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EXHAUST EMISSIONS FROM A SPARK-IGNITION ENGINE OPERATING ON ISO-PROPANOL AND UNLEADED GASOLINE BLENDS

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Abstract

In this study, the effect of blends of iso-propanol and unleaded gasoline on exhaust emissions of a spark-ignition engine were experimentally investigated. Exhaust emission tests were conducted on a four-stroke, four cylinder and direct injection spark-ignition engine. The engine tests were performed at three-fourth throttle opening position at four various speeds in the range of 1000-4000 rpm with 1000 rpm period. The experimental results compared with unleaded gasoline showed that emissions of carbon monoxide (CO) and hydrocarbon (HC) decreased with iso-propanol-unleaded gasoline blends while carbon dioxide (CO2) emission increased.

Key Words: SI engine, iso-Propanol, Unleaded gasoline, Exhaust emissions.

1. Introduction

Increasing environmental pollution is a essential issue that needs to be reduced. It is well known that internal combustion engines are a major environmental pollution contributor due to the exhaust emissions such as nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO2) and hydrocarbons (HC) emissions and smoke in exhaust. Experimental studies have shown that the use of oxygenated alternative fuels in engines has the potential to reduce the exhaust emissions that cause damage to the environment. The main oxygenated fuel used in vehicles powered by spark-ignition engines is alcohol fuels, and they produce lesser exhaust emissions than gasoline operation. Alcohols have long been regarded as promising alternatives to petroleum-based SI engine fuels [1]. Many studies have been carried out on the performance and exhasut emissions of spark-ignition engines fueled with alcohol-gasoline blends, reducing emissions are reported by [2-7]. For instance, Ceviz and Yüksel [8] investigated the effects of ethanol-unleaded gasoline blends on cyclic variability and emissions in a spark-ignited engine. In that study, results showed that using ethanol–unleaded gasoline blends as a fuel decreased the coefficient of variation in indicated mean effective pressure, and CO and HC emission concentrations, while increased CO2 concentration up to 10 vol.%ethanol in fuel blend. Çelik [9] used ethanol as fuel at high compression ratio in a gasoline engine. He found that the engine power increased when running with E50 fuel at high compression ratio compared to the running with pure gasoline fuel, and the reducing specific fuel consumption and exhaust emissions. In another study, Shenghua et al. [10] operated a three-cylinder SI engine with several fractions of methanol (10%, 15%, 20%, 25% and 30%) in gasoline under the full load condition. They found that the engine power and torque decreased, while the brake thermal efficiency improved with the methanol fraction increase in the fuel blend. In the same way, Fan et al. [11] used gasoline-methanol blends as fuels in a port fuel injection (PFI) gasoline engine without any modification. In that study, results showed that methanol-gasoline blended fuels had little influence on the engine engine performance, and the cylinder pressure and heat release rate showed no significant variation with the increase of the methanol content in the blended fuel. Also, methanol-gasoline blended fuels led to decrease in regulated emissions. As seen in the literature review, the effect of ethanol or methanol-gasoline blends on the performance and exhaust emission characteristics of spark-ignited engines has been widely researched. Exhaust emissions for ethanol or methanol-gasoline blends are reported to be lower than that of pure gasoline fuel, and the engine performance and exhaust emissions with ethanol-gasoline blends

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are similar to those with methanol-gasoline blends. Although methanol and ethanol have been investigated extensively in blends with gasoline, very few work has been done or reported on higher alcohols such as propanol, butanol and pentanol, as also stated by Gautam et al. [12] who investigated the emissions and fuel characteristics of higher alcohol/gasoline blends and neat gasoline to determine the advantages and disadvantages of blending higher alcohols with gasoline. This may be due to some features of higher alcohols such as higher production cost and its limited production from non-petroleum resources. Even though they can be produced commercially via fermentation, currently they are produced largely from petrochemical feedstocks [13]. Besides, it should be noted that higher alcohols have some significant properties such as lower vapor pressure, which reduces the chance of vapor lock, and better energy density and water tolerance compared to methanol and ethanol. Therefore, higher alcohol-gasoline blends as fuel have studied in spark ignition engines by researchers [12,14,15,18,19].

