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Makale
(Article)

Atık Lastik Sıvısından Elde Edilen Benzin Benzeri Yakıtın Benzin ile karıştırılarak Motor Performans ve Egzoz Emisyon Üzerindeki Etkisi

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Özet

Bu çalışmada, atık lastik sıvısında üretilen benzin benzeri yakıtın (BBY) ve benzin yakıtına (BY) kütlesel olarak 10%, 20%, ve 30% oranlarında BBY ile yapılan karışımının, buji ateşlemeli (BA) motorda performans ve egzoz emisyon karakteristikleri incelenmiştir. Deneylerde, fren torku, güç, ortalama fren efektif basıncı, fren özgül yakıt tüketimi ve ısıl verimlilik parametreleri test edilmiştir. Ayrıca, egzoz gaz sıcaklığı, NO, NOx, CO, CO_2, ve HC emisyonları analiz edilmiştir. BBY'nin yüzdeliği BY'de artınca güç, fren torku, ortalama fren efektif basıncı ve termal verimlilik artarken fren özgül yakıt tüketimi azalmıştır. BBY oranin karışımda artirilmasiyla, CO_2, NOx, NO emisyonları artarken, CO azalmıştır. Ayrıca, HC ve O_2 emisyonu artmıştır. Test sonuclarina gore, numuneler problemsiz olarak yanmistir.
Anahtar Kelimeler: Atik Lastik Sıvısı, Benzin, Benzin Benzeri Yakıt (BBY), Motor Performansı, Egzoz Emisyonu.

Gasoline-Like Fuel Produced from Waste Tire Mixed with Gasoline and Its' Affect on Engine Performance and Exhaust Emission

Abstract

In this study, engine performance and emission of spark ignition (SI) engine were tested by gasoline Fuel (GF), gasoline-like fuel (GLF) produced from waste tire oil, and blends of GF and GLF with amount of 10%, 20%, 30%. During the experiments, performance parameters such as brake torque (T), power (Pb), mean effective pressure (Bmep), brake specific fuel consumption (Bsfc), and brake thermal efficiency (ηbt) were tested. Furthermore, exhaust gas temperature (EGT) and the engine emission parameters such as, nitrogen oxide (NO), nitrogen dioxide (NOx), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and unburned hydrocarbon (HC) were analyzed. As the GLF percentage were increased at the GF, Pb, T, Bmep, ηbt were increased but Bsfc were decreased. By increasing GLF amount into the mixture, the CO_2, NO, NOx, were increased, while that of CO was decreased. Furthermore, HC and O_2 were increased. The samples burned without any problems according to the test results.
Keywords : Waste tire oil, Gasoline, Gasoline-Like Fuel (GLF), Engine Performance, Exhaust Emission.

1. INTRODUCTION

Industrial utilization and progressively increasing inhabitant have effect on energy demand. Thus,

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alternative energy sources are researched by countries to satisfied energy needs. Another problem is that fossil fuel decreased by high energy consumption as heating, transportation, power generation, and industrial and agricultural companies. Renewable and alternative sources such as hydropower, biomass, wind, solar, geothermal and nuclear are essential to produce new fuels. Besides, municipal and waste solids are others alternatives resources. New energy sources have to figure out environmental, global warming and atmospheric problems [1, 2]. Many waste types were mentioned at the literature, especially as waste oils, trees, plastics, tires, and so on. The waste tire is a high potential sources in the world which are increased by vehicle manufacturing. Rodriguez [3] informed that tire productions amounts were 15 million tons per annual in the European Union, 2.5 million tons per annual in North America, 2.4 million tons per annual in UK, 1 million tons per annual in China, 0.5 million tons per annual in Japan and 0.17 million tons per annual in Korea million tons per annual.

The tire disposal damage human health and environmental if they cannot collect in benefit way. The most common method of waste tire recycling is landfilling. But it caused some problems as possible fires accidents which generate high hazardous emissions. And also stockpiles produce some disease caused by mosquitoes and other insects [3, 4]. Therefore; gasification, pyrolysis and combustion methods are applied to convert to alternative energy products [5–7]. A new and plentiful technique to convert tire to useful products is pyrolysis which is used for energy conversion and environmental preservation. Pyrolysis decompose tire at high temperatures between 300 ^{o}C and 900 ^{o}C. Pyrolysis products are high energy density liquids, char and gases which may be used as fuels or as feedstock for petrochemicals and other applications.

Gartzen López [8] distillated in a conical spouted bed reactor at 425–600 ^{o}C range gives way to a yield of 1.8–6.8 wt.% of gases, 44.5–55.0 wt.% of liquid fraction, 9.2–11.5 wt. % of tar and 33.9–35.8 wt.% of char. The study compared with previous batch processes and observed that the light aromatics, which is lower on the contrary, the heavy liquid fraction or tar, which is higher in the batch process. [9]. The tire oil and activated carbon were produced from scrap tires. It was aimed to pyrolyzed high tire oil yield at high temperature by lower pressure. The results were as 46% of oil, 40% of activated carbon and 14% of gases yielded [10]. Huang [11] investigated waste tire powder pyrolysis in RF plasma reactor under low pressure. As consequence, the solid conversion between 40%-78.4% to the gaseous product which include a high of H_2% and CO% while little methane and other light hydrocarbons percentage. The tire conversion to H_2 concentration are increased by high power and pressure. The results give an idea to recycle polymer waste useful products by feasible RF plasma method.

