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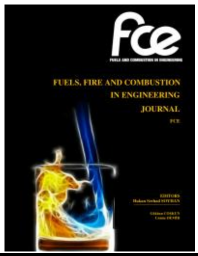

Benzin-metanol (M5-M10) karışımlarının SI motorundaki performans üzerine deneysel bir araştırması

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ÖZ

Alkoller, araçlarda metanol kullanımına artan bir ilgi gösteren, fosil yakıtlara alternatif temel bir kategoridir. Metanol, sıvı olması, benzine benzer çeşitli fiziksel yanma özelliklerine sahip olması ve daha yüksek oktan sayısına sahip olması nedeniyle fosil olmayan yakıt olarak iyi bir aday olmuştur. Metanol ile karıştırılmış benzin, buji ateşlemeli (SI) motordaki motor ayar parametrelerini etkileyerek yakıtın oktan sayısını artırır. Bu makale, 150cc dört zamanlı buji ateşlemeli bir motorda benzin karışımlarında (M5 ve M10) %5-h/h ve %10-h/v metanol kullanılarak ateşleme zamanlamasının ve enjeksiyon süresi ayarının rolü üzerine bir performans araştırması bildirmektedir. Motor Kontrol Modülü (ECM) ile donatılmış. Burada motor performans parametreleri, yani tork, güç ve özgül yakıt tüketimi analiz edilirken, bu çalışmada ölçülen emisyon kalitesi parametreleri karbondioksit, karbon monoksit ve yanmamış hidrokarbonlardır. Sonuçlara göre, 24 ^{0}bTDC ateşleme zamanlamasında ve M5 ve M10 karışımlarının kullanılmasında bir gelişme gösteren + %10 enjeksiyon süresinde optimize edilmiş ayarlı motor, standarttan %2,94 artan motor torku, %1,72 güç ve %7,29 oranında azalan özgül yakıt tüketimi üretir. aynı yakıt karışımını kullanarak motoru ayarlamak.

Anahtar Kelimeler: benzin, ateşleme zamanlaması, enjeksiyon süresi, metanol karışımları, kıvılcım ateşlemeli motor

An experimental investigation of gasoline-methanol (M5-M10) blends on performance in SI engine

ABSTRACT

Alcohols are an essential alternative to fossil fuels, showing a progressive interest in using methanol in vehicles. Methanol has been a good candidate as non-fossil fuel because it is liquid, has several physical-combustion properties similar to gasoline, and has a higher octane number. Gasoline blended with methanol increases the octane number of fuel, influencing engine setting parameters in the spark-ignition (SI) engine. This paper reports a performance investigation on the role of ignition timing and injection duration setting using 5 %-v/v and 10 %-v/v of methanol in gasoline blends (M5 and M10) on a 150cc four-stroke spark-ignition engine fitted with an Engine Control Module (ECM). Here, engine performance parameters were analyzed, i.e., torque, power, and specific fuel consumption, while emission-quality parameters measured in this study are carbon dioxide, carbon monoxide, and unburnt hydrocarbons. Based on the results, optimized-setting engine at 24 ^{0}bTDC ignition timing and + 10% injection duration showing an improvement of using M5 and M10 blends produce an increasing 2.94% engine torque, 1.72% power and decreasing 7.29% specific fuel consumption than standard-setting engine using the same fuel blend.

Keywords: gasoline, ignition timing, injection duration, methanol blends, spark-ignition engine.

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1. INTRODUCTION

An alternative and renewable energy that are more environmentally friendly have been made to reduce fossil fuels and improve environmental air quality. One type of alternative fuel that can be developed for an internal combustion engine is methanol. Methanol is the simplest form of alcohol, having the chemical formula CH3OH. Methanol in the atmosphere is a light, volatile, colourless, flammable liquid. Methanol can be used as a substitute or fuel mixture [1]–[3]. Methanol has high blending octane values (BOV), which are nominal 129-134 for research octane number (RON) and 97-104 for motor octane number (MON). Methanol-gasoline blends effectively increase the octane number of the fuel and improve the fuel's anti-knock properties. Methanol has a higher fire speed, higher latent heat of evaporation, and complete combustion. At low mixed concentrations, the use of a mixture of gasoline and methanol does not require modification to the engine [4]–[6]. Furthermore, it can improve the quality of gasoline, reduce emissions and increase engine efficiency.

Methanol itself has not been used in Indonesia as a fuel substitute or mixture. The use of methanol for the fuel mixture will slowly reduce the consumption of fossil fuels in Indonesia. As already mentioned, one of the uses of methanol is a mixture or substitute for the vehicle’s fuel blend [7]–[9]. Another research showed that maximum torque and power were obtained with M85 (gasoline 15% + methanol 85%) and flex-fuel kit installed, 5.13% higher than its standard fuel. Fuel consumption on a km/l basis was higher with M85 due to the lower calorific value of the fuel blends. The noise of the engine was also noticeably smoother with M85 fuel. The use of M85 resulted in a lower amount of carbon monoxide and a higher amount of nitrogen oxides [10], [11].

Although the utilization of methanol in low concentrations in vehicles does not require engine modification, an optimization of engine performance is still needed to minimize the effect of higher RON and lower heating values [12]. It was clear that the different characteristics between gasoline and methanol, such as the heating value and the octane number influencing it. One thing that can improve engine efficiency is to change the ignition timing and injection rate settings on the engine [13]. Tunka and Polcar [14] studied the effect of various ignition timings on gasoline engine combustion and performances. The experiment was carried on a four-cylinder Audi engine, with test conditions such as wide-open throttle, constant engine speed of 2500 rpm, and stoichiometric mixture fraction. The experiment found that an increase in ignition timing resulted in a rise in engine power and torque, reflecting higher pressure in the cylinder. Sukarno et al. [15] conducted a study about ignition timing changes on the engine performance of automatic motorcycles. Five ignition timing variations were tested. The study determined that optimum ignition timing produced a 12,5% increase in torque, 13,9% increase in power and a 28,95% decrease in fuel consumption than standard ignition timing. Gong et al. [11] studied the influence of ignition timing on combustion and spark ignition methanol engine emissions with added hydrogen. The results indicated that advanced ignition timing increased maximum cylinder pressure and decreased carbon monoxide and unburnt hydrocarbon. Wu et al. [16] studied the effect of injection and ignition timings on performance and emissions from methanol-fueled spark-ignition engines. The research findings were that optimum ignition timing produced the highest indicated thermal efficiency, the shortest ignition delay, and the most negligible coefficient of variation. However, this study showed increased ignition timing increased total hydrocarbon, carbon monoxide, and nitrogen oxides [7], [17]. Wibowo et al. [18], [19] researched optimization of gasoline-ethanol blend fuels in various engine settings. Fuel used was three kinds of gasoline with RON 88, 92, and 98 blended with 40% fuel-grade ethanol. The study concluded that the engine performance could be optimized by advancing the ignition timing and reducing the injection duration. Higher octane in the fuel also leads to a higher increase in torque and power [20]. Therefore, it is necessary to study ignition timing and injection duration settings influenced by low methanol concentrations of 5% and 10% (M5 and M10) on gasoline blend in engine performance.

