{-\dot{Q}_{wu}}{(Bm)_u}\right] \quad (1)$$

$$\dot{p}_u = 10^{-5}\left(\frac{\rho}{\frac{\vartheta p}{\vartheta p}}\right)_u \left[-\frac{\dot{V}}{V} + \frac{1}{\rho_u}\left(\frac{\vartheta p}{\vartheta T}\right)_u \dot{T}_u\right] \quad (2)$$

Where:

$$A_u = \frac{1}{\rho_u}\frac{\left(\frac{\vartheta p}{\vartheta T}\right)_u}{\left(\frac{\vartheta p}{\vartheta p}\right)_u} + c_{pu}\,, B_u = \frac{1}{\left(\frac{\vartheta p}{\vartheta p}\right)_u} \quad (3)$$

Where u is the unburned gas, $\dot{T}_u$ is the temperature and $\dot{P}_u$ is the pressure in combustion process, V is the instantaneous cylinder volume, $\dot{Q}$ is the heat transfer to the wall, ρ is the density and C_p is the specific value at a constant pressure cylinder. Two distinct zones should be considered throughout the combustion process. There are only fully burned gaseous products of combustion (i.e., CO_2, H_2O, etc.) in the unburned portion of the fuel-air combination and the region where combustion has happened. To accurately represent combustion, two distinct sets of equations must be established. We continue to apply equations (1) - (3) in the analysis procedure. The terms Au and Bu allude to "unburned" and "burned" regions, respectively. Obviously, the combustion process begins with the burned quantity all set to zero and concludes with no unburned quantity remaining. It is additionally essential to note that combustion never happens instantly, but rather between tiny intervals of crankshaft angular rotation (a few degrees before and after TDC). This interval is normally between 300 and 400 before TDC in spark plug engines.



a) Schematic of ECU Controller and sensor b) Sensor layout in measured engine

Fig. 1. EFI schematic

Tabel 1 - Specification of Gasoline and Ethanol

Properties	Gasoline	Ethanol
Research octane number (RON)	Various	106 – 115
Chemical formulation	C_8H_{18}	C_5H_5OH
Purity (%)	n/a	99.5
Density (200C) [kg/m3]	3.88	2.06
Viscosity (200C) [cSt]	0.64	1.52
Oxygen content	0	34.73
Surface tension (mN/m)	21.58	22.66
Laten heat of vaporization [kJ/kg]	289	854
Stoichiometric (Air to fuel ratio) [kg/kg]	14.7	9.0

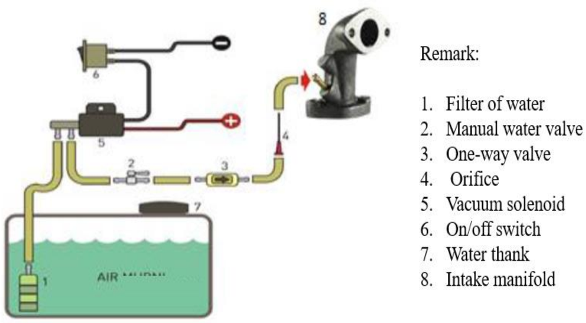
3. Material and method

The concept of Modifying of conventional to EFI fuel system and water injection (Wi)

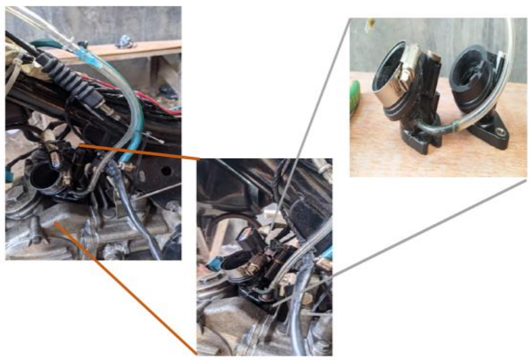
Fig 1 (a) depicts the updated system's architecture, whereas Fig 1 (b) depicts the sensor and component configuration on the prototype engine. The performance of the system employing a programmable ECU prototype in the implementation of this study. Where the ECU will receive input from the mass air flow sensor (MAP), lean angle sensor, engine oil temperature, crankshaft sensor (CKP). From these parameters, the ECU will get the settings for the injector, fuel pump, and fast idle solenoid, according to engine performance. Crankshaft rotation, engine temperature, amount of air, are censored and used as input to balance the amount of fuel that will be sprayed into the intake manifold.