Islam studied on waste tire of Bangladesh bicycle/rickshaw in a fixed-bed fire-tube heating reactor under different conditions to realize final temperature, sweeping gas flow rate and feed size affects on compositions and yields of the products. Final temperature were changed between 375-575 ^{o}C and the optimum temperature was 475 ^{o}C to obtain high yield liquid products. The products properties were analyzed by elemental analyses, FT-IR, 1H-NMR and GC–MS. The waste tire had available chemical feedstock which compare to standard fuels due to the pyrolysis conditions [12]. Onenc et. al. [13] pyrolyzed different types hazardous wastes. The water oil, oil sludge of ship and scrap tires were mixed to expose at 400 and 500 ^{o}C in absence and presence of catalyst as Red Mud. The products were separated into gas, oil and char. The oils were analyzed by using GC-MSD and 1H-NMR. Moreover, temperature and catalyst effect on oil distribution and composition were discussed. The results of the oil can be chemical feed stocks furthermore tire can also be used as chemicals or fuels. Besides, the oil products were friend to environment.

The spark ignition engines (SI) were used to burn gasoline and its derivates such as gasoline mixtures with alcohols, hydrogen, natural gas, liquefied petroleum gas and so on to obtain performance and exhaust emissions fuels effects. But, there are no work on waste tire oil and its fraction which burn in SI engines. Most of the studies, the waste tire oil burned in diesel engines as fuel or mixed with diesel. Effects of the first fraction of waste tire oil affect on performance and exhaust emission, were investigated.

The present study, first fraction called as gasoline like fuel (GLF) was produced from waste tire oil (WTO) at fixed bed pyrolysis system. Four types of fuels burned at SI engine which are gasoline fuel (GF), GLF and 10%, 20% and 30% GLF additions to GF which performance and emissions were investigated experimentally. Therefore, the GLF properties such as density, flash point, and higher heating value and distillation test were analyzed. And then, engine performances as torque, power, brake mean effective power (Bmep), thermal efficiency (ηbt), brake specific fuel consumption (Bscf), and exhaust gas temperature (EGT). Furthermore, exhaust emissions such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen monoxide (NO), nitrogen dioxide (NOx), oxygen (O_2), and unburned hydrocarbon (HC) were analyzed. The GF is burned in SI engine and performance parameter with emission results were compared with GLF and GF-GLF mixture results.

2. RECYCLING UNIT FOR FUEL SAMPLE

The GLF fixed bed pyrolysis unit and its production method are explained shortly. The fixed bed was manufactured in industry for producing fuel samples from WTO which was founded in motor laboratory of Mechanical Engineering Department, University of Gaziantep, Turkey. A previous study, waste lubricant oil (WLO) were used to pyrolysis in the unit [5]. The unit is gathered of a reactor, heaters, a mixer, a condenser, a collector and a control unit. Schematic of the fixed bed unit is declared in figure 1. The main and important part of the system is the reactor which has a cylindrical shape, 30 cm diameter and 40 cm in height. The mixer was used for uniform temperature distribution and pyrolitic expose of the WTO into valuable sample. The reactor were wrapped by an electrical heating, has a 5 kW heating capacity to heat the sample up to maximum temperature as 600 ^{o}C. The electrical heaters, have resistance, were adjusted by a voltage control unit. The evaporated gases were liquefied by a water chiller condenser.

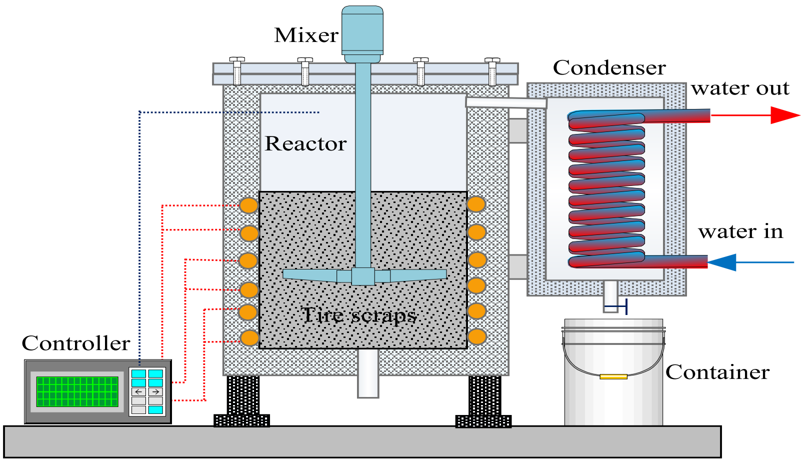

Figure 1. Schematic diagram of the distillation system.

The pyrolysis of the GLF were discussed in the previous study as [16], and explained briefly as follows: The waste tire pyrolyzed to produce pure oil named as waste tire oil (WTO). The WTO was blended with Natural Zeolite (NZ) and lime (CaO) with different mass bases ratio as 2 %, 4 %, 6 %, 8 %, and 10 %, respectively. Each of the samples were collected examined by distillation test. The best and optimum curve observed by 10% CaO which is resemble to diesel fuel standard. The 10% CaO-WTO mixture was boiled at 54 ^{o}C but diesel initial boiling starts from 150 ^{o}C. Thus, first fraction from 54 ^{o}C to 150 ^{o}C distillated into collector and then, second fraction from 150 ^{o}C to 365 ^{o}C collected into another tank. The first and second fractions have mass basis of 18 % and 60 % of total WTO, respectively. The first fraction distillation curve a little bit up from GF curve which named as gasoline like fuel (GLF), and the second fraction curve intersects with diesel which called as diesel like fuel (DLF). The distillation graphs of GLF, GF and GF-GLF were shown at figure 2. At figure 3, the 10% CaO-WTO mixture was heated up to 45 ^oC for 60 min and then incrementally increased temperature up to 150 ^oC for 120. Finally, temperature is fixed 150 ^oC for 40 to observe any droplet drop. During pyrolysis, the mixer worked until the end of the process. The volatile compounds were condensed by water condenser into a container. The GLF and DLF properties were such as, density, flash point and higher heating value analyzed that can be burn in standard engine. In this paper, the GLF, GF and GF-GLF characteristics test results are declared at table 1.

