Al-Khwarizmi Engineering Journal,Vol. 13, No. 1, P.P. 1- 12 (2017)

Al-Khwarizmi Engineering Journal

Experimental Study of the Effect of Fuel Type on the Emitted Emissions from SIE at Idle Period

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(Received 27 January 2016; accepted 2 November 2016)

https://doi.org/10.22153/kej.2017.11.001

Abstract

The present study investigated the impact of fuel kind on the emitted emissions at the idling period. Three types of available fuels in Iraq were tested. The tests conducted on ordinary gasoline with an octane number of 82, premium gasoline with an octane number of 92, and M20 (consist of 20% methanol and 80% regular gasoline). The 2 liters Mercedes-Benz engine was used in the experiments.

The results showed that engine operation at idle speed emits high levels of CO, CO_2, HC, NOx and noise. The produced emission levels depend highly on fuel type. The premium gasoline (ON=92) represents the lower emissions level except for noise at all idling speed. Adding methanol to ordinary gasoline (ON=82) showed high levels of emitted CO, CO_2, HC compared with premium gasoline. Emitted NOx emissions were near zero levels for most of the idle speeds for the tested fuels.

Keywords: *Idle period, engine speed, M20, NOx, CO, HC, noise.*

1. Introduction

The climate change and the greenhouse effects became known to all as the causes of these phenomena are well known also. The burning of fossil fuels produce many pollutants the environment and in its contamination [1]. Combustion of gasoline fuel in spark ignition engine is one of the most used fossil fuel. As the gasoline automotives increased profoundly in Iraq since 2003 to become more than 4.5 million cars with an increment level of 17.5% yearly [2]. About 38% of it concentrated in Baghdad the capital with about 1.75 million vehicles [3].

The Iraqi environment especially Baghdad is much polluted and highly sensitive to pollutants due to subsequent wars and dust storms, as well as, due to fossil fuels burning [4]. Besides to cars, trucks and heavy construction equipment, about 15000 shared electrical generators are operating to compensate the lack of the grid electricity. Hundreds of thousands of small wattage electric generators preserve in Iraqi citizen houses. Besides, the power generation in Iraq depends highly on heavy oils that emitted very high levels of soot and carbon depositions [5].

Idling, which means operating the automotive's engine without loading it or the clutches are in disengaged condition. The engine speed at idling ranges between 800 and 1500 rpm. The engine idle speed increases with using accessories like air conditioning, which is an essential device for Iraqis in summertime [6]. The drivers use idling for many purposes as warming the car engine up in the cold morning, waiting for someone, parking, and waiting at checkpoints. Iraqi citizens are familiar with the last one that takes a long time from their traveling period reached hours in sometimes [7]. The checkpoints spread all over Baghdad streets increased the cars idle time without knowing its hazards.

Idling results in poor air quality, as the streets choked with cars and trucks, emit an enormous amount of harmful emissions. The emitted NOx and volatile organic compound, during the idle period, reacts with sunlight to form ozone that built, especially in long and hot days, to produce smog. Smog is a damaged material, as it is a lungs irritant, attack Asthmatics patients. Idling poses a threat to the drivers as the pollutants contaminations increased inside the driving cabinet more than outside it. Those drivers exposed to elevated health risks as lung cancer. Also, at idling period the noise pollution increased can raise heart rates, blood pressure, and levels hormones stresses [8 - 10].

Many researchers studied this phenomenon and confirmed its damages to climate, health and human morality. KeL (2008) proposed Least Squares Support Vector Machines (LS-SVM) build up a model for engine idling. The study aimed to produce optimal ECU that can automatically define the user behaviors. The results gave good agreements with actual test results and showed enhancement in engine idling performance [10]. Wong (2009) introduced a novel modeling approach for engine idle operation. The study results predicted good agreement with the practical tests [11].

Sharma (2011) tested the resulted benefits from operating engine at idle mode with an ultra-lean burn. For this purpose, the authors used hydrogen as a fuel. The results indicated significant improvements in the emitted emissions [12]. Gharib (2012) used a robust controller for a vehicle based on quantitative feedback theory to control engine at idle speed. After reviewing various designs the required one used. Tracking problems simulation technique used to achieve successful design. The simulation results indicated proper behavior by the designed controller in idling operation [13].

Nordin (2013) measured organic aerosol mass concentrations of gasoline engine operated at idle speed. The study found the emitted aerosols similar to that measured in the urban environment that gives an indication of the high hazards of petrol engine idle operation [14]. Pirs (2014) tested the exhaust emissions sent out by a gasoline automobile fueled with E85 (gasoline-ethanol blend). The tests conducted to assess the effect of fuel additive on engine idle speed emissions. The results showed that NOx reduced while CO and HC increased with using E85 compared with conventional gasoline [15].

