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Ethanol Blends Boost Engine Efficiency and Sustainability

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Abstract: This study evaluates the performance of an 80% ethanol and 20% pertamax fuel blend as an alternative to gasoline in internal combustion engines. Modifications included reducing the cylinder block by 2mm to modify piston overlap and adjusting the piston and combustion chamber design to increase the compression ratio. The experimental results indicate that this blend significantly enhances engine torque and fuel efficiency. These findings support the use of ethanol blends in automotive engines, offering a sustainable alternative to conventional fuels and contributing to the advancement of renewable energy utilization in the automotive sector.

Keywords: Compression Ratio; Efficiency; Engine Performance; Eethanol; Ignition Timing

INTRODUCTION

The increasing need in the Indonesian community for technology, especially motorcycles that can support and facilitate the continuity of activities in various aspects, especially in working.[1] However, the large number of these motorcycles has not yet created alternative fuels.[2] Motor vehicle manufacturers are also competing to mass produce their products. As a result, the use of petroleum will also increase.[3] Meanwhile, the availability of petroleum in the world has begun to dwindle due to the continuously increasing demand year after year.

Therefore, in today's era, innovation such as creating renewable alternative energy[4] is needed with the hope that it will reduce the use or dependence on petroleum and

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[1] Abdülvahap Çakmak and Hakan Özcan, 'Analysis of Combustion and Emissions Characteristics of a DI Diesel Engine Fuelled with Diesel/Biodiesel/Glycerol Tert-Butyl Ethers Mixture by Altering Compression Ratio and Injection Timing', *Fuel*, 315 (2022), 123200 <https://doi.org/10.1016/j.fuel.2022.123200>.

[2] C. Cannilla and others, 'Techno-Economic Feasibility of Industrial Production of Biofuels by Glycerol Etherification Reaction with Isobutene or Tert-Butyl Alcohol Assisted by Vapor-Permeation Membrane', *Journal of Industrial and Engineering Chemistry*, 98 (2021), 413–24 <https://doi.org/10.1016/j.jiec.2021.03.023>.

[3] Yuan Liu and others, 'Molecular Transformation of Petroleum Compounds by Hydroxyl Radicals Produced upon Oxidation of Reduced Nontronite', *Geochimica et Cosmochimica Acta*, 371 (2024), 31–51 <https://doi.org/10.1016/j.gca.2024.02.019>.

[4] Majd Olleik, Hans Auer, and Rawad Nasr, 'A Petroleum Upstream Production Sharing Contract with Investments in Renewable Energy: The Case of Lebanon', *Energy Policy*, 154 (2021), 112325 <https://doi.org/10.1016/j.enpol.2021.112325>.

can also increase performance more maximally[5] and create more efficient and environmentally friendly exhaust emissions.

The latest innovation to respond to the problem of diminishing petroleum fuel is also the preparation of more fuel-efficient automotive vehicles.[6] Modifications to the engine and more advanced supporting components are certainly energy-efficient without reducing the performance of the engine itself.[7] Engine changes that can be made include more perfect combustion[8] heat calorific savings, volumetric savings, and the savings of the energy itself.[9]

In addition to the problems of motor vehicle use and the very high use of fossil fuels, and the dwindling availability of fossil fuels[10] problems also arise from the exhaust gases produced by these motor vehicles, which are quite large[11] causing air pollution that needs to be addressed seriously. And with methanol and ethanol having a high octane value thus preventing engine detonation.[12]

With government regulations that eliminate ron 88 fuel replaced by ron 90 fuel[13] it shows that fuel is getting scarcer.[14] In addition to replacing ron 88 fuel with ron 99, our government is also developing alternative fuels, namely ethanol and bioethanol. The reason being that these fuels can be renewed and are environmentally friendly.

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[5] Julia Hartmann, Andrew C Inkpen, and Kannan Ramaswamy, 'Different Shades of Green: Global Oil and Gas Companies and Renewable Energy', *Journal of International Business Studies*, 52.5 (2021), 879–903 <https://doi.org/10.1057/s41267-020-00326-w>.

