JOURNAL of
MATERIALS and MECHATRONICS:A

e-ISSN 2717-8811
JournalMM, 2023, 4(2), 397-408
https://doi.org/10.55546/jmm.1332369

Araştırma Makalesi / Research Article

Experimental Investigation of the Effects of Gasoline-Methyl Ethyl Ketone Fuel Blends on Engine Performance and Exhaust Emissions

Tolga KOCAKULAK[1], Ahmet UYUMAZ[2*], Emre ARABACI[3], Yusuf DAĞOĞLU[4], Celal ÇAMOĞLU[5]

[1] Burdur Mehmet Akif Ersoy University, Techical Sciences of High Vocational School, Hybrid and Electric Vehicles Program, Burdur, Turkey,
ORCID ID: https://orcid.org/0000-0002-1269-6370, tkocakulak@mehmetakif.edu.tr
[2] Burdur Mehmet Akif Ersoy University, Engineering Architecture Faculty, Department of Mechanical Engineering, Burdur, Turkey,
ORCID ID: https://orcid.org/0000-0003-3519-0935, auyumaz@mehmetakif.edu.tr
[3] Pamukkale University, Technology Faculty, Department of Automotive Engineering, Denizli, Turkey,
ORCID ID: https://orcid.org/0000-0002-6219-7246, earabaci@pau.edu.tr
[4] Burdur Mehmet Akif Ersoy University, Engineering Architecture Faculty, Department of Mechanical Engineering, Burdur, Turkey,
ORCID ID: https://orcid.org/0009-0007-1555-8751, dagogluyusuf@gmail.com.tr
[5] Burdur Mehmet Akif Ersoy University, Engineering Architecture Faculty, Department of Mechanical Engineering, Burdur, Turkey,
ORCID ID: https://orcid.org/0009-0007-0619-3092, celalcamoglu20@gmail.com

Geliş/ Received: 25.07.2023; **Kabul / Accepted:** 12.09.2023

ABSTRACT: Gasoline engines have been widely used because of operating with stoichiometric ratio and lower exhaust emissions compared to compression ignition engines. However, thermal efficiency is less than diesel engines due to lower compression ratio. In the present study, the influences of methyl ethyl addition were researched on engine performance, CO, CO_2 and HC emissions in a single cylinder spark ignition engine. For this purpose, the test engine was run at wide-open throttle, engine speeds of 2400, 2800, 3200, 3600, 4000 rpm and the variations of engine torque, effective power, specific fuel consumption (SFC), thermal efficiency, CO, CO_2 and HC emissions were investigated. It has been observed that engine power and torque increase and SFC decreases as methyl ethyl ketone is added to gasoline. It was observed that the thermal efficiency at 2800 rpm increased by 6.47%, 13.81% and 19.51%, respectively, with MEK20, MEK30 and MEK40 test fuels compared to gasoline. As the methyl ethyl ketone ratio in the blended fuels increased, HC and CO emissions reduced compared to gasoline. As a result, it was seen that methyl ethyl ketone additive can be utilized easily in a spark ignition engine without making any modification.

Keywords: Engine Performance, Exhaust Emissions, Methyl Ethyl Ketone, Gasoline.

*Sorumlu yazar / Corresponding author: auyumaz@mehmetakif.edu.tr

Bu makaleye atıf yapmak için /To cite this article

Kocakulak, T., Uyumaz, A., Arabacı, E., Dağoğlu, Y., Çamoğlu, C. (2023). Experimental Investigation of the Effects of Gasoline-Methyl Ethyl Ketone Fuel Blends on Engine Performance and Exhaust Emissions. Journal of Materials and Mechatronics: A (JournalMM), 4(2), 397-408.

1. INTRODUCTION

The depletion of petroleum-based fuels and the pollution of the atmosphere and nature by pollutants produced from combustion powered vehicles prompted researchers to conduct various studies on internal combustion engines. Compression ignition (diesel) engines have high thermal efficiency because of their high compression ratios and they are more economical than spark ignition (gasoline) engines in terms of fuel consumption because they work with excess air. However, sulfur content of diesel fuel, more harmful exhaust gases than gasoline engines and ignition delay time are some of its disadvantages. The inability to reduce NO_x and soot emissions simultaneously is another handicap in compression ignition engine. Extra cost is needed in order to reduce these emissions using exhaust gas aftertreatment systems. On the other hand, spark ignition engines have recently attracted attention with their reasonable thermal efficiency, considering the reduction of emissions and quieter operation. Pumping losses in the inlet line, the necessity of operating at stoichiometric air/fuel ratios due to the usage of a catalytic converter and lower thermal efficiency according to diesel engines owing to lower compression ratio are their shortcomings (Ackermann et al., 2021; Heywood, 1988; Jenkins et al., 2016; Magara et al., 2012; Majumdar et al., 2019; Oprescu et al., 2014; Prabhahar et al., 2017; Shah et al., 2009; Yang et al., 2016). At this point, improving the combustion process and flame development with different fuel additives come to the forefront in gasoline engines. At the same time, it is aimed to increase the thermal efficiency, which decreases due to the self-ignition characteristics (Heywood, 1988; Kumar et al., 2011; Nabi, 2010; Sarjovaara et al., 2013; Zhao, 2007).

