Performance and Emissions Analysis of BE85-Gasoline

by Helen Riupassa

Automotive Experiences
Vol. 5 No.1 (2022) pp. 40-48
p-ISSN: 2615-6202 e-ISSN: 2615-6636

Research Paper

Performance and Emissions Analysis of BE85-Gasoline Blends on Spark Ignition Engine

Hendry Y. Nanlohy[1], **Helen Riupassa**[1], **Marthina Mini**[1], **Herman Tjolleng Taba**[1], **Basri Katjo**[1], **Nevada JM. Nanulaitta**[2], **Masaki Yamaguchi**[3]

[1]Department of Mechanical Engineering, Jayapura University of Science and Technology, 99351, Indonesia
[2]Department of Mechanical Engineering, Ambon State Polytechnic, 97234, Indonesia
[3]Department of Mechanical Engineering, Keio University, Tokyo, 108-8345, Japan

hynanlohy@gmail.com

https://doi.org/10.31603/ae.6116

Check for updates

Published by Automotive Laboratory of Universitas Muhammadiyah Magelang collaboration with Association of Indonesian Vocational Educators (AIVE)

Article Info
Submitted:
22/10/2021
Revised:
22/11/2021
Accepted:
24/11/2021
Online first:
27/11/2021

Abstract

This study aims to reveal the performance and exhaust emissions of a spark ignition (SI) engine fueled by a gasoline-bioethanol mixture. The main performance characteristics of the SI engine tested are torque, power output; thermal efficiency, brake specific fuel consumption, and brake mean effective pressure. Meanwhile, the exhaust emissions seen are carbon monoxide and hydrocarbons. The test is carried out by comparing the performance of the SI engine under standard conditions without modification with gasoline fuel, with the SI engine with modification with 85% bioethanol fuel. The mass flow of fuel is regulated by modifying the carburetor choke at 3/4 and 7/8. The results show that although slightly lower than gasoline, in general, it can be seen that bioethanol can improve SI engine performance and produce environmentally friendly exhaust emissions.

Keywords: Bioethanol, Gasoline, Engine performance, Exhaust emissions, Fuel mass flow

1. Introduction

It is necessary to utilize alternative energy resources regarding decreasing reserves of fossil fuels, intensifying industrial activity, and the world population grow up [1], [2]. The need for alternative fuels is very important so that further research is needed in line with the fact that the use of alternative fuels still causes pollution that has an impact on increasing the effect of greenhouse gases [3]–[5]. Bioethanol and biodiesel are the most superior alternative fuels used in internal combustion engines [6], [7], but bioethanol has more advantages over biodiesel because it has low production costs, environmentally friendly combustion gases, and has brighter prospects [8]–[10].

On the other hand, ethanol has been applied in SI engines using various types of vegetable raw materials, such as sugarcane, corn, lignocellulose biomass, and starchy biomass, herbaceous, industrial and municipal solid waste [11], [12]. Many studies on the ethanol and gasoline blended in SI engine (E5 to E70) have also been carried out to determine its effect on combustion parameters such as cylinder pressure, cylinder temperature, combustion efficiency, combustion duration, combustion speed, cold start, anti-knock, and emission [9], [13], [14]. The results showed that with a lower calorific value than gasoline, the specific fuel consumption of ethanol increases, so a higher mass of ethanol is required for each unit of power produced [9], [15], [16]. Furthermore, because ethanol has a higher heat of vaporization, the evaporation of fuel occurs at a higher temperature, which is accompanied by an increase in flame speed, increasing fuel conversion efficiency [17], [18]. Moreover, there is an increase in-cylinder pressure and work done on the piston so that the combustion of bioethanol produces a higher volume of product. On the other hand, the lower calorific value of bioethanol results in an increase in specific fuel consumption compared to gasoline, i.e., a higher mass amount of ethanol is required per unit of power generated [19].