[6] Miska Olin and others, 'Engine Preheating under Real-World Subfreezing Conditions Provides Less than Expected Benefits to Vehicle Fuel Economy and Emission Reduction for Light-Duty Vehicles', *Applied Energy*, 351 (2023), 121805 <https://doi.org/10.1016/j.apenergy.2023.121805>.

[7] Hyein Jung and others, 'Hybrid Model Predictive Control for Hybrid Electric Vehicle Energy Management Using an Efficient Mixed-Integer Formulation', *IFAC-PapersOnLine*, 55.7 (2022), 501–6 <https://doi.org/10.1016/j.ifacol.2022.07.493>.

[8] Dominik Hertel, Gerald Bräunig, and Matthias Thürer, 'Towards a Green Electromobility Transition: A Systematic Review of the State of the Art on Electric Vehicle Battery Systems Disassembly', *Journal of Manufacturing Systems*, 74 (2024), 387–96 <https://doi.org/10.1016/j.jmsy.2024.03.013>.

[9] Sabri Baazouzi and others, 'Optimization of Disassembly Strategies for Electric Vehicle Batteries', *Batteries*, 7.4 (2021), 74 <https://doi.org/10.3390/batteries7040074>.

[10] Henri Oikarinen and others, 'Particle Number, Mass, and Black Carbon Emissions from Fuel-Operated Auxiliary Heaters in Real Vehicle Use', *Atmospheric Environment: X*, 16 (2022), 100189 <https://doi.org/10.1016/j.aeaoa.2022.100189>.

[11] Osman Güngör and others, 'District Heating Based on Exhaust Gas Produced from End-of-Life Tires in Erzincan: Thermoeconomic Analysis and Optimization', *Energy*, 294 (2024), 130755 <https://doi.org/10.1016/j.energy.2024.130755>.

[12] Weiming Song, Huilin Liu, and others, 'Dust Removal Ash Coupled with High-Temperature Exhaust Gas to Produce Energy Gas CO and Remove the Heavy Metals Synchronously', *Journal of Cleaner Production*, 410 (2023), 137217 <https://doi.org/10.1016/j.jclepro.2023.137217>.

[13] Weiming Song, Jianan Zhou, Yujie Li, Shu Li, and others, 'Utilization of Waste Tire Powder for Gaseous Fuel Generation via CO2 Gasification Using Waste Heat in Converter Vaporization Cooling Flue', *Renewable Energy*, 173 (2021), 283–96 <https://doi.org/10.1016/j.renene.2021.03.090>.

[14] Weiming Song, Jianan Zhou, Yujie Li, Jian Yang, and others, 'Production of High-Quality Combustible Gas: The Green and Efficient Utilization of Inferior Dust Removal Ash and High-Temperature Flue Gas in Converters', *Journal of Cleaner Production*, 269 (2020), 122265 <https://doi.org/10.1016/j.jclepro.2020.122265>.

Ethanol and bioethanol are the same substance, but they are obtained differently and contain the same component, which is alcohol.[15]

METHOD

The testing phase to be conducted will involve testing on the Honda Scoopyesp gasoline engine by changing the piston diameter and piston stroke to find the required compression ratio for combustion of Pertamax and ethanol fuel variations.

Using free variables with a standard compression ratio of 9.5:1 and modified to 13:1.

Using mixed fuel concentrations:

1. Ethanol 15% + Pertamax 75%.
2. Ethanol 30% + Pertamax 70%.
3. Ethanol 45% + Pertamax 55%.
4. Ethanol 60% + Pertamax 40%.
5. Ethanol 70% + Pertamax 30%.
6. Ethanol 80% + Pertamax 20%.

The tests conducted will determine which torque power is highest and which fuel usage is best at the modified ratios, as well as the impact on the efficiency of the fuel usage required.

