ANALYSIS OF THE ENGINE FUELS IMPACT ON CARBON DIOXIDE EMISSIONS

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Abstract

The article addresses the topic of carbon dioxide emissions into the atmosphere as the result of the hydrocarbon fuels combustion in the combustion engines. Widespread use of individual means of transportation, where the combustion engines function as the basic propulsion source, has caused that they are one of the main sources of carbon dioxide emission into the atmosphere. Therefore, it has been subjected to some restrictions, similar to those applied towards toxic elements contained with exhaust. One of the most effective ways of restriction of carbon dioxide emission is to decrease fuel consumption. In addition, an important item is the implementation of fuels with less potential to create carbon dioxide as a result of their combustion. The article presents the results of comparative measurements conducted on the engine test stand in terms of prepared load characteristics for a spark ignition engine powered by gasoline as well as by natural gas. On the basis of these measurements the article provides the analysis of the impact of fuel composition and combustible mixture on carbon dioxide content in the exhaust gases. In the next stage of analysis, the criterion for the comparison was the value of carbon dioxide emission with reference to 1 kg of fuel resulting from the measurements and theoretical calculations of fuel combustion. The results of measurements and calculations were shown in forms of graphs. The measurements on a test stand were conducted for the engine of the older generation, whose design corresponds to the motors located in a large number of currently used vehicles. This allows a preliminary estimation of the carbon dioxide emissions coming from means of transport.

***Keywords**: internal combustion engine, combustion, engine fuels, emission, carbon dioxide*

1. Introduction

Excessive carbon dioxide emissions resulting from the development of broader human activity is not without significance for the surrounding environment. Therefore, it has been subjected to some restrictions, similar to those applied towards toxic elements emitted into the atmosphere as a result of hydrocarbon fuels combustion.

Widespread use of individual means of transportation, where the combustion engines function as the basic propulsion source, has caused that they are one of the main sources of carbon dioxide emission into the atmosphere. Passenger cars account for about 20% of the total carbon dioxide emissions to the atmosphere [1].

In the case of combustion engines their continuous development can be observed, resulting in a very high technical advancement of these machines. Despite the advancement, this is not a simple task to meet increasingly stringent standards limiting the emission of harmful substances to the atmosphere, including carbon dioxide. One of the most effective ways is to decrease fuel consumption, which is widely used by vehicle manufacturers. In addition, an important item is the implementation of fuels with less potential to create carbon dioxide as a result of their combustion [1].

This was the reason for carrying out measurements in a laboratory during which a spark ignition engine was powered with a commonly used fuel which is petrol, and then the attempts were repeated at the same engine but powered with natural gas. Among the available and suitable for combustion engines fuels, according to the theoretical analysis of the combustion process, natural gas combustion compared to petrol combustion should ensure the lowest emissions of carbon dioxide into the atmosphere [1, 3].

2. Engine test stand

Measurements were done on a test stand in a laboratory of combustion engines at AGH University of Science and Technology. The stand is equipped with Schenk W130 engine brake. To perform the measurements a four-cylinder, in-line combustion engine was used with Fiat 170A1.00 spark ignition and displacement volume of 900 cm^3. The engine is equipped with a standard gasoline system and the system allowing the natural gas supply. In the engine intake system an air flow meter and thermocouple was mounted. Thermocouples were placed also in the engine cooling system and exhaust system – in the exhaust manifold and behind the catalytic converter. Furthermore, the test stand is equipped with a system for measuring volumetric consumption of liquid fuel, flow metering system for gas fuel consumption and exhaust gas analyzer Capelec CAP3201.

3. Methodology of measurements

Measurements were carried out in stable conditions of engine operation, after warm-up period, when temperatures in the engine systems gained the constant values. The adopted methodology of measurement included the engine parameters registration during the preparation of the load characteristics at a speed of 2500 RPM and 3500 RMP. Engine load was varied across the steps of measuring corresponding to brake loading force of 5 N.

Measurements have been done during gasoline and natural gas supply to the engine. At each point fuel consumption was measured together with air mass flow, gas composition and temperature in the intake, exhaust and cooling systems. Based on these results, analyzed the value of fuel consumption, air mass flow supplying the engine and volume concentration of carbon dioxide in engine exhaust gases before the catalytic converter.