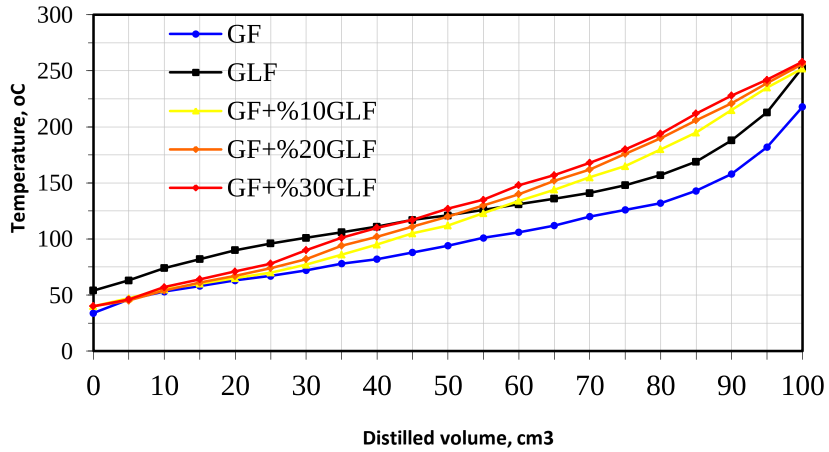

Figure 1. Distillation curves of the GF, GLF and GF-GLF mixtures.

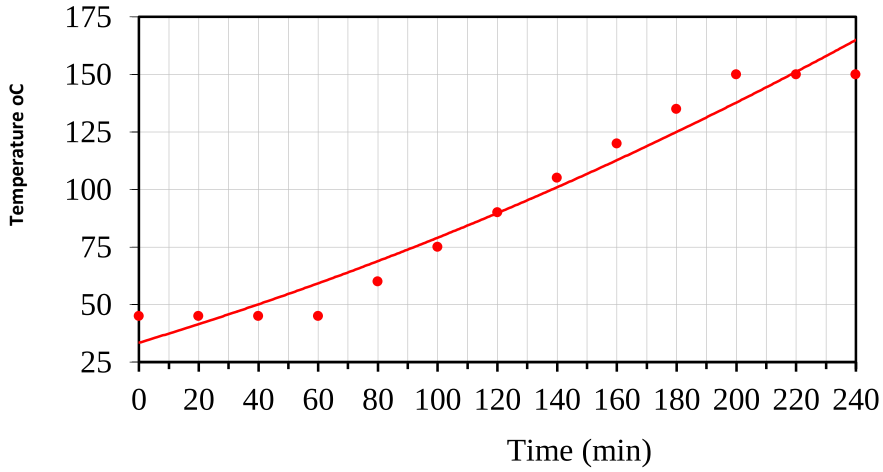

Figure 2. Variation of pyrolitic temperature with time for the GLF.

Table 1. Some characteristics of GF, GLF and its blends

Parameters	Method (ASTM)	GF	GLF	GF+%10 GLF	GF+%20 GLF	GF+%30 GLF
Density (kg/m^3)	D1298	880	740	754	768	782
Flash point (^{o}C)	D93	39	25	26	27	29
LHV (MJ/kg)	D270	44.5	43.0	43.13	43.3	43.45

3. EXPERIMENTAL SET-UP and FUEL SAMPLE TESTS

The experimental set-up and sample tests explained in two main sub-sections: at sub-section 1, characteristic of the fuel tests and testing procedures were expressed. In section 2, description of the performance and emission parameters. The recycling unit is discussed above in detail. The characteristics of the GF, GLF and GF-GLF measurements and, performance and exhaust emission parameters are presented in this section.

3.1. Characteristics of the fuel tests

For any fuel, there are three main valuable point order to predict unless the fuel will be burned in with any problem in an engine. Thus, distillation test, physical and chemical tests connected with fuel composition and its' structure. Some of the physical and chemical tests as density, flash point and higher heating value (HHV); for distillation test is initial and final boiling points (IBP and FBP), were used to determine fuel properties. The American Standards for Testing and Materials (ASTM) chemical methods such as the determination of IBP, FBP, distillation, density and LHV were figured out [7]. Characteristics and distillation test results for the fuel samples are discussed deeply in section 5.

3.2. Measurements of performance and emission parameters

The Fiat 131 SI test engine set-up was installed at Motor Laboratory, Mechanical Engineering Department, University of Gaziantep. Schematic drawing and picture of the SI test engine are represented at Figures 3 and 4. The SI test engine specifications are four-stroke and four cylinders, water cooled cooling system, fueled with carburetor and naturally aspirated. Each cylinder has 76 mm bore and 71.5 mm stroke. The highest engine power output was 52.2 kW at 5500 rpm. The engine specifications are declared at table 2 [7]. Four types of fuels burned at SI engine which are GF, GLF and 10%, 20% and 30% GLF additions to GF. All of the experimental procedure and equipments will be explained through section.