The present study aims to measure and evaluate the impact of the idle period on the emitted pollutants. Three types of fuels used in the study; two of them conventionally employed in Iraq, they are normal gasoline (ON=82) and premium gasoline (ON=92). The third fuel was M20 (80% gasoline (ON=82) and 20% methanol), which recommended as an alternative fuel to the low octane number Iraqi gasoline by many researchers [16- 18].

2. Experimental Setup

2.1. Materials

Two gasoline fuels were used in this study. The first one is the ordinary gasoline with octane number (ON) =82, and the second the premium type with ON=92. Also, 20% methanol with purity of 99.92% added to ordinary gasoline (ON=82) with 80% volume to form M20. Iraqi conventional gasoline characterized by its low octane number and high content of sulfur and lead. The properties of tested fuels were measured in Al-Doura Refinery Laboratory-Baghdad. Table 1 represents the tested fuels properties.

2.2. Tests Apparatus

A Mercedes-Benz with two liters displacement volume spark ignition engine used in the present study. The four strokes engine is water cooled and has four cylinders. The engine coupled to a hydraulic dynamometer to measure the brake torque (This facility was not used due to the absence of its need). Fig. 1 shows the tests rig, and Table 2 lists the used engine technical specifications.

2.3. Exhaust Gas Pollution Analyzing

A gas analyzer type HG-550 (Fig. 2) was utilized to quantify the exhaust gas discharges (CO, CO_2, HC, and NOx). This instrument created by Hephzbah Co. Ltd at 16/10/2013, the calibration sheet took from the industrial facility assessment sheet. A sound pressure level meter sort SL-4010 (Fig. 3) supplied with an amplifier sort 4615was used to quantify the general sound pressure levels. The instrument was calibrated by a standard calibrator sort pisto-telephone 4220.

2.4. Error Analysis

The measurement accuracy in trial examinations is urgent in deciding the outcomes sensibility or not. The error sources are characterized by calibrating the measuring hardware. All the engine measuring devices were calibrated, and the uncertainty levels in the study were estimated. Table 3 demonstrates the adjustment precision of the measuring instruments.

The calculated uncertainty in the present study was less than 5% in all estimations. The trials irregular mistakes minimize in the tests by repeating the tests three times. These trials results reported more than 95% certainty for every tested condition.

Table 1,
properties of gasoline and methanol fuels.

Property	Gasoline	Methanol
Chemical formula	various	CH_3OH
Oxygen content by mass [%]	0.00	50.00
Density at NTP [kg/l]	0.74	0.796
Lower heating value [MJ/kg]	43.12	20.09
Volumetric energy content [MJ/l]	31.70	15.80
Stoichiometric AFR [kg/kg]	14.70	6.40
Energy per unit mass of air [MJ/kg]	42.60	19.85
Research octane number	89-95	108.90
Motor octane number	85	88.60
Boiling point at I bar [ºC]	25-215	64.60
Heat of vaporization [kJ/kg]	180-350	1160.00
Reid vapor pressure [psi]	7.00	4.60

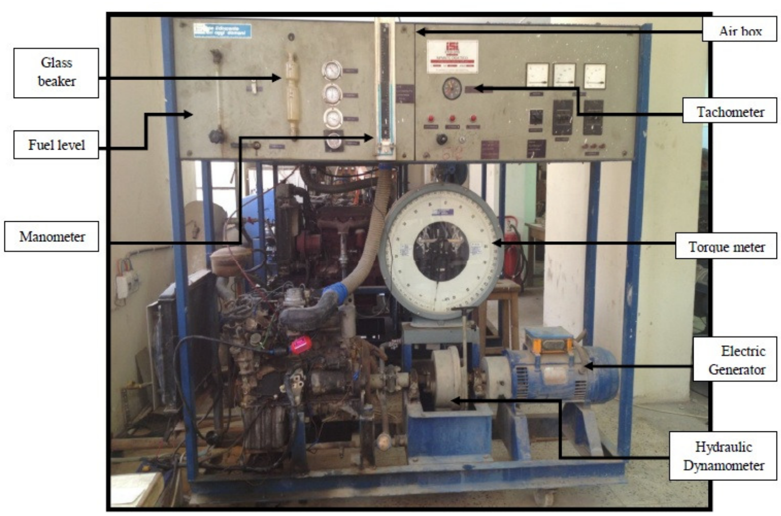

Fig. 1. The experimental rig of SI engine.

Fig. 2. The gas analyzer type HG-550 used in the tests.

Fig. 3. The sound pressure level meter type SL-4010used in the tests.