Furthermore, several studies for the main spark ignition (SI) engine performance characteristics such as engine torque (T), power output (N), thermal efficiency (η_{th}), brake specific fuel consumption (BSFC), and brake mean effective pressure (BMEP). The results found that all parameters of the main SI engine performance characteristics have increased, and this occurs when the engine is in an unmodified condition with an engine speed of around 1500 to 5000 rpm [20], [21]. Therefore, several researchers studied the use of ethanol in SI engines with high engine speeds of around 5500 to 8000-rpm with the engine in standard conditions without modification [22], [23]. The results show that the engine performance has decreased and even fuel consumption is very wasteful, and what is unfortunate is that this happens not only at high-speed engines but also at low engine speeds of 1500 to 5000 rpm. This shows that ethanol has advantages and disadvantages that make it effective but also inefficient.

The same thing happened when using BE85, the results showed that the use of blended gasoline and BE85 in SI engines decreased the combustion duration, combustion speed, combustion temperature, and heat release rate (HRR) [16], [24], [25], and this occurs when the SI engine is in standard and unmodified condition. These facts show that to produce an effective and efficient performance of the SI engine using ethanol fuel, thus the fuels cannot be operated under standard conditions or without modification [20], [26]. In present studies, modifications were made to the carburetor because the carburetor is a crucial part of making modifications, because it is responsible for the mass flow of the fuel mixture entering the combustion chamber [27], [28]. Therefore, this research aims to reveal scientific information regarding the performance of SI engines with BE85 fuel and its exhaust emissions with the modified a carburetor engine and operated by speed variation at wide-open throttle.

2. Material and methods

The raw material for bioethanol comes from coconut flower sap with a percentage of 85% to gasoline 15%. Bioethanol obtained from natural fermentation has a percentage of 43-45%, then a distillation process is carried out using a fractionation column to increase the ethanol content to 94-95%. The fuel mixture (BE 85%-Gasoline 15%) was obtained by mixing it in a test tube and shaking it manually. The test of fuel properties was carried out at the fuel-testing laboratory of PT. Pertamina West Surabaya and the results are presented in **Table 1**. Engine performance test used SI engines 125 ccs, and the engine speed variation at wide-open throttle and choke carburetor variation as 3/4 and 7/8. The modification of the choke carburetor is intended to get enough fuel requirement and to minimize the oxidizer that is composed of bioethanol. The detail of the exhaust gas analyzer is shown in **Figure 1**, and the experimental scheme is shown in **Figure 2.** In general, engine testing is carried out 3 times with the following steps:

a. The load from the water brake dynamometer is adjusted by opening the water intake valve until the engine shows the desired speed, (7500, 7000, 6500, 6000, 5500, 5000, 4500, 4000, 3500, 3000) rpm, observations are made after equilibrium is reached (stable).
b. At every change in engine speed, data is collected on the water brake dynamometer shaft rotation, torque, fuel consumption time every 25 ml, Δh manometer, and exhaust emissions (CO and HC).

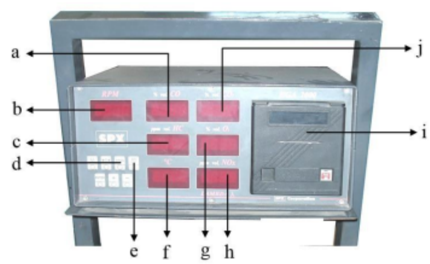

Figure 1. Exhaust gas analyzer

Note: (a) CO display; (b) Engine speed (rpm) button; (c) HC display; (d) On/off button (e) The button to activate the exhaust gas test results (print out); (f) Exhaust gas temperature (°C); (g) O_2 display; (h) NOx and lambda display; (i) Print out results of exhaust gas testing; (j) CO_2 display

3. Result and Discussion

3.1. Torque and power

Figure 3 shows the relationship between torque and engine speed with gasoline compared to the BE-85 C3/4 and BE-85 C7/8 engines. It can be seen

Table 1. The main properties of fuels

Properties	Gasoline	BE-85
Molecular formula	C_7H_{18}	C_2H_5OH
Molecular weight, wt.	100	46
Research octane number (RON)	88 -100	105
Motor octane number (MON)	80 -90	89
Flash Point (°C)	-23	12.78
Caloric value (cal/gr)	10500	8939
Density at 15 °C (kg/m³)	715	780
Viscosity at 20 °C (cSt)	0.6	0.546
Lower heating value, MJ/kg	28	15.3
Latent heat evaporation, kJ/kg	349	784.5
Stoichiometric A/F Ratio	14.5	7.65