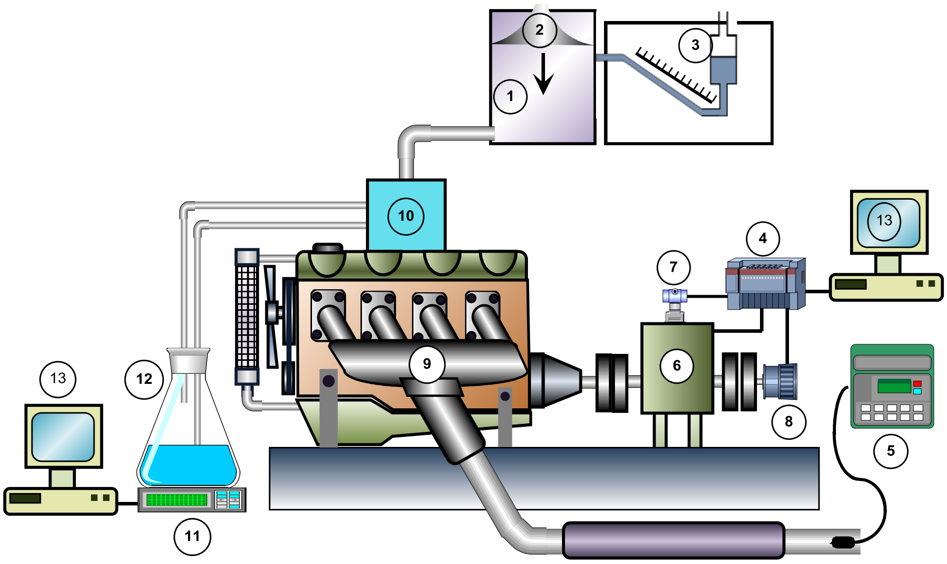

Figure 3. Schematic drawing of the SI test engine. 1) air tank, 2) orifice, 3) inclined manometer, 4) data logger, 5) exhaust gas analyzer, 6) dynamometer, 7) transducer, 8) tachometer, 9) exhaust manifold, 10) carburetor, 11) weighing device, 12) fuel container, 13) computer [7].

Figure 4. Picture of the SI test engine [7].

Table 2. Test engine specifications [7]

Type	Fiat
Engine type	Four-stroke
Fuel type	Gasoline
Swept volume	1297 cm^3
Cylinder bore	76 mm
Cylinder stroke	71.5 mm
Compression ratio	7.8:1
Number of cylinders	4
Cooling type	Water cooled in closed circuit
Fuel supply system	Naturally aspirated carburetor
Maximum torque	12.5 kg.m at 3000 rpm
Maximum power	52.2/70 kW/ HP at 5500 rpm
Engine position	Vertical

The engine test parts are weighing device, inclined manometer, dynamometer, tachometer, transducer, data logger, a personal computer (PC) and exhaust gas analyzer. At Fig. 3, test parts are set up on SI engine which shown schematically. The test parts were adjusted and data logger systems were transferred data into the PC. The SI engine runs 15 minutes to get ready for experiments. The engine worked without any problem. The data logger functions and computer, measuring elements, and techniques of experimental are discussed as follows:

The sensitivity of weighing machine is 0.1 g which was used to measure fuel consumption. Orifice meter coupled to an inclined manometer was used for measuring intake air mass flow rate. A large air tank connected to the engine carburetor with a plastic pipe, was used for damping out the pulsations produced by the engine to form a steady flow of the intake air. Air flow was realized by pressure difference which formed by a pipe bowl at the entrance of the air tank, was measured by a pressure transducer with analog output. Another analog/digital converter was used to change and transfer the digital signal to the PC for a time interval [7].

The hydraulic dynamometer with a range of 0–100 Nm, was used to measure torque. The engine speed mechanism was conducted with spark plug and a microprocessor which counts the ignition number by 1 rpm of engine speed. A step motor controls throttle valve for engine speed which has 1.8^o sensitivity by using this software. Consequently, the small time intervals were realized at different engine speed kinds [7].

Exhaust gas analyzer, Testo 350 model gas analysis device from Drager was used , was calibrated before each test to measure emissions. This device could detect carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_x) emissions with a sensitivity of ±1 ppm, and also oxygen (O_2) and (CO_2) emissions with a sensitivity of ±0.1 ppm. After the engine reached the measurement conditions, the analyzer probe was placed in the exhaust pipe. The emission results and performance parameters results would be explained and discussed in section 5. Besides, a k-type thermocouple and a temperature sensors were used to measure the exhaust gas temperature (EGT).

4. THE PERFORMANCE PARAMETERS OF SI ENGINE

The fuel combustion effect on the engine was explained with the engine performance and exhaust emission parameters by Arpa et. al. [2, 7]. The parameters would give an idea that can be used efficiently and without causing any trouble. Hence, the engine performance parameters are vital and should be specified. These parameters are brake torque (T), brake power (P_b), brake mean effective pressure (Bmep), brake specific fuel consumption (Bsfc) and the brake thermal efficiency. In addition to these, engine parameters were computed by fuel and air expending, HHV_{fuel}, torque and speed [7].

