Article citation info:
Leśny K, Włostowski R, Włóka A, Kaźmierczak A. Analysis of the possibilities of using alternative fuel mixtures as a substitute for conventional fuels. Combustion Engines. 2026;205(2):177-183. https://doi.org/10.19206/CE-214553

Kacper LEŚNY
Radosław WŁOSTOWSKI
Adriana WŁÓKA
Andrzej KAŹMIERCZAK

Combustion Engines
Polish Scientific Society of Combustion Engines

Analysis of the possibilities of using alternative fuel mixtures as a substitute for conventional fuels

ARTICLE INFO

Received: 18 June 2025
Revised: 13 October 2025
Accepted: 21 November 2025
Available online: 13 December 2025

In the face of growing requirements to reduce exhaust emissions and the need for more ecological solutions in the transportation sector, increasing attention is being paid to alternative fuels. This article examines the potential of using fuel mixtures containing bio-components, in particular alcohols and Sustainable Aviation Fuel (SAF), as a substitute for conventional fuels. The research focuses on two key aspects: composition of the fuel mixture and exhaust emissions. The research results aim to determine whether the proposed alternative fuel mixture can be an effective and more environmentally friendly alternative to conventional fuels, while maintaining suitable operating properties. The results of this work can be a valuable contribution to the development of sustainable fuel technologies, helping to reduce the negative impact of transportation on the environment.

Key words: *alternative fuels, exhaust gases analyzer, spark ignition engines, ethanol blends, emission reduction*

1. Introduction

In recent years, the global transportation sector has been facing growing pressure to reduce its environmental footprint due to the urgent need to mitigate climate change and comply with increasingly stringent emission standards. Road transport, in particular, remains a significant contributor to greenhouse gas emissions, as well as the production of nitrogen oxides (NO_x), carbon monoxide (CO), and particulate matter (PM), which not only exacerbate global warming but also have a substantial impact on air quality and public health. In this context, the development and implementation of alternative fuels have become a central focus of research and innovation.

Among various approaches to fuel decarbonization, blending conventional fossil-based fuels with renewable or oxygenated components such as alcohols or esters offers a relatively accessible and scalable strategy. Bioethanol, derived from biomass, is already widely used in gasoline blends (e.g., E10, E85). At the same time, ethyl acetate, a volatile organic ester, has emerged as a promising additive due to its oxygen content and combustion-enhancing properties. Simultaneously, aviation kerosene (Jet A-1), although not renewable, is of interest as a high-energy-density component that may stabilize combustion when used in multi-component blends, especially in experimental or transitional fuel systems.

This study aims to analyze the potential of alternative multi-component fuel blends – specifically those containing ethanol, ethyl acetate, and Jet A-1 – to act as viable substitutes for conventional gasoline. The research is focused on two key aspects: the composition of the proposed blend and its impact on pollutant emissions. A particular emphasis is placed on how such mixtures influence the formation of carbon monoxide and nitrogen oxides during combustion, as these are critical indicators of both efficiency and environmental impact.

The article is structured as follows. Section 2 presents a comprehensive literature review that summarizes existing research on alcohol-based fuels, oxygenated additives, and the role of hydrocarbon carriers, such as Jet A-1. Section 3 outlines the methodology for selecting alternative fuel components. Section 4 outlines the experimental methodology and test setup used to evaluate fuel performance and emissions. Section 5 discusses the results of laboratory tests, comparing the proposed blend against a conventional gasoline baseline. Finally, Section 6 concludes by assessing the feasibility of implementing alternative fuels in practical automotive applications and outlines directions for further research.

2. Biocomponents in engine fuels

2.1. Introduction

Among the various bio-components explored for fuel blends, ethanol remains prominent due to its capacity to enhance combustion efficiency and reduce toxic emissions. Analytical studies, such as those by Balat et al. and Srinivasan and Saravanan, have revealed that ethanol-gasoline blends, like E10 and E20, not only exhibit favorable ignition and combustion properties but also contribute to reductions in both CO and HC emissions. Ethanol's remarkable ability to enhance complete combustion is attributed to its molecular structure, which contains both carbon and significant amounts of oxygen, resulting in overall lower emissions when blended with gasoline [9, 10].

