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The Effect of a Mixture of Methanol and Gasoline on the Operation of an Engine in an Electric Power Generator System

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Methanol, a type of alcohol, with gasoline, a conventional fossil fuel used in internal combustion engines. This blending process is often done to create an alternative fuel that may have certain advantages over using gasoline alone. The combination of methanol and gasoline can offer benefits such as improved combustion efficiency, reduced emissions, and potentially lower overall fuel costs. Methanol has a high-octane rating, which can enhance the combustion characteristics of the fuel mixture. This can lead to more efficient and cleaner combustion in internal combustion engines. Conducting this research is essential to explore potential improvements in fuel efficiency, emission reduction, and overall system performance, which are critical for advancing sustainable energy solutions. The tests were done using a mobile generator Briggs and Stratton ProMax 3500A. The tested fuels were 10 %, 20 % and 50 % blends of methanol in gasoline. The electrical output of the generator was roughly the same for all fuels even at higher load, however consumption increased significantly. The mixtures had a negative effect on the stability of engine operation and engine emissions had a negative effect at most of the measurement points. In some cases, like the concentration of formaldehyde by weight, gasoline fuel mixtures showed a decrease in mass concentration at lower engine loads and an increase at higher loads compared to the reference fuel.

Keywords: Alcohol, Biofuels, Sustainable energy, Emissions, Efficiency

1 Introduction

In pursuit of sustainable energy solutions, the blending of methanol with gasoline emerges as a compelling strategy to mitigate the environmental impact of conventional fossil fuels. (1) Methanol, a versatile alcohol, possesses distinct properties that make it an attractive candidate for fuel blending, offering both environmental and economic advantages. (1, 3) When combined with benzine, methanol creates a blended fuel that not only retains the desirable properties of gasoline but also introduces cleaner-burning characteristics, reducing overall emissions and enhancing the fuel's combustion efficiency. (4)

Methanol, with its chemical formula CH_3OH, is a liquid alcohol that can be derived from various sources, including natural gas, biomass, and even carbon dioxide. (4) Its compatibility with gasoline makes it an ideal candidate for blending, as it seamlessly integrates into existing fuel infrastructure and engines. (4, 5) The blending of methanol and benzine capitalizes on the strengths of both components, with methanol acting as an oxygenate and combustion enhancer. (5, 6) This blending strategy is particularly relevant in regions where regulations mandate the use of oxygenated fuels to reduce air pollution and improve air quality. (5, 6)

The environmental benefits of methanol-gasoline blends are noteworthy. (6) Methanol has a higher-octane rating than traditional gasoline, contributing to improved engine performance and efficiency. (6, 7) Furthermore, the combustion of methanol produces fewer harmful pollutants such as carbon monoxide and particulate matter, fostering a cleaner and more sustainable combustion process. (7, 8) As the world grapples with the challenges of climate change and air quality, the adoption of methanol-gasoline blends represents a tangible step towards meeting stringent emission standards and reducing the overall carbon footprint of the transportation sector. (9)

New vehicles have higher requirements for the reliability of their devices. (10) Methanol-gasoline blends may affect engine wear, especially the surface created by machining, which significantly affects the service life and functional reliability of the component. (12, 13)

Biofuels often have different physical and chemical properties compared to traditional fossil fuels, such as different lubrication characteristics, higher oxygen content, and different thermal conductivity. These dif-

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ferences can lead to increased wear on engine components, such as cylinders, pistons, and fuel injectors. (11) Corrosion can also be an issue, as biofuels may contain higher levels of water and organic acids, which can cause rusting of metal parts in the engine. (11, 14) Although modern engines are often designed to be compatible with a certain percentage of biofuels, the long-term use of pure biofuels may require special additives or engine modifications to minimize these negative impacts. (14)

The aim of this paper is the operational verification and analysis of the applicability of the selected fuels focused on the operational parameters of engine in an electric power generator system.

2 Materials and methods

The measurement was focused on the use of methanol–gasoline blends in engine of electric power generator. For the measurement 10, 20 and 50 % concentrations of methanol in gasoline fuel were used.

Tab. 1 *Basic properties of the fuels*

Fuel	Kinematic viscosity at 15 °C (mm² s⁻¹)	Density at 15 °C (kg m⁻³)	Calorific value (MJ kg⁻¹)	Octane number research method (RON)	Evaporative heat (kJ kg⁻¹)	Ried vapor pressure (kPa)	Carbon content (%wt)	Hydrogen content (%wt)	Oxygen content (%wt)
BA95	0.442	754.47	44 [1]	min. 95 [2]	349 [1]	60–90 [2]	87.5 [1]	9.8–12.5	0–2.7 [2]
Methanol	0.782	797.57	19.6	108.7 [1]	1180 [3]	32.4 [1]	37.5	12.6	49.9
M10	0.479	757	41.4	-	-	-	82.2	10.1	7.7
M20	0.521	760.33	38.9	-	-	-	77	10.4	12.6
M50	0.607	775.33	31.5	-	-	-	61.8	11.2	27

