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Experimental Study With Acetone-Gasoline Fuel Blends on Engine Performance and Exhaust Emissions in a Spark Ignition Engine

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***Abstract* –** This study presents the influences of acetone addition into gasoline on engine performance and exhaust emissions in a spark ignition engine. A single cylinder, four stroke, air cooled spark ignition engine was utilized as the test engine. Tests were performed at wide-open throttle and 2400, 2800, 3200, 3600 and 4000 rpm engine speeds. Engine torque increased with the increase of acetone. Specific fuel consumption (SFC) increased by 3.72%, 9.06% using A10 and A20 compared to pure gasoline at 2800 rpm respectively. Thermal efficiency decreased by about 0.34 % and 1.89 % with A10 and A20 according to pure gasoline at the same engine speed. It was also seen that carbon monoxide (CO) and hydrocarbon (HC) decreased with the increase of acetone fraction in the fuel blends. CO and HC decreased by 2.13% and 5.79% with A10 and A20 according to gasoline at 4000 rpm respectively. Test results also showed that lower CO_2 (carbon dioxide) were measured with fuel mixtures. However, A20 presented higher CO_2 emissions compared that A10 test fuel for all engine speeds. CO_2 emissions decreased by 5.04% and 2.01% with A10 and A20 according to pure gasoline at 4000 rpm engine speed. As a result, acetone can be efficiently used as an additive fuel in spark ignition engines without any modifications.

Keywords – Acetone, Gasoline, Fuel Additive, Engine Performance, Exhaust Emission

I. Introduction

Harmful exhaust gases from motored vehicles threaten human health and atmosphere. As it is known, compression ignition engines have been widely used due to lower fuel consumption, higher thermal efficiency according to spark ignition engines. On the contrary, compression ignition engines emit higher amount of exhaust gases such as nitrogen oxides (NO_x), soot and particulate matter (PM) emissions. On the other hand, gasoline engines have advantages in view of the lower exhaust emissions, quieter operation and cheaper for initial cost [1-9]. However, gasoline engines need to be operated at near stoichiometric air/fuel ratios due to usage of catalytic converter. They also give lower thermal efficiency owing to lower compression ratio. Because compression ratio can not be increased due to auto ignition characteristics of gasoline. At this point, fuel addition into gasoline is seen to be attractive approach in order to increase the engine performance and thermal efficiency [2-10]. Alcohol based alternative fuels have attracted great attention in spark ignition engines due to higher octane number and oxygen content. Acetone can be utilized as fuel additive in spark ignition engines. Acetone having higher octane number can also provide knock resistance. So, compression ratio and thermal efficiency can be increased in spark ignition engines. Besides, oxygen content of acetone is intended to improve combustion [1-13]. At this point, acetone can be called as an ignition improver [14]. Elfasakhany [15] examined the influences of the 3-10% acetone addition into gasoline on energy efficiency and emissions. It was found that 3% acetone-97% gasoline fuel blend presented higher in-cylinder pressure, and torque by about 2.3% and 0.45% according to gasoline respectively. The increase of acetone addition caused to obtain higher engine performance. Wu et al. [16] investigated the effects of acetone-n-butanol-ethanol (ABE) on engine performance and emissions in a spark ignition engine. ABE30 test fuel provided delayed combustion phasing and higher brake thermal efficiency when compared with B30, E30 and G100 test fuels. Similarly, Li et al. [17] analyzed the influences of water containing ABE gasoline fuel mixtures. It was mentioned that ABE29W1 (29 vol.% ABE, 1 vol.% water and 70 vol.% gasoline) delivered higher torque and lower NO_x, CO and HC emissions. In another study, Li et al. [18] observed the effects of acetone-butanol-ethanol/gasoline blends on performance, combustion and emissions. Brake thermal efficiency increased by 0.2-1.4% and CO, HC, NO_x reduced by 1.4-4.4%, 0.3-9.9% and 4.2-14.6% respectively with ABE(361)30 test fuel according to gasoline. Uslu et al. [14] researched the influences of acetone/gasoline fuel mixtures at different engine speed and ignition timings using response surface method and artificial neural network. Optimum results containing 1700 rpm engine speed, 2% acetone addition and 11°CA (crank angle, before top dead center) ignition timing were obtained with optimization study. Li et al. [19] researched the combustion and emissions using acetone-butanol-ethanol (ABE) with direct hydrogen injection. Tests were conducted with different hydrogen blends and spark timings at 1500 rpm and lambda value of 1. It was realized that maximum heat release rate and in-cylinder pressure increased with the increase of hydrogen. Alahmera et al. [20] intended to see the influences of acetone-gasoline fuel mixtures on spark ignition engine performance. 10% acetone-90% gasoline fuel blend (AC10) decreased unburned hydrocarbon (UHC), CO and NO_x by 30.3%, 26.3% and 6.6% respectively. Zhang et al. [21] used acetone-butanol-ethanol (ABE) fuel mixtures and observed the influences on combustion and emissions in a gasoline engine. The lowest HC and NO_x were obtained with ABEDIr=60% test fuel. It was also demonstrated that 80% ABEDIr test fuel was the best choice in view of engine performance. Elfasakhanya [22] obtained bioethanol and bio-acetone mixture for spark ignition (SI) engine and tested in view of engine performance and emissions. 10 vol. % bioethanol and bio-acetone addition into gasoline presented the highest brake power, engine torque, volumetric efficiency and the lowest UHC, CO emissions according to other test fuels. Alahmer [23] investigated the influences of acetone on performance and exhaust emission in a spark ignition engine.10 vol. % acetone and 90 vol.% gasoline (AC10) caused to increase thermal efficiency, and brake power by about 6.9% and 4.39% respectively according to gasoline. Li et al. [24] showed that water containing acetone-gasoline mixtures could be utilized in view of engine performance. 19 vol.% acetone and 1 vol.% water and 80 vol.% gasoline (A19W1) test fuel presented higher brake thermal efficiency and lower NO_x and CO emissions. Usman et al. [25] found that 11.74% and 12.05% increase on brake power and brake thermal efficiency were seen with the usage of 10 vol.% acetone and 90 vol.% gasoline fuel blend (A10) according to gasoline respectively. Prayogi et al. [13] researched the influences of gasoline, acetone and wet methanol blends on engine performance and exhaust emissions. Brake specific fuel consumption increased due to lower calorific value of acetone and wet methanol. It was also implied that wet methanol and acetone mixture addition into premium fuel could improve the performance.