Moreover, the potential incorporation of other oxygenates such as ethyl acetate further enhances the stability and performance of these fuel blends. Ethyl acetate has been noted for improving volatility, thus enabling better cold-start capabilities, while reducing soot and particulate matter emissions – a characteristic highlighted in comparative studies of alcohol-blended fuels [3].

Additionally, the exploration of Jet A-1 kerosene in blends with ethanol and gasoline brings forth intriguing considerations regarding fuel properties, particularly with respect to volatility and heat release characteristics. The research indicates that the addition of Jet A-1 could mitigate particulate matter emissions while simultaneously stabilizing combustion under varying temperature and pressure conditions. Studies conducted within this scope suggest that although small proportions of Jet A-1 might lead to an increase in CO emissions due to incomplete fuel vaporization, the overall combinatory effects on emissions may warrant further investigation [6].

2.2. Ethanol

The use of ethanol, particularly in various proportions such as E10 (10% ethanol), E20 (20% ethanol), and E85 (85% ethanol), has been the subject of extensive research to assess its impact on emissions in spark-ignition engines. One of the primary benefits associated with higher ethanol content in fuel blends is the reduction in carbon monoxide (CO) emissions, largely attributed to ethanol's higher oxygen content. Studies demonstrate that the presence of oxygenate compounds in the fuel promotes more complete combustion, resulting in lower CO emissions across several engine test conditions. For instance, Wu et al. reported that variations in ethanol blending can result in significant reductions in CO emissions, with reductions of 20% to 25% when moving from gasoline to E10 blends, a trend also consistent with findings from Cesur et al., who highlighted the benefits of enhanced combustion characteristics provided by alcohol-based fuels [2, 12].

On the other hand, the effect of ethanol blends on nitric oxides (NO_x) emissions demonstrates a more complex relationship. At moderate ethanol concentrations, such as E10 and E20, studies indicate that while CO emissions decrease, NO_x emissions can increase due to higher combustion temperatures resulting from richer fuel blends. However, for high ethanol blends such as E85, the evaporative cooling effect of ethanol tends to lower combustion temperatures, potentially mitigating the rise in NO_x emissions observed at lower ethanol concentrations. This dual effect of ethanol on NO_x emissions is corroborated by multiple studies, including findings from He et al., Wu et al., and Syarifudin et al., where they reported that while NO_x can increase under certain conditions, the overall emissions profile changes favorably in terms of CO and hydrocarbons (HC) with increased ethanol content [3, 11, 13].

Moreover, unburned hydrocarbons, often exacerbated during cold starts, present another dimension to the emissions profile associated with ethanol-rich blends. Ethanol has lower volatility than traditional gasoline, resulting in delayed vaporization under colder starting conditions, which in turn can contribute to elevated HC emissions. Nevertheless, modern engine management systems have evolved to offset such undesirable effects by optimizing fuel injection and ignition timing. Research by Sasongko and Wijayanti indicated that incorporating ethanol enhances combustion due to increased oxygen availability, thereby leading to a significant reduction in hydrocarbons under optimal conditions [4, 11].

2.2. Jet A-1 kerosene as a fuel blend component

The inclusion of Jet A-1 kerosene into spark-ignition fuel blends introduces possibilities for altering emission profiles and enhancing fuel efficiency. Jet A-1's low volatility and high energy density create a stabilizing influence when blended with more volatile fuels, such as ethanol. Research indicates that such blends can result in lower NO_x emissions due to decreased combustion temperatures when designed judiciously. Moreover, the cooling characteristics of Jet A-1, combined with the combustion enhancements offered by alcohols, could create a unique synergistic effect beneficial to emission profiles [3].

Further analysis indicates that while Jet A-1 enhances combustion stability in ethanol blends, the interplay of fuel properties necessitates meticulous calibration of the air-fuel ratios and ignition timing. While higher ethanol blends may elevate the potential for aldehyde emissions, particularly acetaldehyde, concurrent evaluations challenge the emissions profiles against other regulated pollutants [9]. Continued scrutiny of potential detrimental emissions, in conjunction with the benefits of increased oxygen content, necessitates a balanced approach that emphasizes optimizing combustion parameters for both environmental compliance and vehicle performance.