RESULT AND DISCUSSION

In this study, there are calculated parameters and measured parameters. The calculated parameters include effective power (bhp), mean effective pressure (bmep), specific fuel consumption (sfc), and thermal efficiency. Meanwhile, the measured parameters are torque (kg.m), and fuel consumption time. The unit system used in this study is the SI unit system. Here is an example calculation of engine performance with a compression ratio (CR) of 13 using E80 bioethanol fuel at 5000 rpm. The measured data from this study, which is the initial data for the calculation, includes:

torque = 9.5 nm
power = 6.66hp = 4.971kw
engine speed = 5000 rpm
fuel consumption time = 60 seconds
fc = 0.72 l/hour

1. Fuel Consumption (fc)

In this study, fuel consumption is measured using an internal fuel pump, with variations of fuel mixtures using both modified compression and standard compression. Tested at 2000, 3500, and 5000 rpm, and read on a measuring glass located on the

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[15] Zhen Hu and others, 'Integrating Genetic-Engineered Cellulose Nanofibrils of Rice Straw with Mild Chemical Treatments for Enhanced Bioethanol Conversion and Bioaerogels Production', *Industrial Crops and Products*, 202 (2023), 117044 <https://doi.org/10.1016/j.indcrop.2023.117044>.

external fuel pump with a testing time of 60 seconds. CR=13 fueled by E80 bioethanol at 8000 rpm. The measured data from this study, which is the initial data for the calculation, is 5000 rpm, fuel consumption time 60 seconds, fc 0.72 l/hour.

2. Power Calculation

The power produced by an internal combustion engine comes in three types: brake horsepower (bhp), indicated horsepower (ihp), and friction horsepower (fhp). The power used in this calculation is brake horsepower (bhp). To obtain bhp, the following data is used:

torque = 8.83 nm
engine speed = 5000 rpm = 83.33 rps
Formula:
Bhp = 2 x π x n x t
Bhp = 2 x 3.14 x 83.331 s x 8.83 nm
Bhp = 4620 watts = 4.620 kw

3. Specific Fuel Consumption Calculation (sfc)

Initial data: - fuel consumption time = 60 s
From the initial data and previous calculation results above, the specific fuel

$$\mathrm{Sfc} = \frac{mbb}{bhp}$$

consumption (sfc) of the engine can be calculated. The formula used is:

Mbb= fuel mass flow rate, kg/hour
Bhp = engine power, watts
Therefore, it is also necessary to calculate the fuel flow rate entering through the intake manifold.

$$\mathrm{mbb} = \frac{\mathrm{Q}\,\boldsymbol{etanol + Volume\ BB}}{\mathbf{waktu}}$$

$$\mathrm{mbb} = \frac{798\frac{kg}{m}}{\qquad} \quad \frac{{}^{-4} \quad \frac{3}{3}}{\mathrm{jam}}$$

$$\mathrm{mbb} = 0{,}575\ \mathrm{kg/jam}$$

$$\mathrm{SFC} = \frac{0{,}575\ \mathrm{kg/jam}}{4971\mathrm{Watt}} \ \mathrm{x}\ \frac{1000watt}{1kw}$$

= 0,115kg/kw hour.

Analysis of Discussion Results

After mixing fuel and increasing the compression ratio, testing with dynotest found graphs and results of power and torque produced as follows:

Dynotest results data using a standard compression ratio of 9.5:1 with ethanol fuel mixture variations. Dynotest results data using a standard compression ratio of 9.5:1

with ethanol fuel mixture variations. This study used ethanol fuel by varying 6 different mixtures on a Honda 110 cc automatic engine with a compression ratio of 9.5:1. This test was conducted from 2000 to 8000 rpm at 1000 rpm intervals.

The first step was to position the 110 cc automatic motor onto the dynotest rollers and accelerate to peak rpm to find the necessary data. With the results:

Table 1. Comparison of torque and rpm with variations of ethanol and Pertamax fuel mixtures from dynotest results with compression ratio (9.5: 1)

RPM	E 15	E 30	*E 45*	E60	E70	E80
2000	2.68	2.98	3.23	3.12	3.67	3.01
3000	4.01	3.9	4.12	4.24	4.04	4.23
4000	5.22	4.98	4.9	5.03	4.58	5.04
5000	7.02	7.22	7.38	6.39	6.65	6.04
6000	7.98	8.22	8.78	7.24	7.47	6.83
7000	8.68	9.14	9.89	7.96	8.08	7.65
8000	9.47	9.9	10.51	8.45	8.51	8.57