It was clear that methanol has such great potential as gasoline blends and alternative fuels. Considering the oxygenate content and RON, the impression of performance engine affect methanol as gasoline-methanol (GE) blends is interested in exploring. This study presents the identification of the optimal ignition timing and injection duration settings for the performance of gasoline engines using a mixture of 5% methanol on gasoline (M5) and 10% methanol on gasoline (M10). Here, the engine performance, i.e., torque, power, and specific fuel consumption, was investigated with ignition timing and injection duration optimization on 150 cc four-stroke SI engine.

2. EXPERIMENTAL SETUP

In general, the experimental setup consists of a 150cc four-stroke SI engine fitted with an Engine Control Module (ECM). The design for this experiment is shown in Figure 1. The specification of the test engine is shown in Table 1. The test was carried out on an engine dynamometer to measure performance parameters and an emission analyzer to measure emission qualities. This study used gasoline with RON 90 (sold as Pertalite in Indonesia) and fuel-grade methanol with 99.6% purity. Those two fuels are mixed into two blends (%-volume), which were M5 (95% gasoline + 5% methanol), and M10 (90% gasoline + 10% methanol). The properties of methanol are shown in Table 2, and the properties of gasoline methanol blends are shown in Table 3. The engine performance parameters are carried out, i.e., torque, power, and specific fuel consumption, while emission-quality parameters measured in this study are carbon dioxide, carbon monoxide, and unburnt hydrocarbon.

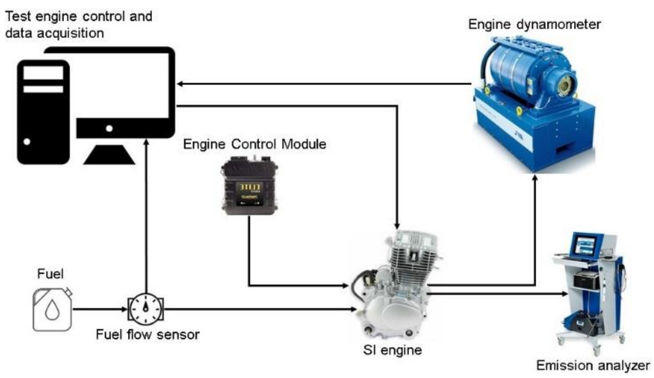

Figure 1. Experiment setup

Table 1. Engine specification

Engine type	Four-strokes, DOHC liquid-cooled
Cylinder number	Single
Bore	57,3 mm
Stroke	57,8 mm
Engine displacement	149,4 cc
Compression ratio	11,3 : 1
Fuel system	Fuel-injection
Transmission	Manual
Ignition system	Pedal and electric
Oil capacity	1,0 liter on the periodic change
Fuel	Unleaded gasoline
Ignition type	Full transistorized, battery
Spark plug	NGK MR9C-9N atau ND U27EPR-N9
Spark plug gap	0,6 - 0,7 mm
Maximum power	16,8 Hp / 9000 rpm
Maximum torque	13,7 Nm / 7000 rpm

Table 2. Fuel properties of methanol

Characteristics	**Value**	**Methods**
Density (kg/m^3)	794	ASTM D 1298
Boiling point (ºC)	65	ASTM D 86
Research octane number	106-115	ASTM D 2699
High heating value (MJ/kg)	22.9	ASTM D 240
Low heating value (MJ/kg)	20.1	ASTM D 240
Molecular weight (kg/kmol)	32.04	-

Table 3. Fuel properties of pure gasoline and blends

Characteristics	**Pristine Gasoline M0**	**M5**	**M10**	**Methods**
Density at 15 ºC (kg/m^3)	736.6	738.72	740.53	ASTM D 1298
Reid vapour pressure (kPa)	51.4	70.3	74.25	ASTM D 5191
Distillation 10% (ºC)	57.1	46.5	46.9	ASTM D 86
Distillation 50% (ºC)	96.9	93.5	89	ASTM D 86
Distillation 90% (ºC)	170.4	166.1	169.7	ASTM D 86
Research Octane Number	90.1	92.3	94.5	ASTM D 2699

3. RESULTS AND DISCUSSION

3.1. Torque

Figure 2 shows the results of the torque test at four engine speed points. The test changes the ignition timing from the standard condition, namely 20 ⁰bTDC, to earlier (2 increments). This time the test was performed with the most advanced ignition timing at 28 ⁰bTDC. The ignition timing is adjusted to obtain the maximum brake torque on the ignition timing point for fuel use [21], [22]. In this experiment, in addition to the standard engine settings, the ignition timing settings were carried out with the exact change in injection duration, which was standard, + 10%, and -10%. The injection duration setting that produces the maximum torque is + 10%, so the ground is selected.

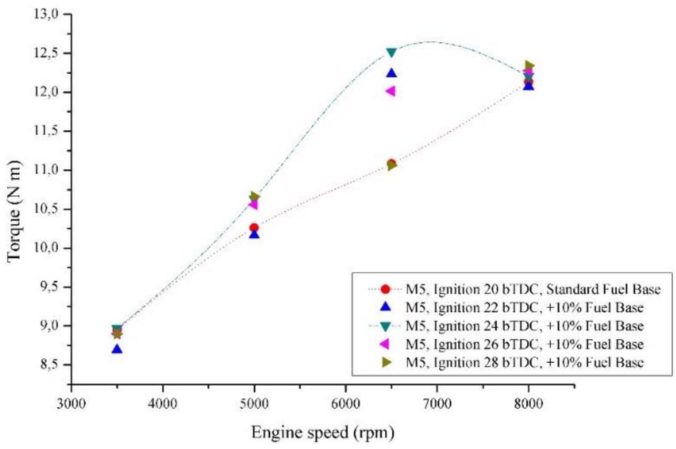

Figure 2. Torque at various ignition timings using M5 fuel

Based on the graph, the torque increases with increasing engine speed until it reaches the highest value at 6500 rpm, then the torque decreases again at the 8000 rpm point. According to engine specifications, it was indicated that the maximum torque is achieved at 7000 rpm engine speed. The first test was carried out using M5 fuel. The result showed M5 fuel with standard engine settings produces a maximum torque of 12.13 Nm at 8000 rpm. The ignition timing setting that produces the maximum torque is 24 ⁰bTDC. The ignition timing setting produces a maximum torque of 12.523 Nm at 6500 rpm, increasing 3.21% over the M5 fuel use with the standard engine setting. The increase in torque occurs because the MBT ignition timing for M5 fuel occurs at an ignition timing that is more advanced than the standard-setting.

