Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 110 (2017) 459 – 464

Energy Procedia

1st International Conference on Energy and Power, ICEP2016, 14-16 December 2016, RMIT University, Melbourne, Australia

Exhaust gas analysis of an eight cylinder gasoline engine based on engine speed

Ali Kilicarslan[a,]*, Mohamad Qatu[b]

[a]Hitit University, Department of Mechanical Engineering, Corum 19030, Turkey
[b]Eastern Michigan University, College of Technology, 109 Sill Hall Ypsilanti 48197, Michigan, USA

Abstract

In this experimental work, exhaust gas analysis of an eight cylinder and v-type gasoline engine, namely, a Chevrolet 5.7, is experimentally performed in terms of engine speed at laboratory conditions by using of an exhaust gas analyzer and the special software called "NetDyn" and "WinDyn". The engine test setup includes a dynamometer to determine the engine torque and data acquisition system. At the experimental works, the engine speed ranges from 2500 rpm to 5250 rpm and step time for successive speeds is held constant as 10 s. A throttle position of 60 is selected for the engine operation. Exhaust gas emissions such as O_2, CO, NO_x and SO_2, are measured in terms of engine speed. Exhaust gas temperature and excess air coefficient are also measured as a function of the engine speed during the experiments.

Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.

Keywords: gasoline engine; engine speed; emission characteristics; NO_x; CO; O_2; SO_2.

1. Introduction

Analyses of energy producing systems with respect to the energy and exergy are not enough itself. The systems should be also analyzed from the environmental aspects. As the gasoline or diesel engines are taken into consideration, the level of exhaust gas emissions from these engines is very important. There are limited studies

* Corresponding author. Tel.: +90-505-319-2498; fax: +90-364-227-4535.
E-mail address: alikilicarslan@gmail.com

Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.
doi:10.1016/j.egypro.2017.03.169

aiming to investigate the exhaust gas emissions of gasoline engines as a function of engine speed in the literature. Some of them are as follows;

The influence of compression ratio on the engine characteristics such as engine torque, maximum brake torque, ignition timing, break specific fuel consumption and exhaust gas emissions (HC and CO) for different ratios of ethanol (E0, E10, E20, E40 and E60) was experimentally carried out by means of a single cylinder gasoline engine. The effect of engine speed on the exhaust gas temperature and emissions, namely HC and CO was also experimentally investigated. The maximum amount of decrease in exhaust gas emissions was observed by using E40 and E60 fuels at 2000 rpm engine speed. HC emission was decreased more when it was compared to CO emission [1]. In order to compare the emissions of diesel and gasoline engines, different blends of diesel and gasoline fueled automobiles were tested at various idle engine speeds in simulated city traffic intersection situations. The tests were carried out for HC, NOx and CO emissions, PAHs (particle-bound poly-aromatic hydro-carbons), particle number and size distribution at engine speeds between 1500 and 3000 rpm with 500 rpm intervals. It was observed that HC, NOx and CO emissions raised as the engine speed raised for all diesel and gasoline engines cars. The amount of NOx emissions for gasoline engines was lower than that of diesel engines [2]. The engine characteristics including engine power and torque, brake mean effective pressure, brake specific fuel consumption and exhaust gas emissions such as CO and brake specific NOx were experimentally tested for different fuels, namely methane, gasoline, methanol, propane, ethanol and hydrogen. The experimental results were validated by means of a simulated computer code. It resulted that CO emission generally raised for all fuels in the study at engine speeds ranging from 1500 to 6000 rpm. The maximum CO emission was determined by using gasoline fuel [3]. The influence of mixture of ethanol and diethyl ether on homogenous charge compression ignition (HCCI) combustion was experimentally carried out by means of a single cylinder, port injection HCCI engine. During the experiments, various ratios of the mixture including 30% ethanol–70% diethyl ether (E30/D70), (E40/D60), (E50/D50) and one hundred percent diethyl ether were tested in the experiments. The experiments were performed at an engine speed of 1200 rpm and various proportions of air-fuel equivalence ratios. The engine characteristics, namely cylinder pressure, heat transfer from the cylinder, indicated mean effective pressure (IMEP), combustion parameters, and thermal efficiency were observed as a function of different ratios of fuels under the study in the experiments. The exhaust gas emissions including CO, HC and NOx were also observed [4]. By means of a numerical model improved, NOx emission and efficiency of a gasoline engine were compared for various fuels such as the natural gas and natural gas-hydrogen gas mixtures [5].