It is predicted that methyl ethyl ketone, which has a high auto-ignition temperature, density and evaporation rate, can be used as an additive into gasoline. The organic solvent methyl ethyl ketone is a low toxic flammable liquid. Methyl ethyl ketone that can be produced from a renewable resource may present a solution on improving combustion in spark ignition engines. It can be also mentioned that high oxygen content of methyl ethyl ketone allows better oxidation reactions. So it is seen as promising fuel additive in spark ignition engines. (Ackermann et al., 2021; Hoppe et al., 2016; Jenkins et al., 2016; Kumar et al., 2011; Magnusson and Nilsson, 2011; Raj et al., 2008; Raj et al., 2010; Samoilov et al., 2020; Torres-Vinces et al., 2020). The general chemical formulation of methyl ethyl ketone is shown in Figure 1. Methyl ethyl ketone is widely used in industry. In some studies, it has been predicted that spark ignition engines provide better performance than gasoline according to certain indicators (Torres-Vinces et al., 2020).

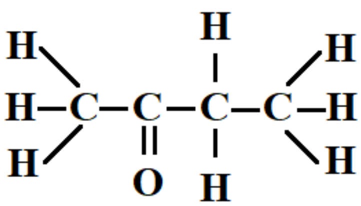

Figure 1. General chemical formula of methyl ethyl ketone (Kumar et al., 2011, Libretexts Chemistry, 2023)

The usage of ketone-ester-alcohol-alkane (KEAA) fuel mixture in a highly efficient spark-ignition engine has been investigated from the point of view of production cost, engine performance etc. It is seen that KEAA fuel provides high efficiency in a research engine. High resistance against auto ignition has also been observed (Ackermann et al., 2021). In a study conducted in a compression ignition engine, two glycerol derivatives were used as additives to diesel. In the experiments performed at full load between 1200-3700 rpm (2-ethyl-2-methyl-1,3-dioxolan-4-yl) methyl hexanoate has shown to be promising for smoke, HC and CO emissions. Reductions of 19.20%, 18.93% and 26.04% were detected in smoke, CO and HC emissions, respectively (Oprescu et al., 2014). A direct injection compression ignition turbocharged diesel engine was operated with diesel, biodiesel (B100) and 20% biodiesel+80% diesel (B20) fuels, and the variation of carbonyl emissions were investigated. Formaldehyde, acrolein + acetone, acetaldehyde, crotonaldehyde, propionaldehyde, and methyl ethyl ketone have more specific emissions with B20 and B100 compared diesel, and lower specific emissions with benzaldehyde and tolualdehyde. Total carbonyl emissions with B20 and B100 were found to be 8% and 32% higher than diesel respectively (Shah et al., 2009). The variation of carbonyl compounds and pollutants were investigated in an idling diesel engine. The changes in emissions were investigated with test fuels consisting of diesel, biodiesel and isobutanol mixtures. The largest carbonyls were found to be formaldehyde, acetaldehyde and acrolein, respectively. With the high rate of biodiesel in fuel blends, CO, NO_x and particulate matter emissions decreased by about 3.45%, 32.5%, and 38.5%, respectively (Yang et al., 2016). Warm three-way catalysts are used for the reduction of non-methane organic gases, NO_x and CO exhaust gases from spark ignition engines. Most emissions from gasoline engines are released under cold operating conditions when the catalyst is inactive. High performance fuel samples were investigated in a hydrothermal three-way warm catalytic converter with synthetic engine exhaust flow reactor system. Many fuel compositions have been studied, such as aromatic ethers, alcohols, alkanes, alkenes, esters, ketones, and oxygen-free aromatic hydrocarbons. It appears that short-chain acyclic oxygenates, including esters, ketones and alcohols tend to react at relatively low temperatures. On the other hand, alkenes, aromatics, and cyclic oxygenates tend to react at relatively high temperatures (Majumdar et al., 2019). Oxygen-containing fuels improve chemical oxygen reactions. In a study which changes in thermal efficiency, specific heat at constant pressure, adiabatic flame temperature, NO_x emissions for different oxygenated fuels were examined theoretically, it is shown that oxygen content of fuel is closely related to combustion parameters. It has been observed that decrease on NO_x is related to the adiabatic flame temperature of oxygenated fuels (Nabi, 2010). However, the usage of dual fuels to improve the combustion process is another method. In an engine used in a heavy-duty vehicle, ethanol was injected into the inlet manifold as the primary fuel, and diesel fuel was injected into the cylinder. The study showed that the concept of dual-fuel combustion with ethanol is feasible and has a lot of potential (Sarjovaara et al., 2013). The variations in aldehyde, ketone, HC, CO and NO_x emissions in a two-stroke chainsaw engine operating with fuels with high oxygen content were investigated. It was observed that the use of four oxygenated fuels (Ethyl tert butyl ether, ethanol, methanol and methyl tert butyl ether) resulted in higher (11, 11, 8.9 and 7.8 g/kWh) total carbonyl emissions compared to both aliphatic and normal gasoline usage (2.1 and 2.6 g/kWh), respectively (Magnusson and Nilsson, 2011). The main physical properties of eight different diol derivatives of gasoline mixture were investigated in a study. They observed that di-glycerol tert butyl ether was the most efficient octane booster (Samoilov et al., 2020). In another study, thermodynamic investigations of 2-methylfuran and methyl ethyl ketone fuels were performed in a spark ignition engine. Longer ignition delay was measured with methyl ethyl ketone than with ethanol and 2-methylfuran fuels. It was seen that the knock resistance increased using 2-methylfuran compared to gasoline under low loads and cold operating conditions. At the same time, it was observed that methyl ethyl ketone increased the combustion stability according to ethanol at low loads and under cold operation. However, compared to ethanol, methyl ethyl ketone and 2-methylfuran caused to increase NO_x. (Hoppe et al., 2016; Torres-Vinces et al., 2020). Methanol and methyl ethyl ketone fumigation can be applied to the intake manifold to improve the performance. An important decrease on the amount of smoke and NO_x was realized compared to diesel (Raj et al., 2008). In a similar study, the variations on performance and emissions were researched by fumigation of methyl ethyl ketone, methanol, and liquefied petroleum gas (LPG) to the intake manifold in a diesel engine. It was found that there was a remarkable decrease on smoke and NO_x emissions with fumigation of all test fuels. But HC and CO increased. While the thermal efficiency increased by a maximum of 7% with methanol fumigation, it was increased by 3% with methyl ethyl ketone (Raj et al., 2010). In a study, 2%, 4%, 6% and 8% naphthalene were added to gasoline and it was observed that while engine performance improved, emissions increased. It was observed that the best fuel mixture was 6%, and it was seen that CO increased as the amount of naphthalene increased (Durgun and Alaçam, 2018).