4. Test results

The measurement results and their analysis are illustrated in forms of graphs with all quantities presented as a function of engine torque. Graphs in Fig. 1, 3, 5 and 7 show the values of air mass flow measured at the engine intake system and the hourly fuel consumption. While in Fig. 2, 4, 6 and 8 there is a summary of hourly fuel consumption curves, the corresponding mass flux of carbon dioxide in the exhaust gases, as well as the volume fraction of carbon dioxide in Nm^3 with a reference to 1 kg of fuel burned.

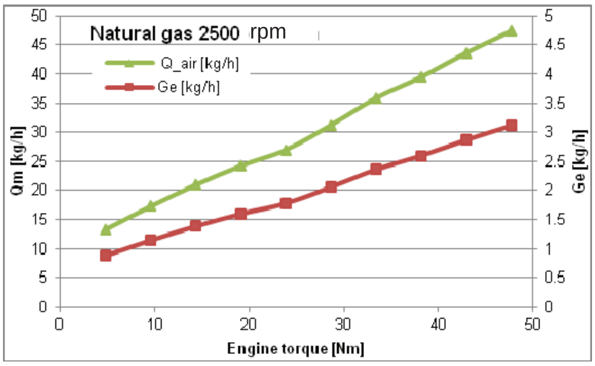

Fig. 1. Air mass flow (Q air) and fuel consumption per hour (Ge) as a function of engine torque for engine powered by natural gas at 2500 RPM

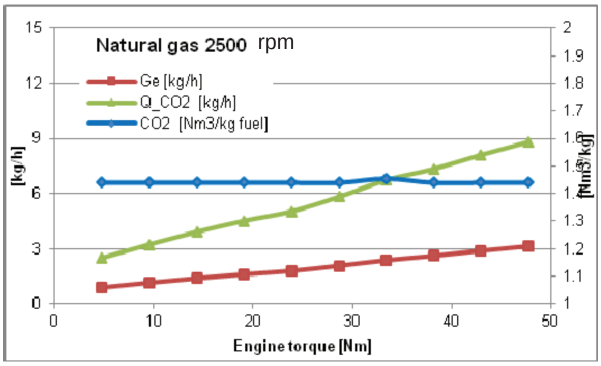

Fig. 2. Mass flow of carbon dioxide in the exhaust gases (Q CO_2), carbon dioxide emission in relation to 1 kg of fuel and fuel consumption per hour (Ge) as a function of engine torque for engine powered by natural gas at 2500 RPM

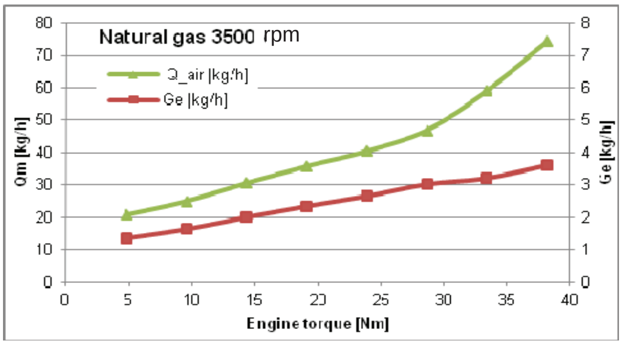

Fig. 3. Air mass flow (Q air) and fuel consumption per hour (Ge) as a function of engine torque for engine powered by natural gas at 3500 RPM

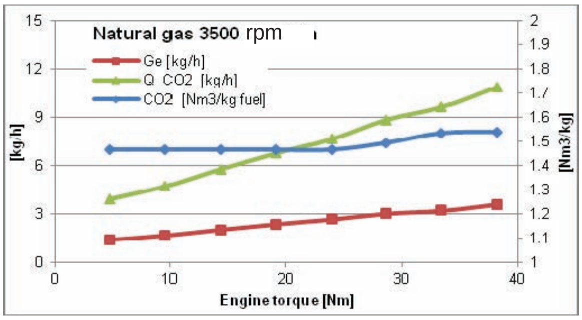

Fig. 4. Mass flow of carbon dioxide in the exhaust gases (Q CO2), carbon dioxide emission in relation to 1 kg of fuel and fuel consumption per hour (Ge) as a function of engine torque for engine powered by natural gas at 3500 RPM