As it is seen from the literature survey summarized above, there are not many studies concerning with the emission characteristics of gasoline engines in terms of engine speed. Our purpose is to make contribution to the researchers conducting research in this area. In this experimental work, NO_x, SO_2, CO and O_2 emissions of a Chevrolet 5.7, v-type, eight cylinder gasoline engine are measured at the speeds ranging from 2133 rpm to 5132 rpm. The principal diversity of this study from the literature is the investigation of the exhaust gas average temperature and excess air coefficient in terms of engine speed function of engine speed and discussed.

Nomenclature

AFR	Air-fuel ratio	
N	Engine speed	rpm
T_{eg}	Exhaust gas temperature	ºC
η_c	Combustion efficiency	
λ	Excess air coefficient	

2. Experimental Work

The experimental works were performed at the Mechanical Engineering Laboratory of Central Michigan University-USA. The engine test apparatus used in the experiments is depicted in Figure 1.

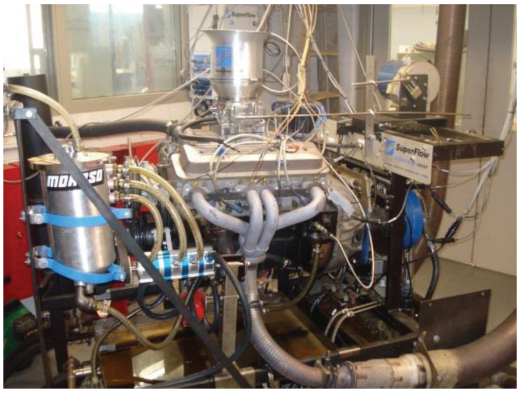

Fig. 1. Gasoline engine test facility

Fig. 2. The exhaust gas analyzer used in the experiments

The unleaded gasoline that has a specific gravity of 0.75 is used as a fuel in the experiments. The exhaust gas analyzer is integrated to the experimental set-up and the engine performance measurements and emission measurements are carried out simultaneously at the desired engine speeds. The exhaust gas analyzer measures the emissions of NO_x (based on NO), SO_2, CO, O_2, and excess air coefficient (λ). Figure 2 depicts the emission analyzer used in this experimental work. The engine speed is changed automatically from 2133 rpm to 5132 rpm with 250 rpm intervals during the tests. At the every engine speed desired in the experiments, the emissions of NO_x, SO_2, CO, O_2 and λ are recorded. The engine features and constant operating conditions in the experimental work are depicted in Table 1.

Table 1. Engine Characteristics and Operating Conditions

Number of cylinder	8	Inertia factor	0.027
Stroke	3.45 inch (87.3 mm)	Atmospheric pressure	28.6 inch Hg (72.6cm Hg)
Displacement	357.3 $inch^3$ (5.855 m^3)	Average relative humidity	53 %
Bore	4.06 inch (103.1mm)	Average air temperature	46.44 F (26 °C)
Cycle	4	Air density	0.07 lb /ft^3
Overall ratio	1	Battery voltage	13.4 VDC

3. Results and Discussions

The emissions including NO_x, SO_2, CO and O_2 are measured at the speeds ranging from 2133 rpm to 5132 rpm. The results are represented graphically and discussed in the following paragraphs. The exhaust gas average temperature and excess air coefficient and are also given as a function of engine speed and discussed.

The variation of exhaust gas temperature with engine speed is depicted in Figure 3. As depicted in Figure 3, the exhaust gas temperature raises with engine speed, reaches to the highest value of 1820°C at an engine speed of 3751 rpm and it remains constant beyond this speed. The engine speed, namely 3751 rpm, can be one of the indications that are required for reaching the maximum power. The increase in the exhaust gas temperature between the engine speeds of 2133 rpm and 3750, the exhaust gas temperature approximately raised 32%.

The change of NO_x emission with the engine speed is depicted in Fig. 4. NO_x formation is mainly caused by combustion chamber temperature, amount of O_2 and chemical reaction time in the combustion chamber [6]. At the minimum engine speed, namely 2133 rpm, NO_x emission decreases sharply and it becomes 366 ppm. NO_x emission continues to decrease at the engine speeds between 2248 and 2745 rpm and then it has a minimum value of 209 rpm. NO_x emission raises sharply between 2994 and 3500 rpm and it reaches the maximum value of 1464 ppm at an engine speed of 3500 rpm. At this speed, maximum engine power is also approximately obtained. Beyond a speed of 3500 rpm, NO_x emission decreases again and finally, it becomes 876 ppm.

