Experimental Researches of Fuelling Systems and Alcohol Blends on Combustion and Emissions in a Two Stroke Si Engine

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Abstract: - Fuelling systems play a major role in the process of air-fuel mixture formation, due to this fact; the aim of this paper was to achieve an optimal mixture, which results in low exhaust emissions and best behavior of the combustion process.

In order to achieve the aim of this paper, the fuelling systems were combined with a flame ionization detector (FID) and CO, CO2 and NOx analyzers for measuring the resulting exhaust emissions.

Comparisons of the two fuelling systems, carburetor (1st) and air-assisted direct injection (2nd), are made with the help of the resulting combustion process and exhaust emissions; other comparisons were made also with the types of fuels used during this experimental research.

By increasing the engine’s efficiency some engine modifications were made and therefore further comparisons were done using the measured combustion process data and the resulting exhaust emissions.

By using the second fuelling system, the air-assisted direct injection (DI), and blending alcohol with gasoline, at similar engine conditions with the conventional fuelling system, results in an improved engine torque and increased engine efficiency, therefore the fuel economy penalty associated with the lower energy content of alcohols can be reduced.

It was also found that the modifications brought to the engine improve the engine’s efficiency and by using alcohol mixtures it increases furthermore.

By replacing the conventional fuelling system, the carburetor, with the second fuelling system, the air-assisted DI, used for comparison, results in lower fuel consumption and lower exhaust emissions.

The air-assisted DI system was electronically manual controlled in order to achieve the optimal combustion process and exhaust emissions results.

Due to the fact that during this experimental research alcohol blends were used, the requirement for delaying or setting earlier the ignition point was accomplished by using a HT-coil.

By using the air-assisted DI system with gasoline – alcohol blends results in achieving an improved engine torque, a good behavior of the combustion process, lower fuel consumption and lower exhaust emissions.

Key-Words: - Engine, Combustion, Exhaust Emissions, Gasoline, Alcohols

1 Introduction

In order to meet the increasing requirements for reducing the engines exhaust emissions calls for cost effective technical solutions. Therefore in this paper it is presented the comparison of the conventional fuelling system of a 2 stroke SI engine, the carburetor (1st fuelling system), with a direct injection fuelling system called the air-assisted direct injection (2nd fuelling system).

The comparisons are made thru the obtained results of the two fuelling systems behavior regarding the exhaust emissions, combustion process and used fuels.

During this experimental research, among the used fuels were also alternative fuels involved, alcohols blended with super gasoline (E85) and pure alcohol (E100).

By increasing the engine’s efficiency, the compression ratio of the engine was increased; therefore further comparisons were done using the measured combustion process data and the resulting exhaust emissions.

Due to the fact that during this experimental research alcohol blends were used, the requirement for delaying or setting earlier the ignition point was accomplished by using a HT-coil.
2 The Air-assisted DI

Fig. 1 The air-assisted DI – system
In figure 1 it can be seen the air-assisted DI fuelling system used in this experimental research. The fuel pumped into the air-fuel mixture formation chamber of the air-assisted DI system had a pressure of 0.6 – 0.7 MPa. The air pressure was induced into the air-fuel mixture formation chamber of the air-assisted direct injection system with a pressure of 4.5 – 5.5 bars. In order to have a constant compressed air pressure an air regulator was mounted on the air inlet system. The air-assisted DI proves in this experimental research that it is the optimal solution regarding lower fuel consumption, lower exhaust emissions and best behavior of the combustion process. Using this kind of a fuelling system for meeting future exhaust emissions legislation shows to be a practical solution due to the fact that it is not very expensive equipment and it doesn’t require complicated engine modifications.

3 The Carburetor or the air-assisted direct injection fuelling system
In order to achieve the aim of this research both fuelling systems were researched and the obtained results are described in the following sub-sections.

3.1 Combustion process

Figure 2 shows the combustion process as it occurs using the carburetor as fuelling system and super gasoline as fuel. It can be seen that the pressure rises in the case of the air-assisted DI fuelling system up to 3.1 MPa at 9° crank angle degrees ATDC. The ignition point is at -43° crank angle degrees BTDC. The combustion process is similar to the carburetor, due to the fact that the ignition timing was left constant.

In figure 3 it can be seen that using E85 the pressure increases up to 3.47 MPa at 4.7° crank angle degrees ATDC, this means also that the power output increases. In this figure we can observe that from -30° crank angle degrees BTDC, during the compression phase, there is a difference between the pressure curves due to the fact that the injection timing was modified and additional compressed air entered the combustion chamber.