This investigation was carried out on a single cylinder, single overhead camshaft, cylinder volume of 113.7 cc, diameter, and piston stroke dimensions of 50 x 57.9 mm, and 9.3:1 is the compression ratio. The maximum power output is 6 KW at 7500 rpm, while the maximum torque output is 8.3 Nm at 4500 rpm. Table 1 shows the parameters of the fuel utilized. While the water used is pure water from nature with schema as shown in Fig 2(a). The arrangement of the *Wi* in the engine measurement as shown in Fig 2(b). Fuel consumption is determined in the automotive engineering department lab using a fuel consumption test. This equipment includes a tiny controller that connects to the injector and ECU socket to compute how much fuel is poured into the intake manifold. Furthermore, the tiny controller will display fuel usage on a monitor based on the input voltage of injector spray frequency and rotation on the ECU. As a result, the fuel consumption at each speed may be measured precisely. In the automotive engineering department's testing laboratories, the electric dynojet250i for torque and power testing, four gas analyzer HG-520, and thermocouple set flux 51-li are available for engine measurement.

Fig. 2 depicts the design of the process of spraying water into the intake manifold in this investigation. The switch directs the power from the positive terminal of the battery to the injector, which activates the vacuum solenoid, which draws water into the water valve, one-way filter, and aperture, and finally into the intake manifold. The water injection mechanism is designed to ensure that neither water nor fuel is injected when the injector sprays fuel; however, when the injector refuses to spray fuel, water is sprayed into the intake manifold. This strategy is based on (Purwanto et al., 2023), who clarify that the effect of water injection is air cooling; the objective is to maintain the air density entering the combustion chamber in order to facilitate the adequate quantity of fuel and air combination entering the combustion area. Fig. 3 shows a comparison of the volume of water with the signal duration of spraying fuel into the combustion chamber. In this study, the injected water of 1.25 to 1.45 ml gasoline blasted by the injector in 60 second. The amount of water injected is determined by a vacuum solenoid connected to the positive terminals of the battery and injector.



a. water injection schematic



b. *Wi* in intake manifold engine measurement

Fig. 2. Water Injection in The Engine Measurement

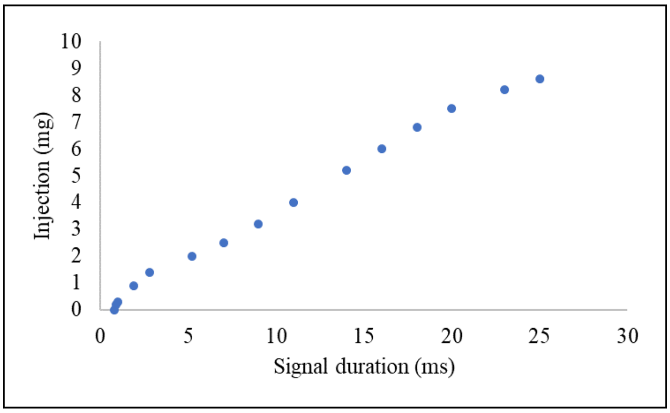


Fig. 3. Water Injector (Wi) Quantities Based on Signal Fuel Injection Duration.

3.2 Experimental methodology

To get the characteristics of the vehicle described by (Örs et al., 2023). In addition to having the best power, torque, it is also followed by a decrease in fuel consumption and exhaust emissions. For this reason, this research focuses on power, torque, emissions, and fuel consumption. To achieve a high level of accuracy, data was collected three times repetition, then an evaluation of the average value. This value will be utilized as the experimental result for the subsequent analysis process. The procedure of measuring exhaust emissions in this study is governed by the Minister of the Environment of the Republic of Indonesia's Regulation No. 20 of 2017, with standard information as shown in Table 2. Moreover, engine performance is governed by Republic of Indonesia Transportation Ministerial Regulation no. 30 of 2020. The measurement was carried out at the automotive engineering department's vehicle testing workshop, as shown in Fig 4.

Table 2 - M1 Category of Vehicle Exhaust Standard.