Table 2,
The main technical specifications of the engine.

Item specification	
Engine	4-cylinder-inline engine (four-stroke)
Displacement	2 liters
Fuel System	Carburetor
Cooling	Water

Table 3,
Measurement type and accuracy for present study.

Measurement	accuracy
Engine speed measurement	±1.3%
Sound pressure level measurement	±1.09%
Exhaust gases concentrations measurement	±0.82%
Exhaust gas temperature measurement	± 0.67

2.5. Tests Procedure

The engine was left to warm by running for several minutes until the cooling water, and lubricant oil reached 75°C. In all tests, the engine was not loaded. The engine left to run at idle speeds of 800, 1000, 1200 &1500 rpm. The concentrations of the emitted emissions CO_2, CO, HC, NOx, and noise measured every 5 minutes. In each test, the measuring period limited to 20 minutes. This time considered because achieving an idling time in this size is possible in Baghdad city practical life and other Iraqi areas due to the spread checking points and traffic strangulations. The resulted emissions from three idling speeds were selected for practical comparison. These are 800 rpm where it is considered as idling speed for cars that do not use accessories. Also, 1000 rpm as an idling speed was chosen for new engines with the drivers using air conditioning while 1500 rpm selected as the higher idle speed for a car engine with using the accessories.

3. Results and Discussions

CO produced from incomplete combustion, and it is a very dangerous and poisonous gas. Fig. 4 A, B, and C represent the emitted CO through the idling period at variable engine speeds for the tested fuels. For ordinary and excellent gasoline the minimum concentrations were at the least values when the engine runs at 800 rpm, as Fig. 4 A shows. The methanol high heat of evaporation needs high combustion chamber temperature, which is not available at 800 rpm. CO concentrations were increased with increasing idling speed higher than 800 rpm while for M20 reduced with this increment. In A and B cases increasing engine idling speed means increasing the consumed fuel at low combustion chamber temperatures that caused incomplete combustion. In constraint, in case C, increasing idling speed which increased the combustion chamber temperature, enhanced methanol evaporation and as a result reduced CO concentrations. Fig. 4 D, E, and F indicate that the lower CO concentrations came out with premium gasoline burning for the three compared speeds. At 800 rpm, the emitted CO from ordinary gasoline and methanol was higher by 127.39% and 256.47% in relation to premium gasoline. At 1000rpm, the emitted CO from ordinary gasoline and methanol was higher by 46.63% and 54.67% compared to excellent gasoline.