In this study, the effect of iso-propanol blending with unleaded gasoline on exhaust emissions of a DI spark ignition engine was experimentally investigated at three-fourth throttle opening position and variable engine speed operating conditions without modification. The obtained results were compared with those of unleaded gasoline operation.

2. Material and Method

The engine tests were conducted on a four-cylinder, four-stroke, water-cooled and Ford Brand direct injection spark-ignited engine. The engine used in experiments has electronic fuel injection (EFI). The experimental set-up consists of a spark-ignition engine, a test bed, exhasut emissions analyzers and control and monitoring system. The emission tests were performed without catalytic converter. The schematic diagram of the experimental set-up is shown in Fig. 1. The experimental set-up is installed in the Engine Laboratory of Department of Automotive Technologies in Fırat University. Iso-propanol with purity of 99.5%, provided from refinery and petrochemistry laboratory of Batman University, Batman, Turkey, were employed as gasoline additive in the experiments. Unleaded gasoline, which was provided a commercial fuelling station, located in Elazığ, Turkey, was used to compare and preparation of unleaded gasoline/alcohol blends. Three kinds of fuels were tested in this study. They were fuel blends of unleaded gasoline and iso-propanol, and also pure unleaded gasoline. P5, in which the content of iso-propanol is 5% by weight; P10, in which the content of iso-propanol is 10% by weight; and G, which is pure unleaded gasoline. The concentrations of the exhaust emissions (CO, CO2 and HC) were measured using a Sun Gas Analyzer MGA 1500 with a resolution of 0.001% for CO emission, 0.1% for CO2 emission and 1 ppm for HC. The exhaust temperature was measured using a CrAl–NiAl thermocouple (type K) located at 0.3 m downstream of the exhaust valve. A scale (Oertling brand, accuracy 0.1 g) and stopwatch were used for measurement of the fuel consumption rate. The engine tests were performed at three-fourth throttle opening position at four various speeds in the range of 1000-4000 rpm with 1000 rpm period. The required engine load was obtained through the dynamometer control. The brake torque and engine speed were recorded by digital indicator of the test ring. For a fixed engine speed, the brake torque was insensitive to the variation of the type of fuel, in the present study. Thus, the fuel consumption and brake torque showed very small changes as the small amounts of propanol was used. For every fuel change, the fuel tank and lines were cleaned. Before running the engine to a new fuel, it was allowed to run for some time to consume the remaining fuel from the previous experiment. The data was taken after the engine was run with the new fuel for enough time.

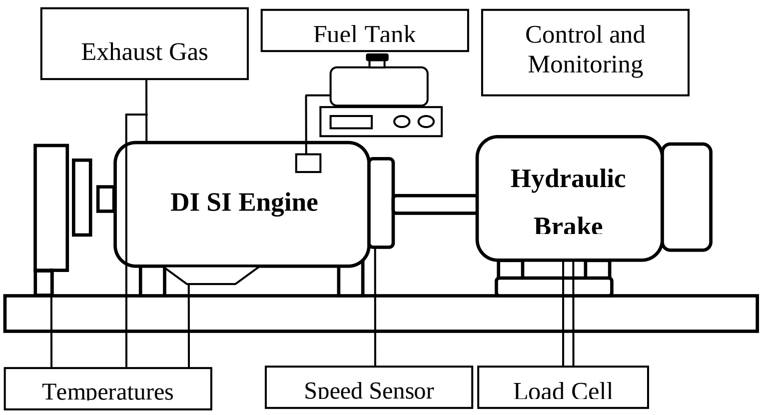

Fig. 1. Schematic diagram of the experimental set-up

The fuel properties of unleaded gasoline and propanol are shown in Table 1, and compared with ethanol properties [12]. As shown in Table 1, compared with ethanol, propanol has higher carbon content, heating value, stochiometric air/fuel ratio (AFR), and a lower elemental oxygen content and heat of vaporization. Compared with unleaded gasoline, propanol has lower carbon content, heating value and stochiometric air/fuel ratio (AFR), and higher heat of vaporization. Propanol contains molecular oxygen, typically unleaded gasoline does not contain. In addition, octane number of alcohol fuels is almost same, and higher that that of gasoline. The other important property is reid vapor pressure (RVP), and propanol has lower RVP than that of gasoline and ethanol.