Category	Parameter	Standard (g/km)	Test Method
M1. GVW 1 ≤ 2.5 ton	CO	1,0	ECE R 83 – 05
	HC	O,1	ECE R 83 – 05
	NOx	0,08	ECE R 83 – 0

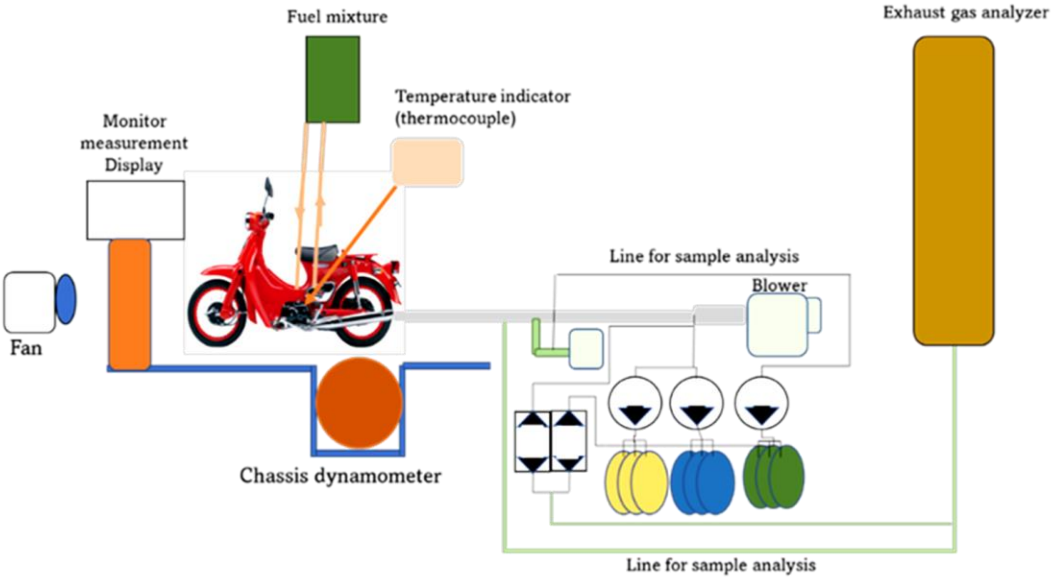
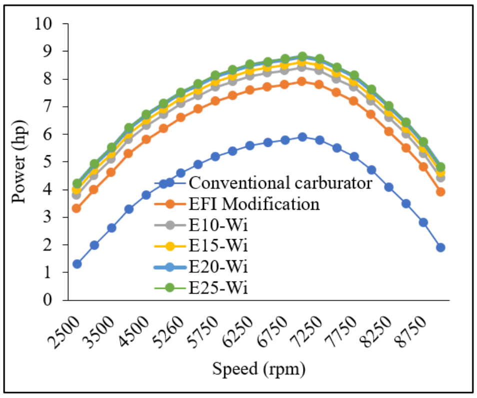
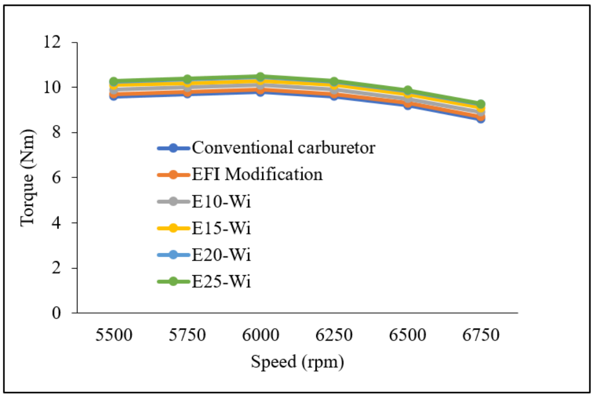


Fig. 4. Schematic of engine performance Measurement



(a) Power vs speed characteristics



(b) Torque vs Speed characteristics

Fig. 5. Power And Torque Characteristics Of The Engine Measured.

4. Experimental results and discussions

Performance improvement ethanol gasoline without water injection

The ability generated by the internal combustion engine to reach the vehicle's top speed is called power. When the vehicle is traveling at high speed to produce maximum rotation, power is needed. While torque is the ability of the vehicle starting from the vehicle moving to speeding. For the initial conditions, a moving vehicle requires torque, while to reach the maximum speed of the vehicle, power is needed (Badawy et al., 2024; Cabir & Yakın, 2024). If the terrain traversed by the vehicle has a lot of inclines, then torque is needed, on the contrary for vehicles that pass through a flat track, power is needed to ensure the speed of the vehicle. Based on the measurement carried out the power characteristics as shown in Fig. 5(a) and torque characteristics as shown in Fig. 5(b) of the vehicle.

