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TECHNICAL SOLUTIONS FOR IMPROVING THE EFFICIENCY OF A TWO STROKE SI ENGINE

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Abstract: *Meeting future emissions reduction legislation is a must for the engine manufacturers and therefore experimental investigations have to be done. Two stroke engines have a simple mechanical construction and a good power-weight ratio. The two stroke spark ignition engine has a short combustion process period and therefore the exhaust emissions are higher in comparison with the 4 stroke spark ignition engine. The aim of this paper was to research the engine's combustion process behavior and resulting exhaust emissions at different compression ratios, different fuels and different fuelling systems.*

Key words: *fuelling systems, compression ratio, alternative fuels, combustion process, exhaust Emissions.*

1. Introduction

In December 2008 the EU Parliament adopted the upper exhaust emissions limits for small spark ignition (SI) engines. They are setting these limits, for small portable engines above 50 cm^3, at:

- 603 g/kWh CO;
- 161 g/kWh HC;
- 5.36 g/kWh NO_x.

From 1st of August these upper limits are decreasing to: 72 g/kWh HC + NO_x [3], [7].

In order to meet these upper limits the two stroke SI engine had to be improved by increasing the compression ratio (CR) from 8:1 at 9:1 and 10:1. Another important improvement was accomplished by changing the engine's conventional fuelling system, the carburetor, with the air-assisted direct injection (DI) system.

Achieving higher engine efficiency was done by using alternative fuels, blended with super gasoline or in pure state.

The combustion process behavior and the resulting exhaust emissions at different compression ratios, different fuelling systems and different fuels, are presented through the results of this experimental research.

A higher CR increases the engine's efficiency and modifies the fuel injection timing; [4], [5], [9] therefore an important attention was given to finding the optimal air-assisted DI working parameters. In order to achieve best combustion process behavior and low exhaust emissions this fuelling system, the air-assisted DI, was manually controlled [1].

Using alternative fuels like alcohols requires delaying or setting earlier of the engine's ignition point [1], [2], [6].

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Fuel consumption and the resulting exhaust emissions are lower by using the air-assisted DI in comparison with the conventional fuelling system, the carburetor [1], [10].

2. Objectives

The objectives of the researches are to reduce fuel consumption, to increase engine efficiency and to reduce exhaust emissions [1].

The aims of this paper are the following:

2.1. By modifying the injection system

- Finding out the best combustion process behavior of the air-assisted DI compared to the conventional fuelling system;
- Obtaining lower exhaust emissions resulting from the engine's combustion process;
- Achieving lower fuel consumption and thus a higher engine torque and output compared to the engine's conventional fuelling system [1].

2.1. By increasing the engine's compression ratio

- Finding out the best combustion process behavior of the air-assisted DI compared to the conventional fuelling system;
- Obtaining lower exhaust emissions resulting from the engine's combustion process;
- Achieving lower fuel consumption and thus a higher engine torque and output compared to the engine's conventional fuelling system [1], [8].

All this studies have to be done by using conventional fuel as well as fuel blends and pure alcohol [1].

For these studies a two stroke spark ignition engine was used. This engine type is used for handheld power tools like blowers, chainsaws and trimmers. The main engine data can be seen in Table 1 [1].

Two stroke spark ignition engine Table 1

Engine type	**Two stroke SI engine for handheld power tool**
No. of cylinders	1
Cylinder displacement	70 cc
Cylinder bore	50 mm
Stroke	36 mm
Power output	4 kW (5.4 HP) at 9500 rpm
	Crankcase scavenging
	Schnürle full loop

3. Development Program

3.1. Modifying the engine's fuelling system

In order to pursue the aims of this engine testing, the following objectives had to be accomplished: building a secondary pipe fuelling system for the air-assisted DI, due to the fact that along this system a fuel pump was mounted to obtain a higher fuel pressure than the pressure used for the conventional fuelling system.

The air-assisted DI was mounted on the engine's cylinder; in order to achieve this goal, some modifications of the cylinder had to be done. So, the engine's cylinder was milled at 135 deg and it was also drilled with a diameter of 8 mm, as seen in Figure 1.

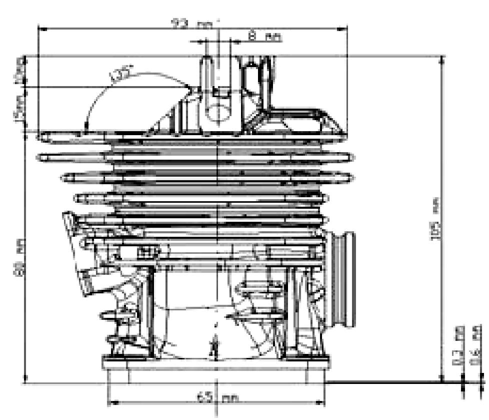

Fig. 1. *Modified engine cylinder for the air-assisted DI mounting* [1]

In order to have a good lubrication of the engine the following engine cylinder modification had to be done (also due to the fact that the fuel was not mixed, as usually, with oil), see Figure 2.