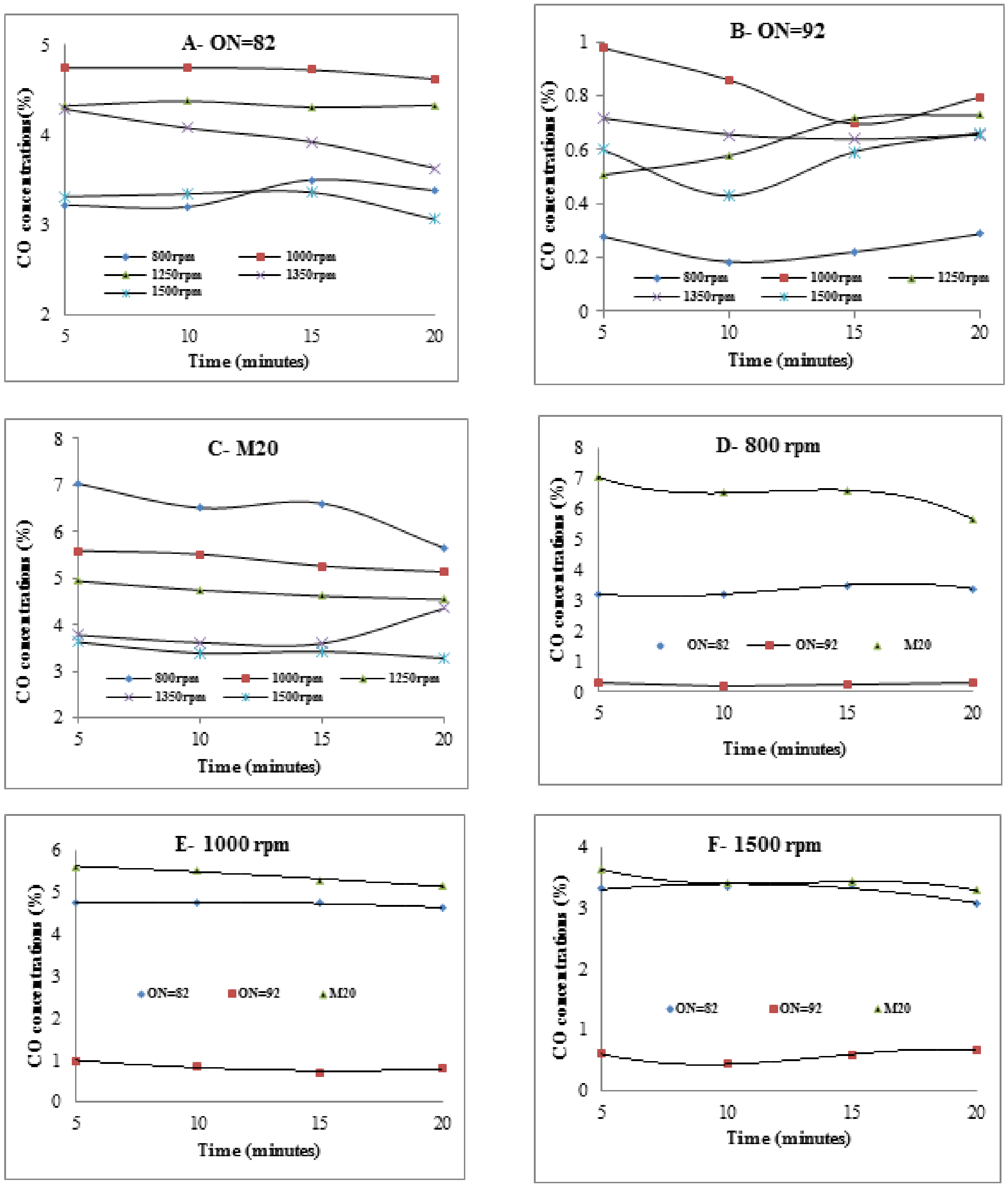

Fig. 4. the idling time effect on emitted CO for tested fuels at variable engines speeds.

Fig. 5 represents the CO_2 concentrations for variable engine speeds through the tested idle period. Fig. 3. A & B are similar to the Fig 4 A & B where CO_2 levels at the lower value when the engine runs at 800 rpm. In Fig 5 C, CO_2 concentrations are higher than the other emitted values with other idle speed except for 1350 rpm. The oxygen existence in the methanol structure enhances the combustion and increases CO_2. Fig 5 D, E and F show that premium gasoline emitted lower CO_2 concentrations compared to the other fuel at all the studied idling speeds as it did with CO_2. This result indicates that premium gasoline is more useful for health and environment except for its lead content where the Iraqi gasoline has a high level from this poisonous material. At 800 rpm, the emitted CO_2 from ordinary gasoline and methanol was higher by 90.71% and 138.24% compared to premium gasoline. At 1000 rpm, the emitted CO from ordinary gasoline and methanol was higher by 41.51% and 47.63% compared to excellent gasoline.

