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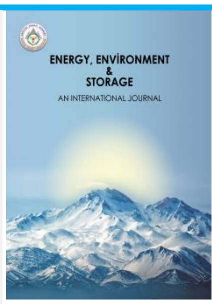


# Experimental Investigation of Energy Analysis of Methanol-Gasoline Mixtures at Different Torque Values

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I. **ABSTRACT**. Despite the increasing use of petroleum-based fuel as a result of ever-increasing energy demands, the search for alternative fuels remains important. In this study, in a Lombardini LGW 523 brand 2-cylinder 4-stroke water-cooled engine, different volumetric ratios of methanol and gasoline fuel mixtures (M10, M20, M30, M40) were used at 4 different torque values (5, 10, 15, 20 Nm) at a constant 3000 engine speed. It is discussed. As a result of the study, engine performance, emission and energy analysis examination was carried out experimentally.

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***Keywords:*** Energy, Exergy, Internal Combustion Engine, Methanol Fuel

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## 1. INTRODUCTION

Unlike fossil fuels, biomass is a renewable alternative energy source because vegetation renews itself every year. Therefore, biomass energy is important as a sustainable energy source. Additionally, while resources such as wood, biomass and biogas are considered non-commercial fuels, for example leaves, corn cobs, pea pods, algae, bacteria, algae and any form of fertilizer are fuels with commercialization potential [1].

Biodiesel, which is an alternative fuel obtained through biomass technology, can be produced from used or unused vegetable and animal oils by various methods. Since biodiesel fuel properties are very similar to those of diesel, it can be used alone or mixed with diesel fuel in different proportions in diesel engines without any problems [2]. Atabani et al.[3], detailed the raw material source of biodiesel, its extraction, biodiesel production methods, properties and quality of biodiesel, problems and potential solutions of using vegetable oil in biodiesel production, advantages and disadvantages of biodiesel, its economic feasibility and sustainability, and its future. They were examined in this way. Suresh et al. [4], in their study, examined the effects of biodiesel obtained from waste cottonseed oil on engine performance and exhaust emissions. According to the test results, they revealed that biodiesel reduces thermal efficiency, low biodiesel ratio reduces specific fuel consumption, increases NO emissions while reducing CO and HC emissions. However, they stated that the addition of biodiesel to diesel fuel increased the maximum cylinder pressure values. Yang et al.[5], examined the use of biodiesel obtained from waste cooking oil directly in a diesel engine and engine performance and emission analysis. As a result, they revealed that biodiesel reduced engine torque and power values and increased specific fuel consumption values. Özsezen and Çanakçı [6], mixed the biodiesel obtained from waste palm oil into diesel fuel at a ratio of 5-20-50% and compared the engine performance and emission parameters according to biodiesel and diesel fuel. They found that there was a decrease in engine torque and an increase in specific fuel consumption associated with the increasing percentage of biodiesel in the mixture. Ref [7] determined the engine performance and exhaust emission values using gasoline, pentanol-gasoline, hexanol-gasoline, and heptanol-gasoline in a spark-ignition engine (SIE) at a different load conditions and under constant speed. They analyzed a lot of parameters (energy, exergy, economic, environmental, and sustainability). Their results concluded that the addition of different heavy alcohols to gasoline, reduces the thermal efficiency and increases the fuel consumption.

Sayin Kul and Ciniviz [8], investigated energy and exergy analyses by blending two different bioethanol with

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gasoline on an SI engine. They prepared their fuels by adding both bioethanol, one of them was produced from waste bread and the other from sugar beet. They carried out the tests at 5 different engine loads and 2500 rpm. As a result of the study, the addition of bioethanol had a reducing effect on the rates of energy loss, exergy destruction and exergy loss.

Doğan et al [9], experimentally investigated effects of fuel blends in different proportions on exhaust emissions and engine performance. Experiments have been carried out at different engine speeds (1250–3000 rpm) and different blends (D100, F5, F10, F20, F30, and F37) in the full load conditions. In their studies, they also conducted exergy, energy, and exorgoeconomic analyses. They observed that the addition of fusel oil to diesel demostrated a significant decrease in NOX, CO2 emissions and a significant increase in particulate matter, CO and HC emissions.