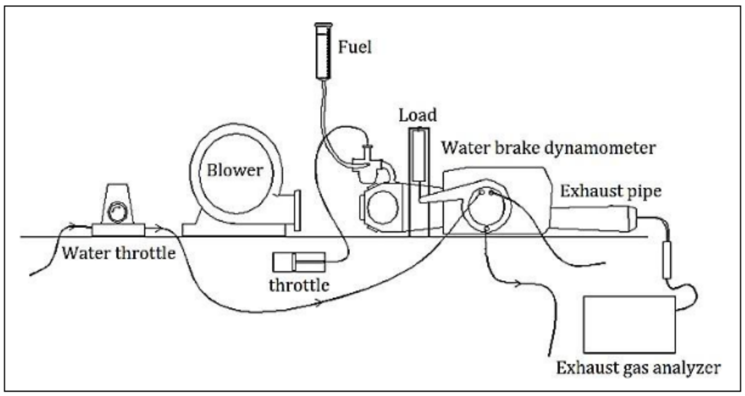

Figure 2. The experimental scheme

that the smallest torque is produced by the BE-85 C3/4 engine, followed by the BE-85 C7/8 engine, and the largest in the gasoline engine. These results also indicate that the energy produced by the combustion of gasoline is greater than BE-85, and this is due to the difference in the energy content of the fuels. **Table 1** shows that gasoline has a calorific value of 10500 cal/gr while BE-85 is about 8939 cal/gr.

This result is confirmed from **Figure 4**, it can be seen that the power generated by the BE-85 C 3/4 engine is smaller than the other fuel. This phenomenon is very possible because the need for oxygen in the combustion process increases due to the addition of getting from the air flowing through the choke valve gap, oxygen is also obtained from the content of ethanol fuel compounds.

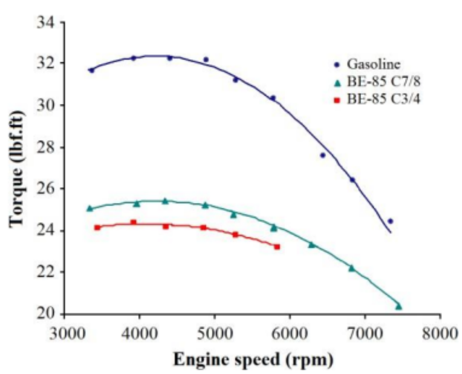

Figure 3. Engine torque for various blends

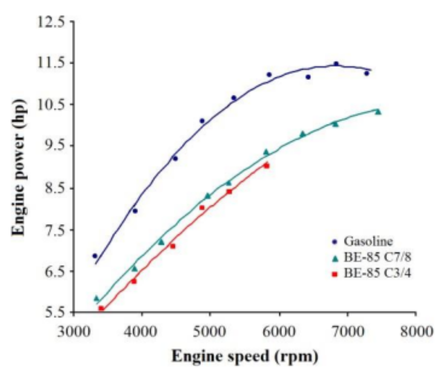

Figure 4. Engine power for various blends

Moreover, Figure 4 shows that the low power is due to the small amount of air and fuel mixture that can be burned because the rate of the first end of the flame is quite slow. Furthermore, the high auto ignition temperature of BE-85 is due to the occurrence of ignition lag or the development of a flame core at the beginning of the combustion reaction, originating from sparks that ignite the fuel-air mixture at the tip of the spark plug electrode. The long ignition lag causes the unburned fuel to be wasted together with the exhaust gases, and this is confirmed by the high exhaust gas levels of the BE-85 HC engine (see Figure 9). This analysis is very possible because when compared with previous research studies, they stated that HC levels decreased when the air and fuel mixture was in stoichiometric conditions [15].