2.3. Alternative fuel blends as gasoline substitutes

The integration of alternative fuels, such as ethanol and ethyl acetate, into gasoline presents a distinctive avenue for reducing greenhouse gas emissions. Studies have shown that when evaluated within the specific context of combustion efficiency, fuels blended with 10% to 20% ethanol can significantly reduce CO emissions and improve overall combustion outcomes when appropriately tuned [1, 13]. Ethanol-laden fuels not only satisfy the demand for more sustainable energy solutions but also demonstrate compatibility with existing fuel infrastructures, particularly for lower ethanol blends like E10. However, transitioning to higher blends, such as E85, necessitates evaluating potential evaporative emissions and incomplete combustion issues arising from the higher alcohol content, especially under high-temperature conditions [3, 8].

There's a compelling argument for developing additional research and long-term assessments of these alternative blends. During cold starts, as highlighted in several studies, including those of Solanki et al. and Elfasakhany, the challenges of managing varying vaporization properties necessitate focused insights for practical use, underscoring a gap that remains to be addressed before the widespread adoption of high-ethanol-content fuels [4, 10]. Further delineation of these effects will be critical in assessing the emissions trade-offs associated with the adoption of such biofuel alternatives.

2.4. Impact of fuel blends on pollutant emissions

A discernible trend is that particulate matter emissions tend to decrease with increasing ethanol concentrations, as evidenced by empirical data showing that E10 leads to significant reductions in PM emissions relative to conventional gasoline. The oxygenate characteristics of ethanol enable more efficient combustion, reducing the formation of soot and aromatic compounds and resulting in lower particulate emissions [7, 12].

Nevertheless, moving toward higher ethanol blends introduces complex dynamics related to aldehyde emissions, particularly acetaldehyde, which can reportedly increase by 50-70% when shifting from gasoline to E40 or higher

Table 1. Parameters of potential blend components

	Mass fraction	RON	Calculated RON	Specific energy [MJ/kg]	Calc. specific energy [MJ/kg]	Flame speed [m/s]	Calc. flame speed [m/s]	Flame temperature [°C]	Calc. flame temperature [°C]
Gasoline	0	95	0	46	0	0.50	0	2100	0
Ethyl acetate	0.28	118	32.85	27	7.52	0.45	0.13	2100	584.66
Kerosene (Jet A-1)	0.22	30	6.65	44	9.75	0.35	0.08	2100	465.34
Methanol	0	112	0	20	0	0.45	0	1900	0
Ethanol	0.50	111	55.50	27	13.50	0.50	0.25	1900	950
Total	1								

blends. This necessitates careful monitoring and potential integration of advanced after-treatment systems designed to capture and reduce unregulated pollutants in these fuel blends [3, 12]. Furthermore, temperature effects – especially with blends containing E20 to E40 – demonstrate cooling due to ethanol evaporation, which counteracts the formation of NO_x emissions. This can translate into reductions in NO_x emissions compared to gasoline, aligning well with regulatory frameworks that mandate lower emissions standards [5, 13].

In summary, while the move toward higher ethanol blends showcases the promise of decreased CO and HC emissions, specific operational parameters must be optimized to avoid potential pitfalls, such as increased aldehyde emissions, and to strike a balance between emissions outcomes for regulated and unregulated pollutants. The complexities of combustion dynamics necessitate extensive future research focused on fine-tuning engine configurations, optimizing fuel management systems, and developing after-treatment solutions to mitigate any unintended consequences of emissions.

3. Selection of fuel components

Based on a literature review, components were selected and then analyzed to select the appropriate proportions. The composition of the analyzed mixture was determined using a spreadsheet that contained fuel parameters and the Solver add-on, with established boundary conditions for the mixture. All calculations were performed for each component of the mixture by multiplying its properties by its mass fraction. The values were then summed to obtain the properties for the entire mixture. To achieve NO_x reduction, the average flame temperature for the fuel was set to a maximum of 2000 degrees. The average flame propagation velocity, calculated based on the mass fraction of components, was set to a minimum of 0.4 m/s. The value of the octane number for the mixture was set to a minimum of RON 95. The specific energy was not set as a target and the goal of the solver solution was to obtain the highest possible value. After the analysis, the weight composition of the mixture was set as follows: 50% ethanol, 28% ethyl acetate, and 22% JET A-1 kerosene, which was later named E50EA28K22. The calculations and parameters are presented in Table 1.