Another variable in this study is the injection duration setting with the same injection amount for each fuel sample and engine setting. This setting is done through the engine control module, which then adjusts the duration of the injector opening expressed in units of time (ms). This study used two injection duration settings, namely + 10% and + 15%, compared to the standard injection duration setting that produces maximum torque. Figure 3 shows that it is found that the maximum torque is still obtained at injection duration + 10%. The injection duration setting + 15% produces a maximum torque of 1.173% lower than the 10% injection duration setting. It shows that the injection duration setting affects the AFR during combustion. AFR that produces maximum torque is obtained at setting injection duration + 10%.

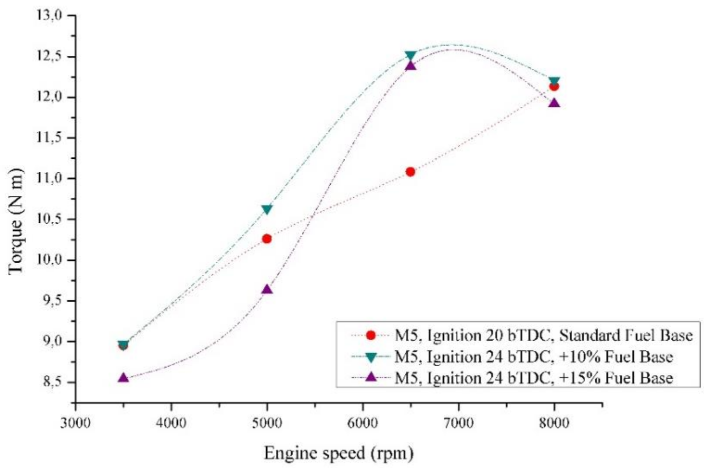

Figure 3. Torque at various injection duration using M5 fuel

Figure 4 illustrates the results of the torque measurement in an experiment using M10 fuel. Torque readings are done at engine speed of 3500, 5000, 6500, and 8000 rpm with wide-open throttle conditions. In this part of the experiment, it is done by varying the ignition timing settings. The injection duration settings this time are all set to + 10%. This is because in the standard ignition timing and injection duration settings, the engine does not produce enough torque at high engine speed so that the experiment cannot be carried out until it is finished. The ignition timing settings used are standard, + 2⁰ bTDC, and + 4⁰ bTDC.

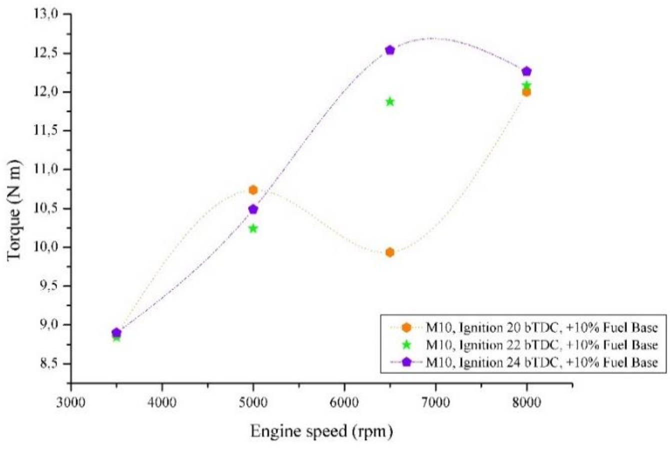

Figure 4. Torque at various ignition timings using M10 fuel

Based on the experimental results, the torque has increased along with the increase in engine rotation speed until it reaches the maximum torque at 6500 rpm, then the torque decreases at 8000 rpm. The ignition timing setting that produces maximum torque is 24^o bTDC or 4^o ahead of standard ignition timing. This arrangement increases torque from 12.002 N m at the standard-setting to 12.538 Nm or 4.462%. This increase shows that the MBT ignition timing in this experiment is 24 ^{o}bTDC.

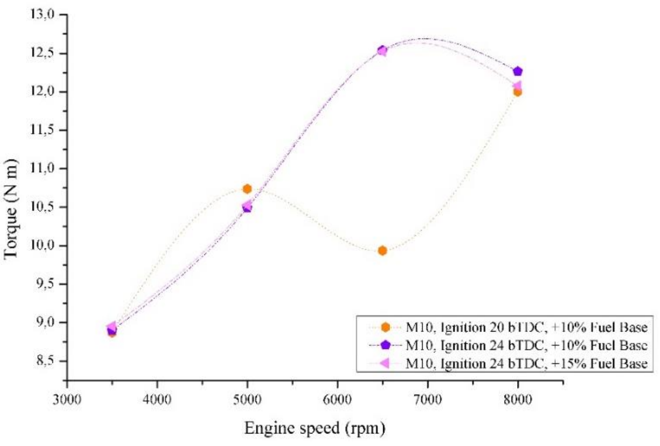

Figure 5. Torque at various injection durations using M10 fuel

The variable in this experiment, besides the ignition timing setting, is the injection duration setting. Increasing injection duration setting is done at ignition timing which produces maximum torque. The injection duration tested is + 10% and + 15% of the standard-setting. Based on this test, there was no significant difference between the two injection duration settings (Figure 5). The difference in the maximum torque value of these two settings is only 0.117%, with the injection duration setting + 10% having a higher value. A more significant difference between the two settings occurs at an engine speed of 8000 rpm. There is a difference in the torque value of 1.582% in this condition, with setting injection duration + 10% resulting in a higher torque value.

3.2. Power

Figure 6 depicts the power generated by the engine at four engine speeds, namely 3500, 5000, 6500, and 8000 rpm. The four-engine speeds represent the range of operating conditions of the engine. The test is carried out with the engine in wide-open throttle to obtain the maximum power value. The first test is done by using a variation of the ignition timing. The standard ignition timing used is 20 ^{o}bTDC, then advanced in increments of + 2^o until it reaches 28 ^{o}bTDC.There is an increase in power and engine speed, where the maximum power occurs at the highest engine speed. It is consistent with engine specifications where the maximum power occurs at a higher engine speed than at maximum torque. Changes in ignition timing affect the power generated by the engine. Changes to the more advanced ignition timing can increase the power generated by the engine to a certain point [1], [23]. In this test, the maximum power obtained at the ignition timing setting is 28 ^{o}bTDC, 10.335 kW at 8000 rpm. However, in this setting, the power at a lower engine speed has a lower value than other ignition timing settings, so the setting is less than optimal. The optimal setting in this test is obtained at an ignition timing of 24 ^{o}bTDC, where this setting reaches the maximum break torque value in the previous parameter. In this arrangement, the power obtained is 10.22 kW at 8000 rpm, and 8.52 kW at 6500 rpm. The maximum torque is increased by 0.59% over standard-setting. It is better than the 28 ^{o}bTDC ignition timing, which gets 10.335 kW at 8000 rpm and only 7.525 kW at 6500 rpm.