In the current study, the influences of acetone addition into pure gasoline were investigated experimentally on engine performance and exhaust emissions.

II. Materials and Method

The experiments were performed at Burdur Mehmet Akif Ersoy University, High Vocational School of Technical Science Automotive Technology laboratory. The tests were performed at wide open throttle and different engine speeds of 2400, 2800, 3200, 3600 and 4000 rpm. Engine test setup consists of test engine, AC dynamometer, torque sensor, computer, precision balance and rheostat as seen in Fig.1.

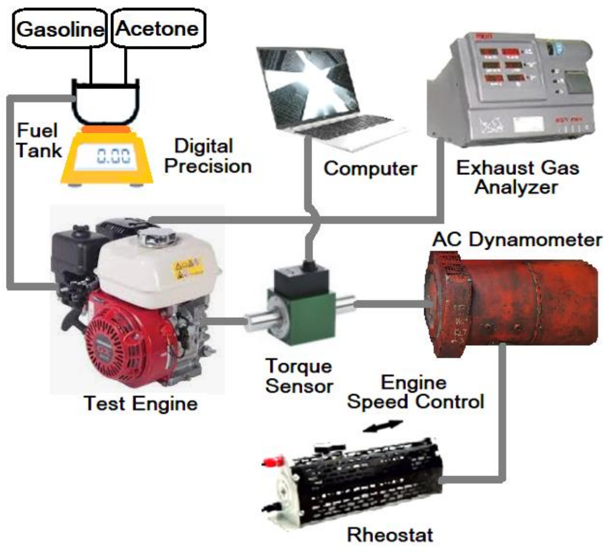

Fig. 1 Engine test setup

Test engine was mounted to AC dynamometer in order to load the test engine. Engine torque and engine speed were measured using Burster 8661 model torque sensor. A single cylinder, four stroke, air cooled spark ignition engine was used as the test engine. The test engine specifications are given in Table 1. The test engine was heated up before each test in order to take more reliable and accurate data. Rheostat was used to load engine. Fuel consumption was determined using precision balance with the accuracy of 0.5 gr.