In this figure the pressure traces appear as they occur in the carburetor and the air-assisted DI as fuelling systems and Ethanol 85 as fuel. It can be seen that increasing the compression ratio and using...
E85 the pressure increases up to 4.8 MPa at 4.2° crank angle degrees ATDC, this means also that the power output increases. In this case we can observe that from -28° crank angle degrees BTDC, during the compression phase, there is a difference between the pressure curves due to the fact that the injection timing was modified and additional compressed air entered the combustion chamber.

Fig. 5 Pressure curves using E100 for DI-system
In this figure the pressure in the combustion chamber of the engine is presented, by using the carburetor and the air-assisted direct injection as fuelling systems and Ethanol 100 as fuel. In this case we can observe that from -35° crank angle degrees BTDC, during the compression phase, there is a difference between the pressure curves due to the fact that the injection timing was modified and additional compressed air entered the combustion chamber. The pressure increases up to 3.41 MPa at 5.3° crank angle degrees ATDC.

Fig. 6 Pressure curves at higher compression ratio (E100)
In figure 6 the pressure increases up to 4.54 MPa at 5.4° crank angle degrees ATDC in the case of the air-assisted direct injection. The carburetor was also used as fuelling system and E100 as fuel. In this case we can observe that from -25° crank angle degrees BTDC, during the compression phase, there is a difference between the pressure curves due to the fact that the injection timing was modified and additional compressed air entered the combustion chamber.

Fig. 7 Torque diagram
In figure 7 it can be observed that the 2-stroke SI engine reaches maximum torque at 6000 rpm’s. In case of the carburetor and of the air-assisted DI the maximum torque is achieved at 6000 rpm and as it can be seen maximum torque is achieved by using pure ethanol and direct injection at 6000 rpm. An increase of torque is seen also between the used fuels in the direct injection, such as E85 and super gasoline, the maximum torque achieved by the Ethanol blend lies at 6000 rpm and has a value of 4.8 [Nm] in comparison with super gasoline which reaches a maximum value of 4.7 [Nm].

4 Emissions analysis

Fig. 8 HC – Emissions
Figure 8 shows that by using the air-assisted DI system instead of the conventional fuelling system
the HC emissions are decreasing. In case of the air-assisted DI it can be observed that the HC emissions are decreasing furthermore by using Ethanol blends extended to using pure Ethanol fuel.

The HC Emissions were recalculated after the measurements due to the fact that Ethanol fuel has a different chemical composition than super gasoline. The C number of Ethanol is 2 compared to the calibration gas (Propane) which has 3 Carbon atoms, due to this fact the unburned Hydrocarbon results were recalculated by using the response factor of Ethanol fuel which is 0.71.

**5 Conclusions**

Using advanced fuelling systems like the air-assisted DI shows that not only the exhaust emissions and fuel consumption are lower but also the engine efficiency increases.

The combustion process has a very good behavior in all cases due to the fact that the air-assisted DI was electronically manual regulated. The pressure rises due to higher compression ratio and the power output reaches its peak when using E100.

In order to gain power output from a spark ignition engine without bringing important changes to it, increasing the compression ratio is one technical solution and another solution is by using as fuel alcohols blended with Super Gasoline (E85) or in pure state (E100).

Working with alcohols requires the replacement of the machines conventional ignition system with a HT – coil so that the start of ignition could be delayed or set earlier in order to achieve the best combustion process behavior.

HC Emissions dropped by 60% in comparison with the carburetor fuelling system and they decreased furthermore by using alcohols in pure state (E100) or blended with Super Gasoline (E85).

By using the air-assisted DI fuelling system the CO emissions drop by 44%. When using the air-assisted DI CO\textsubscript{2} emissions dropped also by 44% compared to the carburetor fuelling system.

NO\textsubscript{x} emissions increase when using the air-assisted DI with super gasoline due to the fact that the engine worked with a leaner air-fuel mixture.

It can be observed that by using alcohols and the air-assisted direct injection and Ethanol the NO\textsubscript{x} emissions are lower.

Overall, using the air-assisted DI fuelling system in the combustion chamber with alcohols leads to higher power output, lower emissions and lower fuel consumption. Replacing conventional fuel with alternative fuel shows an improvement in power output and exhaust emissions decrease.

Using ethanol and the air-assisted DI is one answer to have an improved engine combustion process behavior and a cleaner environment for the human health.
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