Tab. 2 *Basic parameters of the Briggs and Stratton ProMax 3500A generator*

Electrical parameters	
Parameter	**Specification**
Producer	Briggs & Stratton Vanguard
Type	PROMAX 3500A
Rated power	2.7 kW
Output voltage	230 V
Output Frequency	50 Hz
Output current	11.6 A
Engine parameters	
Parameter	**Specification**
Producer	Vanguard
Type	030395
Rated power	2.7 kW
Max. torque	18.7 Nm at 2,880 rpm
Cooling	Air
Fuel tank capacity	15 l
Weight	51 kg
Operating time at 50 % load	13hr. 26 min
Fuel consumption at 50 % load	1.12 l/h

Due to the different stoichiometric ratio of methanol, given by its high oxygen content, a choke was used to maintain the air excess coefficient λ ≈ 1 when measuring.

Fig. 1 *Briggs and Stratton ProMax 3500A*

Fuel consumption was measured using a Vibra AJ 6200 laboratory scale (accuracy 0.1g, resolution 0.01g), on which an external fuel tank was placed. Electrical parameters were measured using a ZPA ED310 power meter, equipped with RS485 (accuracy 0.05%). The frequency was used to recalculate the engine speed. Data from the electricity meter and from the laboratory scale were stored on the hard disk using the RS482 to RS232 interface and the LabView application developed for this purpose with a frequency of 1 Hz.

For the purposes of this measurement, five specific measuring points were determined and calibrated using electric direct heaters that function as resistors, with each step being approximately 650 W. The measurements were conducted under stable conditions, ensuring that the engine operated consistently at various load levels. These load levels were as follows:

- Idle – 0% load (point no. 1),
- 650 W – approximately 25% load (point no. 2),
- 1300 W – approximately 50% load (point no. 3),
- 1950 W – approximately 75% load (point no. 4),
- 2600 W – 99% load (point no. 5).

This approach was designed to cover a broad range of operating conditions, from no load at all to nearly full load, providing a comprehensive understanding of the engine's performance and behavior under different stress levels.

Once the engine's operating conditions stabilized at each measuring point, a range of parameters were meticulously recorded. These included electrical parameters such as current, voltage, and frequency. Additionally, fuel consumption was monitored to assess the engine's efficiency at each load level. Emissions data were also gathered, focusing on the production of gaseous components, to evaluate the environmental impact under various operating conditions. The data collection was carried out with precision, ensuring that all parameters were recorded at the appropriate frequency for a duration of approximately one minute. This methodical approach allowed for accurate and reliable data, providing valuable insights into the engine's performance metrics across the specified load range. A Bruker MATRIX-MG5 FTIR (Fourier-transform infrared) spectroscopic analyzer was used to analyze the gaseous components of the emissions. OPUS Gas Analysis, the software package supplied by the manufacturer of the analyzer, was used to evaluate individual components of emissions from spectral data. Data from the emission analyzer was recorded on a hard disk with a frequency of 5 Hz. Both regulated and unregulated harmful components of exhaust gases were evaluated. Specifically, the following gaseous components of the emissions were concerned:

Carbon dioxide – CO_2, Carbon monoxide – CO, Nitric oxide – NO, Nitrogen dioxide – NO_2, Nitrous oxide – N_2O, Methane – CH_4, Formaldehyde – HCHO, Acetaldehyde – CH_3CHO

The measurement was made using a Briggs and Stratton ProMax 3500A gasoline generator (Figure 1). The basic parameters of the generator are listed in Table 2.

3 Results and discussion

Consistent with other studies (15,16) adding methanol to gasoline increases both kinematic and dynamic viscosity compared to BA95, this slight increase in viscosity can affect fuel injection and atomization, potentially impacting combustion efficiency and stability. The calorific value of fuel mixtures decreases with higher concentrations of biofuel. Methanol's lower energy content compared to gasoline reduces the blend's overall calorific value, leading to increased fuel consumption to produce the same energy.

Figure 2 shows the electrical power consumed at each measuring point for all tested fuels. It can be seen from the figure that the largest difference in the consumed electrical power when using mixed fuels compared to the reference fuel BA95 was about 2.9 % in point 1. Despite the variations in fuel properties, the electrical performance of the generator remained comparable across all tested fuels, even under higher load conditions. This indicates that the engine-generator system can adapt to different fuel mixtures without significant loss of electrical output. However, the increased fuel consumption with higher methanol content points to a trade-off between using renewable fuel sources and maintaining fuel efficiency. Previous research (15, 16, 17) supports this observation, showing that while alcohol-gasoline blends can be used effectively in engines, they often result in higher fuel consumption due to lower energy density.