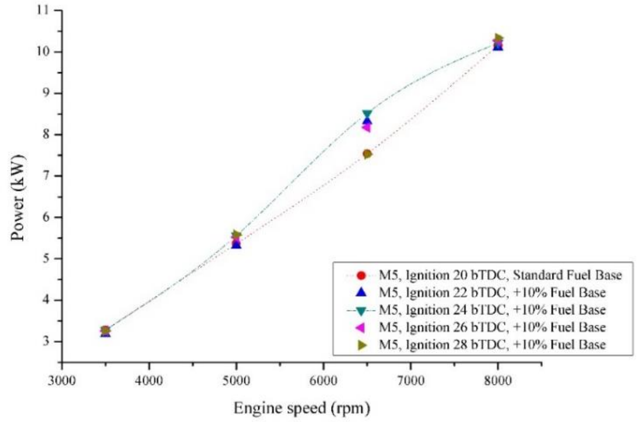

Figure 6. Power at various ignition timings using M5 fuel

In addition to ignition timing settings, another setting is injection duration. This setting shows a duration that the injectors are open to distribute fuel. The injection duration setting used is + 10% and + 15% from the baseline setting. The variation of these settings is applied to the optimal ignition timing settings. Based on Figure 7, it was found that the optimal injection duration setting is + 10% from the baseline. There was a power increase of 0.59% on the + 10% injection duration setting, while there was a decrease in power by 1.772% in the + 15% injection duration setting. It shows that the AFR that produces the maximum power is obtained at the + 10% injection duration setting.

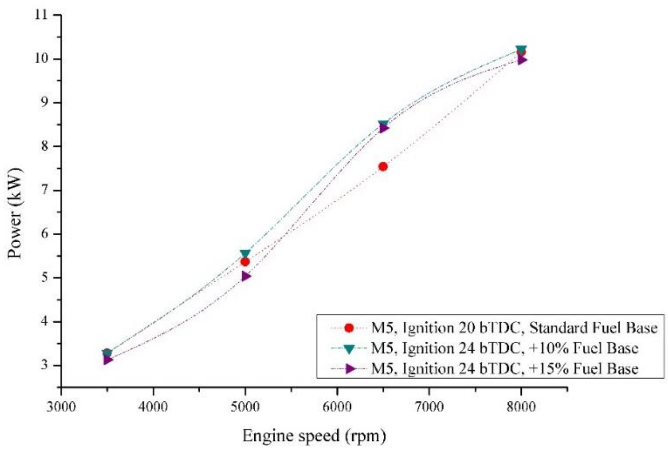

Figure 7. Power at various injection durations using M5 fuel

Figure 8 shows engine power measurements at four speeds, i.e., 3500, 5000, 6500, and 8000 rpm. The engine is operated at wide-open throttle. The variation of engine settings that will be tested first is the ignition timing. The ignition timing settings used in the M10 test are 20 ºbTDC, namely the standard-setting, 22 ºbTDC, and 24 ºbTDC. The ignition timing setting is limited to this point because the more advanced ignition timing settings did not complete the test cycle, with the engine stopping when the test reached 6500 rpm. The increase in power is directly proportional to the rise in engine rotational speed, where the maximum power is obtained at the ignition timing setting of 24 ºbTDC. This setting produces a full power of 10.27 kW, an increase of 2.18% from the standard-setting, making 10.05 kW.

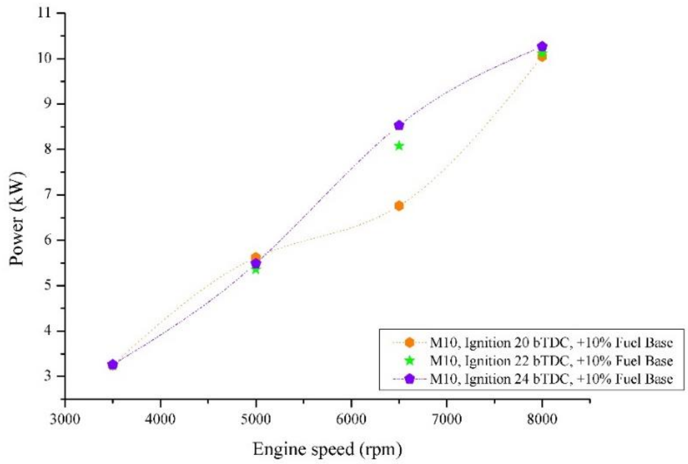

Figure 8. Power at various ignition timings using M10 fuel

Another setting that will be tested is injection duration. These variations are used for optimum ignition timing settings. The injection duration setting to be tested + 10% and + 15% from the baseline setting. Figure 9 shows that the highest power is obtained at the + 10% injection duration setting. This setting produces a power of 10.27 kW, 1.58% higher than the injection duration + 15%, which makes a power of 10.11 kW. Optimum injection duration will have the optimum AFR, which is when the lambda is 0.86.

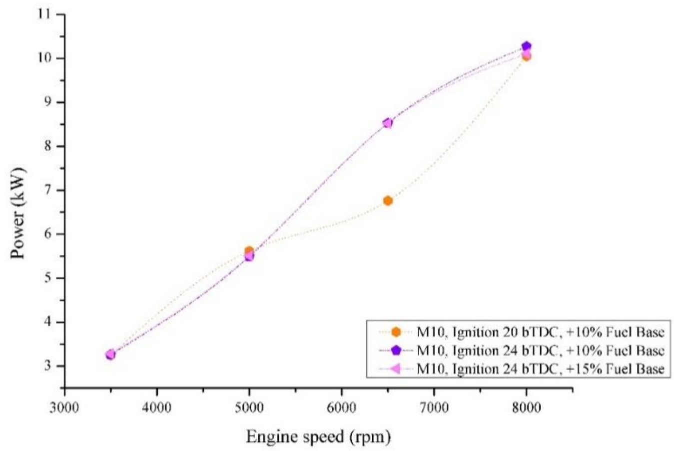

Figure 9. Power at various injection durations using M10 fuel

3.3. Specific Fuel Consumption

Figure 10 shows the calculation of specific fuel consumption obtained at four engine speeds, namely 3500, 5000, 6500, and 8000 rpm. The test was carried out with the engine in wide-open throttle conditions. The independent variable in this experiment is the ignition timing setting. The ignition timing used is the standard setting of 20 ⁰bTDC, and the advanced ignition timing is 22, 24, 26, and 28 ⁰bTDC.