In the present study, the influences of methyl ethyl ketone addition to gasoline on engine torque, engine power, specific fuel consumption, thermal efficiency, CO, CO_2 and HC emissions were experimentally investigated.

2. MATERIALS AND METHODS

2.1 Materials

Experimental study was carried out at Burdur Mehmet Akif Ersoy University Technical Sciences of High Vocational School Automotive Technology Laboratory. The schematic view of the test setup is seen in Figure 2. A single-cylinder, four-stroke spark ignition engine was utilized to investigate the effects of methyl ethyl ketone additive on engine performance and emissions (CO, CO_2 and HC). The engine specifications are given in Table 1.

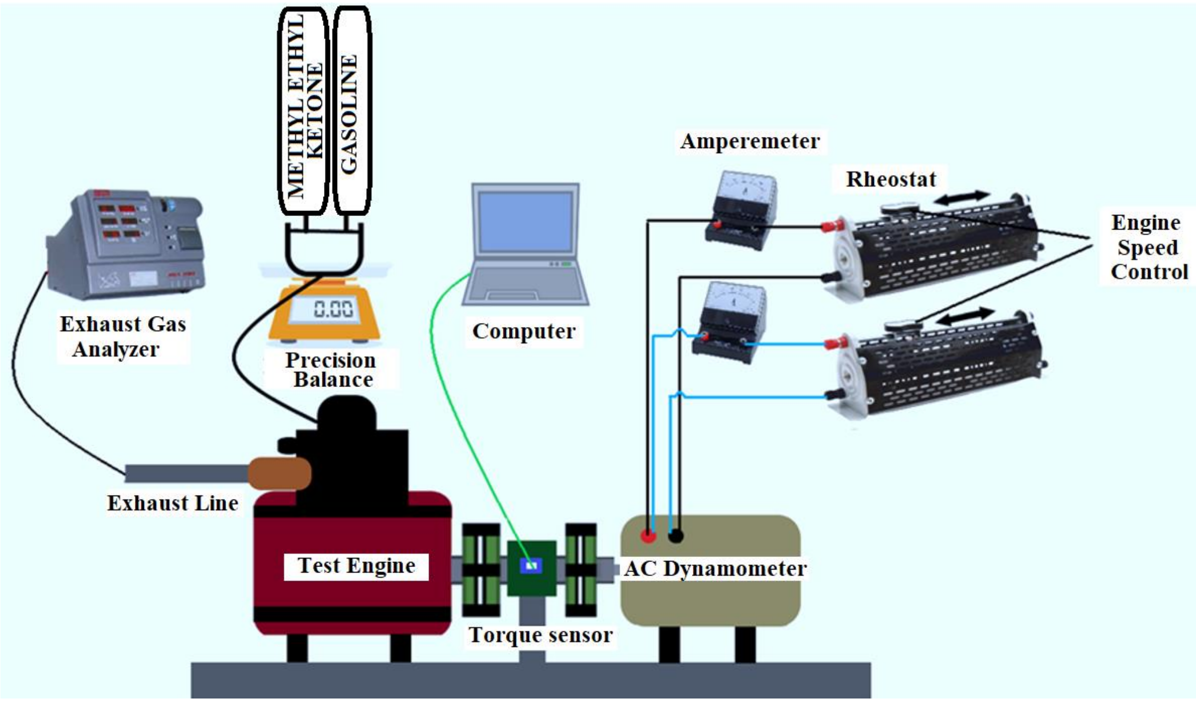

Figure 2. Schematic view of the test setup

Measurements were made after the test engine reached operating temperature in order to reduce experimental errors and to obtain more precise data. Measurements were carried out after stable operation was achieved. The test engine was run with gasoline, gasoline/methyl ethyl ketone fuel mixtures at wide open throttle and 2400, 2800, 3200, 3600 and 4000 rpm engine speeds. In the experiments, test fuels were obtained by mixing methyl ethyl ketone gasoline with 10%, 20%, 30%

and 40% by volume. The mixing ratios and names of the test fuels used in the experiments are shown in Table 2.