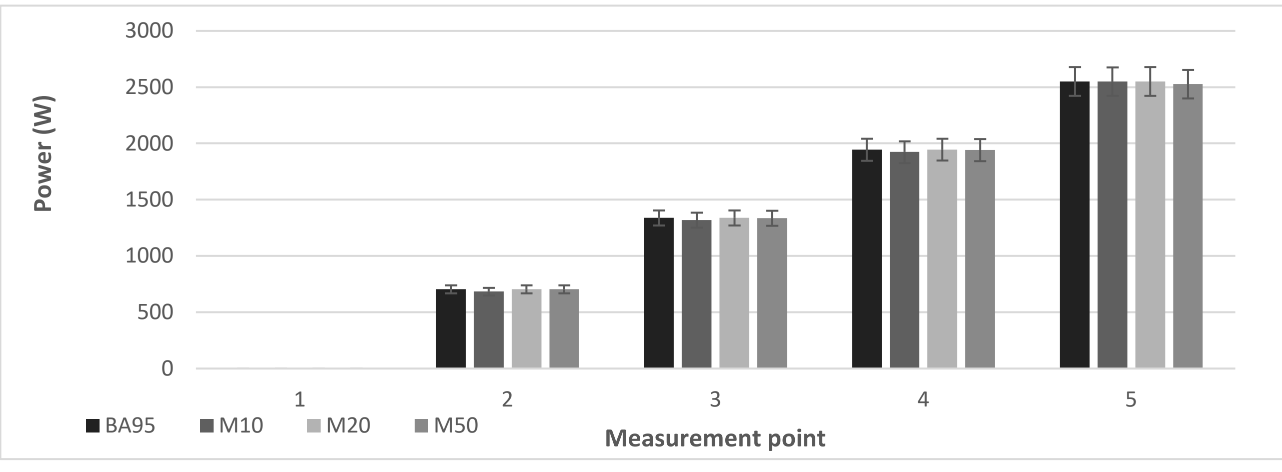

Fig. 2 *Electrical output of the generator for all fuels at all measuring points*

Figure 3 shows the fuel consumption by weight, and Figure 4 shows the specific fuel consumption for all tested fuels at all measurement points. It is evident that mixtures with a higher content of biocomponents have a higher consumption than the reference fuel. The only M10 fuel consumed four points lower, but at the last measuring point with a high load, it achieved higher consumption. The maximum difference in weight consumption was recorded at the last measurement point for M50 fuel, by about 38.2 %. In terms of specific fuel consumption, the maximum increase was also for M50 fuel in point 5 by approximately 39.5 %. The increase in consumption is mainly due to the lower calorific value of blended fuels compared to BA95 fuel.