5. RESULTS AND DISCUSSION

The present work, waste tire was cleaned from dust, other impurities were washed by water, and then dried. The waste tire was liquefied to oil (WTO). The WTO mixed with at different mass bases ratio of 2, 4, 6, 8 and 10 percent with Natural Zeolite (NZ) and lime (CaO) exposing for resemble to standard fuel. The distillation curves of each samples were compared with diesel fuel. the best curve was 10% CaO-WTO mixture, and then it separate into fraction bu temperature differences as first fraction from 54 ^oC to 150 ^oC distillated into collector and then, second fraction from 150 ^oC to 365 ^oC collected into another tank. The first fraction was named as GLF, mentioned above. Distillation and some characteristics of the GLF, GF and 10%, 20% and 30% GLF additions to GF were tested. These characteristics, distillation, performance and exhaust emission test results were given in figures and were discussed separately in the following sections.

5.1. Physico-Chemical Properties and distillation tests

The physical, chemical properties of fuels are important for combustion. The most easy way to realize characteristic of fuel by distillation test. The method of distillation is that each of liquid evaporate and condensate due to boiling point of each droplet. Every boiling point of the droplet determine fuel characteristics and easily to indicate how combustion will take place in the engine combustion chamber. Four types of fuels were presented in this study. Some characteristics of the used fuels and gasoline given in Reference [16] and briefly tabulated at table 1.

5.2. Engine performance tests

The performance and emissions of the GF, GLF and GF-GLF mixtures were tested to compare. During the experiments, Performance parameters such as brake torque (T), power (Pb), mean effective pressure (Bmep), specific fuel consumption (Bsfc), and brake thermal efficiency (η_{bt}) were tested. The parameters were presented in figures to discussed in this section. Figure 4-8 show the effect of the GF and its blends with GLF at ratios of 10%, 20% and 30% on the performance parameters of Pb, T, Bmep, η_{bt} and Bsfc, respectively. T increase by engine speed; Pb, Bmep increase up to 2500 rpm, and then they start to decrease gradually with the engine speed [14], [15]; EGT increases by engine speed at Figure 9.

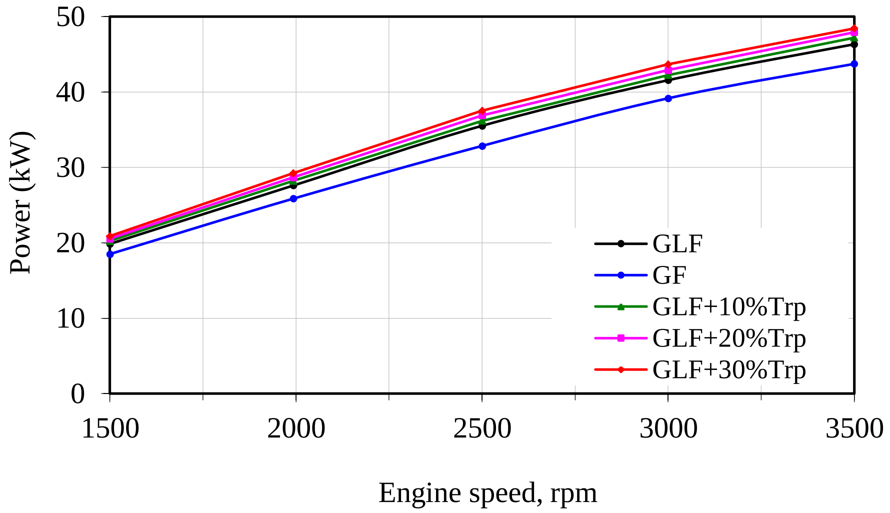

Figure 4. Effects of the GF, GLF and GF-GLF on power.

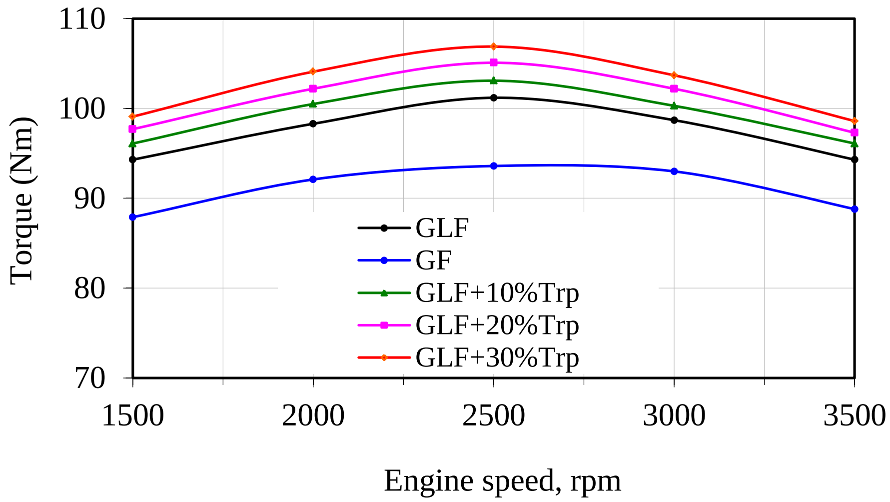

Figure 5. Effects of the GF, GLF and GF-GLF on torque.