Table 1. Fuel Properties of unleaded gasoline, propanol and ethanol

Properties	Gasoline (UTG 96)	Ethanol	Propanol
Chemical formula	C8H15	C2H5OH	C3H7OH
Oxygen content, wt. %	-	34.73	26.62
Carbon content, wt. %	86.3	52.2	59.9
Stoichiometric AFR	14.5	8.94	10.28
Specific gravity	0.743	0.7894	0.8037
Lower heating value, kj/l	31913	21183	23970
Heat of vaporization, kj/l	223	725	585
Research octane number, RON	96.5	111	112
Motor octane number, MON	87.2	92	-
Reid vapor pressure, kPa	61.4	19.3	9

3. Results and Discussion

Figure 2 shows the percent variation of the CO emissions of engine for unleaded gasoline-iso-propanol blends with reference to unleaded gasoline. The CO emission decreases with the increase of the propanol ratio. This is in agreement with the results of Yanju et al. [16], who found that the CO emissions of the engine decrease with the increase in methanol concentration. Compared to unleaded gasoline operation, CO emissions decreased with P5 and P10. This can be attributed to a better combustion as a result of the oxygen content in the propanol. He et al. [17] reported that decreasing CO emissions can be explained by the fact that the oxygen atom in ethanol molecule is more effective in improving combustion in rich mixture than that in air. Reducing CO emissions with the use of alcohol fuels have been reported intensively by researchers [18-20]. Furthermore, as shown in Table 1, propanol contains about 60% carbon (compared to unleaded gasoline which contains about 86%); therefore, it reduces carbon level in combustion chamber when blended fuels are used since corresponding increasing oxygen level may reduce quantitatively the CO formation during combustion.

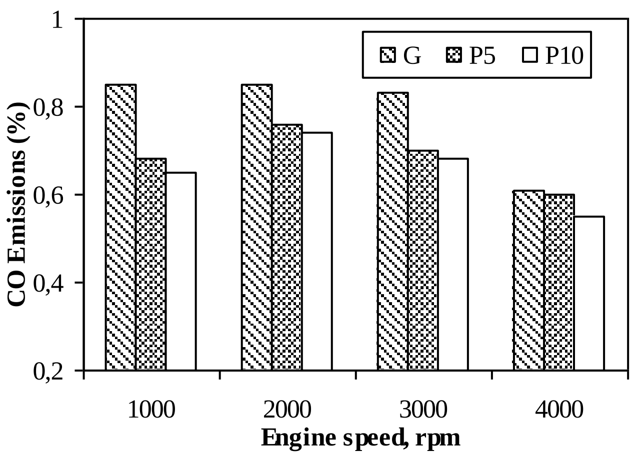

Figure 2. Change in the CO emissions.

Figure 3 shows the percent variation of the CO2 emissions of engine for unleaded gasoline-iso-propanol blends with reference to unleaded gasoline. The change in CO2 emissions have an opposite behavior when compared to the CO emissions, and this can be seen in both Figs. 2 and 3. Compared with unleaded gasoline, CO2 emissions of P5 and P10 are slightly increased, as shown in Fig. 3. This is likely due to improving the combustion process as a result of the oxygen enrichment coming from the propanol. It is noted that adding alcohol can promotes the oxidation of carbon in the fuel during combustion, thus leading to lower CO and higher CO2 emissions in comparison to unleaded gasoline.