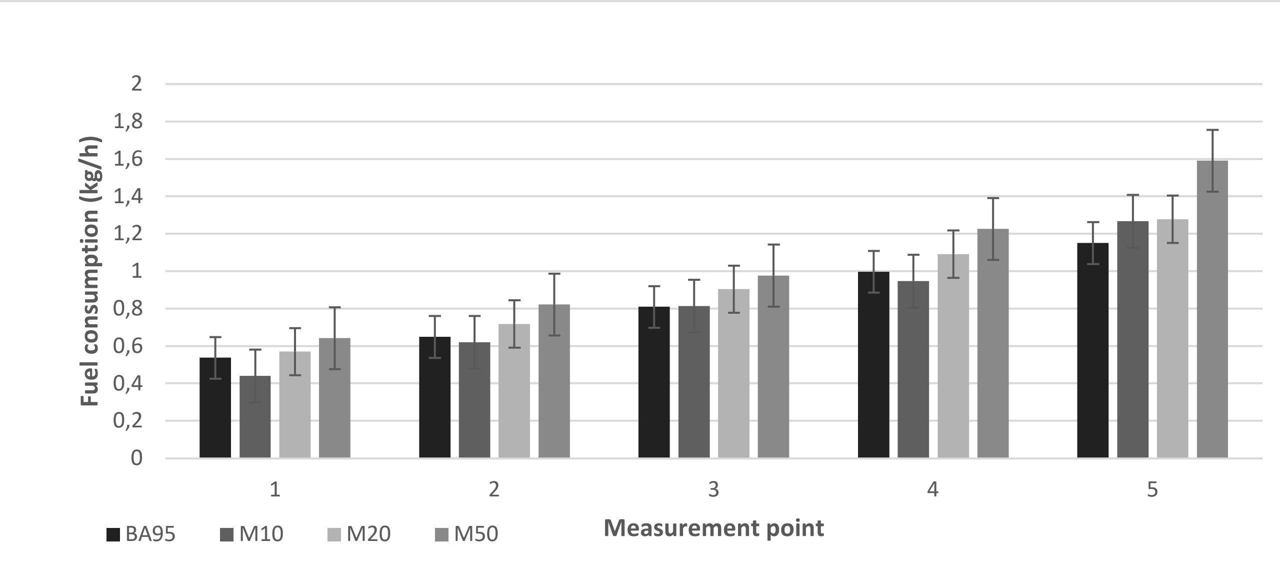

Fig. 3 *Fuel consumption for all fuels at all measuring points*

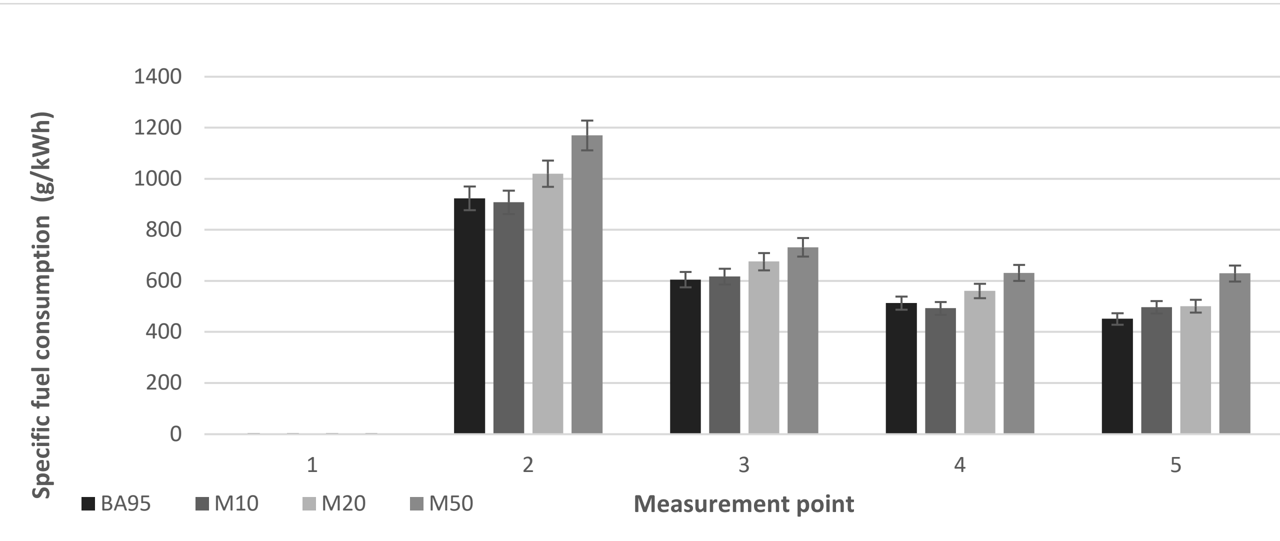

Fig. 4 *Specific fuel consumption for all fuels at all measuring points*

Regarding the fact that the measured concentration of acetaldehyde emissions (CH_3CHO) was in the vast majority of measured points below the standard deviation level for all tested fuels and was at the limit of the accuracy of the instrument, this component of emissions is not presented in this chapter.

Figure 5 shows the mass concentration of methane in the exhaust gases using all tested fuels at all measured load points. It is evident that, like most hydrocarbons, its concentration decreases with increasing load, mainly due to higher engine temperatures. The highest difference was measured in point 1 when using M50 fuel – an increase of about 30.1 %. The differences in concentration compared to BA95 fuel are most likely caused by the different richness of the mixture in the cylinder, which is also evident from Figures 19 and 20, where it can be seen at identical points (point 1 – M50, point 2 – M10, point 5 – M10) reduced production of CO_2 and increased production of CO, indicating a richer mixture of less efficient combustion.