Table 3 - Torque and Power Characteristics Base on Speed References

Power (hp)						
Speed (rpm)	Conventional carburetor	Modification EFI	E10-Wi	E15-Wi	E20-Wi	E25-Wi
7000	5.9	7.9	8.1	8.3	8.45	8.88
Remark		Increase 33.9%	Increase 37.29%	Increase 40.68%	Increase 43.22%	Increase 43.73%
Torque (Nm)						
6000	9.8	10.1	10.3	10.5	10.65	10.68
Remark		Increase 3.06%	Increase 5.1%	Increase 7.14%	Increase 8.67%	Increase 8.9%

In terms of power as shown in Fig. 5 (a) and (b), Table 3 shows the EFI modification has increased by 33.9% from the conventional system. However, this modification of the system will increase by 43.73% after applying gasoline-ethanol E25-Wi. The increase is due to the injection mechanism controlled by the ECU. According to (Farooq & Vinay Kumar, 2023; Kumar, 2020; Kumara & Singh, 2023) that method ensures the amount of air and fuel, the form of mist, and the air-fuel mixture in the stoichiometric intake manifold, according to the engine speed and load. while the increase after the application of E10-Wi until E25-Wi was further increased due to the oxygen content. In addition, it has a positive impact on the combustion process, bringing to the precision of combustion (Inbanaathan et al., 2023). In accordance with (Hasan et al., 2018; Shetty & Shrinivasa Rao, 2022) reported that with the same mass of atomized fuel and a higher RON at E10 to E25, the fuel efficiency is enhanced. In the meantime, the latent heat of vaporization of ethanol is greater than that of fossil fuels, resulting in a lower intake manifold temperature and greater volumetric efficiency than fossil fuels. As a result, the combustion process is complete, resulting in an increase in horsepower and torque. While torque increases, the increase is not as significant as power. At the time the EFI modification was implemented, there was only a 3.06% increase. This is due to the combustion process in the same cylinder volume does not increasing significantly (Cesur & Uysal, 2024; Y. Li et al., 2024). The results are in line with research that has been conducted by (Amaral et al., 2021; Kaya, 2022). These results illustrate that when this engine goes through an up and down trajectory, its capabilities liven up by 3.06% and gain torque 8.97% when applying E25.

Fuel Consuption

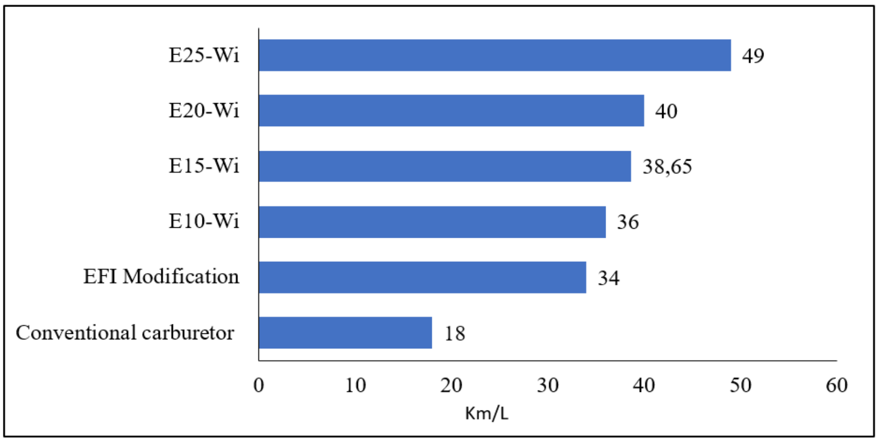


Fig. 6. Fuel consumption

E25-Wi has a higher RON and latent heat than pure gasoline, resulting in a lower intake manifold temperature and greater volumetric efficiency than fossil fuels. As a result, the combustion process is more complete, resulting in increased power and torque (Elshenawy et al., 2023; Nanlohy et al., 2022). RON and latent heat, on the other hand, optimize the air-fuel mixture in the intake manifold for the combustion process (Asnawi et al., 2022; Dhande, 2021). These results are indicated by the same amount of fuel can increase the distance traveled by the vehicle as shown in Fig 6. By applying modifications to the EFI system, an increase of 88.8% is obtained. and continues to increase along with the application of gasoline ethanol by 172% in the application of E25-Wi. Thus, increasing the mixture of fuel and air and RON in ethanol will automatically improve the quality of combustion and increase efficiency in the use of fuel, this is in accordance with the opinion (Kirkpatrick, 2020).