Kerosene is primarily used as an ingredient to increase calorific value. The octane number and combustion speed when using only alcohols are higher than in the case of adding kerosene, however, in the aspect under consideration, there is no need to obtain a higher octane number than standard E10 petrol. In contrast, without kerosene participation, there is a significant decrease in specific energy, resulting in higher fuel consumption. The calculated decrease in calorific value (Equation 1) compared to petrol is approximately 33%. Table 2 presents the expected emission levels resulting from the combustion of the fuels. This table was taken into consideration when choosing fuel blend components and helped achieve the expected results.

$$\Delta SE = (1 - \frac{CSE}{SE}) \times 100\% \quad (1)$$

$$\Delta SE = (1 - \frac{30.77}{46}) \times 100\%$$

$$\Delta SE \approx 33.11\%$$

where: ΔSE – specific energy difference [%], CSE – calculated specific energy of the blend [MJ/kg], SE – specific energy of gasoline [MJ/kg].

Table 2. Assumed emission profiles

Fuel	CO_2 [g/MJ]	CO	NO_x	HC	PM
Gasoline	~73	High	Medium	High	Medium
Kerosene (Jet A-1)	~72	High	Medium	Medium	Medium
Ethanol	~69	Medium	Low	Medium	Low
Methanol	~67	Medium	Low	Medium	Low
Ethyl acetate	~65	Medium	Medium	Medium	Low

4. Description of the measuring station and measurement methodology

In order to carry out the measurements, a test stand was built, containing a power generator in which engine fuel mixtures were burned. Diagram of the measuring system is shown in Fig. 1.

The measuring station comprises a Honda EU22 generator and a Stage V-compliant single-cylinder combustion engine with a displacement of 120 cm³, as well as an AC generator with a nominal power of 2.2 kW. To generate a torque load on the combustion engine, resistors were electrically connected in the generator circuit to measure the generated electrical power. Fuel consumption was measured by measuring the mass loss of the fuel container in defined time intervals using a Radwag APP 35.3Y.1 precision scale (d = 0.1 g). The measurement of exhaust component concentrations was performed using a Horiba PG-300 and a MAHA MET6.3 exhaust gas analyzer. The measuring ranges of the analyzers are presented in Table 3.

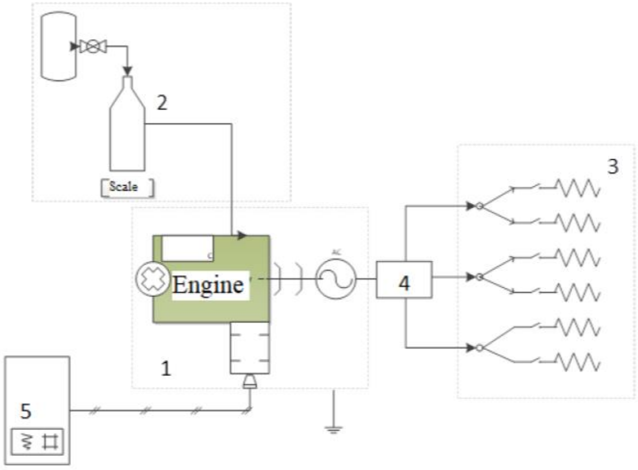

Fig. 1. Measuring system: 1 – generator, 2 – mass fuel consumption measurement system, 3 – resistive load, 4 – wattmeter, 5 – exhaust gas analyzers

Table 3. Measuring ranges

Device		Range	Repeatability
Horiba PG300	CO	0–10,000 ppm	±0.5% FS
	CO_2	0–20% vol	±0.5% FS
	NO	0–2500 ppm	±0.5% FS
	SO_2	0–200 ppm	±0.5% FS
MAHA MET 6.3	HC	0–30,000 ppm	±0.5% FS
	Lambda	0–9.9	–
	O_2	0–25% vol	±0.02% FS

Six measurement points were determined for different electrical load configurations. Due to the difference in energy delivered per unit mass for the tested fuels, it was necessary to adjust the throttle opening angle. This was achieved using a lever to obtain an excess air coefficient of 1. Adjustment was necessary for each load change. After setting the appropriate throttle opening angle value, the unit was operated for about 2 minutes to stabilize the values on the exhaust gas analyzers. Then, fuel consumption and the values of the measured compounds in the exhaust gases were recorded. For each fuel, the measurements at all points were repeated three times in order to obtain an average of the measurements.

