Investigation on the Effects of Gasoline Fuel Types on Exhaust Emissions

Naseer Salman Kadhim, Qais Hussein Hassan

***Abstract:** An experiment was executed at internal combustion engines laboratory/ Institute of Technology Baghdad – Middle Technical University to evaluate the performance and emission of a single-cylinder, four-stroke naturally aspired gasoline engine. The tested engine was fueled by four types of fuel: imported gasoline (A1), Al-Shuaiba refinery gasoline (A2), Al-Dora refinery gasoline (A3), and Al-Nasiriyah refinery gasoline (A4). The engine was operated within three levels of speed 1500, 2000 and 2500rpm under three levels of torques 2, 4 and 6Nm. The engine exhaust emissions which include oxygen gas (O_2), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x) and unburned hydrocarbons (HC) were measured using a gas analyzer device and smoke meter. The experimental results were statistically analyzed using the Split-Split plot design and SAS (2012) software based on a complete randomized design (CRD) within three replications. The least significant differences (L.S.D = 0.05) under probability of 0.05 was utilized to compare the means of treatments. The results show that the lowest value of O_2 that was 20.1% was recorded within the A1 while this gas increased to be 22.95% by using A4. The value of CO with A1 decreased to be 0.1% while it raised to be 6.21% with A4. The CO2 increased within A1 to be 20.11% whereas it declined with A4 to be 11.26%. The rates of HC and NO_x decreased within A1 to be 39 and 275.7 parts per million (ppm); however, they increased by using A4 to be 341 and 2393.3 ppm, respectively.*

***Keywords:** exhaust emissions, engine speed, engine torque, gasoline fuels, and environment*

I. INTRODUCTION

The principle of internal combustion engines is to burn the fuel and air mixture inside the engine cylinder, where the chemical energy of fuel in the combustion process is converted to thermal energy. There are many factors such as fuel characteristics, engine design, engine speed and torques will affect the exhaust gas emissions. These gases that include O2, CO, CO2, NOx, and HC are harmful to the environment, especially if their concentrations dramatically increase. These gases also cause damage to humans and plants as a result of omission refined fuel well (Akram, 2005). The Increasing of NO_X emissions are representing a threat to humans and plants, according to US Environmental Research (EPA, 2004). Sehmus, (2010) claimed that the increasing of engine rotational speed leads to decrease CO and HC and to increase O2, CO2.

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Siddegowda, (2007) who conducted his study on a four-stroke tri-cylinder engine demonstrated that when the engine torques raise, the O2 and CO decline while CO2 increases. Sayin and Kilicaslan (2005) confirmed that the effect of using gasoline fuel on exhaust gas emissions. In that research, the authors used gasoline RON 95 and RON 91 and they concluded that emissions of harmful exhaust gases were reduced when using RON 95 octane. Sayin C (2012) investigated the effect of different octane gasoline fuels on emissions of exhaust gases and the results showed the reduction in emissions of hazardous exhaust gases when the high octane that is required by the engine was used. Another study was conducted by Mohamad and How (2014) on a 1.6-L, four-cylinder Mitsubishi 4G92 engine with CR 11:1. The engine was run at a constant speed that was between 1500 and 3500rpm with an increment of 500rpm under various torque conditions. The RON 95 produced a higher engine performance for all torques. In terms of exhaust emissions, RON95 produced the lowest value of NOx that was 7.7% while it produced highest rates of CO2, CO and HC that were 7.9%, 36.9% and 20.3%, respectively. A further study was carried out by Nik Rosli and Nafis Syabil (2014) on various engine speeds and torques by using a single-cylinder spark four-stroke gasoline engine coupled to a dynamometer. The standard air intake system resulted from a rich combustion process while incomplete combustion reduced the air intake. Therefore, for better combustion it is necessary to increase the air intake pressure to produce the highest engine efficiency. That paper experimentally investigated the possibility of increasing the engine performance while simultaneously reducing the emission of hazardous gases and optimizing the combustion parameters of SI engines. This was done by using of a suitable RON fuel to ensure the emission of less pollutant gases and improved efficiency through the use of three gasoline fuels (RON 95, 97 and 102). The main objectives of this paper are to study the effects of four types of gasoline fuel in emissions of exhaust gases including NOX, HC, CO2, CO and O2. It will also find the most appropriate fuel type and its impact on the environment. It will also determine the most appropriate engine speed and torque within the fuel type that reduce the emission rates of harmful exhaust gases.