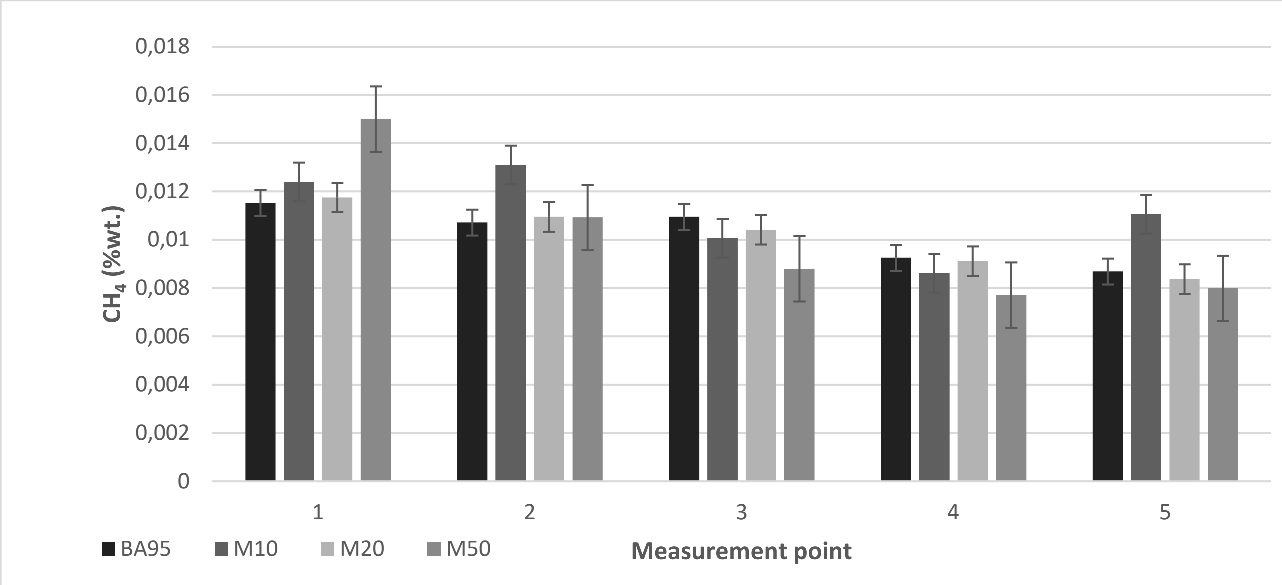

Fig. 5 *Mass concentrations of CH_4 for all fuels at all measurement points*

Figure 6 shows the mass concentrations of formaldehyde at all measured load points using all tested fuels. Formaldehyde is one of the intermediates in the combustion of methanol. Within blended fuels with methanol, an increase can be seen with a higher concentration of methanol at all points. Compared to BA95 fuel, there is a noticeable lower production in low engine load and an increase in mass concentration in higher loads. The course of BA95 fuel is most likely influenced by engine temperature at low engine load and lower oxygen content compared to blended fuels. The most significant difference compared to BA95 was achieved in point 5 with M50 fuel – an increase of about 58. 3 %.

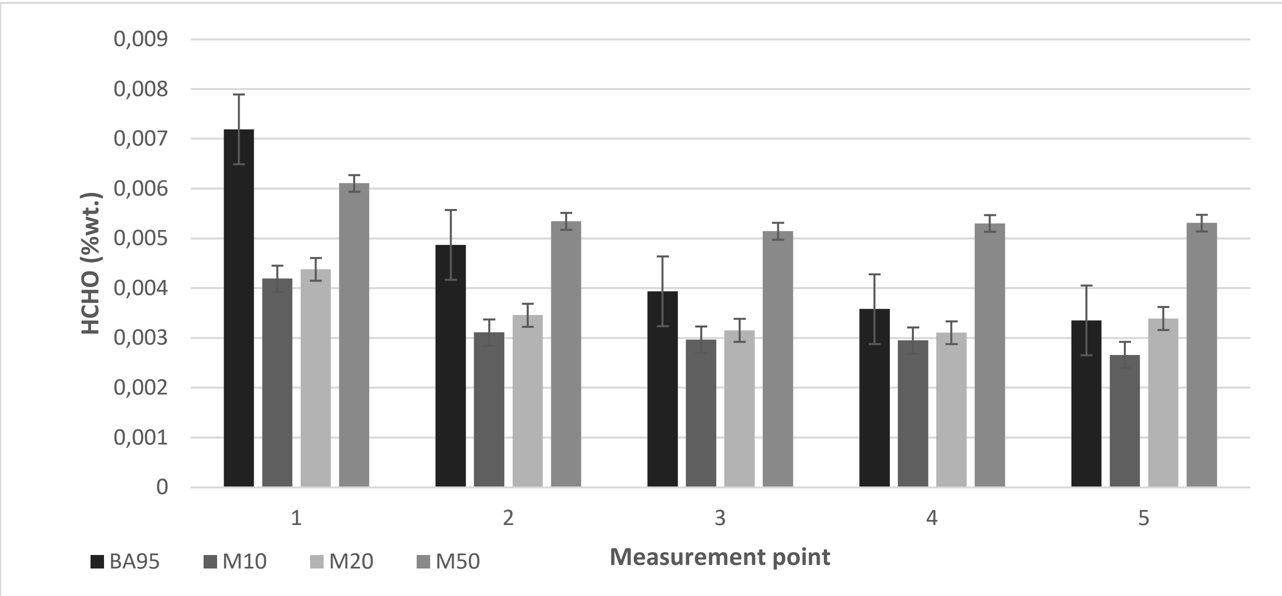

Fig. 6 *Mass concentration of HCHO for all fuels at all measurement points*

Figure 7 shows the mass concentration of carbon dioxide and Figure 8 shows the mass concentration of carbon monoxide in the exhaust gases for all tested fuels at all measured points. Carbon dioxide is tied to fuel consumption. In the case of the tested engine, which is not equipped with a catalytic reactor, relatively high differences in the concentration of carbon monoxide, which is a product of incomplete combustion, can be noticed. The points where a high concentration of CO was reached correspond to points with a lower concentration of CO_2, which is caused by different combustion efficiency, given by the different richness of the mixture in the cylinder. The maximum difference in terms of CO_2 emissions was achieved in point 1 when using M20 fuel – an increase of about 17.5 %, in terms of CO, the largest difference was recorded in point 5 when using M10 fuel – an increase of about 58.3 %.