Table 1. Engine specifications

Model	Honda GX160
Bore x stroke [mm]	68x45
Cylinder volume [cm³]	163
Compression ratio	8.5:1
Maximum power BG@3600 d/d	5.5
Maximum Torque [Nm] @2500 d/d	10.78
Cooling system	Air cooled

Table 2. Test fuels and mixing ratios

Gasoline	%100 Gasoline
MEK10	%10 Methyl ethyl ketone + %90 Gasoline
MEK20	%20 Methyl ethyl ketone + %80 Gasoline
MEK30	%30 Methyl ethyl ketone + %70 Gasoline
MEK40	%40 Methyl ethyl ketone + %96 Gasoline

Some properties of the used test fuels are shown in Table 3.

Table 3. Properties of the test fuels (Methyl Ethyl Ketone-Cameo Chemicals,2023; Hoppe et al., 2016; Tüpraş, 2023)

	Gasoline	Methyl ethyl ketone
Density [kg/m^3]	746	805
Latent heat of vaporization [kJ/kg]	331.6	444
Flash point [°C]	-43	-9
Auto ignition temperature [°C]	257.2	505
Boiling point [°C]	30-225	79.6
Oxygen mass [%]	2.70	22.19
RON	95	117

2.2 Method

In order to obtain the full load speed characteristics of the spark ignition engine, the test engine was connected to the AC dynamometer as seen in Figure 2. With the gradual operation of the circuit elements (resistances) connected to the dynamometer output, the test engine operating at wide open throttle was loaded and operated at different speeds. In order to protect the resistances used during the loading of the test engine, the current passing through the circuit was measured with an ampere meter. In order to determine the fuel economy, PLT Power brand precision balance that can measure with 0.5 gr precision was used. Engine torque and engine speed were measured by the Burster 8661 brand torque sensor mounted between the AC dynamometer and the test engine. Measured engine speed and torque data were transferred to the computer via cable connection. Engine speed and torque data were continuously monitored and recorded with the Digivision interface. The properties of the torque sensor are shown in Table 4.

Table 4. Properties of the torque sensor

Model	Burster 8661
Nominal supply voltage range [V DC]	10-30
Nominal torque output voltage [V]	+10
Insulation resistance [MΩ]	> 5
-3 dB cutoff frequency [Hz]	200
Fluctuation [mV]	<50
Driver signal (K pin) [V DC]	10…30

SUN MGA1500 gas analyzer was utilized to determine CO, CO_2 and HC emissions. The technical properties of the exhaust gas analyzer are shown in Table 5.

Table 5. Technical properties of the exhaust gas analyzer

	Operating range	Accuracy
CO	% 0-14	% 0.001
HC	0-9999 ppm	1 ppm
NO_x	0-5000 ppm	1 ppm
CO_2	% 0-18	% 0.1
O_2	% 0-25	% 0.01
λ	0-4	0.001

3. RESULTS AND DISCUSSION

3.1 Engine Performance

The engine torque and engine power output values obtained by adding methyl ethyl ketone which is an organic solvent, to gasoline are seen in Figure 3. It is worth mentioning that engine test rig setup was by the authors and a partially worn and previosly used spark ignition engine was used as test engine. So, it was seen that the measured performance values are slightly less than the original performance values of the engine. Thus, maximum engine torque and power ouput were obtained at 2800 and 4000 rpm respectively. As seen in Figure 3-a, as a result of the experiments performed at full load and and different engine speeds, it was found that the engine torque decreased with MEK10 fuel. However, it is seen that engine torque increases with the increase of methyl ethyl ketone. It has been found that the maximum engine torque increased by 2.85% with MEK40 fuel at 2800 rpm compared to gasoline. As the engine speed increases, gas leakages and thermal losses for each stroke increase, and torque decreases for all test fuels. Although the thermal energy of methyl ethyl ketone is lower than gasoline (REF), its high oxygen content improves oxidation reactions. It can be also stated that higher octane number of methyl ethyl ketone resulted in higher in-cylinder gas pressure and temperature at the end of compression. Hence, in-cylinder pressure increases as a result of combustion. As shown in Figure 3-b, the effective engine power increases with all test fuels depending on engine speed. Power increase slows down due to the increase in mechanical and flow losses after the maximum power engine speed. Maximum engine power output was calculated at 4000 rpm for all fuels. With MEK10, the calculated effective power is reduced compared to gasoline. It is predicted that higher density and latent heat of vaporization of methyl ethyl ketone resulted in lower engine torque and power output with MEK10. Nevertheless, it was found that the effective engine power increased as methyl ethyl ketone is added. Chemical oxidation reactions are improved with methyl ethyl ketone additive with high oxygen content. At the same time, the high auto-ignition temperature may increase temperature and pressure of the charge mixture during the compression process. Besides, gas pressure and temperature increase as a result of combustion.