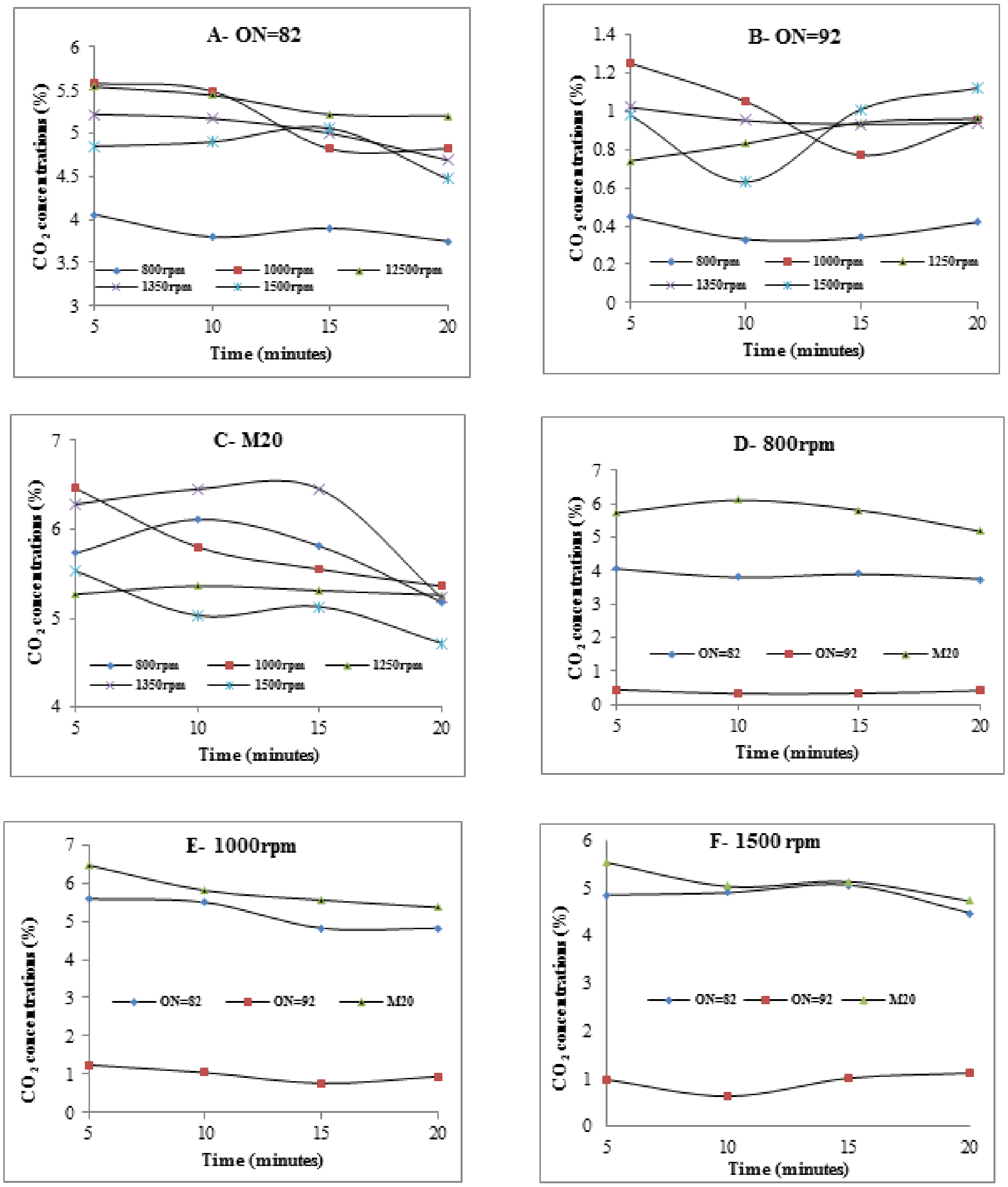

Fig. 5. the idling time effect on emitted CO_2 for tested fuels at variable engines speeds.

Fig. 6 shows the effect of idle speed on emitted HC for the tested period intervals. From the figures A, B & C, HC concentrations are in the lowest values at 1500 rpm for all fuels. However, the concentrations values varied largely as ordinary gasoline emitted 250 ppm HC at the lowest value while premium gasoline emitted 25 ppm. Figures D, E, and F, compare between the emitted HC at three idling speeds. The figures shows high HC concentrations with M20 operation, which indicates the hazard from using this alternative at idle speed whatever it was. At 800 rpm, the emitted HC from regular gasoline and methanol was higher by 82.01% and 220.11% compared to premium gasoline. At 1000 rpm, the emitted HC from ordinary gasoline and methanol was higher by 53.24% and 71.80% compared to premium gasoline.