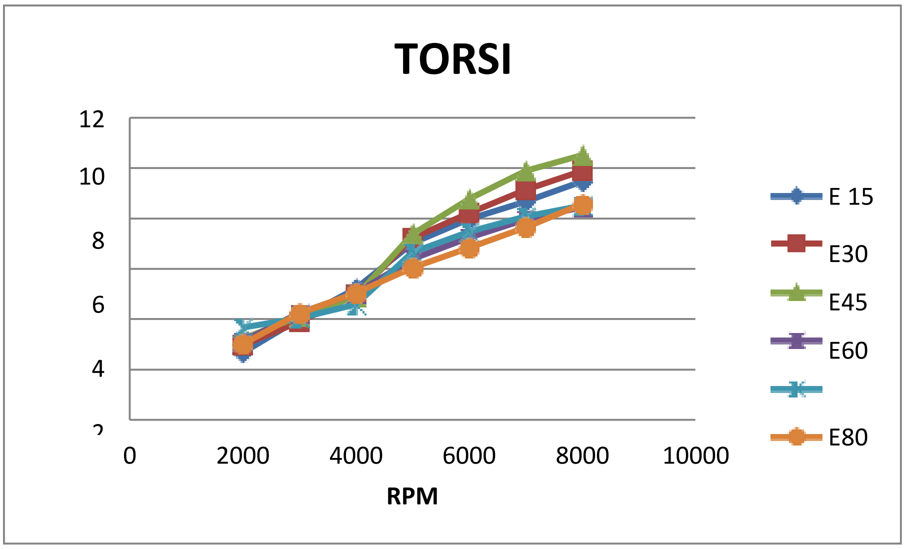

Figure 1. Torque and RPM Comparison at Standard compression (9.5:1)

From the torque versus RPM graph, it is evident there is a trend of increasing torque starting from low revolutions until reaching maximum torque at a certain RPM. Then, torque decreases at higher revolutions. This happens because the higher the engine speed, the greater the turbulence of the incoming flow to the combustion chamber, which results in better mixing of fuel and air and faster propagation of the flame, thus increasing torque. After the engine speed increases further, greater losses occur, such as friction losses and less perfect combustion. Higher engine speeds also result in greater friction. Additionally, the combustion of the fuel and air mixture in the combustion chamber takes time. At high speeds, it is possible that the ignition is not fast enough to burn all the fuel in the combustion chamber, or in other words, there is increasingly unburned fuel residue in the combustion chamber. In the graph, we limit the results of RPM versus torque to 8000 RPM because the author only takes the best torque data for the fuel mixture that matches the compression ratio.

The magnitude of torque is directly proportional to the pressure generated inside the combustion chamber. If the pressure is high, then the torque produced is high. In the torque versus RPM graph, the highest torque shifts to the right as the fuel mixture increases, but this variation in fuel mixture also affects the torque values produced.

At the standard compression ratio using a fuel mixture variation of ethanol and premium gasoline, the best graph is shown at E45. In other mixtures, torque decreases because with higher octane above 100, the less optimal pressure results in less optimal piston thrust, thus reducing the torque value.

1. Analysis of Power CR 9.5: 1

At low speeds, power is relatively low and will increase as engine speed increases. Theoretically, as engine speed increases, motor power also increases because power is a multiplication of torque and shaft rotation.

Table 2. Comparison of power and rpm at variations of ethanol and firstx fuel blends dynotes results with standard compression ratio (9.5: 1)

RPM	E15	E30	E45	E 60	E 70	E 80
2000	2.19	2.22	2.88	2.22	2.22	2.16
3000	3.03	3.22	3.7	3.13	2.9	3.1
4000	4.35	4.55	5.06	4.23	4.33	4.44
5000	5.66	5.83	6.2	5.14	5.79	5.74
6000	7.01	7.37	7.69	6.72	6.48	6.68
7000	8.28	8.69	9.03	7.33	7.53	7.81
8000	9.34	9.9	10.08	8.87	8.67	8.67

2. SFC Analysis of Specific Fuel Consumption 13:1

Specific Fuel Consumption (SFC) Analysis can be defined as the rate of fuel flow to obtain effective power. The value of specific fuel consumption depends on the mixture of air and fuel burned in the combustion chamber. With more complete combustion, the resulting SFC is better.