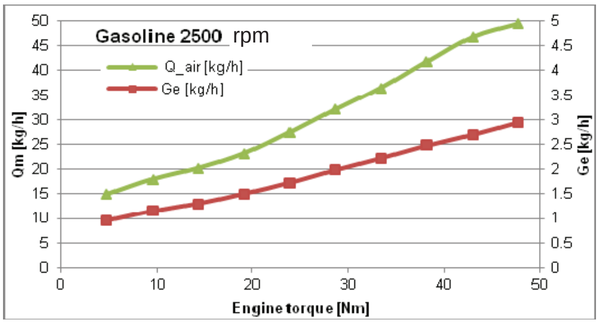

Fig. 5. Air mass flow (Q air) and fuel consumption per hour (Ge) as a function of engine torque for engine powered by gasoline at 2500 RPM

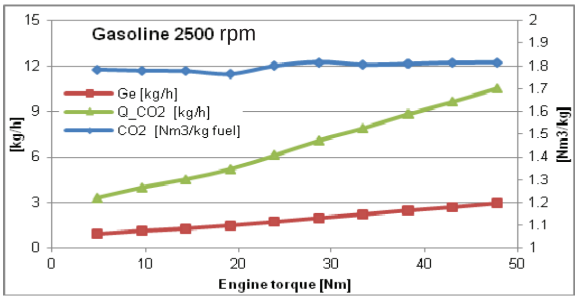

Fig. 6. Mass flow of carbon dioxide in the exhaust gases (Q CO2), carbon dioxide emission in relation to 1 kg of fuel and fuel consumption per hour (Ge) as a function of engine torque for engine powered by gasoline at 2500 RPM

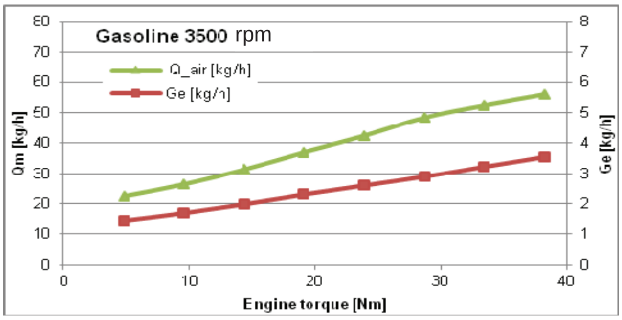

Fig. 7. Air mass flow (Q air) and fuel consumption per hour (Ge) as a function of engine torque for engine powered by gasoline at 3500 RPM

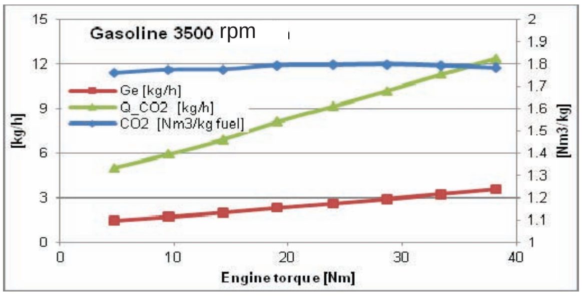

Fig. 8. Mass flow of carbon dioxide in the exhaust gases (Q CO2), carbon dioxide emission in relation to 1 kg of fuel and fuel consumption per hour (Ge) as a function of engine torque for engine powered by gasoline at 3500 RPM

Figures 2 and 3 show the results of measurements and calculations for engine powered by natural gas, operating at a constant speed of 2500 RPM in the range of torque from 4.8 Nm to 47.75 Nm. In this range the hourly fuel consumption varied from about 0.87 kg/h to 3.16 kg/h, while a stream of air masses from about 13.28 kg/h to 47.34 kg/h. Corresponding to these engine parameters, the mass flow of carbon dioxide in the exhaust gases amounted from about 2.47 kg/h to 8.82 kg/h. As a result, the carbon dioxide emission in relation to 1 kg of natural gas was 1.44

Nm^3. Fig. 6 and 7 show the results of measurements and calculations for gasoline-powered engine operating in the same conditions as when powered by natural gas. In this case, the hourly fuel consumption varied from about 0.95 kg/h to 2.95 kg/h, a stream of air masses from about 14.90 kg/h to 49.40 kg/h and the mass flow of carbon dioxide from about 3.32 kg/h to 10.5 kg/h. The received emissions of carbon dioxide in relation to 1 kg of gasoline were within 1.78 Nm^3 to 1.81 Nm^3.