Furthermore, although the amount of BE-85 fuel supplied to the engine has been increased by increasing the choke to 7/8, it has not been able to increase engine power like gasoline. In addition, this makes the carburetor coke position no longer enlarged because it has the potential to cause the air-fuel mixture that enters the combustion chamber to be too rich so that the air and fuel mixture cannot be burned completely. Moreover, this excessive amount of fuel can lower the combustion temperature and this is very detrimental because it has the potential to reduce engine power.

BE-85 fuel cannot produce more power than gasoline for at least four reasons. The first is the value of the energy content expressed by the calorific value of BE85 fuel which is smaller than gasoline. In addition, its also influenced by differences in the structure of the fuel compounds. Gasoline with chemical formula C_7H_{18} and chemical formula of ethanol which is the largest constituent (85%) of BE-85 is C_2H_5OH, meaning the number of carbon (C) atoms of gasoline is about three times compared to the number of atoms of carbon possessed by BE-85. The same applies to the number of hydrogen (H) atoms, where the hydrogen atoms in gasoline are about three times higher than the number of hydrogen atoms in BE-85. C and H atoms easily react with oxygen, and if present in sufficient quantities will form CO_2 gas (carbon dioxide) and release energy, while H atoms when reacting with O_2 will form H2O (water vapor) and release energy. So if the more C and H atoms are contained by fuel, the greater the energy released during the combustion of the fuel. Another cause is the stoichiometric ratio of air and fuel (A/F) that can cause the combustion process to take place completely, meaning that all fuel can be burned and the indications of CO and HC exhaust gases are very low. If the amount of fuel is increased by increasing the choke, the resulting mixture will be too rich. This is because the cross-sectional area of the carburetor inlet and venture throat is less large. While the last cause is because power is also influenced by the rate of combustion, where the greater the rate of combustion, the greater the energy resulting from combustion. This is due to the more of the air and fuel mixture can be burned, especially at the high engine speed, which is around 7000 rpm, thus the combustion time faster.

3.2. *Brake mean effective pressure and fuel consumptions*

Figure 5 shows that the BMEP continues to decrease with increasing engine speed (rpm), and this is because at high rpm there is the fuel that does not burn completely so that it becomes a cooling medium and decreased the combustion temperature. This factor has the potential to delay the rate of combustion and decrease BMEP. This analysis follows the results of previous studies which stated that the combustion rate decreased along with the increase in unburned hydrocarbons as an indicator that some of the fuel had not been burned [18].

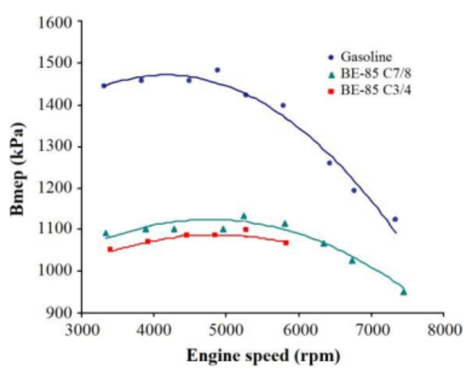

Figure 5. Brake mean effective pressure for various blends

This phenomenon is also supported by the results on fuel consumption (bsfc). Figure 6 shows that the BE-85 fuel consumption is higher than gasoline due to the modification of the choke on the carburetor so that the venturi throat volume is dominated by fuel. Therefore, the mass flow rate of air becomes slower while the mass flow rate of fuel becomes faster so that only a small amount of fuel can be burned. This analysis is confirmed by the high exhaust emissions of HC (see **Figure 9**) on the BE-85 engine with 3/4 and 7/8 choke variations.

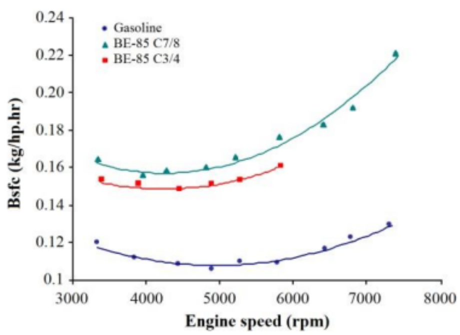

Figure 6. Brake specific fuel consumption for various blends

3.3. *Thermal efficiency*

In general, as presented in **Figure 7**, it can be seen that the thermal efficiency produced by the BE-85 engine is greater or an increase of 17% when compared to the gasoline engine with standard conditions. This is due to the low calorific value of BE-85 but can produce an output power that is almost the same as gasoline. This result looks a little strange but it is very possible because, with close observation, it is proven that BE-85 can produce higher efficiency when compared to gasoline. This phenomenon is very reasonable because at 4000 rpm the power output of the BE-85 drops by 16% lower than gasoline.