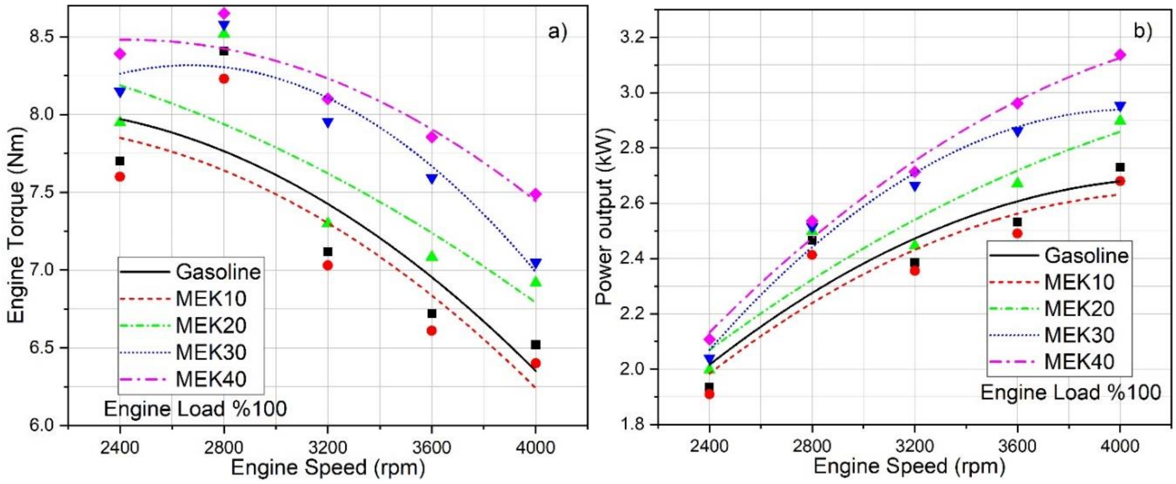

Figure 3. a) The variations of engine torque b) The variations of effective power

In Figure 4, the variations of SFC values versus engine speed are seen. The lowest SFC was calculated at 2800 rpm for all test fuels. Gas leakages and heat losses increase with higher engine speeds and SFC tends to increase. It is seen that the SFC decreases as the methyl ethyl ketone ratio increases in the fuel blends. Maximum SFC was determined with MEK10 fuel. Higher density of methyl ethyl ketone causes to increase SFC. But, higher octane number and oxygen content of methyl ethyl ketone improved the oxidation reactions. Hence, it was seen that SFC decreased and thermal efficiency increased with the increase of methyl ethyl ketone addition in the fuel blends. With MEK40, it was observed that SFC decreased by 5.78% at 2800 rpm compared to gasoline. Methyl ethyl ketone, which contains more oxygen in its chemical structure, improves oxidation reactions and increases the average gas temperature at the end of combustion. Oxidation conditions are thermodynamically improved in the combustion chamber and and fuel consumption decreases.

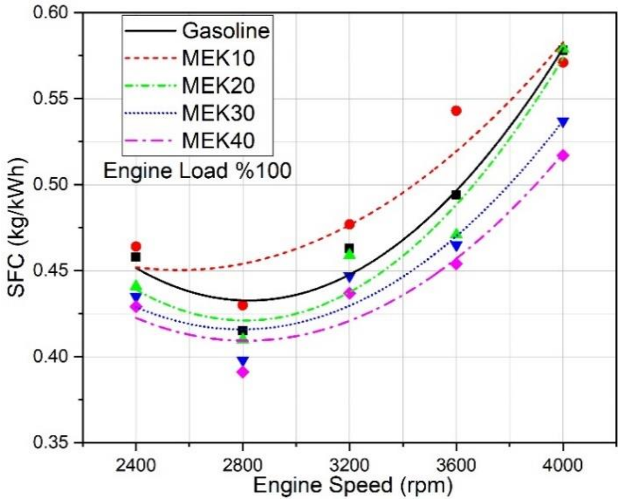

Figure 4. The influences of methyl ethyl ketone on SFC

Figure 5 shows the obtained thermal efficiency changes with the test fuels. Thermal efficiency, which expresses the conversion of obtained heat energy with fuel to the network, is an important performance parameter (Heywood, 1988). Maximum thermal efficiency was determined at 2800 rpm for all test fuels. It was determined that the thermal efficiency increased by approximately 19.51% with MEK40 fuel at 2800 rpm compared to gasoline. With high oxygen content fuel additive, oxygen molecules can be reacted more easily, and combustion reactions are improved. Since the engine speed increases, the mechanical losses increase and the oxygen concentration decreases. So, combustion reactions slow down. Thus, thermal efficiency decreases.