Table 3. Comparison of SFC and RPM in variations of ethanol and premium gasoline fuel mixtures from dyno tests with a compression ratio (13:1)

Mixed	2000	3500	5000
E15	0.128	0.124	0.111
E30	0.141	0.123	0.112
E45	0.138	0.128	0.115
E60	0.114	0.106	0.101
E70	0.118	0.115	0.108
E80	0.125	0.115	0.102

In general, the specific fuel consumption from low to high rpm will decrease until a certain engine speed will increase again. This is due to the higher turbulence of the flow along with the increase in engine speed, so that the homogeneity of the fuel and air mixture becomes good and produces more perfect combustion. The high and low fuel consumption in theory is influenced by the amount of power produced by the engine. Higher power becomes a divider in the calculation of fuel consumption. Sfc is best at e60 in compression 13. Where the sfc graph at a compression ratio of 13: 1 tends to be inhomogeneous caused by compression that is not high enough and causes indications of knocking on the engine this occurs in the mixture of e70 and e80.

CONCLUSION

This study successfully demonstrates the potential of ethanol-pertamax fuel blends as an effective alternative to conventional gasoline in internal combustion engines. The modifications made to the 110 cc Honda Scoopyesp engine, which included reducing the cylinder block and altering the piston geometry to increase the compression ratio, resulted in significant improvements in engine torque and fuel efficiency across various ethanol concentrations. Notably, a compression ratio of 13:1 using an E80 fuel mixture achieved the highest torque and power output, underscoring the benefits of higher ethanol content in enhancing engine performance. Furthermore, the E60 fuel mixture at this ratio also exhibited superior fuel efficiency, suggesting that such modifications could offer substantial benefits in terms of both performance and sustainability. These findings pave the way for further research into optimizing engine designs for higher ethanol blends and evaluating the long-term impacts on engine durability and emissions, contributing to the advancement of renewable energy utilization in the automotive sector.

CONFLICT OF INTEREST STATEMENT

The author[s] declare that this article was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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REFERENCES

Baazouzi, Sabri, Felix Paul Rist, Max Weeber, and Kai Peter Birke, 'Optimization of Disassembly Strategies for Electric Vehicle Batteries', *Batteries*, 7.4 (2021), 74 <https://doi.org/10.3390/batteries7040074>

Çakmak, Abdülvahap, and Hakan Özcan, 'Analysis of Combustion and Emissions Characteristics of a DI Diesel Engine Fuelled with Diesel/Biodiesel/Glycerol Tert-Butyl Ethers Mixture by Altering Compression Ratio and Injection Timing', *Fuel*, 315 (2022), 123200 <https://doi.org/10.1016/j.fuel.2022.123200>

Cannilla, C., G. Giacoppo, L. Frusteri, S. Todaro, G. Bonura, and F. Frusteri, 'Techno-Economic Feasibility of Industrial Production of Biofuels by Glycerol Etherification Reaction with Isobutene or Tert-Butyl Alcohol Assisted by Vapor-Permeation Membrane', *Journal of Industrial and Engineering Chemistry*, 98 (2021), 413–24 <https://doi.org/10.1016/j.jiec.2021.03.023>

Güngör, Osman, Alperen Tozlu, Cihat Arslantürk, and Emrah Özahi, 'District Heating Based on Exhaust Gas Produced from End-of-Life Tires in Erzincan: Thermoeconomic Analysis and Optimization', *Energy*, 294 (2024), 130755 <https://doi.org/10.1016/j.energy.2024.130755>

Hartmann, Julia, Andrew C Inkpen, and Kannan Ramaswamy, 'Different Shades of Green: Global Oil and Gas Companies and Renewable Energy', *Journal of International Business Studies*, 52.5 (2021), 879–903 <https://doi.org/10.1057/s41267-020-00326-w>