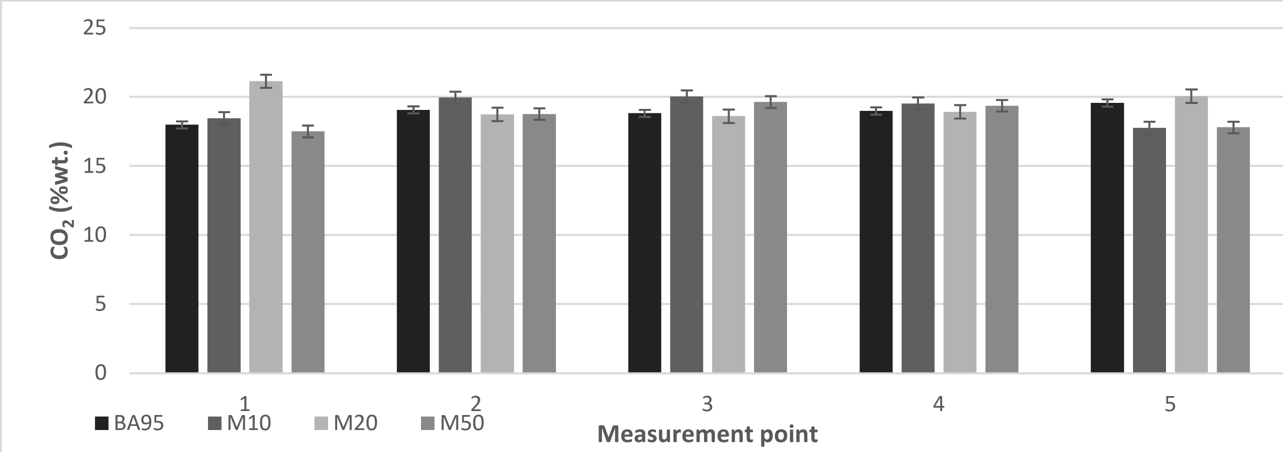

Fig. 7 *CO_2 mass concentrations for all fuels at all measuring points*

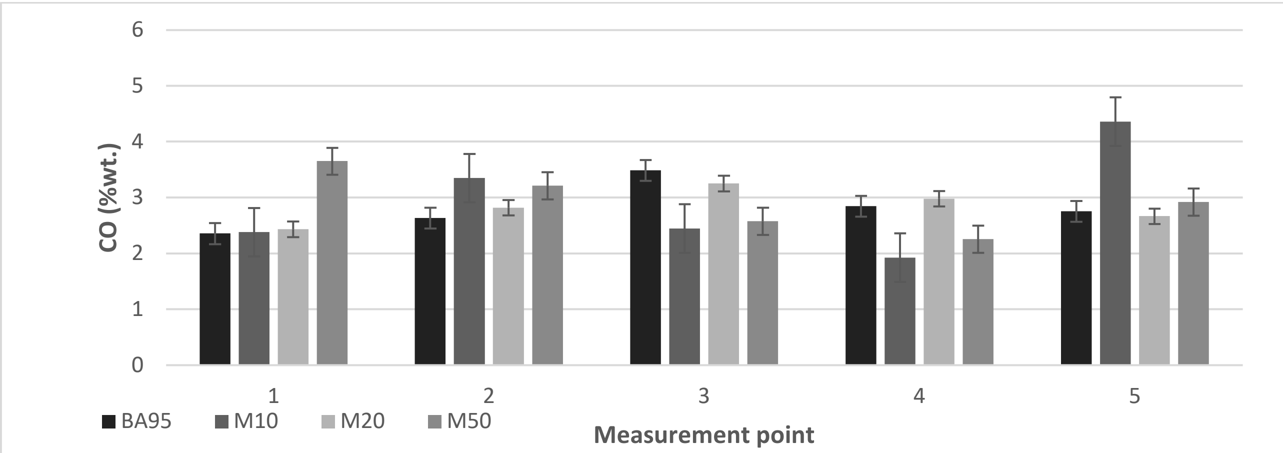

Fig. 8 *Mass concentration of CO for all fuels at all measurement points*

Figure 8 shows the mass concentration of carbon monoxide for all measured points and all fuels tested.

Figure 9 shows the mass concentration of nitrogen oxides for all measured points and all fuels tested. It is noticeable that as the concentration of methanol increases, the concentrations of nitrogen oxide emissions decrease. The exception is point No. 5 – maximum load. This is due to the lower combustion temperature, due, among other things, to the high heat of evaporation of methanol, as can be seen from Table 5. Compared to BA95 fuel, the most significant increase in point 1 was when using M10 fuel by about 99.6 %, the maximum decrease was also recorded in point 1 when using M50 fuel by about 31.6 %. This is due to the different value of the excess air coefficient and the cooling effect of methanol evaporation in the mixture.