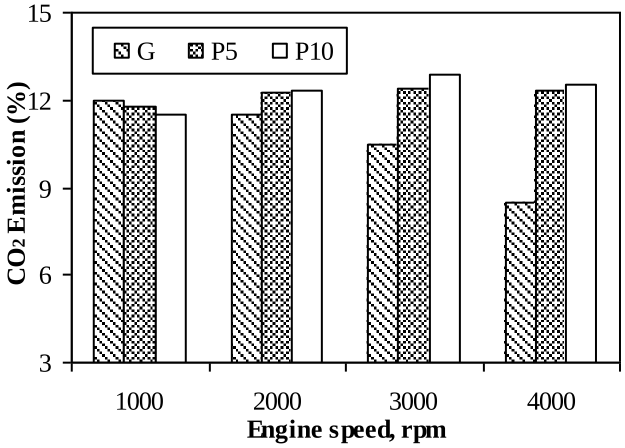

Figure 3. Change in the CO2 emissions.

Figure 4 shows the variation of the HC emissions of engine for unleaded gasoline-iso-propanol blends with reference to unleaded gasoline. It can be seen in Fig.4 that HC emissions of iso-propanol-unleaded gasoline blends are lower than that of unleaded gasoline. This may be a result of the leaning effect and oxygen enrichment caused by alcohol addition, as stated by Koç et al. [2], as unburned HC is the product of incomplete combustion.

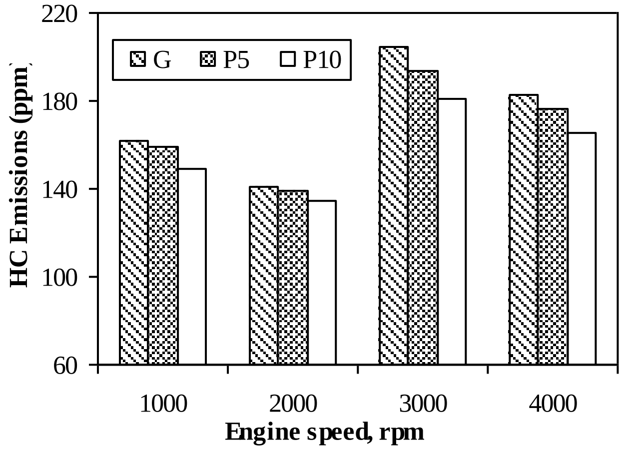

Figure 4. Change in the HC emissions.

Figure 5 shows the variation in exhaust gas temperature for unleaded gasoline-iso-propanol blends with reference to unleaded gasoline. P5 produced the highest exhaust gas temperature except at an engine speed of 2000 rpm, where G gave the highest. As seen in Table 1, propanol has higher heat of vaporization and lower heating value than unleaded gasoline. These properties may be reduced the gas temperature during the combustion process. In case of P5, the oxygen content of P5 may promotes the fuel oxidation of during combustion, thus leading to slightly higher exhaust gas temperature in comparison to other fuels tested.

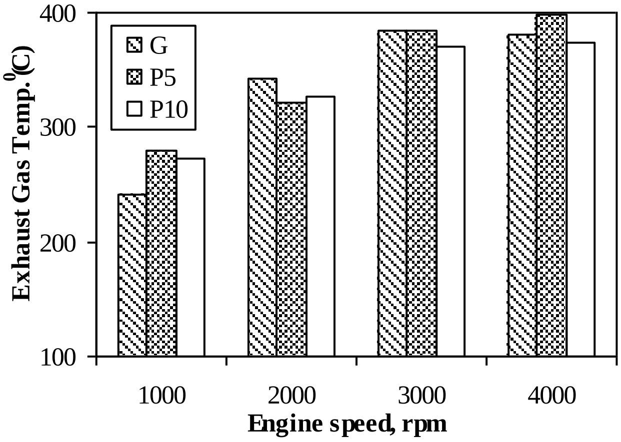

Figure 5. Change in the exhaust gas temperature

4. Conclusion

In this study, 5% and 10% of iso-propanol were blended with unleaded gasoline and tested in a direct injection spark-ignited engine. Iso-propanol and unleaded gasoline blends could be used in modern SI engine without any modifications. The use of iso-propanol-unleaded gasoline blends caused a decrease in CO and HC emissions compared with unleaded gasoline whereas CO2 emissions increase because of the improved combustion. Although the obtained results in this study are in agreement with literature reviewed regarding alcohol fuels such as methanol and ethanol, a detailed analysis of the combustion process is required to explain the results for all blends in future studies.

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