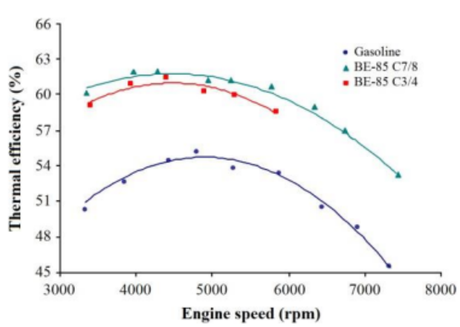

Figure 7. Thermal efficiency for various blends

Moreover, it shows that fuel consumption at 4000 rpm increased by 34% greater than gasoline. However, it should be realized that the calorific value of BE-85 is smaller than the calorific value of gasoline so that the input power of the BE-85 engine is also smaller than gasoline. These results are alignment with previous studies by Max et al. [16].

3.4. *Exhaust emissions (CO and HC)*

As presented in **Figure 8**, it can be seen that the level of CO produced by the BE-85 engine using a 7/8 choke is very large when compared to the BE85 engine using a 3/4 choke. However in general the result shows that the CO content produced by BE85-fueled engines is still higher than gasoline fueled engines. This is due to the excess of fuel and lack of oxygen causing a fuel mixture to be too rich so that the combustion process takes imperfect and potentially increasing carbon monoxide levels. This analysis is very possible and confirmed from the results of previous studies [25], [29] (see **Figure 10**), which can be seen that CO and HC emissions decrease when the fuel gets the right oxygen needs. They state that when the carbon atom gets enough oxygen, there is a formation of carbon dioxide gas and accompanied by the release of large combustion energy. Conversely, if the carbon atom does not get enough oxygen, it will be formed gas and be followed by a weak energy release.

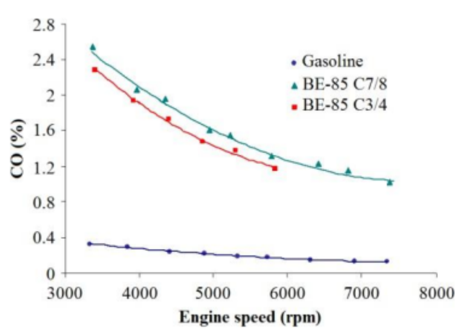

Figure 8. Carbon monoxide for various blends

Furthermore, high CO levels are not only caused by a mixture that is rich or lacking in oxygen but also due to the dissociation of CO_2 into CO and O_2 that occurs at high temperatures of around 1000 – 1500 Celsius degree. Moreover, the presence of CO in the exhaust gas is also caused by incomplete combustion in the combustion chamber caused by the lack of air in the fuel mixture entering the combustion chamber or due to the lack of time to complete the combustion time. Moreover, carbon monoxide is also taken place because of the quality of the fuel mixture, homogeneity, and the air-fuel ratio. Lack of oxygen causes carbon to react imperfectly so that CO is formed [30]. As confirmed in Figure 8 that the higher the engine speed, the lower the CO emissions produced. Whereas Figure 8 shows that the HC of the BE85 engine using a 7/8 choke is higher than that of gasoline or BE85 using a 3/4 choke. This is due to the incomplete combustion due to a slow combustion rate, as evidenced by the low engine speed, and the other hand produced very high HC accompanied by increased fuel consumption (see Figure 6).