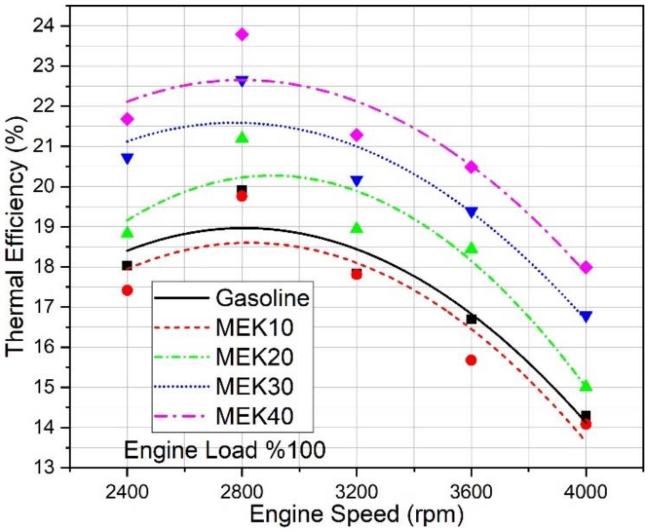

Figure 5. Thermal efficiency

3.2 Exhaust Emissions

Figure 6 depicts the variations of CO and CO_2 emissions. Insufficient temperature and oxygen causes to form CO which is incomplete combustion product. It is clearly presented that CO is reduced with the addition of methyl ethyl ketone. The methyl ethyl ketone additive increases the oxidation rate due to containing of high oxygen content and the formation of CO is reduced. The oxygen required for the oxidation of the fuel is provided by methyl ethyl ketone. As seen in Figure 6-a, CO emissions decrease as methyl ethyl ketone is added. With the increase of engine speed, the gas temperature after combustion increases and the formation of CO decreases. On the other hand, CO formation tends to increase due to insufficient oxygen intake into the cylinder at high engine speeds. With MEK40 test fuel at 4000 rpm, it is seen that CO emissions are reduced by 38.91% compared to gasoline. Figure 6-b exhibits the change of CO_2 with test fuels. It is possible to state that there is an inverse relationship between CO and CO_2 emissions. Oxidation reactions and CO_2 formation increases with fuel additive with high oxygen content. When Figure 6-b is examined, CO_2 emissions increase as the methyl ethyl ketone addition increases.

Due to the increase in pumping losses at high engine speeds and the decrease in the oxygen density in the combustion chamber, CO formation increases and CO_2 emissions decrease. It can be stated that methyl ethyl ketone with high auto-ignition temperature and octane number increases the temperature and pressure at the end of compression. In this case, in-cylinder gas temperature increases after combustion. Warmer combustion chamber causes the oxidation rate increase. As a result, CO_2 formation increases.

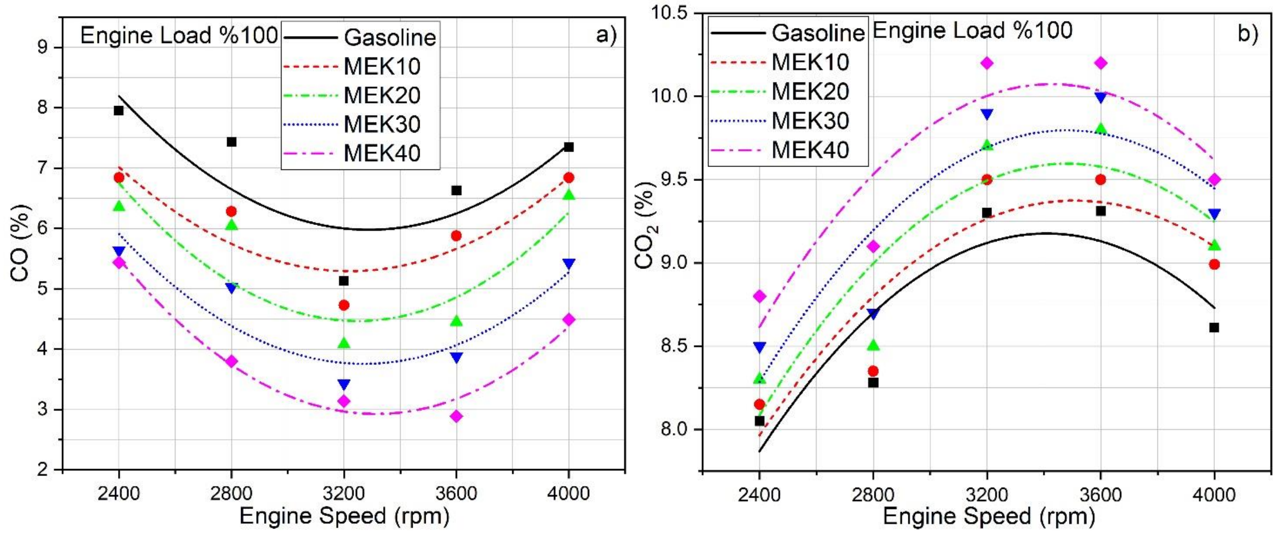

Figure 6. a) CO emissions b) CO_2 emissions

HC emissions are formed due to the inability to oxidize the remaining hydrocarbon molecules in the combustion chamber, in the hollow parts, on the edges of the pistons and rings. At the same time, the flame can go out when the flame front reaches to the cold cylinder walls after the combustion starts. In this case, the fuel remaining in the corners of the combustion chamber cannot react with the oxygen molecules and they are discharged from the cylinder. Figure 7 shows the effects of methyl ethyl ketone addition on HC emissions. It is seen that HC emissions decrease as the methyl ethyl ketone addition increases. Methyl ethyl ketone with high oxygen content causes to improve oxidation reactions and HC formation decreases. Minimum HC emissions were measured with MEK40 fuel. At 3600 rpm, HC emissions decreased by about 19.46% with MEK40 test fuel compared to gasoline. In cylinder gas temperature increases after combustion, and the heat losses per cycle decrease at high engine speeds. In the combustion chamber with a high temperature, the oxidation rate rises and the HC formation reduces. Because of the increase in mechanical and flow losses at high engine speeds, the volumetric efficiency decreases and the amount of oxygen that is delivered into the cylinder decreases. In this case, the fuel molecules cannot find enough oxygen for oxidation. As a result, HC formation begins to increase.