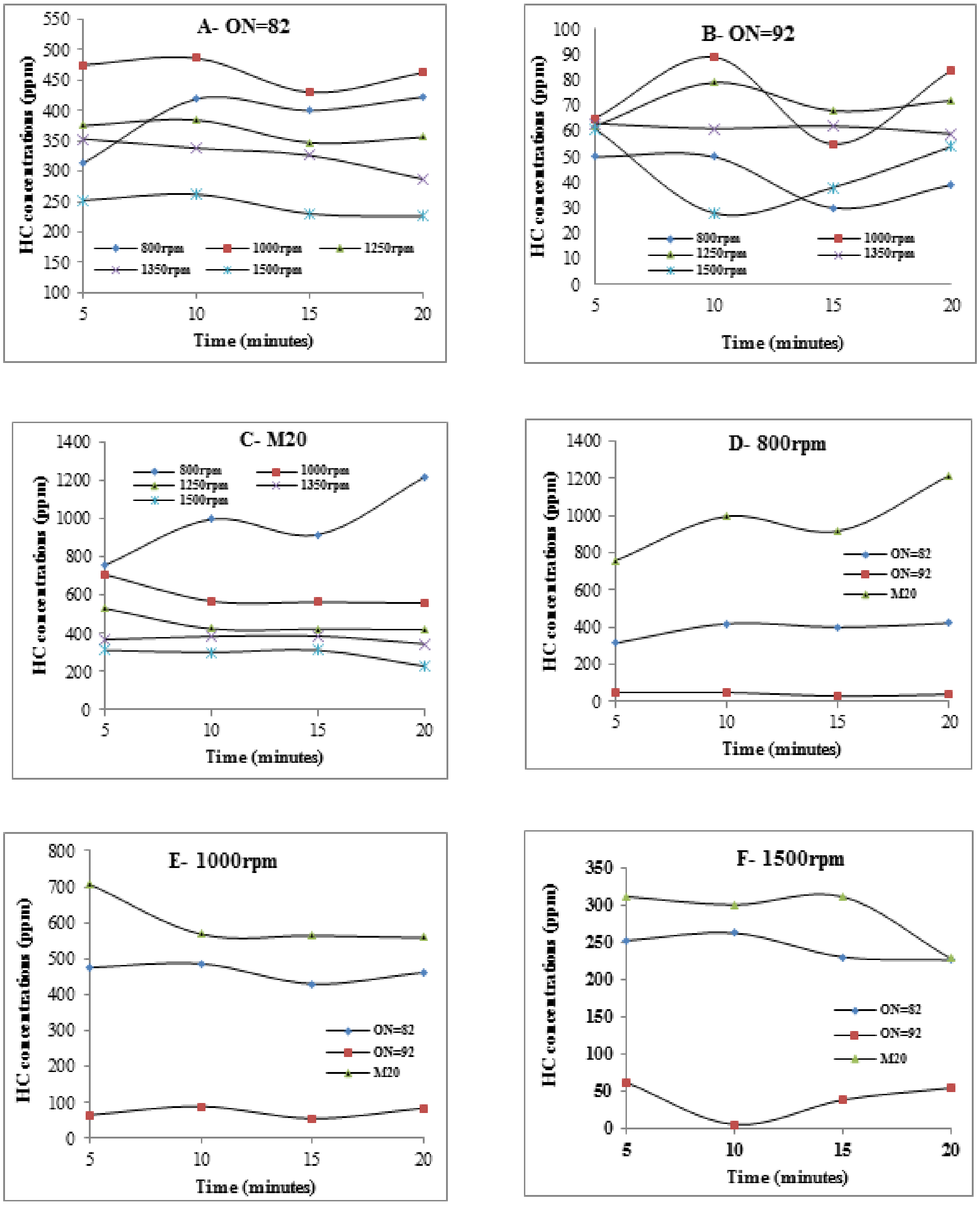

Fig. 6. the idling time effect on emitted HC for tested fuels at variable engines speeds.

Fig. 7 represents the emitted NOx for the studied cases. NOx concentrations are very low and reach zero sometimes at idle speed except for 1350 and 1500 rpm for regular gasoline and M20. When premium gasoline is used the resulted NOx are zero for all the tested idle speeds. Figure D, E, and F, represent the comparison between the emitted NOx for the used fuels. The emitted NOx at 800 and 1000 rpm are zero for the three fuels while at 1500 rpm the emitted NOx increased for M20 and ordinary gasoline. Until now, all the emitted emissions from excellent gasoline are better than the resulted from other fuels.