5. Results

Table 4 presents data read from the wattmeter, exhaust gas analyzers, and calculated fuel consumption for E10 petrol. At point 6, the NO measurement range for the analyzer was exceeded. However, this point is not taken into account in the final comparison due to probable measurement inaccuracy.

The average results for the E50EA28K22 blend are shown in Table 5. Measurement point number 6 was rejected because the engine did not achieve sufficient torque to maintain the specified load for the tested alternative mixture. This is due to the lower calorific value of the fuel. Therefore, the average of 5 points was taken for comparison.

Comparison of the fuels for each corresponding measuring point is shown in Table 6. Point number 6 is included for transparency regarding each fuel blend; however, it is not considered in the comparison. The average change was calculated and is shown in Fig. 2. The average emission changes of E50EA28K22 relative to E10 are as follows:

- Nitrogen oxides (NO_x) – E50EA28K22 showed a reduction of ~30% in NO_x emissions. This is attributed to the cooling effect of ethanol evaporation and lower combustion temperatures compared to gasoline. The high oxygen content of the blend also promotes more complete combustion at lower temperatures.
- Hydrocarbons (HC) – Unburned hydrocarbon emissions decreased by ~10% for the alternative blend. Ethanol and ethyl acetate enhance oxidation during combustion, thus reducing HC emissions.
- Carbon monoxide (CO) – CO emissions were reduced by approximately 5% with the alternative blend. This is likely due to the high oxygen content of ethanol and ethyl acetate, which supports more complete combustion and reduces the formation of partial oxidation products, such as CO.
- Sulfur dioxide (SO_2) – A significant increase in SO_2 (~65%) was observed with the E50EA28K22 blend. This is directly linked to the sulfur content in Jet A-1, which remains much higher than the ultra-low sulfur levels mandated for gasoline. This result underscores the need for cleaner kerosene alternatives such as Sustainable Aviation Fuels (SAF).
- Carbon dioxide (CO_2) – CO_2 emissions increased by about 10%. This is consistent with the reduced CO levels and indicates a more complete oxidation of carbon-containing compounds to CO_2, a sign of improved combustion efficiency.

Lambda values for both fuels remained centered around 1, confirming stoichiometric combustion. The throttle adjustments and real-time lambda monitoring ensured consistent excess air levels, validating the methodology and reproducibility of the experimental results. The comparison only shows average changes for different fuels, serving as a summary indicator of relative trends.

Table 4. Results for gasoline E10

Average										
Measuring point	Assumed electrical power	Electrical power	Fuel consumption	HC	Lambda	NO	CO	CO_2	O_2	SO_2
[-]	[W]	[W]	[g/s]	[ppm]	[-]	[ppm]	[ppm]	[% vol]	[% vol]	[ppm]
1	0	0	0.15	228	1.027	27	8070	4.56	8.81	73.40
2	650	708	0.17	133	0.984	95	8570	6.96	6.62	20.10
3	850	907	0.17	111	0.988	195	8914	9.05	4.72	17.50
4	1300	1377	0.18	86	0.976	1232	7703	13.22	1.31	13.70
5	1500	1556	0.19	71	0.995	1914	5285	14.27	0.75	12.50
6	2150	2166	0.25	69	0.995	2803	4519	14.54	0.52	12.50

Table 5. Results for E50EA28K22 blend

Average										
Measuring point	Assumed electrical power	Electrical power	Fuel consumption	HC	Lambda	NO	CO	CO_2	O_2	SO_2
[-]	[W]	[W]	[g/s]	[ppm]	[-]	[ppm]	[ppm]	[% vol]	[% vol]	[ppm]
1	0	0	0.19	222	1.023	23	8414	5.43	8.58	66.27
2	650	708	0.22	127	0.981	69	8842	8.26	5.84	34.50
3	850	908	0.22	91	0.983	121	9136	9.62	4.87	29.20
4	1300	1377	0.25	76	0.981	820	6832	13.90	1.13	26.83
5	1500	1556	0.27	62	1.003	1253	3920	14.61	0.78	25.40
6	2150	1717	0.30	64	1.009	1523	3381	14.69	0.75	24.67