II. EXPERIMENTAL DESIGN AND METHODS

Experimental Design: An experiment was executed at internal combustion engines laboratory/ Institute of Technology Baghdad – Middle Technical University to evaluate the performance and emission of a single-cylinder, four-stroke naturally aspired gasoline engine (see Figure 1).

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The tested engine was fueled by four types of fuel: imported gasoline (A1), Al-Shuaiba refinery gasoline (A2), Al-Dora refinery gasoline (A3), and Al-Nasiriyah refinery gasoline (A4). Table 1 shows the most important characteristics of these fuel types. The engine was operated within three levels of speed 1500, 2000 and 2500rpm under three levels of torques 2, 4 and 6Nm. The engine exhaust emissions which include oxygen gas (O_2), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x) and unburned hydrocarbons (HC) were measured using a gas analyzer device and smoke meter.

Fig. 1: Schematic diagram of the experimental setup

Experimental Method: The engine was operated at three speeds: (1500, 2000, and 2500) rpm and three levels of torques (2, 4, and 6) Nm. The exhaust system (AIRREX.HG-54) was used as shown in Figure 2. The experimental results were statistically analyzed using the Split-Split plot design and SAS (2012) software based on a complete randomized design (CRD) within three replications. The least significant differences (L.S.D = 0.05) under probability of 0.05 was utilized to compare the means of treatments (see Table 2).

Fig. 2: Gas analyzer device

Table 1: Properties of fuels

	Test	imported gasoline (A1)	Shuaiba refinery gasoline (A2)	Al-Dora refinery gasoline (A3)	Al-Nasiriyah refinery gasoline (A4)
1	RON	95.9	84.4	81.5	79.4
2	L.C.V	8232.4045 Cal/g	9996.2870 Cal/g	9080.6129 Cal/g	8382.2759 Cal/g
3	Sp.Gr @15.60c	0.7433	0.7320	0.7299	0.7321

Table (2) Technical specifications of the engine

Item	Specification
Engine Manufacturer	gasoline TD211
Number of cylinders	1
Number of Strokes	4
Bore	67mm
Connecting Rod Length	49mm
Engine Capacity	$172cm^3$
Compression Ratio	8.5:1
Oil Type	10w- 30
Cooling system	Airy

III. RESULTS AND DISCUSSIONS

Oxygen Gas (O_2): Table (3) and Figure (3) are showing that the triple interference between fuel, speed and torque has a significant effect on the percentage of the oxygen emissions. In this case, the lowest value of O2 was recorded within A1 at engine speed (2500 rpm) and engine torque 6Nm to be 20.1% while it increased when the A4 fuel was used at engine speed (1500 rpm) and engine torque (2Nm). The reason for O2 reduction at A1 is because that A1 has a high octane number that helps to improve the fuel combustion with oxygen and this makes agreement with Najafi et. al (2009).

Table 3: Effects of fuel types, engine speeds and torques on O2

Fuel Types	Speed (rpm)	Interaction between fuel, Speed and Torque		
		Torque (N.m)		
		2	4	6
A1	1500	20.97	20.72	20.58
	2000	20.71	20.56	20.51
	2500	20.46	20.29	20.10
A2	1500	21.99	21.76	21.56
	2000	21.78	21.65	21.44
	2500	21.61	21.58	21.31
A3	1500	22.86	22.63	22.39
	2000	22.63	22.41	22.25
	2500	22.46	22.27	22.11

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A4	1500	22.95	22.87	22.72
	2000	22.73	22.56	22.45
	2500	22.58	22.38	22.29
LSD= 0.005	*4.832			