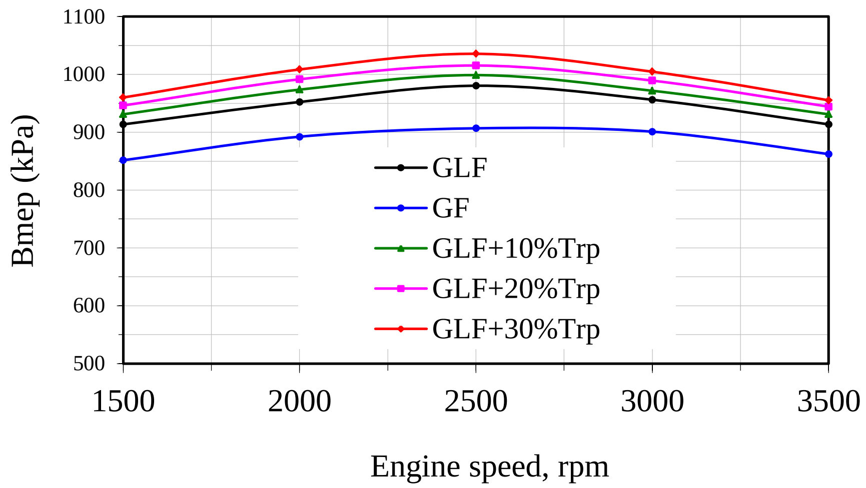

Figure 6. Effect of the GF, GLF and GF-GLF on Bmep.

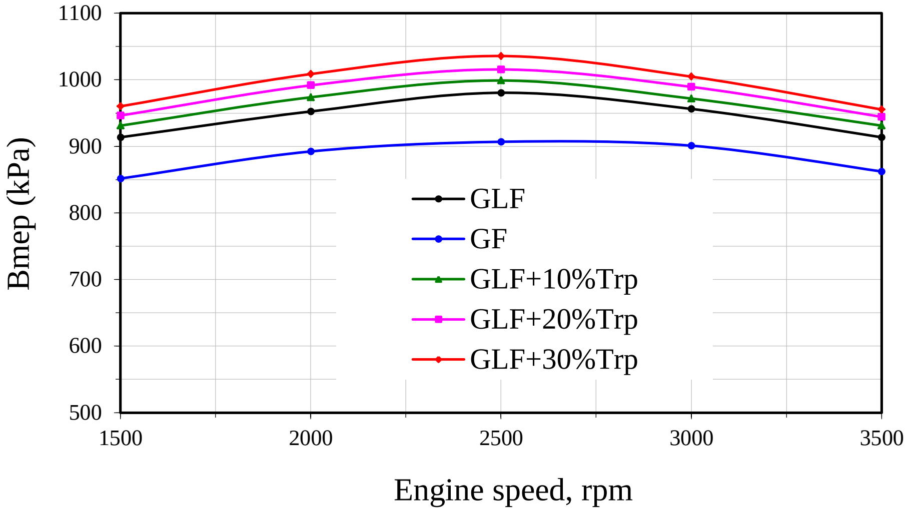

Figure 7. Effect of the GF, GLF and GF-GLF on brake thermal efficiency.

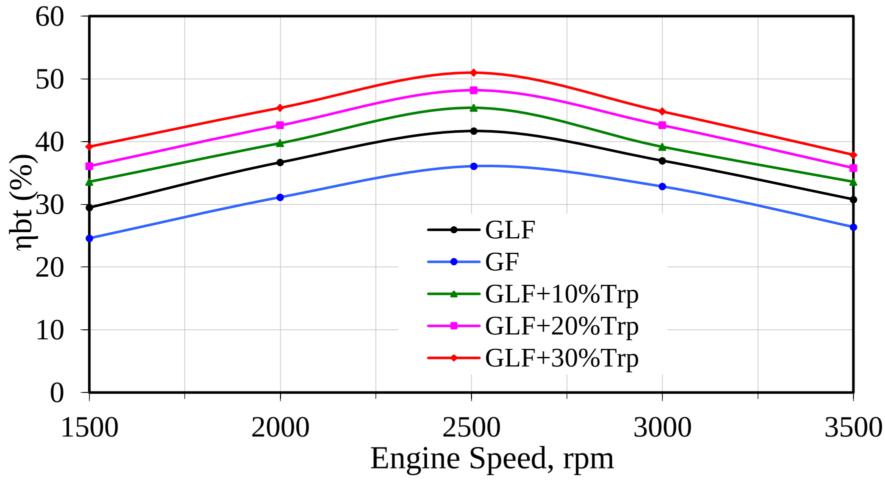

Figure 8. Effect of the GF, GLF and GF-GLF on Bsfc.

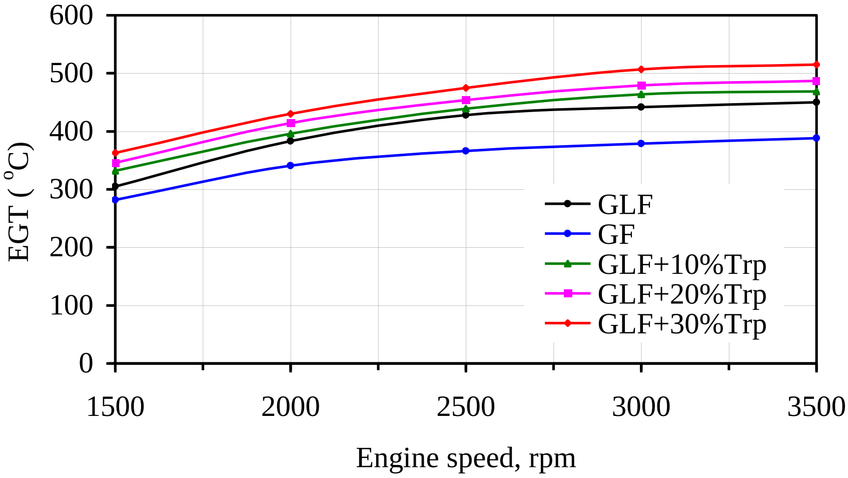

Figure 9. Effect of the GF, GLF and GF-GLF on exhaust temperature.