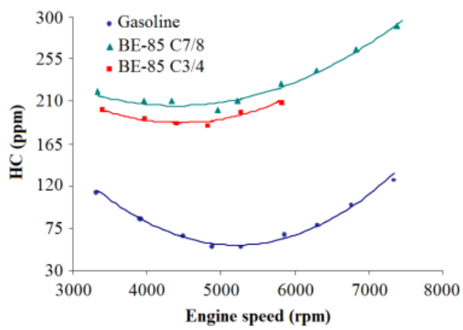

Figure 9. Hydrocarbon for various blends

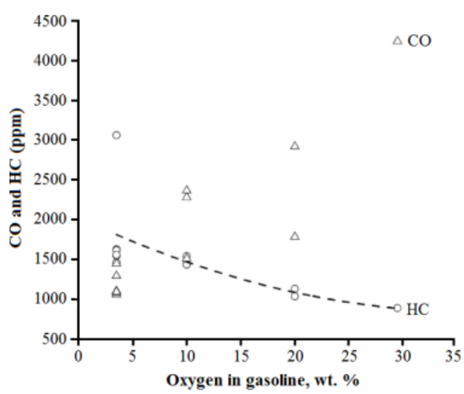

Figure 10. CO and HC concentrations in oxygen [25].

4. Conclusion

Experimental research has been conducted on SI engine performance characteristics with BE-85, and the result shows that BE-85 is successful to improve SI engine performance and is environmentally friendly. Furthermore, the most important thing that must be considered to improve the performance of the SI engine with BE-85 is to adjust the composition of the amount of air mass and BE-85 by varying the carburetor choke by 3/4 and 7/8. To get the maximum benefit from bioethanol, further research is needed using bioethanol with a low level of mixture or 100 percent in SI engines with engine speeds of around 5000 to 8000 rpm. Several studies have found that without modification, bioethanol-fueled SI engines produce different performance (advantages and disadvantages), therefore, it can be tried to modify the engine on the compression ratio and ignition degree.

Acknowledgement

Thank you to the Fuel and Combustion Laboratory of the Department of Mechanical Engineering for their support of research materials and equipment, and to the Institute for Research and Community Service, Jayapura University of Science and Technology for their funding support.

Author's Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

Funding

No Information funding from the authors

Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

Additional information

No additional information from the authors.

References

[1] D. Londoño-Pulgarin, G. Cardona-Montoya, J. C. Restrepo, and F. Muñoz-Leiva, "Fossil or bioenergy? Global fuel market trends," *Renewable and Sustainable Energy Reviews*, vol. 143, no. February, 2021, doi: 10.1016/j.rser.2021.110905.

[2] S. Adams, F. Adedoyin, E. Olaniran, and F. V. Bekun, "Energy consumption, economic policy uncertainty and carbon emissions; causality evidence from resource rich economies," *Economic Analysis and Policy*, vol. 68, pp. 179–190, 2020, doi: 10.1016/j.eap.2020.09.012.

[3] M. A. Aktar, M. M. Alam, and A. Q. Al-Amin, "Global economic crisis, energy use, CO2 emissions, and policy roadmap amid COVID-19," *Sustainable Production and Consumption*, vol. 26, pp. 770–781, 2021, doi: 10.1016/j.spc.2020.12.029.

[4] H. Purnama, I. V Hartoko, M. Mujiburohman, and N. Hidayati, "Effect of graphene oxide on the characteristics of speek-chitosan membranes for direct methanol fuel cells," *Automotive Experiences*, vol. 3, no. 1, pp. 1–5, 2020, doi: 10.31603/ae.v3i1.3039.

[5] F. B. Elehinafe, O. B. Okedere, Q. E. Ebong-Bassey, and J. A. Sonibare, "Data on Emission Factors of Gaseous Emissions from Combustion of Woody Biomasses as Potential Fuels for Firing Thermal Power Plants in Nigeria," *Mechanical Engineering for Society and Industry*, vol. 1, no. 2, pp. 75–82, 2021, doi: 10.31603/mesi.5548.

[6] A. Kolakoti, M. Setiyo, and B. Waluyo, "Biodiesel Production from Waste Cooking Oil: Characterization, Modeling and Optimization," *Mechanical Engineering for Society and Industry*, vol. 1, no. 1, pp. 22–30, 2021.