Table 1. Engine specifications

Model	Honda GX160
Engine	Four stroke-Single cylinder
Bore x stroke (mm)	68x45
Cylinder volume (cm^3)	163
Compression ratio	8.5:1
Maximum power output (HP)@3600rpm	5.5
Maximum Torque (Nm)@2500 rpm	10.78

Acetone was used as an additive into pure gasoline. Acetone was mixed with gasoline at 10% and 20% by vol. Test fuels have been described as A10 (10%acetone+90% gasoline), A20 (10% acetone+80% gasoline) and pure gasoline. Some properties of the gasoline and acetone are given in Table 2.

Table 2. Some properties of the test fuels [14-20, 26-32]

	Gasoline	Acetone
Density [kg/m^3]	746	791
Calorific value [kJ/kg]	43400	29600
Latent heat of vaporization [kJ/kg]	380-500	518
Flash point [°C]	-45 to -38	17.8
Octane number	96.47	110
Auto ignition temperature [°C]	228-470	465

Torque sensor was mounted between the test engine and AC Dynamometer. Engine speed and torque data were instantly measured and transferred to the computer. CO and HC emissions were measured using exhaust gas analyser which of the technical properties are presented in Table 3.

Table 3. 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

III. RESULTS

The influences of acetone on engine torque is seen in Fig.2. As seen in Fig. 2. engine torque variations are seen versus engine speed. It was found that the increase of acetone addition caused to increase engine torque. Heat losses and gas leakages increase at higher engine speeds [9,33]. Hence, engine torque decreases with the increase of engine speed.

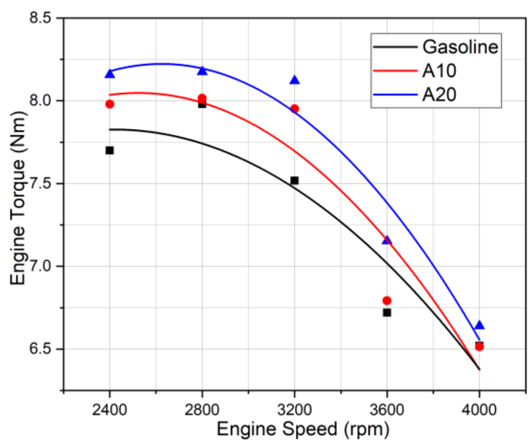

Fig. 2 Engine torque variations

Fig.3 depicts the variations of SFC with test fuels. The rise of engine speed leads to mechanical and flow losses. In addition, sufficient oxygen can not be taken into cylinder at higher engine speeds due to insufficient time. These phenomena causes to occur incomplete combustion due to insufficient oxygen [9,33].

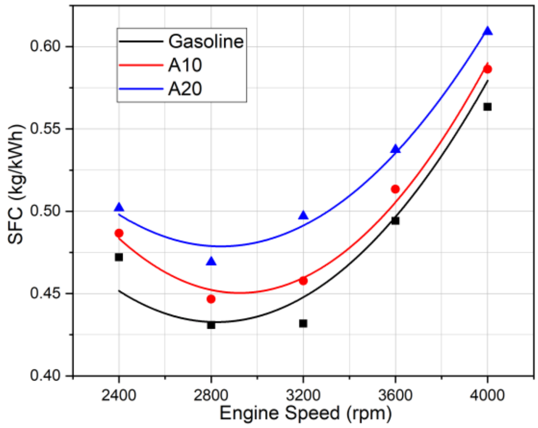

Fig. 3 The effects of acetone on SFC

Fig.4 shows the influences of acetone on thermal efficiency. It shows that how heat energy of fuel is converted to net work. At low engine speeds, heat can be transferred to the cylinder wall due to enough time. Average combustion chamber temperature decreases owing to higher amount of heat transfer. So, oxidation reactions deteriorate with lower in-cylinder temperature. Hence, thermal efficiency decreases. Similarly, thermal efficiency decreases at higher engine speeds, because sufficient oxygen could not be taken into the cylinder. Fuel molecules can not be oxidized well because of the insufficient oxygen concentration [9,33].