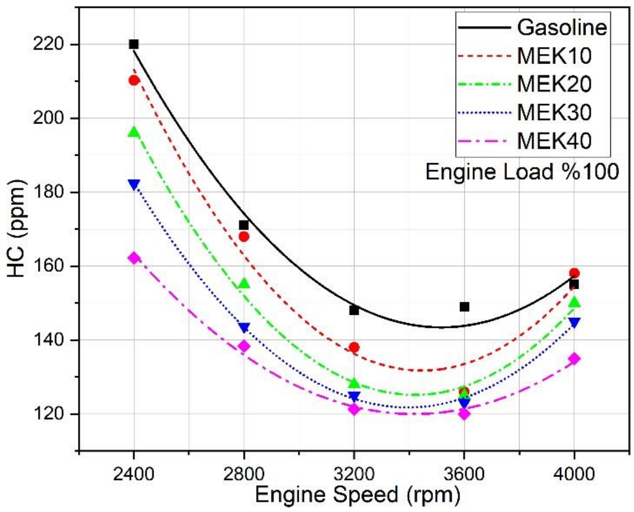

Figure 7. HC emissions

4. CONCLUSION

In this study, the influences of methyl ethyl ketone addition on engine performance and exhaust emissions were researched experimentally.

The changes in engine torque, effective power, SFC, thermal efficiency, CO, CO_2 and HC emissions were investigated at full load and at engine speeds of 2400, 2800, 3200, 3600 and 4000 rpm.

- It is found that the engine torque increases with the addition of methyl ethyl ketone. Engine torque increased by 1.30%, 2.02% and 2.85% with MEK20, MEK30 and MEK40 test fuels at 2800 rpm compared to gasoline, respectively.
- Engine power at 4000 rpm with MEK20, MEK30 and MEK40 test fuels increased by 6.11%, 8.12% and 14.86%, compared to gasoline, respectively.
- As the methyl ethyl ketone ratio increases in the fuel blends, SFC decreases. With MEK20, MEK30 and MEK40 test fuels, SFC decreased by 1.2%, 4.09% and 5.78% at 2800 rpm compared to gasoline, respectively.
- It was observed that the thermal efficiency decreased by 0.73% with MEK10 fuel at 2800 rpm compared to gasoline, and increased by 6.47%, 13.81% and 19.51%, respectively with MEK20, MEK30 and MEK40 test fuels compared to gasoline.
- HC and CO emissions were reduced with the addition of methyl ethyl ketone, and CO_2 emissions increased. It was found that CO emissions reduced by 6.93%, 11.02%, 26.12% and 38.91%, respectively, with MEK10, MEK20, MEK30 and MEK40 fuels at 4000 rpm according to gasoline. In addition, HC emissions decreased by 3.22%, 6.45% and 12.90% with MEK20, MEK30 and MEK40 fuels respectively at 4000 rpm compared to that of gasoline.
- Engine performance and exhaust emissions are improved with the addition of methyl ethyl ketone. However, it was found that CO_2 increased as the methyl ethyl ketone ratio increases in fuel blends.
- Engine performance and exhaust emissions can be investigated with different with alcohol-derived fuel additives based on different engine loads. The effects of methyl ethyl ketone on NO_x emissions can be also observed.
- As a result, it is seen that methyl ethyl ketone can be used as an additive in a spark ignition engine without any modification.

5. CONFLICT OF INTEREST

Authors approve that to the best of their knowledge, there is not any conflict of interest or common interest with an institution/organization or a person that may affect the review process of the paper.

6. AUTHOR CONTRIBUTION

Tolga KOCAKULAK: Determining the Concept and/or Design Processes of the Research, Preparation of the Manuscript, Data Collection, Final Approval and Full Responsibility

Ahmet UYUMAZ: Management of the Concept and/or Design Process of the Research, Determining of the Concept and/or Design Processes of the Research, Critical Analysis of the

Intellectual Content, Final Approval and Full Responsibility

Emre ARABACI: Management of the Concept and/or Design Process of the Research, Critical Analysis of Intellectual Content, Data Analysis and Interpretation of the Results, Final Approval and Full Responsibility

Yusuf DAĞOĞLU: Data Collection, Preparation of the Manuscript, Data Analysis and Interpretation of the Results, Final Approval and Full Responsibility

Celal ÇAMOĞLU: Data Analysis and Interpretation of the Results, Preparation of the Manuscript, Data Collection, Final Approval and Full Responsibility

7. REFERENCES

Ackermann P., Braun K.E., Burkardt P., Heger S., König A., Morsch P., Lehrheuer B., Surger M., Völker S., Blank L.M., Du M., Alexander Heufer K., Roß-Nickoll M., Viell J., Von der Aßen N., Mitsos A., Pischinger S., Dahmen M., Designed to Be Green, Economic, and Efficient: A Ketone-Ester-Alcohol-Alkane Blend for Future Spark-Ignition Engines. Chemistry-Sustainability-Energy- Materials, ChemSusChem, Chemistry Europe 14, 5254–5264, 2021.