[7] M. Setiyo, D. Yuvenda, and O. D. Samuel, "The Concise Latest Report on the Advantages and Disadvantages of Pure Biodiesel (B100) on Engine Performance: Literature Review and Bibliometric Analysis," *Indonesian Journal of Science and Technology*, vol. 6, no. 3, pp. 469–490, 2021, doi: 10.17509/ijost.v6i3.38430.

[8] M. Wahyu, H. Rahmad, and G. J. Gotama, "Effect of Cassava Biogasoline on Fuel Consumption and CO Exhaust Emissions," *Automotive Experiences*, vol. 2, no. 3, pp. 97–103, 2019, doi: https://doi.org/10.31603/ae.v2i3.2991 Published.

[9] M. Renzi, M. Bietresato, and F. Mazzetto, "An experimental evaluation of the performance of a SI internal combustion engine for agricultural purposes fuelled with different bioethanol blends," *Energy*, vol. 115, pp. 1069–1080, 2016, doi: 10.1016/j.energy.2016.09.050.

[10] R. A. Alenezi, Erdiwansyah, R. Mamat, A. M. Norkhizan, and G. Najafi, "The effect of fusel-biodiesel blends on the emissions and performance of a single cylinder diesel engine," *Fuel*, vol. 279, no. X, 2020, doi: 10.1016/j.fuel.2020.118438.

[11] S. Mujiarto, B. Sudarmanta, H. Fansuri, and A. R. Saleh, "Comparative Study of Municipal Solid Waste Fuel and Refuse Derived Fuel in the Gasification Process Using Multi Stage Downdraft Gasifier," *Automotive Experiences*, vol. 4, no. 2, pp. 97–103, 2021.

[12] D. Singh *et al.*, "A comprehensive review of physicochemical properties, production process, performance and emissions characteristics of 2nd generation biodiesel feedstock: Jatropha curcas," *Fuel*, vol. 285, no. April 2020, p. 119110, 2021, doi: 10.1016/j.fuel.2020.119110.

[13] S. Syarifudin, F. L. Sanjaya, F. Fatkhurrozak, M. K. Usman, Y. Sibagariang, and H. Köten, "Effect Methanol, Ethanol, Butanol on the Emissions Characteristics of Gasoline Engine," *Automotive Experiences*, vol. 4, no. 2, pp. 62–67, 2020, doi: 10.31603/ae.4641.

[14] M. Göktaş, M. Kemal Balki, C. Sayin, and M. Canakci, "An evaluation of the use of alcohol fuels in SI engines in terms of performance, emission and combustion characteristics: A review," *Fuel*, vol. 286, no. July 2020. doi: 10.1016/j.fuel.2020.119425.

[15] M. K. Mohammed, H. H. Balla, Z. M. H. Al-Dulaimi, Z. S. Kareem, and M. S. Al-Zuhairy, "Effect of ethanol-gasoline blends on SI engine performance and emissions," *Case Studies in Thermal Engineering*, vol. 25, no. May 2020, p. 100891, 2021, doi: 10.1016/j.csite.2021.100891.

[16] S. Shirvani, S. Shirvani, A. H. Shamekhi, and R. D. Reitz, "A study of using E10 and E85 under direct dual fuel stratification (DDFS) strategy: Exploring the effects of the reactivity-stratification and diffusion-limited injection on emissions and performance in an E10/diesel DDFS engine," *Fuel*, vol. 275, no. April, p. 117870, 2020, doi: 10.1016/j.fuel.2020.117870.

[17] Z. Guo *et al.*, "Research on the combustion and emissions of an SI engine with acetone-butanol-ethanol (ABE) port injection plus gasoline direct injection," *Fuel*, vol. 267, no. February, p. 117311, 2020, doi: 10.1016/j.fuel.2020.117311.

[18] A. Biswal, S. Gedam, S. Balusamy, and P. Kolhe, "Effects of using ternary gasoline-ethanol-LPO blend on PFI engine performance and emissions," *Fuel*, vol. 281, no. July, p. 118664, 2020, doi: 10.1016/j.fuel.2020.118664.