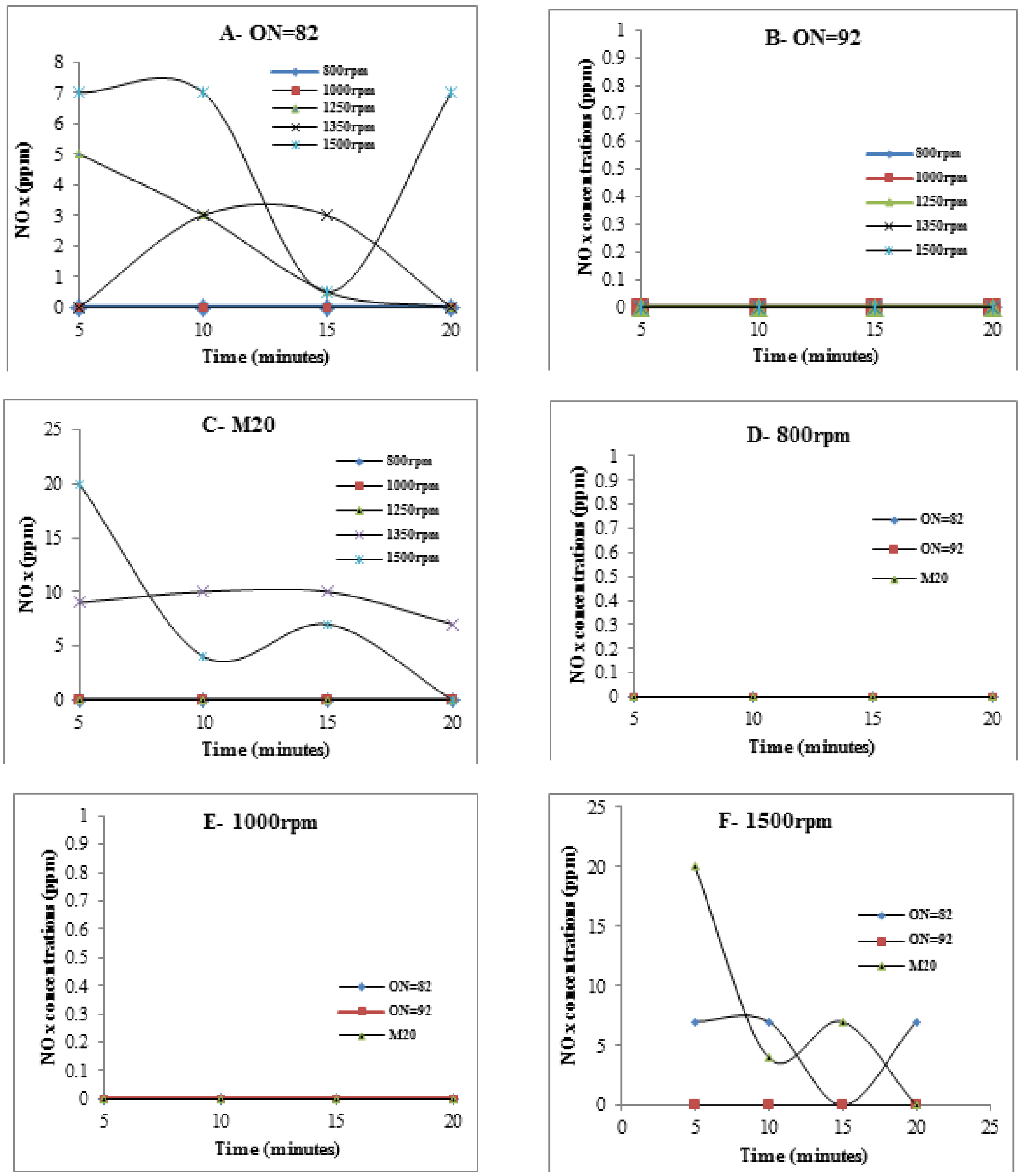

Fig. 7. The idling time effect on emitted NOx for tested fuels at variable engines speeds.

Noise radiated from the engine through the intake and exhaust strokes, and from the fluctuations in components of the engine. Most of the engine noise generated by the combustion process, while others caused by friction, unbalanced components, and cooling fans. A higher noise level exists at lower frequencies as in idling speed case. Fig. 8 shows lower noise levels at high idling speeds for the tested fuels. At medium and higher speeds the noise pressure waves interfere with each other's causing lower noise levels. Figures D, E, and F, clarify that M20 has the lower noise values for the tested speeds. The M20 has lubricating facilities better than the other fuels that manage it to produce lower noise at all the tested idle speeds. At 800 rpm, the produced noise from ordinary and excellent gasoline was higher by 7.19% and 1.24% compared to methanol. At 1000 rpm, the resulted noise from ordinary and excellent gasoline was higher by 2.19% and 1.43% compared to methanol.