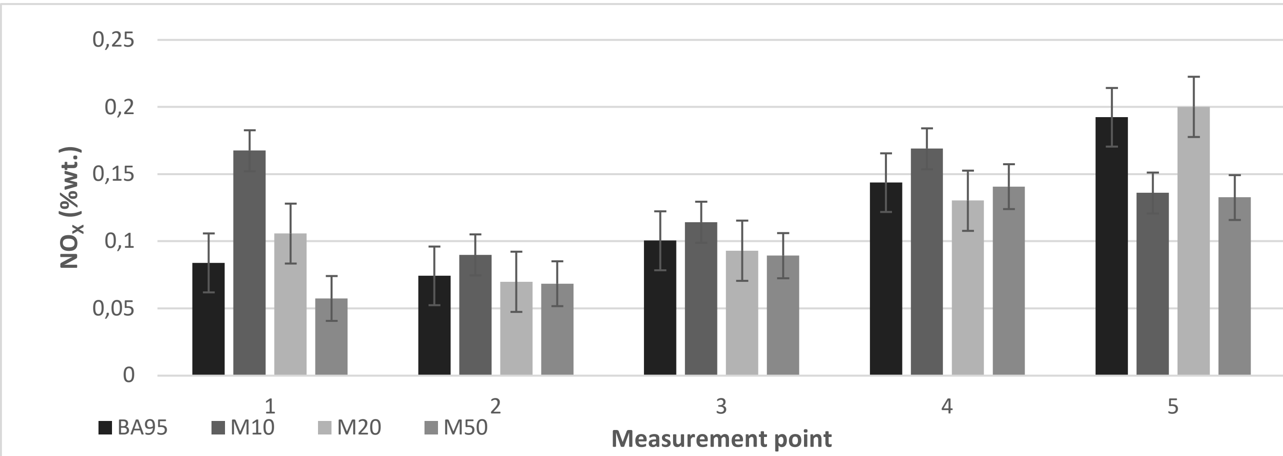

Fig. 9 *Mass concentrations of NO_X for all fuels at all measuring points*

Figures 10 to 12 show the results of the individual components of nitrogen oxide emissions (NO, NO_2, N_2O) for all measured points and all fuels tested. It is evident that in a lower load there is a clear excess of oxygen and fuels with methanol show a higher production of NO_2 compared to BA95, on the other hand, in a high engine load, when a richer mixture of fuel and air is transported to the cylinder, fuels containing methanol show a higher production of NO compared to BA95.