Fig. 2. *Modified engine cylinder for engine lubrication* [1]

The measurements of the resulting pressure during the combustion process and exhaust emissions occur as follows: the ignition point of Engine 1 was measured and it was found at –43° crank angle degrees BTDC; the injection timing was manually found and regulated in order to achieve optimal functioning at the same working conditions as for engine 1; also the ignition point for engine 2 was set as for engine 1. The pressure occurring during the combustion process was measured for each engine; fuel type and fuelling system and the resulting exhaust emissions also at the same working conditions as for the base engine [1].

Base measurements on the conventional engine are the main basis of results comparison [1].

4. Experiments and Results

This two stroke SI engine type is mainly used for handheld power tools like chainsaws, blowers and trimmers.

In order to observe the conventional fuelling system, the carburetor, and the air assisted DI system behavior, normally the used fuel is an oil-gasoline blend. In this case the oil was separately pumped into the two stroke engine by using a two stroke oil pump, as shown in Figure 3.

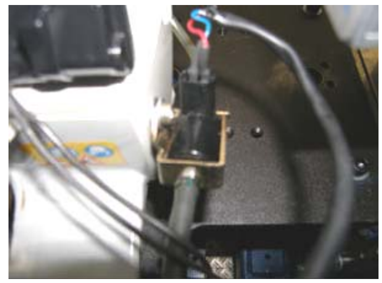

Fig. 3. *Two stroke engine oil pump*

In order to have a good overview on both fuelling systems they were tested by using different fuels at different engine compression ratios [1].

By milling the engine's cylinder, the compression ratio was increased in order to obtain improved engine efficiency [1].

Three fuel types were used:

- Super gasoline;
- Super gasoline blended with ethanol (E85);
- Pure ethanol (E 100).

Also three engines were prepared for this research:

- Engine 1: Compression ratio (8:1);
- Engine 2: Cylinder with increased compression ratio (9:1);
- Engine 3: Cylinder with increased compression ratio (10:1).

In the next figures, the indicated diagrams describe the combustion process as it occurs at different compression ratios and by using different fuel types [1].

The combustion process as it occurs in the engines by using the carburetor as fuelling system and super gasoline as fuel is presented in Figure 4 and it can be observed that the pressure rises in the case of Engine 3 up to 3.91 MPa at 10.4° crank angle degrees ATDC. The ignition point is at –43° crank angle degrees BTDC.

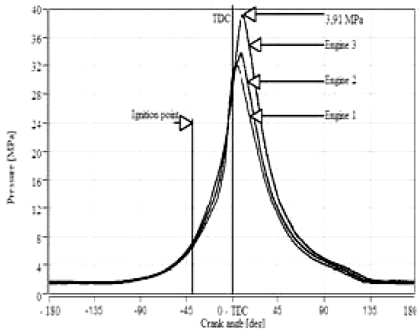

Fig. 4. *Pressure curves development using the carburetor*

Next figure shows pressure traces of the researched engines by using the air assisted direct injection as fuelling system and super gasoline as fuel. The pressure rises in case of Engine 3 up to 4.40 MPa at 6.1° crank angle degrees ATDC. Milling the cylinder changes the compression ratio and determines also a small outlet and overflow timing change.

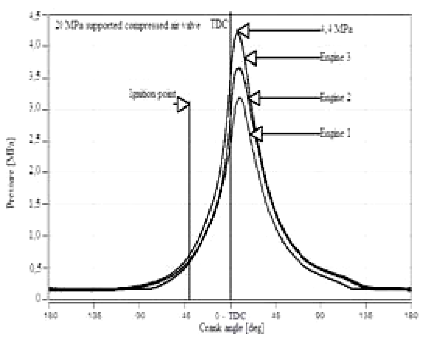

Fig. 5. *Pressure traces development by using the air-assisted DI*

As shown in Figure 6 the engines combustion process pressure traces, using the air-assisted DI as fuelling system and ethanol 85 as fuel, are increasing up to a maximum of 4.75 MPa at 4.9° crank angle degrees ATDC, also resulting in a increase of the power output.