5.3. Exhaust gas temperature and emission tests

In this study, the engine emission parameters such as, NO, nitrogen oxide (NO), nitrogen dioxide (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and unburned hydrocarbon (HC) were analyzed by Testo 350 gas device. Figures 10-14 show that the 10%, 20% and 30% GLF-GF mixtures of CO_2, NO, NOx, were increased, while that of CO were decreased. Furthermore, HC and O_2 were increased. The samples burned without any problems according to the test results.

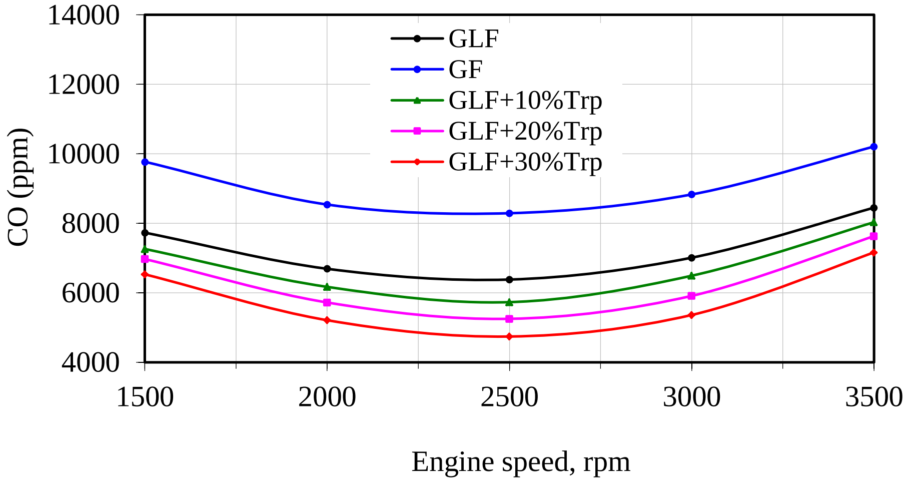

Figure 10. Effect of the GF, GLF and GF-GLF on CO emission.

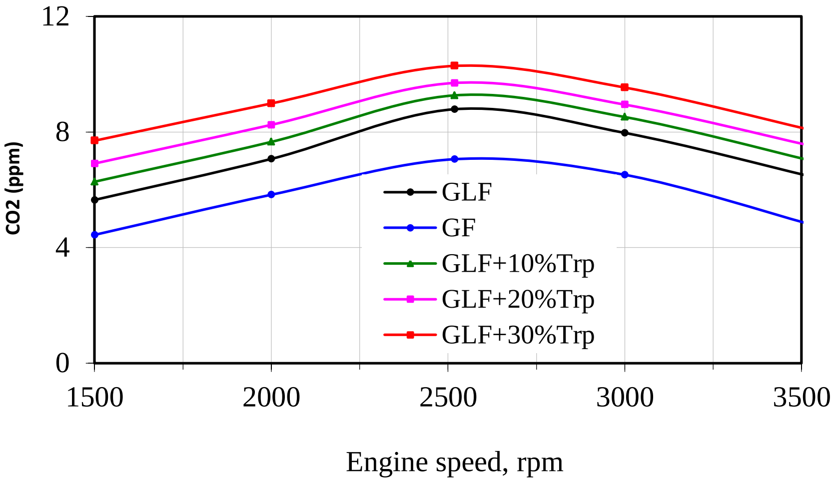

Figure 11. Effect of the GF, GLF and GF-GLF on CO_2 emission.

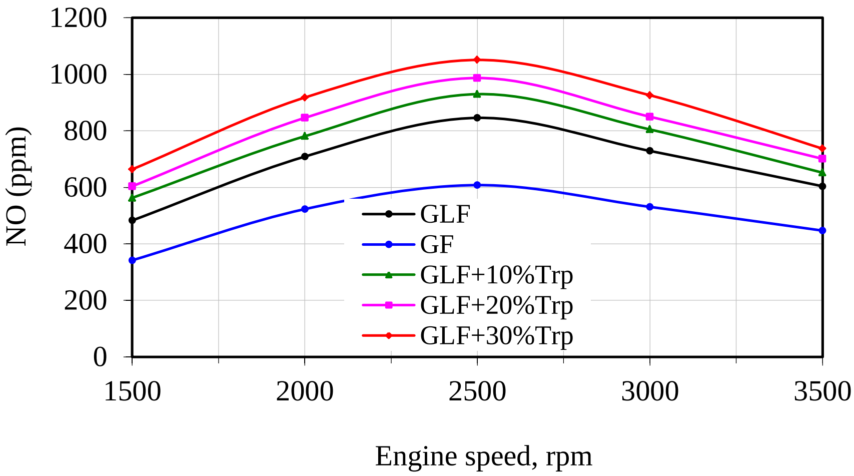

Figure 12. Effect of the GF, GLF and GF-GLF on NO emission.