Table 6. Comparison of the E50EA28K22 to gasoline E10

Average									
Measuring point	Electrical power	Fuel consumption	HC	Lambda	NO	CO	CO_2	O_2	SO_2
[-]	[W]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
1	0	26.8	–2.6	-0,4	–16.0	4.3	19.2	–2.6	–9.7
2	708	35.0	–4.5	-0,3	–27.4	3.2	18.7	–11.8	71.6
3	907	29.3	–18.0	-0,5	–38.2	2.5	6.3	3.2	66.9
4	1377	36.3	–12.0	0,5	–33.5	–11.3	5.1	–14.0	95.9
5	1556	41.7	–12.2	0,8	–34.5	–25.8	2.4	4.0	103.2

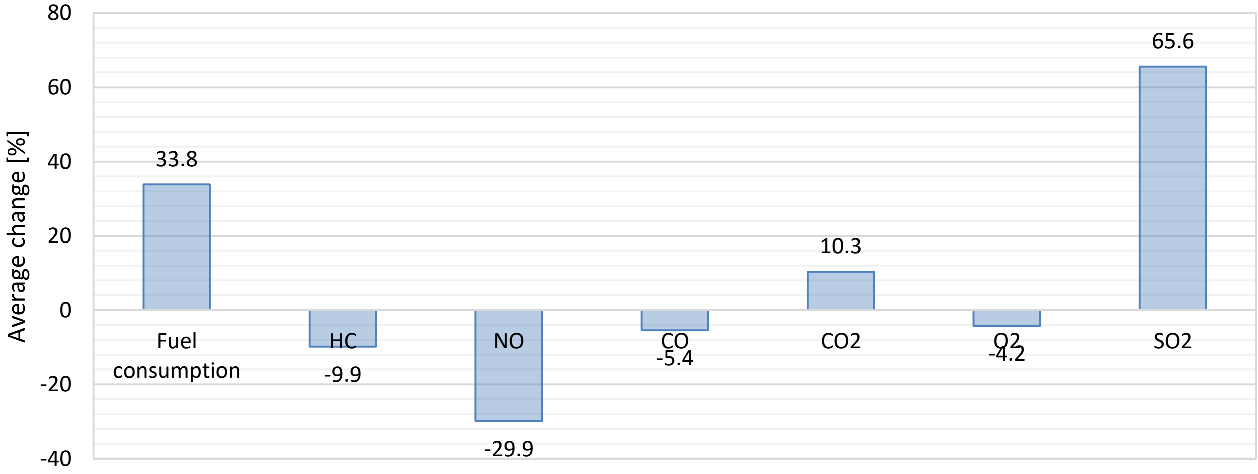

Fig. 2. Average change in comparison of the fuels

The addition of kerosene to the fuel causes a significant increase in sulfur dioxide, due to the fuel's chemical composition. The ASTM D1655 standard specifies a maximum sulfur content of 3000 ppm in aviation kerosene. This is 300 times more than the allowable content for gasoline, which is 10 ppm. Typically, the sulfur content in JET A-1 is lower, at around 500 ppm. Additionally, since the kerosene content in the mixture is only 22%, chemical analyses must be performed to determine the exact sulfur content. The studies focused only on the emission of sulfur dioxide during combustion.

Table 7 shows measured fuel consumption and electrical power for E10 gasoline. Later, specific fuel consumption was calculated using Equation 2. The same data is shown for E50EA28K22 blend in Table 8. The first measurement point is not taken into account because the generator was operating without an electrical load, so the generated electrical power is equal to 0. However, this does not mean that the engine generates zero power; due to the measurement of only electrical power, it is not possible to determine the mechanical power. If the power is assumed as 0, the specific fuel consumption will also be 0, which is not in accordance with reality.