In this case we can observe that from –44° crank angle degrees BTDC, during

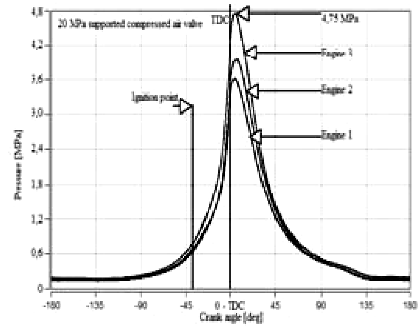

Fig. 6. *Pressure curves development by using the air-assisted DI and E85*

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 [1].

Figure 7 shows the indicated diagram of the experimental researched engines by using the air-assisted direct injection as fuelling system and Ethanol 100 as fuel and in this case it can be observed that from –42° 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

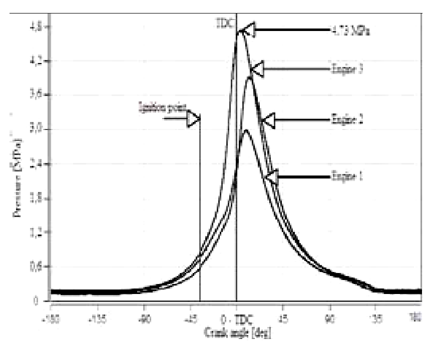

Fig. 7. *Pressure curves development by using the air-assisted DI and E100*

modified and additional compressed air entered the combustion chamber [1]. The pressure increases up to 4.73 MPa at 5.9° crank angle degrees ATDC.

5. Emissions Analysis

By using the air-assisted DI system, as shown in Figure 8, instead of the conventional fuelling system, the HC emissions are significantly lower.

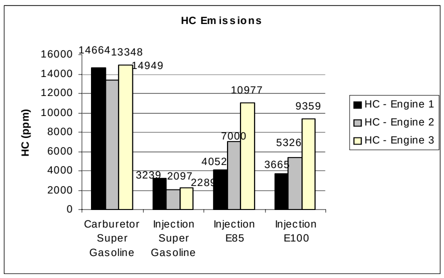

Fig. 8. *HC Emissions*

In Figure 9 it can be seen that the CO and CO_2 emissions are significantly lower, when changing the conventional system with the air-assisted DI system.

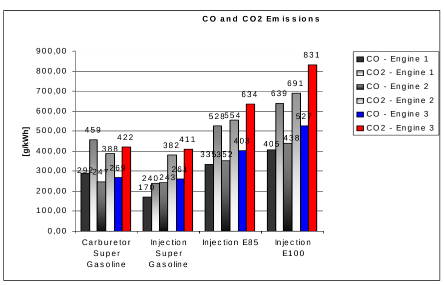

Fig. 9. *CO and CO_2 Emissions*

The effect when changing to E85 is that the amount of CO and CO_2 increase due to the fact that Ethanol fuel has a lower energy value as gasoline and therefore more fuel had to be injected into the combustion chamber.

In Figure 10 it can be observed that the NO_x emissions increase by using the air-assisted direct injection and super gasoline, but this increase is a result of burning a slightly lean mixture [1]. It can be seen that by using E85 with the air-assisted DI the NO_x emissions are significantly lower.

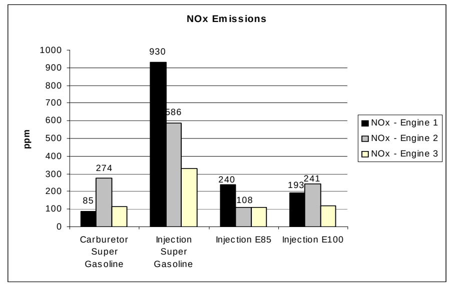

Fig. 10. *NO_x Emissions*

6. Conclusions

Using advanced fuelling systems like the air-assisted DI shows that not only the efficiency of the engine is increased but also the exhaust emissions and fuel consumption are lower. 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 [1].

The combustion process has a very good behavior in all cases due to the fact that the air-assisted DI was manually regulated in order to achieve this. 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 the second solution is by using alcohols blended with super gasoline (E85) or in pure state as fuel [1].

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 [1].

HC Emissions dropped by 73% in comparison with the carburetor fuelling system and they slightly increase by using alcohols in pure state (E100) or blended with Super Gasoline (E85), due to the lower heating value of Ethanol.

Using the air-assisted DI fuelling system shows that the CO emissions are lower by 45% compared to the carburetor.

CO_2 emissions dropped also by 45% compared to the carburetor fuelling system.

NO_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 [1].

It can be observed that by using alcohols and the air-assisted DI NO_x emissions are significantly lower.

Overall, using the air-assisted DI fuelling system 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 [1].

Using ethanol and the air-assisted DI is one answer to have an improved engine combustion process behavior, a cleaner environment and therefore protecting human health [1].

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