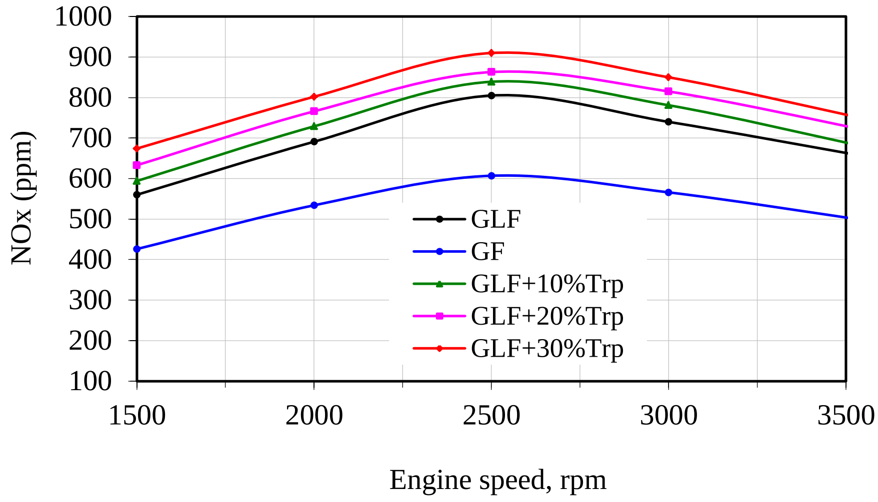

Figure 13. Effect of the GF, GLF and GF-GLF on NO_x emission.

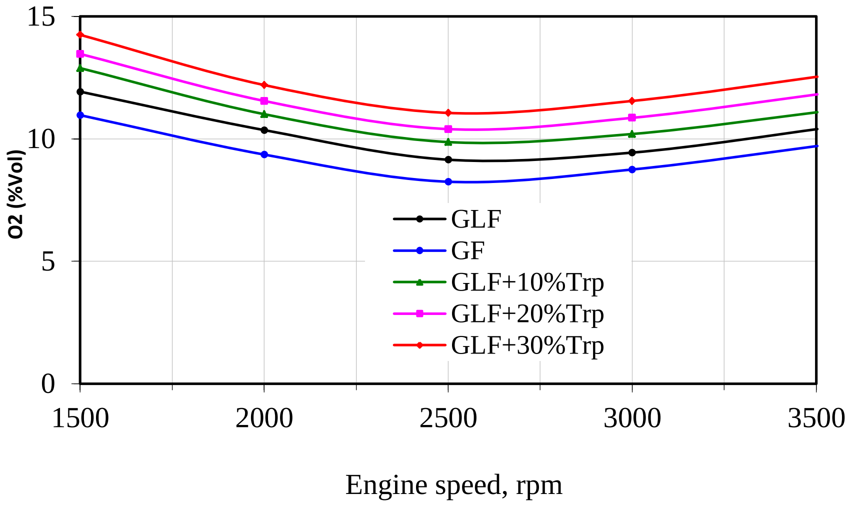

Figure 14. Effect of the GF, GLF and GF-GLF on O_2 emission.

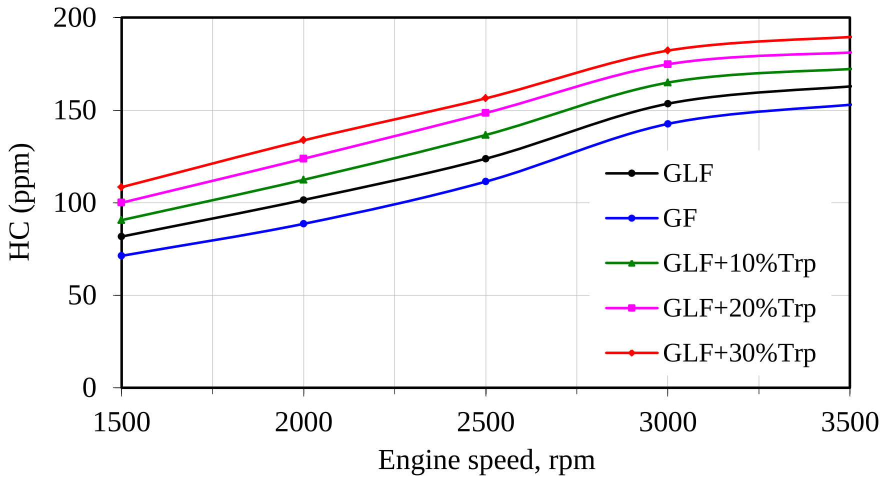

Figure 15. Effect of the GF, GLF and GF-GLF on HC emission.

6. CONCLUSIONS

The gasoline, GF, GLF and GF-GLF mixtures were tested to obtain performance and exhaust emission. The important results are presented below:

1. The GLF was obtained at different ratios from waste tire oil. The GLF is burned in the engine without any problem. The GLF was mixed with GF and reacted only as a fuel. In addition, GF/ GLF mixtures at 10 wt.%, 20 wt.% and 30 wt.% ratios were also burned in the SI engine without any problem.
2. The GLF is become a little bit higher than GF and by adding GLF into GF; P_b, T, Bmep, and Bsfc parameters were all increased, conversely, Bsfc value was decreased. But, by adding GLF into GF at 10 wt.%, 20 wt.% and 30 wt.%, the EGT of GF was increased. By increasing GLF in its GF mixture; CO_2, NO and NOx were increased, while CO amount was decreased. The O_2 was increased by increasing GLF, which has a positive effect on burning. The HC increases up to 3000 rpm than it increased slightly. The GLF has higher amount of HC than GF in emission results. By adding GLF into GF, the HC was increased. As a result, the amount of unburned fuel increases and more HC ends up in the exhaust.

7. ACKNOWLEDGEMENTS

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