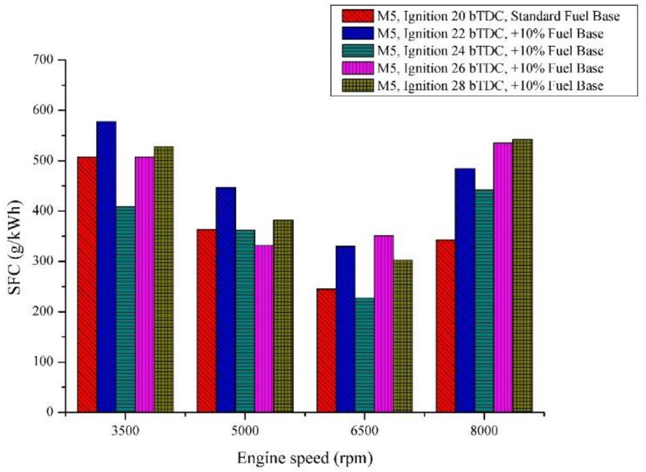

Figure 10. Specific fuel consumption at various ignition timing using M5 fuel

Fuel-injection engine system is affected by injection duration that an increasing the engine speed will extend the duration of fuel injection. It was clear that the amount of fuel entering the combustion chamber would increase—different engine speeds result in a different fuel consumption trend. Furthermore, at an engine speed of 8000 rpm, the engine's mechanical losses increase, so an equivalent increase in power does not accompany an increase in fuel consumption. It causes the specific fuel consumption value to be high.

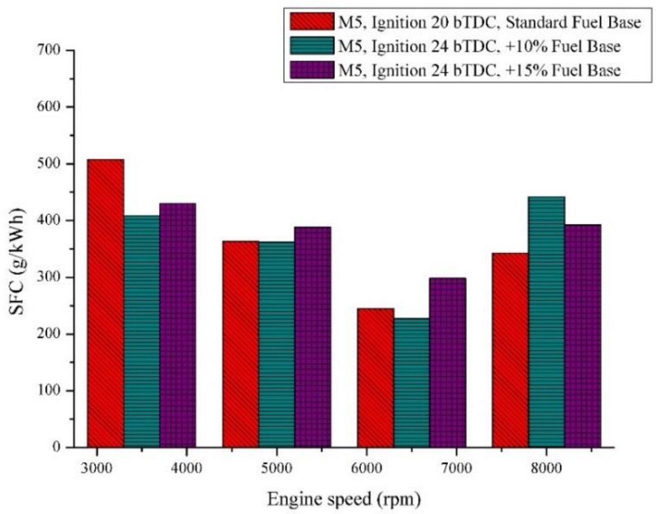

Figure 11. Specific fuel consumption at various injection durations using M5 fuel

Based on Figure 11, the lowest specific fuel consumption is obtained at the 24 ⁰bTDC ignition timing setting with a value of 226.99 g / kWh at an engine speed of 6500 rpm. This value decreased by 7.29% compared to the standard-setting. It was also influenced by the amount of power generated in the ignition timing settings. Another setting in this study is injection duration, which is used to adjust the duration of the fuel injector opening when injecting fuel. The settings used are + 10% and + 15% from the standard-setting. The addition of injection duration from + 10% to + 15% increases the value of specific fuel consumption at 6500 rpm engine speed by 31.41%. This increase was due to increased fuel consumption not accompanied by an increase in the power generated.

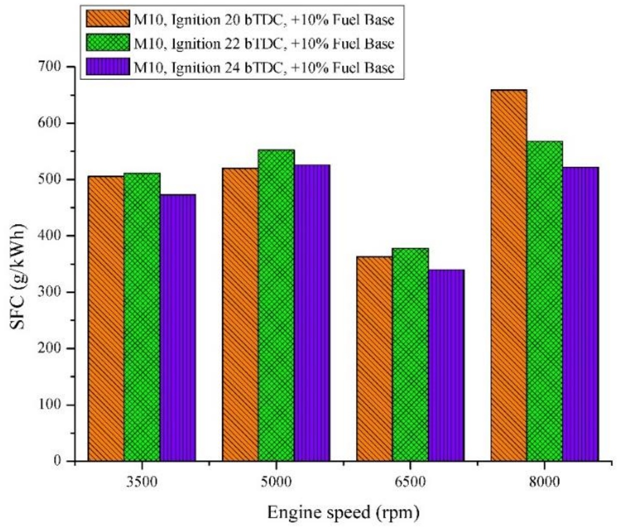

Figure 12. Specific fuel consumption at various ignition timings using M10 fuel

Figure 12 shows the results of testing specific fuel consumption values at different ignition timing settings. The ignition timing is the default setting at 20 ⁰bTDC, and the advanced settings are 22 and 24 ⁰bTDC. Based on the graph, the specific fuel consumption values increase with increasing engine speed, except at 6500 rpm. The increase in power occurs highest at the engine speed so that the value of the specific fuel consumption is low. Minimum specific fuel consumption is achieved at a setting of 24 ⁰bTDC at 6500 rpm. This value is 6.27% lower than the specific fuel consumption value at the standard-setting. In addition, ignition timing settings were used to be the independent variable is the injection duration setting [24], [25]. The injection duration setting used is + 10% and + 15% from the standard-setting. This variation of setting is tested on the ignition timing setting, which produces a maximum break torque ignition timing, which is 24 ⁰bTDC. Figure 13 shows that it is found that increasing injection duration from

+ 10% to + 15% increases the value of specific fuel consumption.