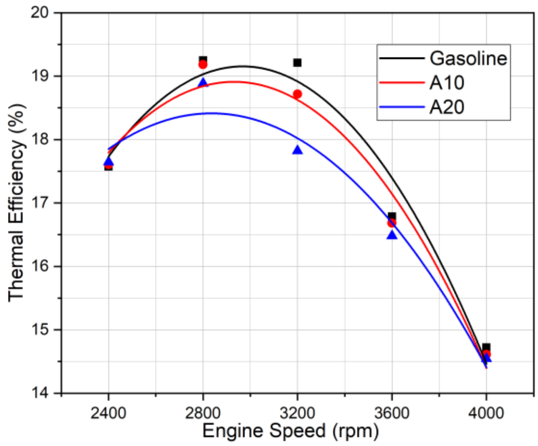

Fig. 4 Thermal efficiency

Fig. 5 illustrates the effects of acetone on CO emissions. CO emission reduces with the increase of acetone addition. It can be implied that CO emissions first increased and then decreased with the increase of engine speed. CO is produced due to insufficient temperature and insufficient oxygen. So, it can be defined as incomplete combustion product [9,33]. As shown in Fig. 5, the addition of acetone reduced CO emissions. The lowest CO emissions were measured with A20 test fuel.

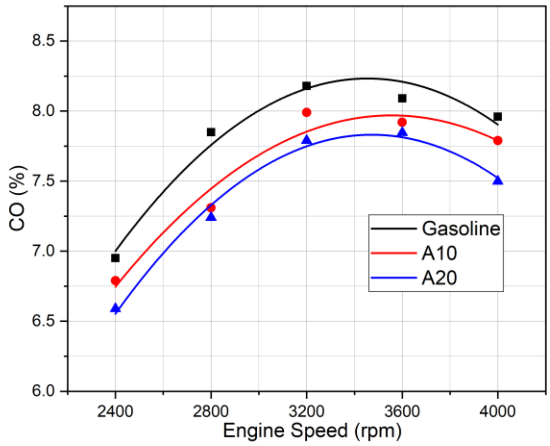

Fig. 5 CO emissions

The changes of CO_2 emissions are shown in Fig. 6. Lower CO_2 emissions were obtained with fuel mixtures compared to gasoline. CO_2 emissions increased with the rise of engine speed. The highest CO_2 emissions were measured with pure gasoline. CO_2 first decreased with A10 and then increased with A20. It was seen that the addition of acetone (A20) resulted in higher CO_2 emissions.

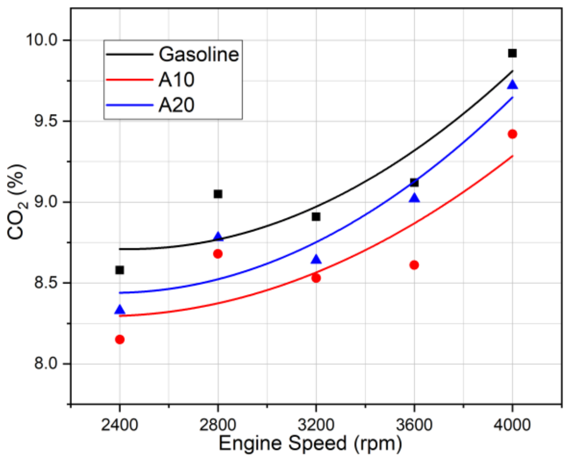

Fig. 6 CO_2 emissions

HC emissions are highly affected by fuel mixture composition. HC occurs due to incomplete combustion at the edges and corners of the combustion chamber [9,33]. It can be mentioned that HC emissions decreased with the rise of engine speed as seen in Fig.7. The rise of engine speed improves the homogeneity of the charge mixture. This event improved the oxidation reactions between fuel and oxygen molecules [9,33].