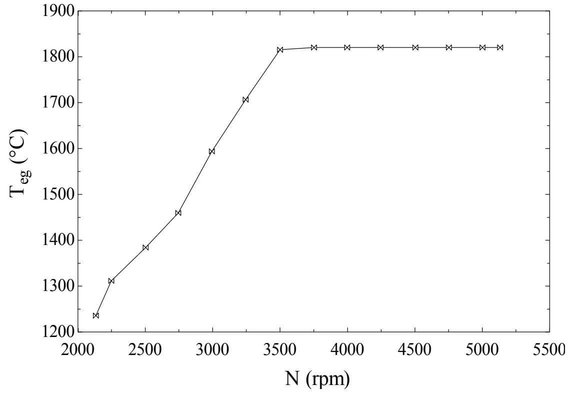

Fig. 3. Exhaust gas temperature with engine speed

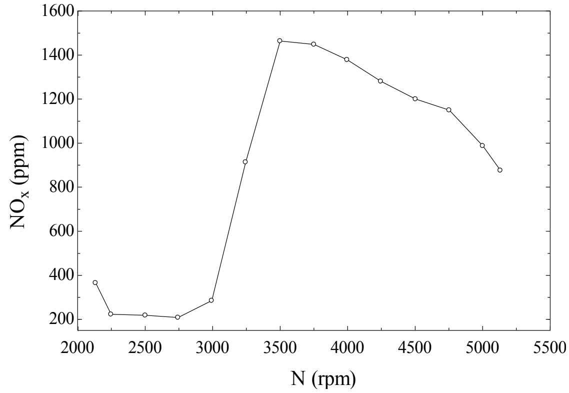

Fig. 4. Variation of NOx emission with engine speed

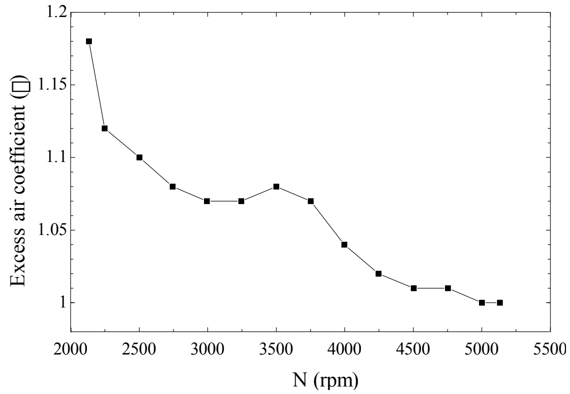

Fig. 5. Variation of λ with engine speed

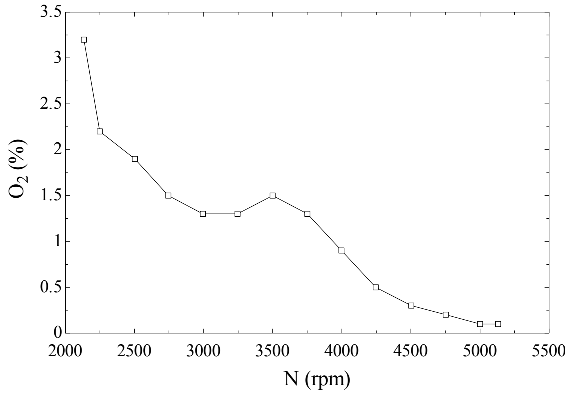

Fig. 6. Variation of O2 emission with engine speed

The change of the excess air coefficient (λ) with respect to the engine speed is depicted in Figure 5. As shown in Fig.5, λ generally decreases as the engine speed raises. As the engine speed raises, the amount of fuel entering the combustion chamber of the engine raises as it is compared the amount of air. This causes λ to decrease. λ decreases from 1.18 to 1 while the engine speed ranges from 2132 to 5132 rpm.

The change of O_2 emission with the engine speed is depicted in Fig. 6. As it is depicted in Fig. 6, O_2 emission generally decreases as the engine speed raises. As the engine speed raises, more amount of fuel is introduced to the engine. This causes air-fuel ratio (AFR) to decrease. As a result of this, O_2 emission decreases as shown in Fig. 6. O_2 is directly related to λ, and therefore Figure 8 shows the same tendency with Figure 7. Amount of O_2 emission decreases from 3.2 to 0.11 %.