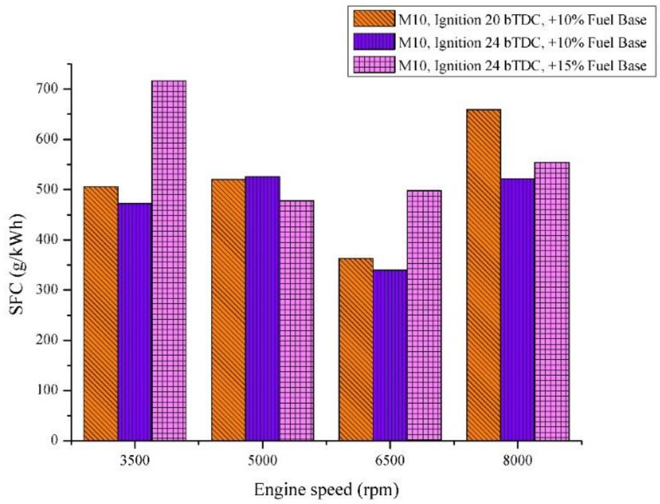

Figure 13. Specific fuel consumption at various injection durations using M10 fuel

3.4. An Optimization Engine Setting

Figure 14 shows the torque generated when using RON 90 gasoline at standard settings and M5 and M10 fuel blends with optimized engine settings to get maximum break torque. Testing using gasoline RON 90 at standard engine settings produces a torque of 12.18 Nm at 6500 rpm. Then the two mixed fuels produce a maximum break torque at the same engine setting, namely ignition timing at 24 ⁰bTDC and injection duration + 10%. Based on this graph, the M5 and M10 fuels produce a maximum torque that does not differ much, with a 0.118% difference. The highest torque in this experiment is achieved when using M10 fuel, with a maximum torque of 12.538 Nm. This value increases from the torque when using RON 90 gasoline by 2.936%.

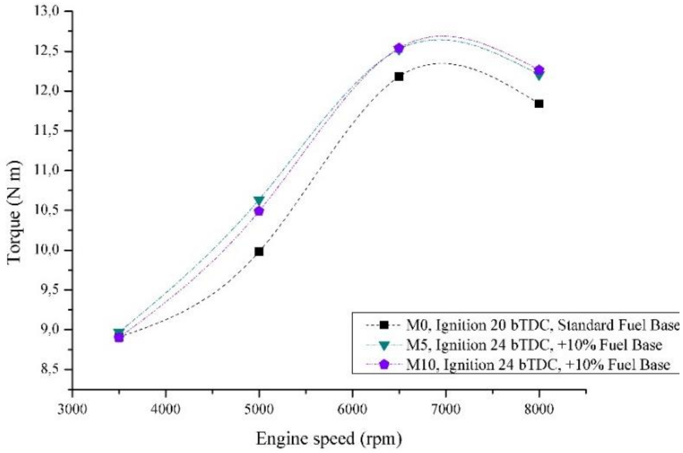

Figure 14. Torque using M0 at standard engine setting, M5 and M10 at optimized engine settings

Figure 15 compares the resulting power between gasoline RON 90 at standard engine settings and the M5 and M10 fuels at the optimal engine settings. Based on Figure 15, the two mixed fuels produce power that is not much different, and both of them produce higher power than RON 90 gasoline. The highest power is obtained at ignition timing 24 ⁰bTDC and injection duration + 10%. It shows that optimized engine settings resulted in an optimum combustion process with minimum power loss, resulting in high power output.

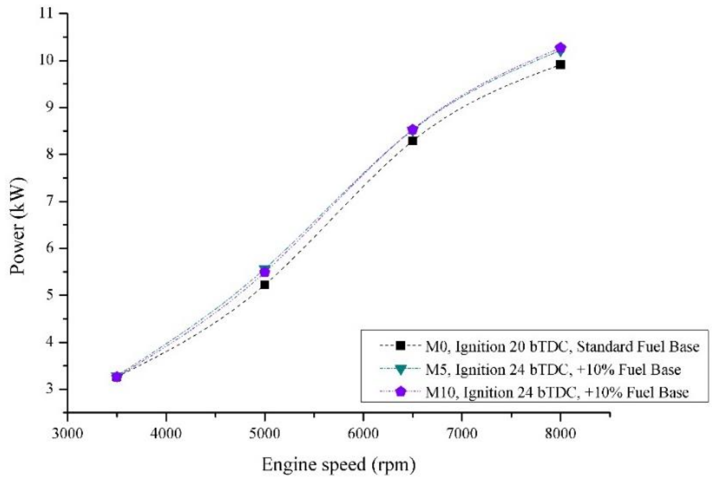

Figure 15. Power using M0 at standard engine setting, M5 and M10 at optimized engine settings

Figure 16 illustrates the comparison between gasoline RON 90 at standard settings and the use of M5 and M10 fuel at optimal settings. The optimum setting used for the benefit of both mixed fuels is 24 ⁰bTDC ignition timing and injection duration + 10% from the standard-setting. This setting produces the lowest specific fuel consumption value for the use of both fuels.

Based on Figure 16, the lowest specific fuel consumption value is achieved by M5 fuel. It shows that an optimization engine setting has been made to M5 with 24 ⁰bTDC ignition timing and injection duration + 10% from the standard-setting. An increase in ignition timing resulted in a rise in engine power and torque, reflecting higher pressure in the cylinder [20], [22]. On the other hand, a higher specific fuel consumption value is generated by M10 fuel. It was clear that M10 fuel has a lower heating value than M5, requiring a more significant amount of fuel to produce the same power, with the same optimization engine setting (24 ºbTDC ignition timing and injection duration + 10% from the standard-setting).

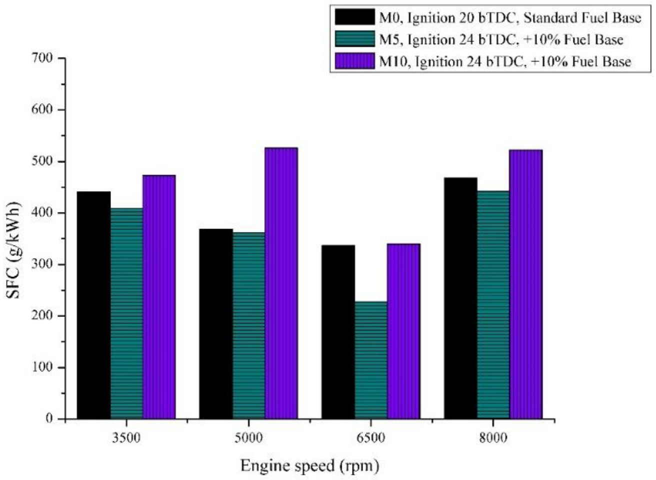

Figure 16. SFC using M0 at standard engine setting, M5 and M10 at optimized engine settings

Figure 17 compares gasoline RON 90 at standard engine settings and the use of M5 and M10 fuels at the optimum engine setting for testing carbon dioxide levels in exhaust gas emissions. The three fuels produce the highest carbon dioxide levels at an ignition timing of 20º bTDC. At engine speeds of 3500 and 5000 rpm, the highest levels of carbon dioxide are produced by RON 90 gasoline, but at engine speeds of 6500 and 8000 rpm. The highest level of CO2 is produced when using M5 fuel with standard ignition timing and injection duration at an engine speed of 6500 rpm, with the resulting carbon dioxide content of 10.994%.