At the engine speed of 3500 RPM measurements were performed in the torque from 4.8 Nm to 38.2 Nm. Fig. 4 and 5 show the results for engine powered by natural gas. Under these conditions, the engine hourly fuel consumption varied from about 1.36 kg/h to 3.60 kg/h, a stream of air masses from about 20.68 kg/h to 74.3 kg/h and corresponding to the values the mass flow of carbon dioxide from approximately 3.92 kg/h to 10.89 kg/h. Whereas carbon dioxide emissions related to 1 kg of natural combusted gas ranged from 1.47 Nm^3 to 1.54 Nm^3. Then Fig. 8 and 9 show the results of measurements and calculations for gasoline-powered engine at a constant speed of 3500 RPM. The obtained values of the hourly fuel consumption range from about 1.45 kg/h to 3.54 kg/h, a stream of air masses from about 22.5 kg/h to 56.02 kg/h and the mass flow of carbon dioxide contained in the exhaust gases from about 5.02 kg/h to 12.4 kg/h. Carbon dioxide emissions in relation to 1 kg of gasoline ranged from 1.76 Nm^3 to 1.8 Nm^3.

5. Conclusions

During the measurements on a test stand in terms of the prepared load characteristics, when a combustion engine with a spark ignition was being powered with liquid and gas fuel, in the same engine operating conditions, the comparable values of the hourly fuel consumption were achieved. Simultaneously it has been found that at both engine speeds, at the lower range of applied loads the gasoline consumption is on average about 8% higher, while at the upper load range the natural gas consumption is on average higher by about 4%.

Recorded by the exhaust gas analyzer the values of the carbon dioxide concentration in the exhaust gases, expressed in percent by volume, illustrated the dependence of this component on the combustible mixture supplied to the engine. This confirms the validity of controlling and checking the mixture composition.

Calculated on the basis of the measured values, the carbon dioxide mass flow [2, 3] in the exhaust gases was always higher for gasoline combustion. The differences ranged from about 14% to about 34%, with greater differences observed at the lower engine load.

In the next stage of analysis the emissions of carbon dioxide in the exhaust gases was brought to 1 kg of the combusted fuel [1-3]. And thus the following values were obtained:

- Natural gas, 2500 RPM: average 1.44 Nm^3/kg fuel,
- Natural gas, 3500 RPM: average 1.5 Nm^3/kg fuel,
- Gasoline, 2500 RPM: average 1.79 Nm^3/kg fuel,
- Gasoline, 3500 RPM: average 1.78 Nm^3/kg fuel.

Combustion of gasoline in the combustion engines causes more carbon emissions into the atmosphere than the combustion of natural gas in the same engine, which confirms the effect of fuel composition on the carbon dioxide content in the exhaust gases. However, the values obtained during the measurements differ from the values arising from the theoretical calculations. Such calculation presented in [1] indicates that the combustion of 1 kg of gasoline should give 1.59 Nm^3 of carbon dioxide while 1 kg of natural gas combustion 1.4 Nm^3 carbon dioxide. The resulting differences are the result of the fact that the process of combustion in a combustion engine is a phenomenon proceeding in a dynamic manner, subject to constant changes, therefore, is far from ideal theoretical calculations assumed during combustion. In addition, the fuel combustion process and thus the composition of the generated exhaust gases are affected by air-fuel mixture. Even slight variations in an excess air rate during the measurements are reflected in the concentration of carbon dioxide in the exhaust gases and its share per 1 kg of the fuel burned.

The above measurements on a test stand were conducted for the engine of the older generation, whose design corresponds to the motors located in a large number of currently used vehicles. This allows a preliminary estimation of the carbon dioxide emissions coming from means of transport. With present, modern technical solutions such as direct fuel injection in spark ignition engines and the electronic engine control system, there are much greater possibilities for optimal selection of the combustion process parameters, and therefore also the possibility of significant reducing carbon dioxide emissions into the atmosphere coming from the means of transport.

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