Table 7. Fuel consumption of E10 gasoline

E10			
Measuring point	Fuel consumption	Electrical power	Specific fuel consumption
[–]	[g/s]	[W]	[g/kWh]
2	0.17	708	838.86
3	0.17	907	676.71
4	0.18	1377	480.91
5	0.19	1556	440.81
6	0.25	2166	420.09

Table 8. Fuel consumption of E50EA28K22

E50EA28K22			
Measuring point	Fuel consumption	Electrical power	Specific fuel consumption
[–]	[g/s]	[W]	[g/kWh]
2	0.22	708	1132.82
3	0.22	908	874.80
4	0.25	1377	655.27
5	0.27	1556	624.54
6	0.30	1717	634.68

$$g_u = \frac{G_u \cdot 3600000}{N_u} \quad (2)$$

where: g_u – specific fuel consumption [g/kWh], G_u – mass fuel consumption [g/s], Nu – electrical power [W].

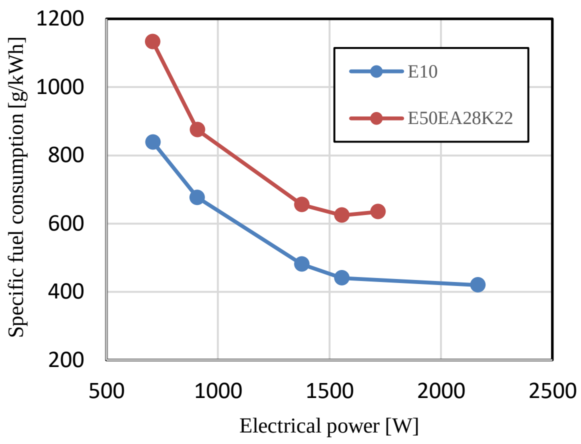

Fig. 3. Specific fuel consumption

The test results showed a clear increase in fuel consumption for the E50EA28K22 blend compared to conventional E10 gasoline (Figure 3). This was anticipated due to the lower specific energy content of the alternative mixture. On average, specific fuel consumption increased by approximately 34%, necessitating a greater mass of fuel to maintain the same power output. This trade-off highlights a limitation in energy density but may be justified by improvements in emission performance.

6. Conclusions

This study demonstrates the potential of a novel multi-component fuel blend composed of 50% ethanol, 28% ethyl acetate, and 22% Jet A-1 kerosene as a feasible substitute for conventional E10 gasoline in spark-ignition engines. The blend was engineered to balance octane requirements, flame speed, and combustion temperature while maximizing energy efficiency within the constraints of regulated emissions.

Key findings include:

– Reduced Emissions: The alternative blend significantly lowered NO_x emissions (by ~30%) and unburned hydrocarbons (by ~10%) compared to E10, indicating more complete and cleaner combustion due to the oxygen-rich alcohols.
– Increased Fuel Consumption: Due to its lower specific energy, the blend required a higher fuel mass flow to maintain equivalent power output, resulting in a ~34% increase in fuel consumption.
– Trade-off in SO_2 Emissions: The addition of Jet A-1 increased sulfur dioxide emissions, highlighting a trade-off between calorific value enhancement and environmental impact, especially regarding sulfur content.
– Feasibility for Transition Fuels: Despite limitations, the blend meets standard octane requirements (RON 95) and performs within acceptable emission limits, making it a strong candidate for use in transitional or supplementary fuel systems.
– Substitution of Jet A-1 with Sustainable Aviation Fuels (SAF): SAFs derived from biomass, waste oils, or synthetic pathways offer lower sulfur content and improved lifecycle emissions profiles. Their use could mitigate the SO_2 emissions observed with Jet A-1 while maintaining the desired combustion stability.

Future research should focus on long-term engine durability, cold-start performance, and after-treatment systems to mitigate sulfur-related emissions. By replacing Jet A-1 kerosene with Sustainable Aviation Fuel, future fuel designs can better align with both regulatory emissions targets and sustainability goals. It should also be performed on a dyno with a combustion engine, which will allow for the analysis of exhaust gases at different loads and with different rotational speeds.