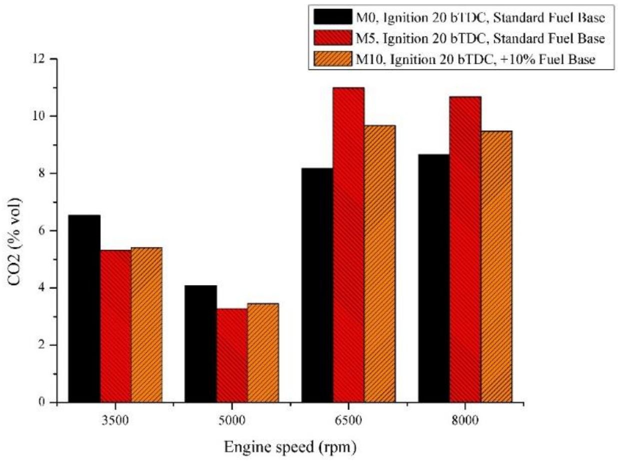

Figure 17. Carbon dioxide percentage using M0 at standard engine setting, M5 and M10 at optimized engine settings

Figure 18 compares gasoline RON 90 at standard engine settings and the use of M5 and M10 fuels at the optimum engine settings for testing carbon monoxide levels in exhaust emissions. The two mixed fuels tested produced the lowest carbon monoxide levels at different engine settings. M5 fuel produces the lowest carbon monoxide at an ignition timing of 28 ºbTDC, while M10 fuel at 22 ºbTDC. The lowest carbon monoxide content was produced in the M5 fuel test with an ignition timing of 28 ºbTDC at an engine speed of 6500 rpm, namely 0.1075%. It means that the combustion that occurs is close to stoichiometry, so that the combustion hardly produces carbon monoxide.

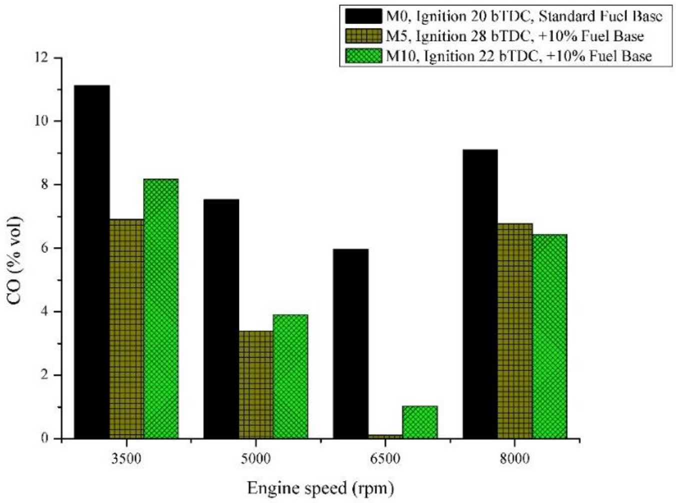

Figure 18. Carbon monoxide percentage using M0 at standard engine setting, M5 and M10 at optimized engine settings

Figure 19 compares gasoline RON 90 at standard engine settings and the use of M5 and M10 fuels at the optimum engine settings for testing hydrocarbon levels in exhaust emissions. The two mixed fuels tested produced the lowest hydrocarbon levels at different engine settings. M5 fuel produces the lowest carbon monoxide at an ignition timing of 28 ºbTDC, while M10 fuel at 22 ºbTDC. The lowest hydrocarbon content was built in the M10 fuel test with an ignition timing of 22 ºbTDC at an engine speed of 6500 rpm, 17.1 ppm. It means that the combustion that occurs is close to stoichiometry, so combustion hardly produces hydrocarbons [26], [27].

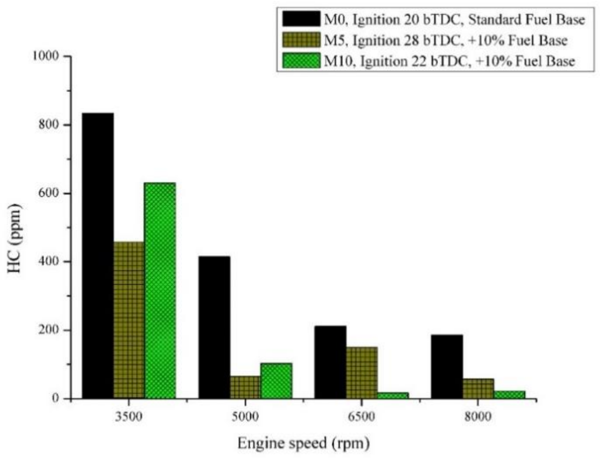

Figure 19. Unburnt hydrocarbon percentage using M0 at standard engine setting, M5 and M10 at optimized engine settings

CONCLUSION

Improved engine performance and emission qualities of 150cc four-stroke SI engines with gasoline RON 90 and methanol blends (M5 and M10) were studied using optimized ignition timing and injection duration. The results showed that optimized ignition timing and injection duration settings improved engine performance and emission content qualities. The engine setting with the highest performance improvement was 24 ^{0}bTDC ignition timing and +10% injection duration. The optimized engine settings on M5 fuel blend resulted in up to 12.99% of engine torque, 1.72% increase in engine power, and 7.2% decrease in specific fuel consumption and improvements in exhaust gas qualities with decreased carbon monoxide levels. At the same time, there was a slight increase in unburnt hydrocarbon compared to the standard engine setting. Finally, it can also be concluded that in the use of methanol as a gasoline fuel mixture, the engine settings must be changed from the initial setting to produce optimum performance because methanol has different fuel properties with gasoline.

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REFERENCES

[1] I. M. Yusri *et al.*, "Alcohol based automotive fuels from first four alcohol family in compression and spark ignition engine: A review on engine performance and exhaust emissions," *Renew. Sustain. Energy Rev.*, vol. 77, no. October 2015, pp. 169–181, 2017.

[2] A. A. Yusuf and F. L. Inambao, "Progress in alcohol-gasoline blends and their effects on the performance and emissions in SI engines under different operating conditions," *Int. J. Ambient Energy*, vol. 0, no. 0, pp. 1–17, 2018.

[3] T. Miller, T. Beer, T. Grant, D. Batten, D. Lamb, and D. Trimm, "Methanol as an alternative transport fuel," *Proc. 14th Int. Union Air Pollut. Prev. Environ. Prot. Assoc. World Congr. 2007, 18th Clean Air Soc. Aust. New Zeal. Conf.*, no. 4000096701, 2007.

[4] S. Aghahossein Shirazi, B. Abdollahipoor, J. Martinson, B. Windom, T. D. Foust, and K. F. Reardon, "Effects of dual-alcohol gasoline blends on physiochemical properties and volatility behavior," *Fuel*, vol. 252, no. April, pp. 542–552, 2019.