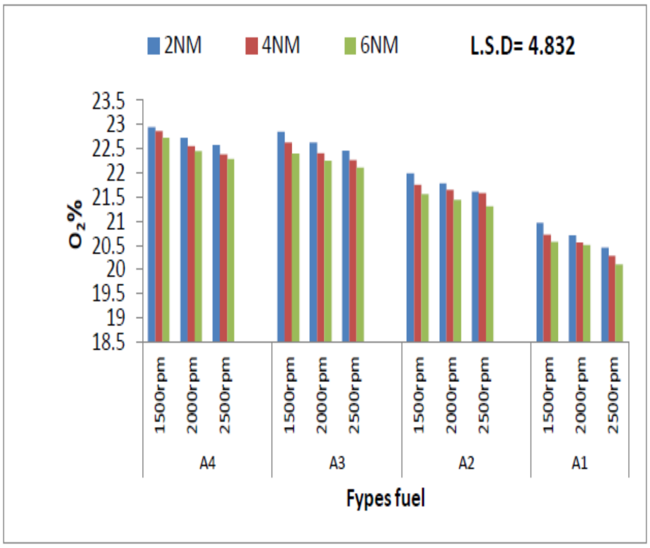

Fig. 3: Effect fuel types, engine speeds and torques on O_2

Carbon monoxide (CO): The triple interference between fuel, speed and torque has a significant effect on the rates of the carbon monoxide CO emissions as shown in Table (4) and Figure (4). In this case, the value of CO that was recorded within A1 at engine speed (2500 rpm) and engine torque 6Nm decreased to be 0.1% while it increases to be 2 6.21% when the A4 fuel was used at engine speed (1500 rpm) and engine torque (2Nm). The reason for the reduction of CO concentrations is because the high speeds of the engine cause the vortex of the fuel and air inside the combustion chamber to be more homogenous. This improves the combustion of fuel to completely burn and therefore, the emissions of CO is reduced and this makes agreements with Cenk et al., (2003) and Adnan et al., (2016).

Table 4: Effects of fuel types, engine speeds and Torques on CO

Interaction between fuel, Speed and Torque				
Torque (N.m)			Speed	Fuel Types
6	4	2	(rpm)	
0.26	0.41	1.83	1500	A1
0.21	0.28	1.21	2000	
0.1	0.11	0.24	2500	
0.93	1.75	3.52	1500	A2
0.38	1.6	2.19	2000	
0.12	0.19	0.26	2500	
2.36	3.78	5.52	1500	A3
0.97	2.21	4.17	2000	
0.19	0.26	0.36	2500	
2.83	5.36	6.21	1500	A4
1.36	4.12	5.44	2000	
0.84	1.98	2.41	2500	
*2.283				LSD= 0.005

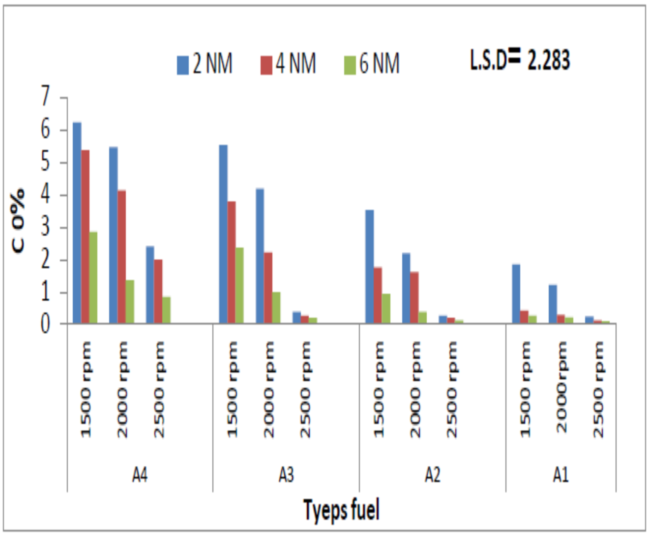

Fig. 4: Effects of fuel types, engine speeds and torques on CO

Carbon dioxide (CO_2): The percentage of emissions of the carbon dioxide CO_2 is affected by the triple interference between fuel, speed and torque (see Table (5) and Figure (5)). In this case, the value of CO_2 that was recorded within A1 at engine speed (2500 rpm) and engine torque 6Nm increased to be 20.11% while it decreased to be 11.26% when the A4 fuel was used at engine speed (1500 rpm) and engine torque (2Nm). The reason for the reduction of CO_2 concentrations at small torques is because a small amount of fuel cargo will enter to the combustion chamber in comparison with the high torque that needs more fuel. In such a case, there is a sufficient amount of oxygen to completely burn the charge of fuel and oxygen combustion and this make agreements with Siddegowda, (2007) and Haroun et. al., (2014).