Using safflower (Carthamus tinctorius L.) oil methyl ester (SOME) and conventional diesel at varying engine loads and constant engine speed (1500 rpm), Yaman [10] examined the energy and exergy analyses. Their findings demonstrate that as load and CR increased so did the energetic and exegetic efficiency values. In an internal combustion engine operating at less than 100 Nm, biodiesel and diesel fuels were experimentally examined by Yıldız et al. [11]. Energy, energy consumption, and environmental effects were examined with and without an after treatment system using a silicon carbide-based diesel particle filter (SiC-DPF). When SiC-DPF is used, CO2 emissions from biodiesel fuel are reduced, while those from diesel fuel are increased. The methanol/biodiesel blends were studied by Xu, G. et al. [12] under various engine loads, speeds, and conditions. Several structural factors, including average particle size, specific surface area, average pore radius, and pore volume of particulate matter, were taken into account in their investigations. The effects of methanol additives and Jatropha biodiesel-diesel blends on a single-cylinder diesel engine were obtained by Rai, R. V. et al. [13]. They observed that engine power, effective efficiency, volumetric efficiency, and specific fuel consumption value were all increased when biodiesel-methanol blend fuels were used.

As can be seen when the literature is examined, there are many studies on energy and exergy analyzes of biomass-fueled thermal power plants, and recently, studies on energy and exergy analyzes in internal combustion engines have increased. This study contributed to the literature by presenting energy analysis for methanol added to gasoline at different torque values.

## 2. MATERIALS AND METHODS

### *2.1 The Experimental Setup*

The experimental setup consists of engine, eddy current dynamometer, measurements system, emission device, and fuels (gasoline and methanol). The experiments were carried out in Dept. of Mechanical engineering engine laboratory in Erciyes University. The experimental setup system is given in Fig. 1.

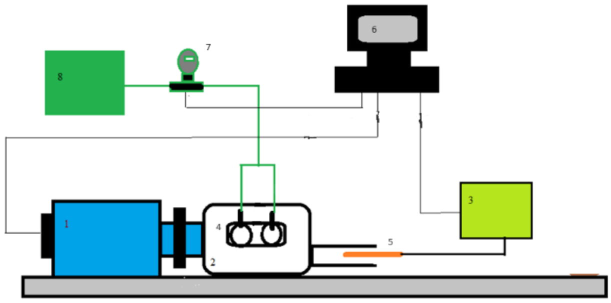


**Fig. 1.** Schematic view of the experimental setup

1 dynamometer, 2 engine, 3 exhaust emission device, 4 petrol injectors, 5 exhaust probe, 6 computer, 7 liquid flow meter, 8 fuel tank,

A 2-cylinder, 4-stroke spark ignition Lombardini LGW 523 MPI engine, whose specifications are given in Table 1, was used in the experiments. In the experiments, 90% gasoline - 10% methanol (M10), 80% gasoline - 20% methanol (M20), 70% gasoline - 30% methanol (M30) and 60% gasoline - 40% methanol (M40) mixtures were used at 3000 rpm. It was tested at 4 different torque values (5, 10, 15 and 20 Nm) at constant engine speed.

**Table 1.** Lombardini LGW 523 engine features [14]

| **Engine Type** | **Unit** | **Value** |
|---|---|---|
| Number of cylinders | - | 2 |
| Diameter of the cylinder | mm | 72 |
| Stroke | mm | 62 |
| Cylinder volume | cc | 505 |
| Stroke ratio | - | 10, 7:1 |
| Revolution maximum | rpm | 5500 |
| Max. of the power (5000 rpm) | kW/HP | 15/20.4 |
| Max. of the torque (2150 rpm) | Nm | 34 |

SAJ brand SE150 model eddy current electric dynamometer was used for torque and power measurements. Gasoline and Methanol flow rates were determined with a liquid mass Krohne Optimass 3300C brand device. Exhaust gas measurements were carried out with a Bosch BEA 060 gas analyzer, and the features and error ranges of the equipment and sensors are given in Table 2.

**Table 2**. Specifications and error ranges

| Instrument | Values | Accuracies |
|---|---|---|
| Liquid flow meter | 1.2–130 kg/h | ±0.035% |
| Hot film air mass meter (Bosch HFM 5) | 10–480 kg/h | ≤3% |
| Eddy Current Dynamometer | 150 kW/8000 rpm | ±1 rpm |
| **Exhaust gas analyzer (Bosch BEA 060)** | | |
| CO | 0–10% Vol | 0.001% vol |
| $CO_2$ | 0–18% Vol | 0.010% vol |
| $O_2$ | 0–22% Vol | 0.010% vol |
| $NO_x$ | 0–5000 ppm | 1.0 ppm |
| HC | 0–9999 ppm | 1.0 ppm |
| Lambda | 0.5–9.999 | 0.001 |

Before the experiments, the test engine was run at idle until it reached the regime temperature. After the engine reached the regime temperature, the load was gradually increased with the Eddy Current dynamometer until the maximum load value, and the tests were repeated at different torque values by applying load to the engine.