Durgun O., Alaçam S. A., Benzin–Naftalin Karışımının Buji Ateşlemeli Motorun Performansına ve Eksoz Emisyonlarına Etkisinin Deneysel İncelenmesi. 2nd International Symposium on Innovative Approaches in Scientific Studies, Samsun, 3, 569-571, 2018.

Heywood, J., Internal Combustion Engines Fundamentals. McGraw-Hill, New York, 1988.

Hoppe F., Burke U., Thewes M., Heufer A., Kremer F., Pischinger S., Tailor-Made Fuels from Biomass: Potentials of 2-butanone and 2-methylfuran in direct injection spark ignition engines. Fuel 167, 106-117, 2016.

Jenkins R.W., Moore C.M., Semelsberger T.A., Chuck C.J., Gordon J.C., Sutton A.D., The Effect of Functional Groups in Bio-Derived Fuel Candidates. Chemistry-Sustainability-Energy-Materials, ChemSusChem, Chemistry Europe 9, 922-931, 2016.

Kumar S., Nayek M., Kumar A., Tandon A., Mondal P., Vijay P., Bhangale U.D., Tyagi D., Aldehyde, ketone and methane emissions from motor vehicle exhaust: a critical review. American Chemical Science Journal 1(1), 1-27, 2011.

Libretexts Chemistry, The Basics of GOB Chemistry, Nice CXOne, https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Basics_of_General_Organic_and_Biological_Chemistry_(Ball_et_al.)/00%3A_Front_Matter/03%3A_Table_of_Contents 2023, (Accessed on 04.08.2023).

Magara-Gomez K. T., Olson M. R., Okuda T., Walz K. A., Schauer J. J., Sensitivity of hazardous air pollutant emissions to the combustion of blends of petroleum diesel and biodiesel fuel. Atmospheric Environment 50, 307-313, 2012.

Magnusson R., Nilsson A. C., The influence of oxygenated fuels on emissions of aldehydes and ketones from a two-stroke spark ignition engine. Fuel 90(3), 1145-1154, 2011.

Majumdar S. S., Pihl J. A., Toops T. J., Reactivity of novel high-performance fuels on commercial three-way catalysts for control of emissions from spark-ignition engines. Applied Energy 255, 113640, 2019.

Methyl Ethyl Ketone-Cameo Chemicals, 1999, https://cameochemicals.noaa.gov/chris/MEK.pdf, June, 1999, (Accessed on 16.07.2023).

Nabi M. N., Theoretical investigation of engine thermal efficiency, adiabatic flame temperature, NO_x emission and combustion-related parameters for different oxygenated fuels. Applied Thermal Engineering 30(8-9), 839-844, 2010.

Oprescu E-E., Dragomir R.E., Radu E., Radu A., Velea S., Bolocan I., Stepan E., Rosca P., Performance and emission characteristics of diesel engine powered with diesel–glycerol derivatives blends. Fuel Processing Technology, 126, 460-468, 2014.

Prabhahar M., Sendilvelan S., Prakash S., Saravanakumar M., Investigation of pine oil methyl ester blends with diesel on a compression ignition engine to control oxides of nitrogen and soot particles. Rasayan Journal of Chemistry 10,4, 1075-1079, 2017.

Raj C. S., Arul S., Senthilvelan S., Some comparative performance and emission studies on DI diesel engine fumigated with methanol and methyl ethyl ketone using microprocessor controlled fumigator. The Open Fuels Energy Science Journal 1(1), 74-78, 2008.

Raj C. S., Arul S., Sendilvelan S., Saravanan C. G., A comparative assessment on performance and emissions characteristics of a diesel engine fumigating with methanol, methyl ethyl ketone, and liquefied petroleum gas. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects 32(17), 1603-1613, 2010.

Samoilov V. O., Borisov R. S., Stolonogova T. I., Zarezin D. P., Maximov A. L., Bermeshev M. V., ... Kapustin V. M., Glycerol to renewable fuel oxygenates. Part II: Gasoline-blending characteristics of glycerol and glycol derivatives with C3-C4 alkyl (idene) substituents. Fuel 280, 118585, 2020.

Sarjovaara T., Alantie J., Larmi M., Ethanol dual-fuel combustion concept on heavy duty engine. Energy 63, 76-85, 2013.

Shah A. N., Yun-Shan G., Jian-wei T., Carbonyls emission comparison of a turbocharged diesel engine fuelled with diesel, biodiesel, and biodiesel-diesel blend. Jordan Journal of Mechanical and Industrial Engineering 3(2), 2009.

Torres-Vinces L., Contreras-Zarazua G., Huerta-Rosas B., Sánchez-Ramírez E., Segovia-Hernández J. G., Methyl ethyl ketone production through an intensified process. Chemical Engineering Technology 43(7), 1433-1441, 2020.

Tüpraş,2023.https://www.tupras.com.tr/uploads/Urunler_en/UNLEADED_MOTOR_GASOLINE_95_RON-243.pdf, (Accessed on 16.07.2023).

Yang P. M., Lin K. C., Lin Y. C., Jhang S. R., Chen S. C., Emission evaluation of a diesel engine generator operating with a proportion of isobutanol as a fuel additive in biodiesel blends. Applied Thermal Engineering 100, 628-635, 2016.

Zhao H., HCCI and CAI Engines for the Automotive Industry. Elsevier Science, 2007.