[19] Q. Tang, P. Jiang, C. Peng, H. Chang, and Z. Zhao, "Comparison and analysis of the effects of spark timing and lambda on a high-speed spark ignition engine fuelled with n-butanol/gasoline blends," *Fuel*, vol. 287, no. August, p. 119505, 2021, doi: 10.1016/j.fuel.2020.119505.

[20] A. K. Thakur, A. K. Kaviti, R. Mehra, and K. K. S. Mer, "Progress in performance analysis of ethanol-gasoline blends on SI engine," *Renewable and Sustainable Energy Reviews*, vol. 69, no. December 2015, pp. 324–340, 2017, doi: 10.1016/j.rser.2016.11.056.

[21] S. M. Sarathy, A. Farooq, and G. T. Kalghatgi, "Recent progress in gasoline surrogate fuels," *Progress in Energy and Combustion Science*, vol. 65, pp. 67–108, 2018, doi: 10.1016/j.pecs.2017.09.004.

[22] Z. Liu, P. Sun, Y. Du, X. Yu, W. Dong, and J. Zhou, "Improvement of combustion and emission by combined combustion of ethanol premix and gasoline direct injection in SI engine," *Fuel*, vol. 292, no. November 2020, p. 120403, 2021, doi: 10.1016/j.fuel.2021.120403.

[23] A. Elfasakhany, "Gasoline engine fueled with bioethanol-bio-acetone-gasoline blends: Performance and emissions exploration," *Fuel*, vol. 274, no. April, p. 117825, 2020, doi: 10.1016/j.fuel.2020.117825.

[24] B. Sayin Kul and M. Ciniviz, "An evaluation based on energy and exergy analyses in SI engine fueled with waste bread bioethanol-gasoline blends," *Fuel*, vol. 286, no. P2, p. 119375, 2021, doi: 10.1016/j.fuel.2020.119375.

[25] I. Schifter, U. González, L. Díaz, R. Rodríguez, I. Mejía-Centeno, and C. González-Macías, "From actual ethanol contents in gasoline to mid-blends and E-85 in conventional technology vehicles. Emission control issues and consequences," *Fuel*, vol. 219, no. January, pp. 239–247, 2018, doi: 10.1016/j.fuel.2018.01.118.

[26] H. Y. Nanlohy, "Perbandingan Variasi Derajat Pengapian Terhadap Efisiensi Thermal Dan Konsumsi Bahan Bakar Otto Engine BE50," *Dinamika*, vol.3, no.2 pp. 1–4, 2012.

[27] X. Duan, M. Lai, M. Jansons, G. Guo, and J. Liu, "A review of controlling strategies of the ignition timing and combustion phase in homogeneous charge compression ignition (HCCI) engine," *Fuel*, vol. 285, no. May 2020, p. 119142, 2021, doi: 10.1016/j.fuel.2020.119142.

[28] R. K. Prasad, N. Mustafi, and A. K. Agarwal, "Effect of spark timing on laser ignition and spark ignition modes in a hydrogen enriched compressed natural gas fuelled engine," *Fuel*, vol. 276, no. May 2019, p. 118071, 2020, doi: 10.1016/j.fuel.2020.118071.

[29] I. Schifter, L. Diaz, J. P. Gómez, and U. Gonzalez, "Combustion characterization in a single cylinder engine with mid-level

hydrated ethanol-gasoline blended fuels," *Fuel*, vol. 103, pp. 292–298, 2013, doi: 10.1016/j.fuel.2012.06.002.

[30] P. Chansauria and R. K. Mandloi, "Effects of Ethanol Blends on Performance of Spark Ignition Engine-A Review," *Materials Today: Proceedings*, vol. 5, no. 2, pp. 4066–4077, 2018, doi: 10.1016/j.matpr.2017.11.668.

Performance and Emissions Analysis of BE85-Gasoline

ORIGINALITY REPORT

10%	3%	9%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

1%

★ Meltem Göktaş, Mustafa Kemal Balki, Cenk Sayin, Mustafa Canakci. "An evaluation of the use of alcohol fuels in SI engines in terms of performance, emission and combustion characteristics: A review", Fuel, 2021

Publication

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		

Performance and Emissions Analysis of BE85-Gasoline

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9