### *2.2 Thermodynamic Analyses*

First law analysis of thermodynamics was discussed to determine the energy inputs and outputs in the system. Exergy analyzes are calculated with combustion products obtained from combustion reaction equations. For this reason, calculations were made for combustion according to the combustion reaction equation 1 given in the literature [15]. The complete combustion equation is also shown in equation 2.

$$a(C_{X1}H_{Y1}) + b(C_{X2}H_{Y2}O_{Z2}) + c(C_{X3}H_{Y3}) + d(O_2+3,76N_2) \rightarrow e(CO_2) + f(CO) + g(O_2) + h(H_2O) + i(N_2) \quad (1)$$

$$a(C_{X1}H_{Y1}) + b(C_{X2}H_{Y2}O_{Z2}) + c(C_{X3}H_{Y3}) + d(O_2+3,76N_2) \rightarrow e(CO_2) + f(H_2O) + g(N_2) \quad (2)$$

The following assumptions were made for energy and exergy analyses.

- The engine operates in steady state,
- The combustion air is assumed an ideal gas,
- There is no water vapor in the combustion air,
- Potential and kinetic energy effects are neglected.

### *2.3 Energy Analyses*

As predicted by the first law of thermodynamics, the energy balance equation for the current engine system is shown by equation 3-5.

$$\sum \dot{E}_{in} = \sum \dot{E}_{out} \quad (3)$$

$$\dot{E}_{in} = \dot{E}_{fuel} \quad (4)$$

$$\dot{E}_{out} = \dot{E}_{W} + \dot{E}_{ex} + \dot{E}_{loss} \quad (5)$$

$\dot{E}_{in}$ total entering energy, $\dot{E}_{out}$ total outgoing energy,

$\dot{E}_{fuel}$ total chemical energy of the fuel entering the system

$\dot{E}_{W}$ net power produced, $\dot{E}_{ex}$ energy of the exhaust gases, $\dot{E}_{loss}$ the energy losses occurring in the system. $\dot{E}_{fuel}$, $\dot{E}_{W}$, $\dot{E}_{ex}$ and $\dot{E}_{loss}$ were calculated according to equations 6, 7, 8, 9 and 10, respectively.

$$\dot{E}_{fuel} = \dot{m}_{fuel}\, H_U \quad (6)$$

$$\dot{E}_{W} = \frac{2.\pi.M.n}{60\,.1000} \quad (7)$$

$$\dot{m}_{ex} = (\dot{m}_{fuel} + \dot{m}_{air})\, 0,98 \quad (8)$$

$$\dot{E}_{ex} = \dot{m}_{i}\varepsilon_{t} \quad (9)$$

$$\dot{E}_{loss} = \dot{E}_{fuel} - \dot{E}_{ex} - \dot{E}_{W} \quad (10)$$

Thermal efficiency of the system:

$$\eta = \frac{\dot{E}_{W}}{\dot{E}_{fuel}} \quad (11)$$

## 3. RESULTS AND DISCUSSION

### *3.1 Fuel consumption*

M10 fuel was prepared by mixing the gasoline and methanol fuel used in the experiments volumetrically (90% gasoline + 10% methanol). Since methanol fuel has a lower calorific value, more fuel must be used to give the same torque values at the same speed. When fuel consumption is examined, as the amount of methanol increases, the hourly fuel amount increases. Figure 2 shows the variation of specific fuel consumption with Torque values. As torque values increased, specific fuel consumption values decreased. The reduction rate between 5 and 20 Nm torque values is 57.6% for M10 fuel, 52.8% for M20 fuel, 52.4% for M30 fuel and 51.1% for M40 fuel.