Table 5: Effects of fuel types, engine speeds and torques on CO2

Fuel Types	Speed (rpm)	Interaction between fuel, Speed and Torque		
		Torque (N.m)		
		2	4	6
A1	1500	15.68	17.73	19.62
	2000	16.13	18.25	20
	2500	17	19.46	20.11
A2	1500	14.28	15	17.85
	2000	16.66	17	18.10
	2500	16.90	17.74	20
A3	1500	12.18	14.20	14.30
	2000	14.84	15.43	16.77
	2500	16.35	16.60	19.36
A4	1500	11.26	13.40	15.40
	2000	14.36	15.18	16.58
	2500	14.60	15.43	17.20
LSD= 0.005	*6.052			

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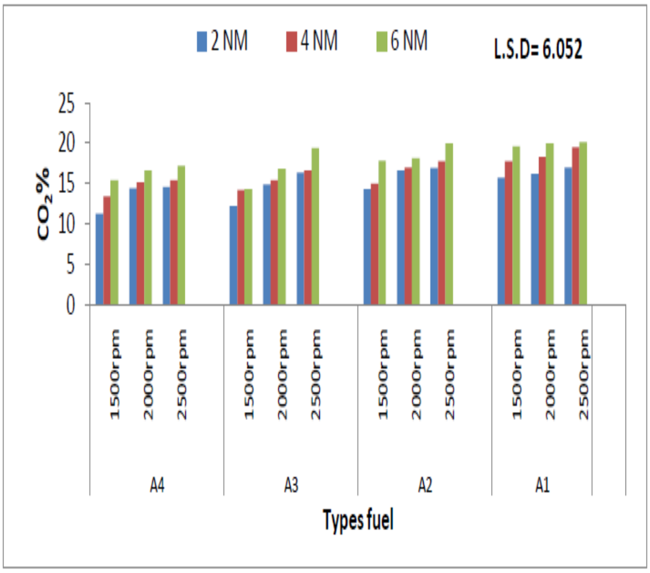

Fig. 5: Effect fuel types, engine speeds and torques on CO_2

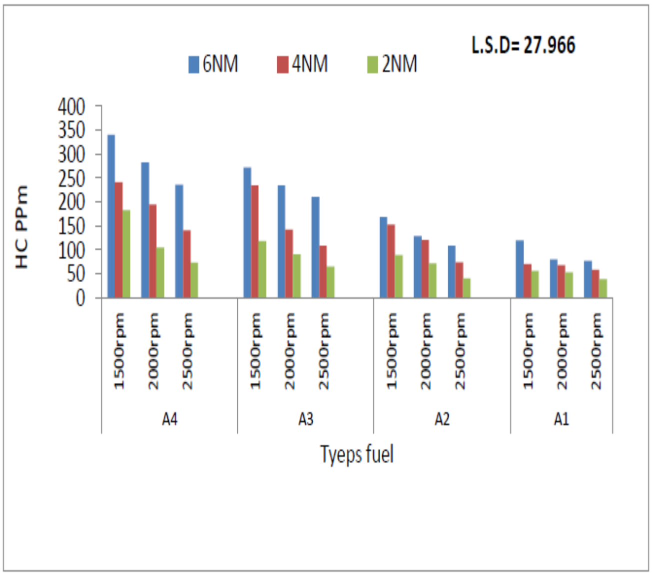

Fig. 6: Effect fuel Types, engine speeds and torques on HC

Unburned Hydrocarbon (HC): Table (6) and Figure (6) are showing that the triple interference between fuel, speed and torque has a significant effect on the percentage of emissions of the unburned hydrocarbons HC concentrations. In this case, the value of HC that was recorded within A1 at engine speed (2500rpm) and engine torque 2Nm decreased to be 39ppm while it increased to be 341ppm when the A4 fuel was used at engine speed (1500rpm) and engine torque (6Nm). The reason for the reduction of HC concentrations is that when the engine speeds are increased, the temperature of the engine raises and this leads to completely burn the fuel mixture that enters into the combustion chamber and therefore, HC decreases. These results make agreement with the results obtained by Adnan et.al., (2016).