[5] V. F. Andersen, J. E. Anderson, T. J. Wallington, S. A. Mueller, and O. J. Nielsen, "Vapor pressures of alcohol-gasoline blends," *Energy and Fuels*, vol. 24, no. 6, pp. 3647–3654, 2010.

[6] M. Amine and Y. Barakat, "Properties of gasoline-ethanol-methanol ternary fuel blend compared with ethanol-gasoline and methanol-gasoline fuel blends," *Egypt. J. Pet.*, vol. 28, no. 4, pp. 371–376, 2019.

[7] H. Liu, Z. Wang, Y. Long, S. Xiang, J. Wang, and S. W. Wagnon, "Methanol-gasoline Dual-fuel Spark Ignition (DFSI) combustion with dual-injection for engine particle number (PN) reduction and fuel economy improvement," *Energy*, vol. 89, pp. 1010–1017, 2015.

[8] S. Verhelst, J. W. Turner, L. Sileghem, and J. Vancoillie, "Methanol as a fuel for internal combustion engines," *Prog. Energy Combust. Sci.*, vol. 70, pp. 43–88, 2019.

[9] S. Iliev, “A comparison of ethanol and methanol blending with gasoline using a 1-D engine model,” *Procedia Eng.*, vol. 100, no. January, pp. 1013–1022, 2015.

[10] H. Zhao *et al.*, “Effects of different mixing ratios on emissions from passenger cars fueled with methanol/gasoline blends,” *J. Environ. Sci.*, vol. 23, no. 11, pp. 1831–1838, 2011.

[11] C. Gong, Z. Li, Y. Chen, J. Liu, F. Liu, and Y. Han, “Influence of ignition timing on combustion and emissions of a spark-ignition methanol engine with added hydrogen under lean-burn conditions,” *Fuel*, vol. 235, no. June 2018, pp. 227–238, 2019.

[12] R. J. Pearson, J. W. G. Turner, A. Bell, S. De Goede, C. Woolard, and M. H. Davy, “Iso-stoichiometric fuel blends: Characterisation of physicochemical properties for mixtures of gasoline, ethanol, methanol and water,” *Proc. Inst. Mech. Eng. Part D J. Automob. Eng.*, vol. 229, no. 1, pp. 111–139, 2015.

[13] R. Feng *et al.*, “Experimental study on SI engine fuelled with butanol-gasoline blend and H2O addition,” *Energy Convers. Manag.*, vol. 74, pp. 192–200, 2013.

[14] L. Tunka and A. Polcar, “Effect of various ignition timings on combustion process and performance of gasoline engine,” *Acta Univ. Agric. Silvic. Mendelianae Brun.*, vol. 65, no. 2, pp. 545–554, 2017.

[15] D. Rio and B. Syaka, “PENGARUH PERUBAHAN IGNITION TIMING TERHADAP KINERJA MESIN SEPEDA MOTOR AUTOMATIC 115CC Ragil Sukarno , Darwin Rio Budi Syaka , Adhitya Randa Asier Program Studi Pendidikan Teknik Mesin , Fakultas Teknik - Universitas Negeri Jakarta Email : ragil-sukarno@u,” no. April, pp. 45–50, 2017.

[16] B. Wu, L. Wang, X. Shen, R. Yan, and P. Dong, “Comparison of lean burn characteristics of an SI engine fueled with methanol and gasoline under idle condition,” *Appl. Therm. Eng.*, vol. 95, pp. 264–270, 2016.

[17] J. Li, C. M. Gong, Y. Su, H. L. Dou, and X. J. Liu, “Effect of injection and ignition timings on performance and emissions from a spark-ignition engine fueled with methanol,” *Fuel*, vol. 89, no. 12, pp. 3919–3925, 2010.

[18] C. S. Wibowo, F. Adian, M. Masuku, Y. Nugroho, and B. Sugiarto, “The Optimization Performance of Mixed Fuel Gasoline RON 88 , 92 , 98 with Bioethanol on Spark Ignition Engine,” vol. 9, no. 09, pp. 989–992, 2020.

[19] C. Wibowo, F. Adian, Y. Nugroho, and B. Sugiarto, “The optimization of the relationship between octane number of gasoline-ethanol blend fuels in various settings of the engine control module,” *Evergreen*, vol. 7, no. 4, pp. 587–592, 2020.

[20] O. I. Awad *et al.*, “Alcohol and ether as alternative fuels in spark ignition engine: A review,” *Renew. Sustain. Energy Rev.*, vol. 82, no. January, pp. 2586–2605, 2018.

[21] G. Martini *et al.*, *Effect of oxygenates in gasoline on fuel consumption and emissions in three Euro 4 passenger cars Contact information*. 2013.

[22] K. Kar, W. Cheng, and K. Ishii, “Effects of ethanol content on gasohol PFI engine wide- open-throttle operation The MIT Faculty has made this article openly available . Please share Citation SAE International Publisher Version Accessed Citable Link Terms of Use Detailed Terms Effects of,” *SAE Int. J. Fuels Lubr.*, vol. 2, pp. 895–901, 2009.

[23] C. S. Wibowo *et al.*, “The Performance of a Spark Ignition Engine using 92 RON Gasoline with Varying Blends of Bioethanol (E40, E50, E60) Measured using a Dynamometer Test,” *Int. J. Technol.*, vol. 11, no. 7, pp. 1380–1387, 2020.

[24] T. G. Leone *et al.*, “The Effect of Compression Ratio, Fuel Octane Rating, and Ethanol Content on Spark-Ignition Engine Efficiency,” *Environ. Sci. Technol.*, vol. 49, no. 18, pp. 10778–10789, 2015.

[25] J. E. Anderson *et al.*, “High octane number ethanol-gasoline blends: Quantifying the potential benefits in the United States,” *Fuel*, vol. 97, pp. 585–594, 2012.

[26] R. J. Pearson, J. W. G. Turner, A. Bell, S. De Goede, C. Woolard, and M. H. Davy, “Iso-stoichiometric fuel blends: Characterisation of physicochemical properties for mixtures of gasoline, ethanol, methanol and water,” Proc. Inst. Mech. Eng. Part D J. Automob. Eng., vol. 229, no. 1, pp. 111–139, 2015.

[27] J. W. G. Turner, R. J. Pearson, E. Dekker, B. Iosefa, K. Johansson, and K. ac Bergström, “Extending the role of alcohols as transport fuels using iso-stoichiometric ternary blends of gasoline, ethanol and methanol,” Appl. Energy, vol. 102, pp. 72–86, 2013.