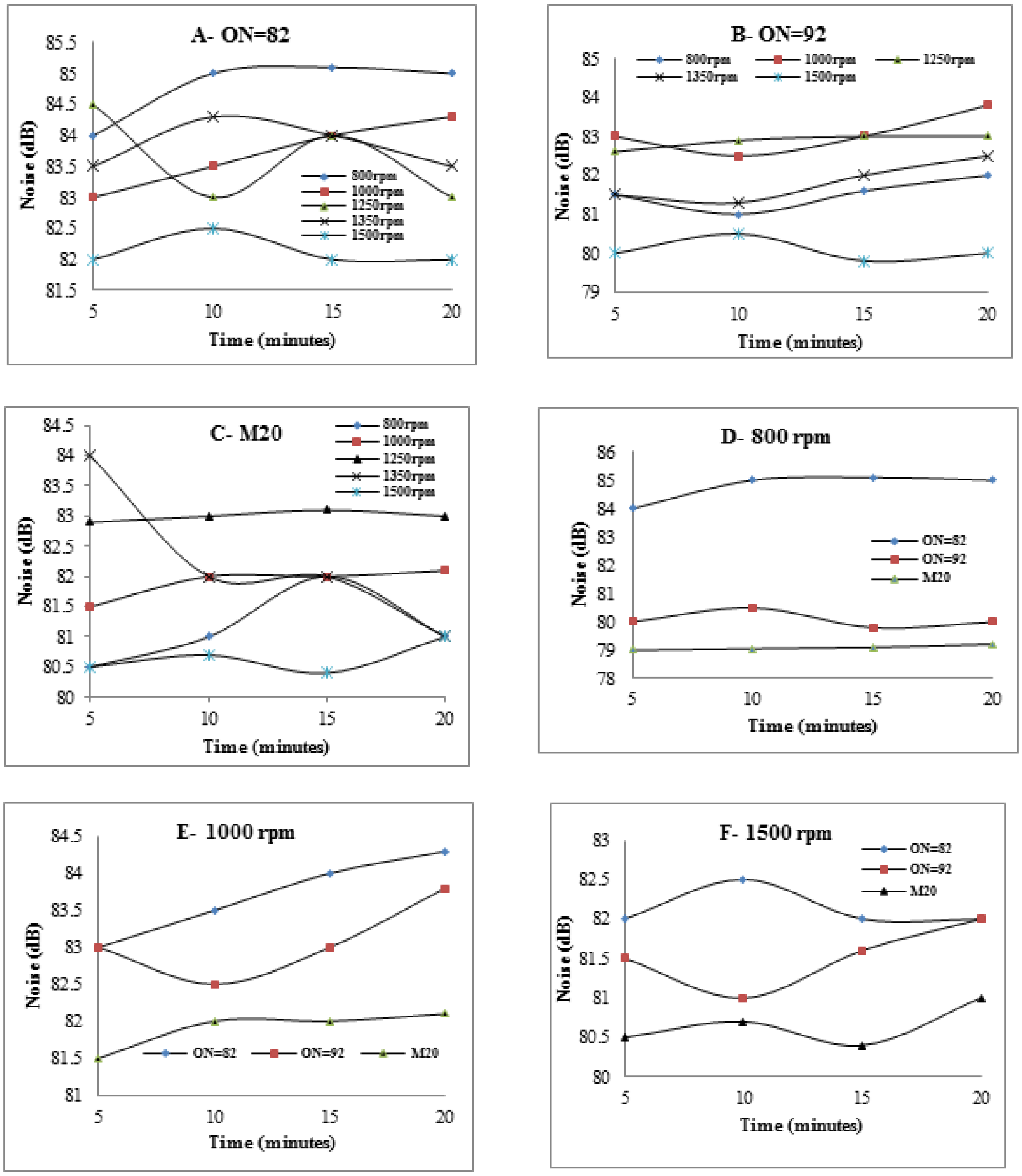

Fig. 8. The idling time effect on emitted Noise for tested fuels at variable engines speeds.

4. Conclusions

The engine operation at idle speed produces regular emissions (CO, CO_2, HC, NOx and noise) with hazard levels. The present study confirms that these levels depend highly on fuel type. From the three tested fuels the premium gasoline (ON=92) represents the lower emissions. Adding methanol for ordinary gasoline (ON=82) showed bad emitted emissions trends for CO, CO_2, HC which were at high levels compared with premium gasoline. The high methanol temperature of evaporation causes fuel evaporation difficulties for parts of the fuel, which increases the previous mentioned emissions. Emitted NOx was near zero levels for most of the idle speeds for the tested fuels. Engine noise reduced with increasing idle speed. Also, M20 showed the lowest noise levels compared to other ones.

Notation

BTDC Before top dead center
CO Carbon monoxide
CO_2 Carbon dioxide
dB Decibel
EGR Exhaust gas recirculation
HC unburned hydrocarbon
IT Injection timing
NOx Nitrogen oxides

5. References

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دراسة عملية لتاثير نوع الوقود على الملوثات المنبعثة من محرك اشتعال بالشرارة خلال فترة الحياد

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الخلاصة

تبحث الدراسة الحالية تأثير نوع الوقود على الانبعاثات الصادرة أثناء فترة الحياد. تم اختبار ثلاثة أنواع من الوقود المتوافرة في العراق. إذ أجريت التجارب باستخدام البنزين العادي ذي عدد أوكتاني ٨٢، البنزين الممتاز بعدد أوكتاني ٩٢، وM20 (تتكون من ٢٠ ٪ ميثانول و ٨٠ ٪ من البنزين العادي). استخدم في التجارب محرك مرسيدس بنز ذو حجم ٢ ليتر .

بينت النتائج أن تشغيل المحرك بسرعة الحياد تنبعث مستويات عالية من CO و CO_2، HC، وNOx والضوضاء. تعتمد مستويات الانبعاثات الناتجة إلى حد كبير على نوع الوقود. أظهر البنزين الممتاز (ON = 92) مستوى انبعاثات أقل باستثناء الضوضاء لكل سرع الحياد المختبرة . إن اضافة الميثانول إلى البنزين العادي (ON = 82) نتج عنه مستويات عالية من CO، CO_2، HC المنبعثة مقارنة مع البنزين الممتاز. كانت انبعاثات أكاسيد النيتروجين قريبة من الصفر لمعظم سرع الحياد و لجميع انواع الوقود المدروسة.