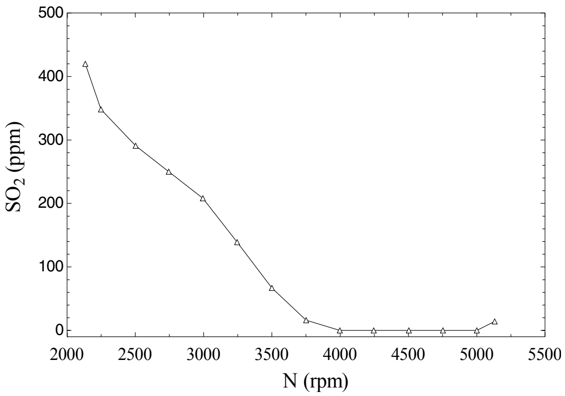

Fig. 7. Variation of SO_2 emission with engine speed

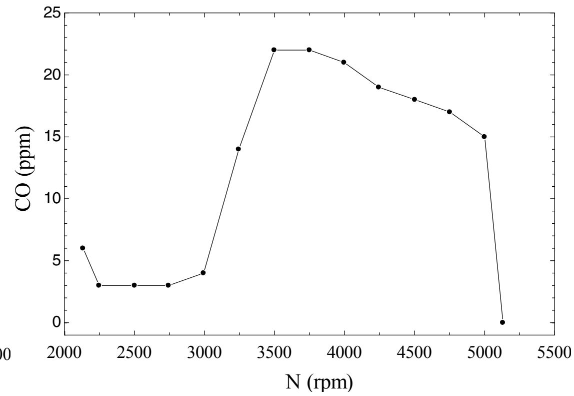

Fig. 8. Variation of CO emission with engine speed

The variation of SO_2 emission with engine speed is shown in Figure 7. As shown in Figure7, SO_2 emission decreases in the most of the engine speeds studied in the experiments. The increase in the engine speed causes the exhaust gas temperature to raise until the engine reaches the operating temperature. SO_2 emission is inversely proportional to the exhaust gas temperature of the engine. It decreases with the increase in the exhaust gas temperature as the exhaust gas temperature reaches a constant stable value of 1820°C. SO_2 emission decreases from 420 to 0 ppm while the engine speed raises from 2133 to 3997 rpm. SO_2 emission doesn't change between the engine speeds between 3997 rpm and 5001 rpm. Beyond the speed of 5001 rpm, SO_2 emission raises and it has a value of 14 ppm at a speed of 5132 rpm.

The change of CO emission with the engine speed is shown in Fig. 8. Deficient amount of O_2 during the combustion mainly causes CO emission in the exhaust products. The trend displayed by CO emission is very similar to that by NO_x emission. Firstly, CO emission decreases from 6 ppm to 3 ppm while the engine speed raises from 2133 rpm to 2248 rpm, and then it becomes constant within two successive speed intervals. Later, CO emission raises until it reaches the maximum value of 22 ppm, and then it decreases to a minimum value of 0.

4. Conclusions

Exhaust gas analysis of the gasoline engine was performed by using an exhaust gas analyzer. The engine speed was raised from 2133 rpm to 5132 rpm and the emissions including NO_x, SO_2, CO and O_2 were measured simultaneously. The important results are as follows;

- The exhaust gas temperature raised with engine speed until the temperature reaches a value of 1820°C at an engine speed of 3751 rpm. The average increase in the exhaust gas temperature was 32%.
- NO_x and CO emissions showed similar trends and both decreased between the engine speeds 2133 rpm and 2745 rpm, and raised at the engine speeds between 2745 rpm and 3500 rpm.
- The variations displayed by O_2 emission and excess air coefficient with the engine speed were very similar. Both decreased in average as the engine speed raised.
- SO_2 emission decreased from 420 to 0 ppm at the engine speeds ranging from 2133 to 3997 rpm. At the engine speeds higher than 3997 rpm, SO_2 emission had generally a value of 0 ppm.
- The maximum emissions of NO_x, O_2, CO and SO_2 during the experiments were 1464 ppm, 3.2 %, 22 ppm and 420 ppm, respectively.

Acknowledgements

We would like to thank you to School of Engineering and Technology of Central Michigan University MI-USA, for supporting this experimental study and special thanks to the technical staff, Mark Allen Blackmer for his help during the experiments.

References

[1] Yücesu HS, Topgül T, Çinar C, Okur M. Effect of ethanol–gasoline blends on engine performance and exhaust emissions in different compression ratios. Applied Thermal Engineering 2006;26: 2272–2278.
[2] Agarwal AK, Gupta T, Bothra P, Shukla PC. Emission profiling of diesel and gasoline cars at a city traffic junction. Particuology 2015;18: 186–193.
[3] Pourkhesalian AM, Shamekhi AH, Salimi F. Alternative fuel and gasoline in an SI engine: A comparative study of performance and emissions characteristics. Fuel 2010;89:1056–1063.
[4] Polat S. An experimental study on combustion, engine performance and exhaust emissions in a HCCI engine fueled with diethyl ether–ethanol fuel blends. Fuel Processing Technology 2016; 143:140–150.
[5] Mariani A, Morrone B, Unich A. Numerical evaluation of internal combustion spark ignition engines performance fueled with hydrogen - natural gas blends. International Journal of Hydrogen Energy 2012;37:2644-2654.
[6] Sayin C. Engine performance and exhaust gas emissions of methanol and ethanol–diesel blends. Fuel 2010;89:3410–3415.