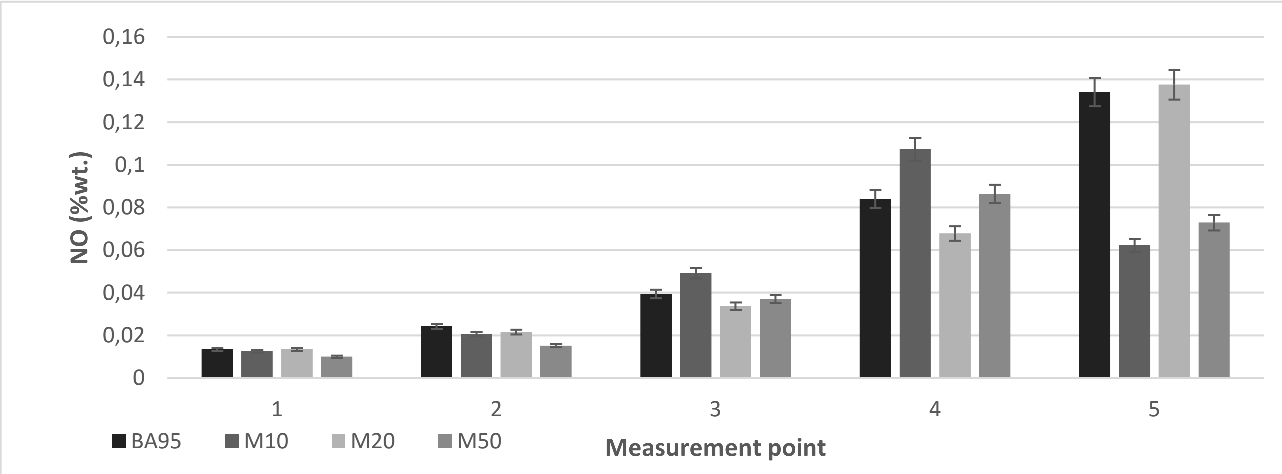

Fig. 10 *Mass concentration of NO for all fuels at all measurement points*

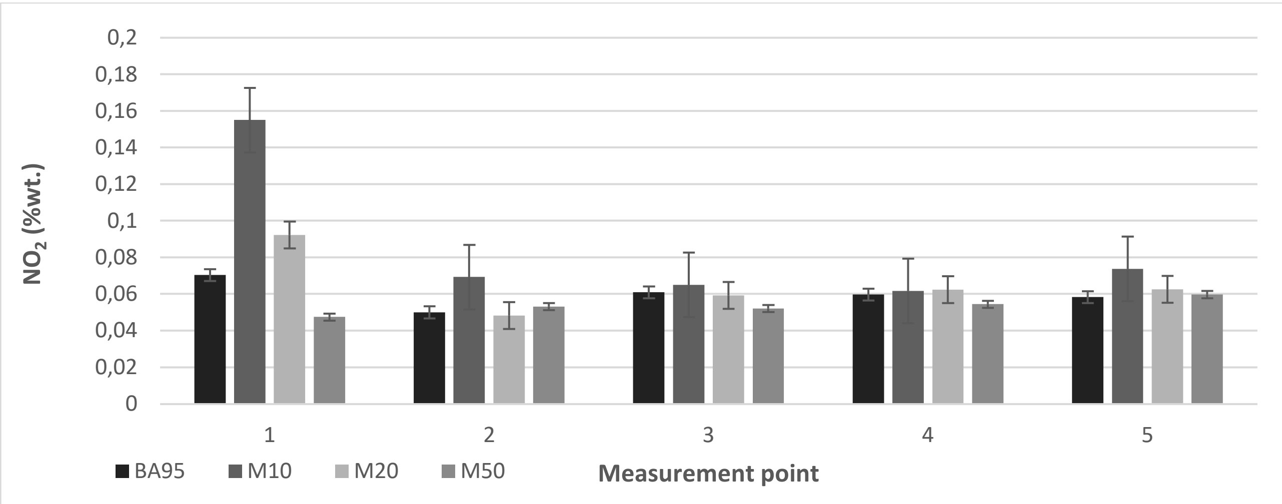

Fig. 11 *Mass concentration of NO_2 for all fuels at all measuring points*

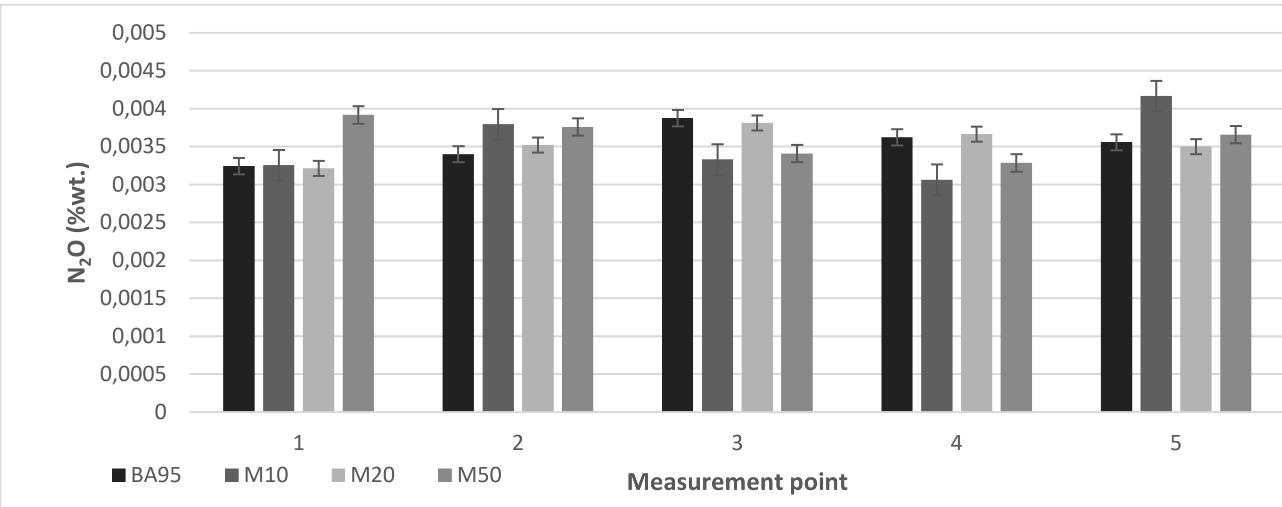

Fig. 12 *Mass concentration of N_2O for all fuels at all measurement points*

The impact on engine emissions was another critical aspect of the study. Consistent with what other authors have found (18,19), generally, the mixtures had a negative effect on emission stability across most measurement points. The increased oxygen content in methanol can lead to higher combustion temperatures and thus more NOx emissions, while incomplete combustion can result in higher CO and unburned hydrocarbons. However, a notable exception was observed with the concentration of formaldehyde emissions. At lower engine loads, the mass concentration of formaldehyde decreased for the fuel mixtures compared to the reference fuel, while it increased at higher loads. This phenomenon could be attributed to the varying combustion efficiencies at different loads and the chemical pathways involved in the formation of formaldehyde during methanol combustion.

4 Conclusions

- Analysis of the fuels used (BA95, M10, M20 and M50) showed that the fuel mixtures could be used as propellants for the engines tested. In the case of petrol blends, the kinematic and dynamic viscosity increases slightly compared to the reference fuel, while the calorific value of the mixtures decreases according to the degree of use of the biofuel component.
- The electrical performance of the generator was comparable at all points for all tested fuels even at higher loads. However, consumption increases significantly for all mixtures with a higher biocomponent content compared to the reference fuel.
- All mixtures were found to have a negative effect on the stability of engine operation, especially at higher loads.
- The effect of the mixtures on engine emissions had a negative effect at most of the measurement points. In some cases, such as the concentration of formaldehyde by weight, the fuel mixtures of gasoline had a decrease in mass concentration compared to the reference fuel at a lower engine load and an increase in mass concentration at a higher load.

The findings suggest that while methanol-gasoline blends can be used as alternative fuels in generator engines, there are significant challenges related to fuel consumption, engine stability, and emissions that need to be addressed. Future research should focus on optimizing the blend ratios and exploring advanced combustion techniques to mitigate these issues and improve the overall feasibility of using methanol as a sustainable fuel additive.

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