Table 6: Effects of fuel types, engine speed and torques on HC

Fuel Types	Speed (rpm)	Interaction between fuel, Speed and Torque		
		Torque (N.m)		
		2	4	6
A1	1500	56.30	70.30	119.67
	2000	53.30	68	80.30
	2500	39	59	77.67
A2	1500	88.67	152	168.60
	2000	72	121	129
	2500	40.30	75	109
A3	1500	118	234	272
	2000	90.3	142	234
	2500	66	108.67	211
A4	1500	183.30	241.30	341
	2000	105.30	194.67	282.30
	2500	73.67	140.30	235.60
LSD= 0.005	*27.966			

Nitrogen oxide (NO_X): The triple interference between fuel, speed and torque has a significant effect on the percentage of emissions of the Nitrogen Oxide (NO_X) concentrations as shown in Table (7) and Figure (7). In this case, the value of NO_X that was recorded within A1 at engine speed (1500 rpm) and engine torque 2Nm decreased to be 275.7ppm while it increased to be 2393.3ppm when the A4 fuel was used at engine speed (2500 rpm) and engine torque (6Nm). The reason for the reduction of NO_X concentrations is that A1 has a high octane number that helps to delay ignition and improve combustion and thus decrease NO_X concentrations. These results are consistent with the results obtained by Adnan et. al. (2016).

Table 7: Effects of fuel types, engine speeds and torques on NO_X

Fuel Types	Speed (rpm)	Interaction between fuel, Speed and Torque		
		Torque (N.m)		
		2	4	6
A1	1500	275.70	332	368.91
	2000	306.80	475	1084.50
	2500	337.60	533.70	1871
A2	1500	301.30	360.31	372.50
	2000	420	618.31	1653.41
	2500	609.70	1164.62	2163.81
A3	1500	406.20	870.91	1037
	2000	454.50	1148.60	1365.70
	2500	997	1273.50	2175
A4	1500	318	1051.61	1066.31
	2000	483.30	1188.70	2297.70
	2500	1261.70	1425	2393.30
LSD= 0.005	*33.261			

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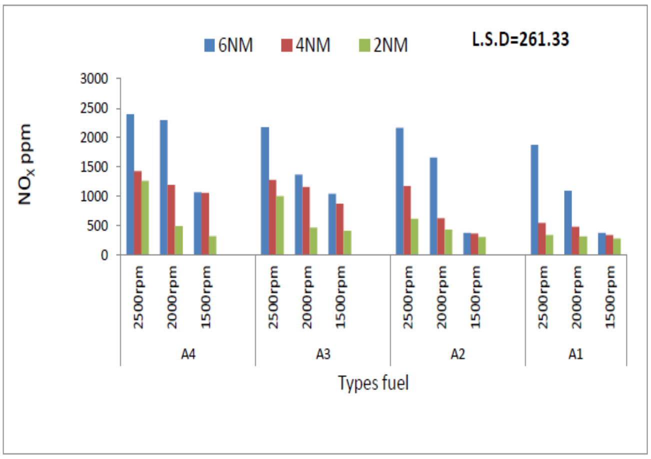

Fig. 7: Effect fuel types, engine speeds and torques on NO_X

IV. CONCLUSIONS

The combustion characteristics of different types of gasoline were examined. Exhaust gas emissions from the fuel that is used in Iraq were evaluated and tested experimentally on the four-stroke single-cylinder engine. From the experimental results, it was concluded that:

1. The value of oxygen gas, carbon monoxide, unburned hydrocarbons and nitrogen oxides declined while carbon dioxide increased when imported gasoline fuel is used in comparison with other fuels.
2. When the engine speeds are increased, the oxygen, carbon monoxide and unburned hydrocarbons decreased while the emissions of carbon dioxide and nitrogen oxides increased.
3. When the engine torques increase from 2Nm to 6Nm, the oxygen gas and carbon monoxide decreased while carbon dioxide and Unburned Hydrocarbons and nitrogen oxides increased.
4. The improved gasoline must be used within gasoline engines to obtain the lowest emissions of carbon monoxide, unburned hydrocarbons and nitrogen oxides.

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