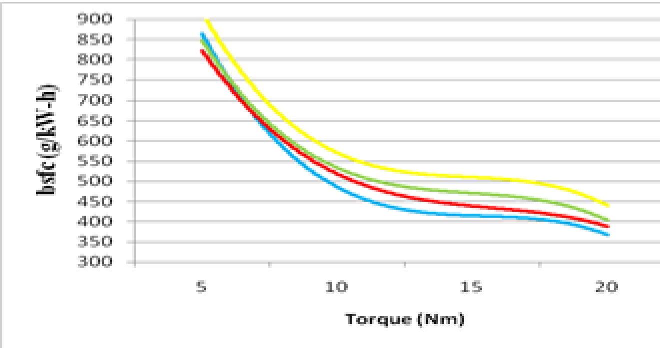


**Fig. 2.** Torque values versus the brake specific fuel consumption.

Figures 3 shows the changes in CO, CO2, HC, and NOx emissions depending on the torque value, respectively. When CO emissions were examined, it was observed that as the amount of methanol in the fuel increased, the amount of CO emissions decreased. The best results in CO2 emissions were obtained with M40 fuel. When HC emissions are examined, the amount of HC emissions is at a minimum level in the experiments conducted with M30 fuel. The calorific value of M10 blend fuel is the highest compared to other fuel blends, so the in-cylinder temperature is high. NOx emissions increased because the in-cylinder temperature was high. The high in-cylinder temperature also increased the exhaust gas energy and did not adversely affect combustion, on the contrary, it worsened the thermal efficiency. For this reason, it has been observed that HC emissions also increased. Regarding NOx emissions, it was observed that the highest NOx value was obtained in M10 fuel, as the calorific value of the fuel decreases as the amount of methanol in the fuel increases. In addition to increasing the amount of methanol in the mixture, the in-cylinder combustion temperature will decrease due to the low calorific value of methanol. For this reason, it is normal that the highest NOx emissions are in M10 fuel.

Energy distributions at different torque values are presented in Figures 4. As can be seen from this graph, as the torque value increased, the fuel energy values also increased. The formation of high combustion temperature with the increase in applied load increased the oxidation reaction of the products entering the combustion chamber. Additionally, higher temperature results in higher useful energy. As the torque value increases, the energy lost increase due to engine cooling water and exhaust gases, heat transfer and friction increases. It can be said that the reason for this increase is due to the increase in combustion temperature. As the torque increases, the rate of lost energy decreases. The best results in terms of fuel energy were obtained with M10 fuel. In terms of exhaust losses and lost energy, M30 fuel gave better results.