Engine Emission

Table 4 - Engine Exhaust Emissions

Parameter	Conventional carburettor	EFI Modification	E10-Wi	E15-Wi	E20-Wi	E25-Wi	Indonesian Government Regulation
CO (g/km)	2,3	1,91	1,871	1,811	1,512	1,192	1
HC (g/km)	0,25	0,198	0,183	0,181	0,162	0,142	0,1
NOx (g/km)	0,27	0,192	0,159	0,156	0,132	0,112	0,08

If the carbon element in the fuel burns completely, it produces CO2. Meanwhile, if it does not burn completely, it will increase the CO element (S. H. Li et al., 2022; Puglia et al., 2023). Moreover, the element of CO is significantly affected by the ratio of fuel and air in the combustion chamber. Table 4 shows the characteristics of the test machine on bung gas emissions. It is known that the exhaust gas emission results from conventional carburetor modifications to EFI obtained a decrease of 16.96% CO levels or from 2.3 to 1.91 g/km. This means the combustion process can occur better. The process of fogging fuel into the intake manifold mixes perfectly with air and then enters the combustion chamber, as described (Tamam et al., 2021; Verma et al., 2022).

If the fogging and mixing of fuel with air does not occur properly, as a result all elements of the fuel cannot be burned properly. This causes an increase in the emission of hydrocarbon (HC) and NOx elements (Elfasakhany, 2015; Puglia et al., 2023). With the modification by using the EFI system there is a decrease in exhaust emissions in HC and NOx. Where the HC emissions decreased by 20.8% and NOx emissions 28.9%. The change in emissions is further reduced by applying the gasoline ethanol fuel system. Where the application of E25-Wi will reduce CO emissions by 48.17%, HC of 43.2%, and NOx by 58.52%. These results are in line with the results of previous studies conducted by (Asnawi et al., 2022; Sidoarjo et al., 2021). Where the reduction in exhaust emissions is not only due to fuel spray on the injectors according to engine needs, but also to RON and latent heat contained in ethanol fuel.

The decrease in exhaust emissions that has been accomplished, as shown in Table 4, is still not meeting the standard established by the Indonesian government, as shown in Table 2. Consequently, innovation is required, particularly in the field of combustion components. (Dhande et al., 2021; Kirkpatrick, 2020; Pirmana et al., 2020) explain that the combustion process in a spark ignition engine is affected by the quality of the flame ignited in the combustion chamber, the ignition and injector timing, and the homogeneity of the air and fuel mixture. Therefore, the recommendations for future research must center on flames, injection, and ignition timing in order to meet Indonesian government regulations for exhaust emissions. In the study, it was not possible to apply the amount of ethanol higher than E25. In experimental measurement was found that the larger the mixture, the faster the separation process between gasoline and ethanol in the tank. As a result, starting the engine, the engine feels very difficult to start.

4. Conclusion

This study provides an overview for motorcycle modifiers in Indonesia who still apply conventional carburetor technology to EFI technology. in this study it can be concluded that EFI technology is able to increase engine power by 33.9% and when applying E25-Wi by 43.73%. In addition to power, torque also increased by 3.06% and 8.97% after applying the E25-Wi. Meanwhile, the mileage that can be produced with the EFI modification increases by 88.89% and increases by 172% if ethanol gasoline is applied. Increased power, torque, and mileage, followed by a decrease in exhaust emissions of the engine. Where the resulting emissions tend to decrease and continue to decline along with the application of gasoline ethanol. This study provides an overview of the modification of the EFI system and the resulting performance. The results are expected to be a consideration for vehicle modifiers in Indonesia, in addition to prioritizing aesthetics, they are also concerned with reducing environmental pollution caused by spark ignition engine emissions. Through the results of this study, further and in-depth studies are needed, especially on the effect of ignition, injection timing, air regulation, and how to keep the air and fuel mixture in the tank well mixed.

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