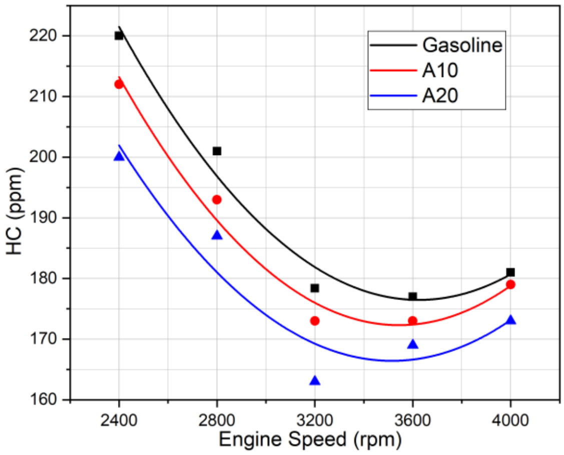

Fig. 7 HC emissions

IV. DISCUSSION

Chemical construction of the fuel additive highly affected the combustion phasing and engine performance [9,33]. Engine torque increased using acetone in the fuel mixtures. The highest engine torque was obtained with A20 among the test fuels for each engine speed. It can be said that higher density caused to take more charge mixture by mass into combustion chamber. Hence, higher torque can be obtained via combustion of more charge mixture. Besides, more temperature and pressure can be achieved in the combustion chamber towards the end of the compression stroke owing to higher octane number of acetone. Hence, oxidation reactions improve with the usage of acetone addition. Oxygen content of acetone also causes to increase engine torque, because oxidation reactions are improved. On the other hand, SFC increased because of higher density and lower calorific value of acetone compared to gasoline when fuel mixtures were used. More fuel should be combusted to produce the same engine power in case acetone addition was used in the fuel blends. SFC increased by 3.72%, 9.06% using A10 and A20 compared to pure gasoline at 2800 rpm respectively. The highest thermal efficiency was computed at 2800 rpm for all test fuels. Thermal efficiency decreased due to lower calorific value of acetone with fuel blends according to pure gasoline. Obtained heat energy decreases with the combustion of fuel mixtures according to pure gasoline. Hence, thermal efficiency decreased with acetone-gasoline fuel mixtures. Remarkable decrease was found on CO and HC emissions with fuel mixtures according to gasoline. CO and HC decreased by 2.13% and 5.79% with A10 and A20 according to gasoline at 4000 rpm respectively. CO is formed due to lower temperature and oxygen concentration. It can be mentioned that CO emissions can be reduced owing to higher auto ignition temperature, octane number and oxygen content of acetone. This event provides to improve oxidation reactions. Thus, CO formation is reduced. Lower CO_2 emissions were measured with fuel mixtures compared to gasoline. However, CO_2 increased using A20 compared to A10 test fuel. At this point, higher oxygen content of acetone supports to form CO_2. It was also found that HC reduced with the increase of acetone fraction in the fuel mixtures. The lowest HC emissions was determined with A20. When the flame front reaches the cold cylinder walls, it goes out and incomplete combustion is seen. Since air and fuel do not mix well at the edges and corners of the combustion chamber, oxidation reactions worsen [9,33]. Therefore, HC increases. HC reduces with the rise of engine speed until a certain engine speed and then tends to increase. HC reduced with acetone-gasoline fuel mixtures according to gasoline. It can be attributed that higher auto ignition temperature, octane number and oxygen content of acetone improve the oxidation reactions. Hence, HC formation is reduced.

V. CONCLUSION

The aim of this study is to research the influences of acetone addition into pure gasoline on engine performance, CO, CO_2 and HC emissions in a spark ignition engine. It was found that engine torque increased with acetone-gasoline fuel mixtures. Engine torque increased by 0.43% and 2.44% with A10 and A20 according to gasoline at 2800 rpm engine speed respectively. SFC increased by 3.72%, 9.06% using A10 and A20 compared to pure gasoline at 2800 rpm respectively. It was also found that thermal efficiency decreased by 0.34 % and 1.89 % with A10 and A20 according to pure gasoline at the 2800 rpm. Test results also showed that acetone addition into pure gasoline provided significant reductions on exhaust emissions. CO and HC emissions reduced by 2.13% and 5.79% with A10 and A20 according to gasoline at 4000 rpm respectively. In addition, CO_2 emissions decreased by 5.04% and 2.01% with A10 and A20 according to pure gasoline at 4000 rpm. As a result, acetone as fuel additive can be utilized in spark ignition engines without any modifications.

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