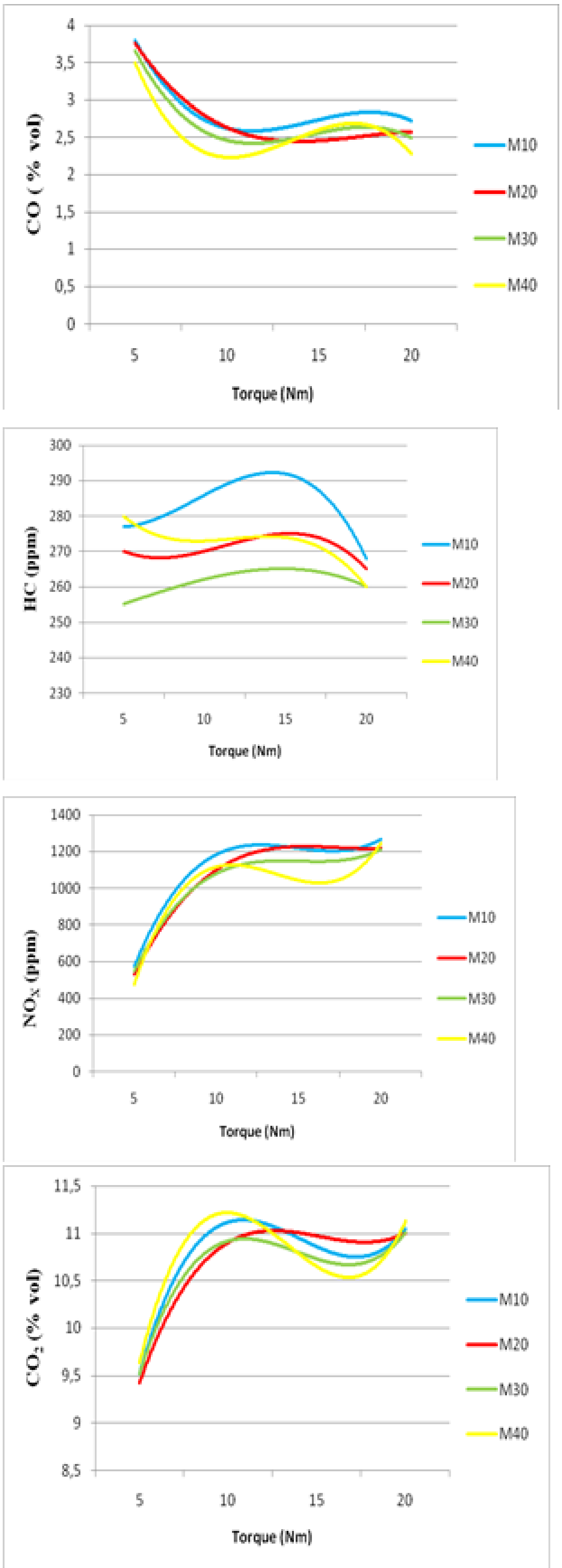


**Fig. 3.** Emission changes versus the torque values

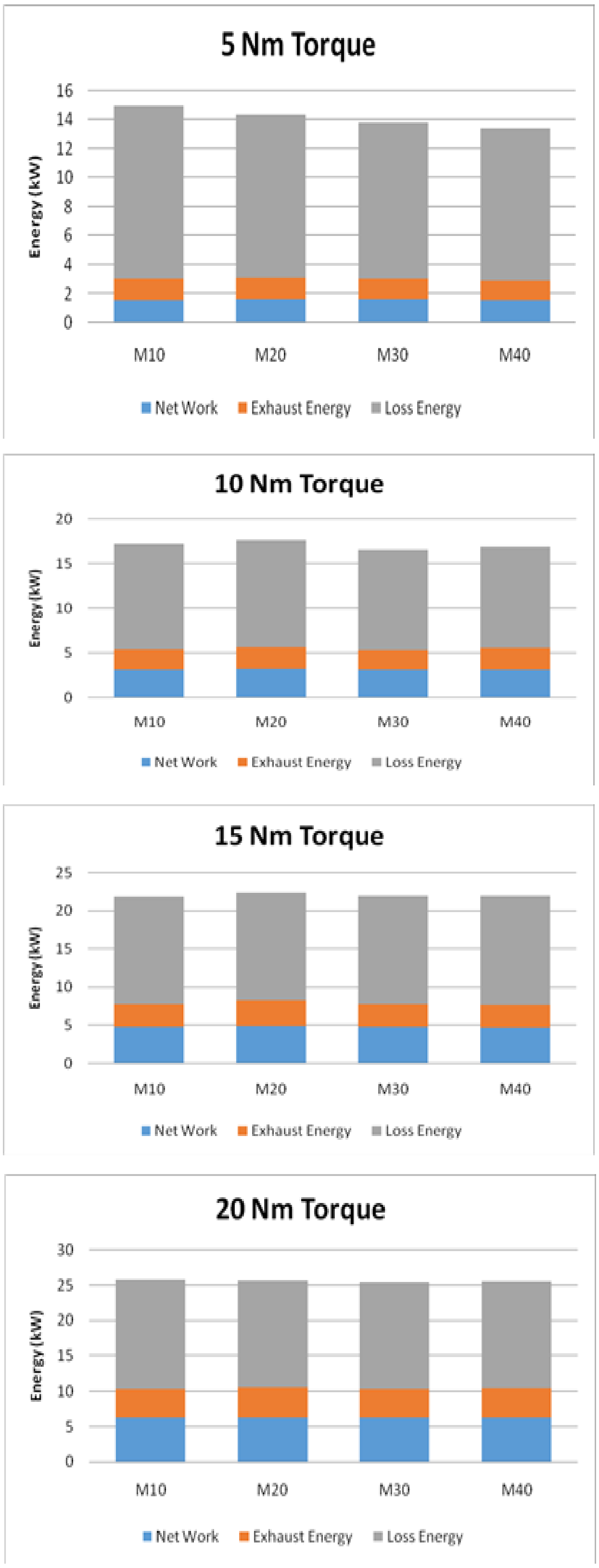


**Fig 4.** Energy changes at different torque values of different fuel mixtures

## 4. CONCLUSION

In this study, experimental examination of different volumetric ratios of methanol and gasoline fuel mixtures (M10, M20, M30, M40) at constant engine speed (3000 rpm) and 4 different torque values (5, 10, 15, 20 Nm) was carried out. The results obtained are briefly:

- When the torque values increase, the specific fuel consumption values decrease.
- Methanol added to the fuel resulted in a decrease in CO emissions. The best outcome in terms of CO2 emissions was achieved when using M40 fuel. When examining HC emissions, it was observed that the minimum level of HC emissions occurred in the experiments conducted with M30 fuel. In terms of NOx emissions, it was found that the highest NOx value was observed in the experiments conducted with M10 fuel.
- It was noticed that the fuel energy values increased with an increase in torque.
- When the torque increases, the rate of energy loss decreases.
- The M10 fuel produced the best fuel energy results, while M30 fuel had better results in terms of exhaust losses and lost energy.

**Nomenclature**

CI Compression Ignition

CO Carbon Monoxide

CR Compression Ratio

HC Hydrocarbon

HEP25 25% 1-heptanol + 75% gasoline

HEX25 25% 1-hexanol + 75% gasoline

NO Nitrous oxide

PEN25 25% 1-pentanol + 75% gasoline

SiC-DPF silicon carbide-based diesel particle filter

SOME Safflower oil methyl ester

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