Nomenclature

CO	carbon monoxide
CO_2	carbon dioxide
HC	hydrocarbons
NO	nitrous oxide
PM	particulate matter
RON	research octane number
SAF	sustainable aviation fuels
SO_2	sulfur dioxide

Bibliography

[1] Bielaczyc P, Szczotka A, Woodburn J. A study of gasoline-ethanol blends influence on performance and exhaust emissions from a light-duty gasoline engine. SAE Technical Paper 2012-01-1052. 2012. https://doi.org/10.4271/2012-01-1052

[2] Cesur İ, Eren B, Zengin A. Reducing emissions and promoting environmental sustainability in spark-ignition engines with isopropyl alcohol blends. International Conference on Modern and Advanced Research. Konya 2023. https://doi.org/10.59287/icmar.1264

[3] Chen M. A review of research on emission characteristics of ethanol-diesel blends in diesel engines. Trends in Renewable Energy. 2023;9(1):1-12. https://doi.org/10.17737/tre.2023.9.2.00155

[4] Kumar R, Chaurasia O. A review on performance and emissions of compression ignition engine fueled with ethanol-diesel blend. Journal Européen Des Systèmes Automatisés. 2019;52(2):205-214. https://doi.org/10.18280/jesa.520214

[5] Qadiri U, Wani M. Performance combustion and emission characteristics of 3-cylinder SI engine fuelled conventional gasoline, ethanol blends, and micro-emulsion used as an alternative fuel. Math Model Eng Probl. 2019;6(4):541-549. https://doi.org/10.18280/mmep.060409

[6] Sasongko M. and Wijayanti W.. Effect of ethanol addition on the performance and exhaust emissions of a spark ignition engine. J Mech Eng Sci. 2017;11(2):2734-2742. https://doi.org/10.15282/jmes.11.2.2017.14.0248

[7] Seggiani M, Prati M, Costagliola M, Puccini M, Vitolo S. Bioethanol–gasoline fuel blends: exhaust emissions and morphological characterization of particulate from a moped engine. Journal of the Air & Waste Management Association. 2012;62(8):888-897. https://doi.org/10.1080/10962247.2012.671793

[8] Sharudin H, Abdullah N, Najafi G, Mamat R, Masjuki H. Investigation of the effects of iso-butanol additives on spark ignition engine fuelled with methanol-gasoline blends. Appl Therm Eng. 2017;114:593-600. https://doi.org/10.1016/j.applthermaleng.2016.12.017

[9] Solanki T, Jain S, Goyal A. Analysis on emissions of gasoline engine with different ethanol blends at different compression ratio. Ymer Digital. 2022;21(08):18-28. https://doi.org/10.37896/ymer21.08/04

[10] Srinivasan C, Saravanan C. Emission reduction on ethanol–gasoline blend using fuel additives for an SI engine. Energy Sources Part A: Recovery Utilization and Environmental Effects. 2013;35(12):1093-1101. https://doi.org/10.1080/15567036.2011.584114

[11] Syarifudin S, Sanjaya F, Fatkhurrozak F, Usman M, Sibagariang Y, Köten H. Effect methanol, ethanol, butanol on the emissions characteristics of gasoline engine. Automotive Experiences. 2021;4(2):62-67. https://doi.org/10.31603/ae.4641

[12] Wu T, Chang C, Wu T, Shen Y. Emission characteristics of ethanol blending fuels from a laboratory gasoline engine. Applied Mechanics and Materials. 2012;253-255:2227-2230. https://doi.org/10.4028/www.scientific.net/amm.253-255.2227

[13] Wu T, Hsu Y, Wu T. Comparisons of alcohol blending fuels' emission from a laboratory gasoline engine. Adv Mater Res. 2013;772:536-542. https://doi.org/10.4028/www.scientific.net/amr.772.536

Kacper Leśny, MEng. – Faculty of Mechanical Engineering, Wrocław University of Science and Technology, Poland.
e-mail: *kacper.lesny@pwr.edu.pl*

Adriana Włóka, MEng. – Faculty of Mechanical Engineering, Wrocław University of Science and Technology, Poland.
e-mail: *adriana.wloka@pwr.edu.pl*

Radosław Włostowski, DEng. – Faculty of Mechanical Engineering, Wrocław University of Science and Technology, Poland.
e-mail: *radoslaw.wlostowski@pwr.edu.pl*

Prof. Andrzej Kaźmierczak, DSc., DEng. – Faculty of Mechanical Engineering, Wrocław University of Science and Technology, Poland.
e-mail: *andrzej.kazmierczak@pwr.edu.pl*