Hertel, Dominik, Gerald Bräunig, and Matthias Thürer, 'Towards a Green Electromobility Transition: A Systematic Review of the State of the Art on Electric Vehicle Battery Systems Disassembly', *Journal of Manufacturing Systems*, 74 (2024), 387–96 <https://doi.org/10.1016/j.jmsy.2024.03.013>

Hu, Zhen, Hao Peng, Jingyuan Liu, Huiyi Zhang, Sufang Li, Hailang Wang, and others, 'Integrating Genetic-Engineered Cellulose Nanofibrils of Rice Straw with Mild Chemical Treatments for Enhanced Bioethanol Conversion and Bioaerogels Production', *Industrial Crops and Products*, 202 (2023), 117044 <https://doi.org/10.1016/j.indcrop.2023.117044>

Jung, Hyein, Tae Hoon Oh, Hyun Min Park, Heeyun Lee, and Jong Min Lee, 'Hybrid Model Predictive Control for Hybrid Electric Vehicle Energy Management Using an Efficient Mixed-Integer Formulation', *IFAC-PapersOnLine*, 55.7 (2022), 501–6 <https://doi.org/10.1016/j.ifacol.2022.07.493>

Liu, Yuan, Yahe Zhang, Guo Chen, Yang Li, Qiang Zeng, Jinglong Hu, and others, 'Molecular Transformation of Petroleum Compounds by Hydroxyl Radicals Produced upon Oxidation of Reduced Nontronite', *Geochimica et Cosmochimica Acta*, 371 (2024), 31–51 <https://doi.org/10.1016/j.gca.2024.02.019>

Oikarinen, Henri, Miska Olin, Sampsa Martikainen, Ville Leinonen, Santtu Mikkonen, and Panu Karjalainen, 'Particle Number, Mass, and Black Carbon Emissions from Fuel-Operated Auxiliary Heaters in Real Vehicle Use', *Atmospheric Environment: X*, 16 (2022), 100189 <https://doi.org/10.1016/j.aeaoa.2022.100189>

Olin, Miska, Ville Leinonen, Sampsa Martikainen, Ukko-Ville Mäkinen, Henri Oikarinen, Santtu Mikkonen, and others, 'Engine Preheating under Real-World Subfreezing Conditions Provides Less than Expected Benefits to Vehicle Fuel Economy and Emission Reduction for Light-Duty Vehicles', *Applied Energy*, 351 (2023), 121805 <https://doi.org/10.1016/j.apenergy.2023.121805>

Olleik, Majd, Hans Auer, and Rawad Nasr, 'A Petroleum Upstream Production Sharing Contract with Investments in Renewable Energy: The Case of Lebanon', *Energy Policy*, 154 (2021), 112325 <https://doi.org/10.1016/j.enpol.2021.112325>

Song, Weiming, Huilin Liu, Yifeng Huang, Xiaoqing Chen, Sheng Zhang, and Jianan Zhou, 'Dust Removal Ash Coupled with High-Temperature Exhaust Gas to Produce Energy Gas CO and Remove the Heavy Metals Synchronously', *Journal of Cleaner Production*, 410 (2023), 137217 <https://doi.org/10.1016/j.jclepro.2023.137217>

Song, Weiming, Jianan Zhou, Yujie Li, Shu Li, and Jian Yang, 'Utilization of Waste Tire Powder for Gaseous Fuel Generation via CO2 Gasification Using Waste Heat in Converter Vaporization Cooling Flue', *Renewable Energy*, 173 (2021), 283–96 <https://doi.org/10.1016/j.renene.2021.03.090>

Song, Weiming, Jianan Zhou, Yujie Li, Jian Yang, Xiang Zhang, and Shu Li, 'Production of High-Quality Combustible Gas: The Green and Efficient Utilization of Inferior Dust Removal Ash and High-Temperature Flue Gas in Converters', *Journal of Cleaner Production*, 269 (2020), 122265 <https://doi.org/10.1016/j.jclepro.2020.122265>