COMBUSTION AND EMISSIONS ANALYSIS OF DIFFERENT ALCOHOL BLENDS IN A TWO – STROKE SI ENGINE

[1]Mihai Aleonte*, [1]Radu Cosgarea, [1]Corneliu Cofaru, [2]Kai Beck,

[2]Amin Velji, [2]Ulrich Spicher

[1]Transilvania University of Braşov, Romania, [2]Karlsruhe Institute of Technology (KIT), Germany

KEYWORDS – Gasoline, Alcohol Blends, Emissions, Torque

ABSTRACT – The automotive industry needs to be in a continuous challenge regarding reduced fuel consumption and reduced emissions driven by both legislation and customer needs. In order to optimize the combustion process the DI-spark ignition engines were developed (DI – direct injection). The advanced gasoline engine technologies include reduced engine friction losses, direct gasoline injection, engine downsizing with turbocharger, variable valve actuation (VVA) and homogeneous charge compression ignition (HCCI). Using alcohols reduce the oil dependency and enables a substantial increase in the gasoline engine fuel efficiency. This concept uses a controlled air – assisted direct injection of alcohol and alcohol blends with gasoline into the engine combustion chamber. The engine will also be operated at higher compression ratios. Increase of fuel efficiency was obtained by increasing the compression ratio. In order to reach these goals some minor changes of the present gasoline engine and its fuelling system were undertaken. This paper presents two methods, which were used to improve the combustion process and its exhaust emission in a two stroke SI engine. Comparisons are made with other engine fuelling systems, regarding the combustion process and the resulting emissions.

INTRODUCTION

In the 1970's the first oil crisis appeared. Since then researchers intensified their efforts to reduce the dependency of this primary source of energy. 2008 was the year in which this phenomenon appeared again, due to this fact a stronger research began worldwide for finding alternative fuels. One solution was found and used; it is the alternative fuel Ethanol. Ethanol is the alcohol obtained by the distillation of agricultural products through the fermentation process. This kind of alcohol is a very good additive for gasoline. By mixing the two fuels better performance is obtained in the combustion process and also the exhaust emissions are lower. Ethanol can also be produced using Fischer – Tropsch synthesis through which corn husks, leaves, stems, trees and other agricultural crops and wastes are converted into bio – fuel, called cellulosic ethanol. The fact that waste can be converted to alternative fuel means a major step towards a cleaner planet we live in, an example being that in the past used car tires were burned for disposal, emissions of the combustion were a natural disaster impacting both the environment and human health. Today, these tires are cut into small pieces, the metal being separated from rubber and the rubber left is melted and used in the production of new tires. In this manner we can say that the major advantage in the production of bioethanol is a closed CO_2 circuit because the CO_2 emissions produced from burning the fuel is subsequently absorbed by plants used in its production. Stimulating agricultural production and forestry can create systems that can support each other without causing the disadvantages caused by using fossil fuels. This type of systems will prove useful for the human society in terms of health and environment protection.

EXPERIMENTS AND RESULTS

This paper will confirm the fact that by reducing the oil dependency the ethanol obtained from agricultural products and also synthetic ethanol plays a major role in developing the human society. The research described in this paper refers to the usage of ethanol in a 2 stroke spark ignition engine (Otto – engines). The engine type is used for handheld power tools like chainsaws, trimmer and blowers. The 2 stroke Otto – engine is described in the following table:

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

Table 1 – two stroke spark ignition engine

As fuelling systems two types were used: the 1st is the carburetor with two – stroke mixture, gas/oil mixture (standard) and the 2nd is the direct injection, which was fixed on the cylinder. The conventional carburetor system was tested so that a first comparison could be made between the two fuelling systems. The cylinder was modified so that the direct injection system could be fixed on it and the cylinder was also modified to allow the fuel to be injected into the combustion chamber. During the experiments the cylinder was further modified in order to obtain improved combustion and lower emissions. In this research we use an external two – stroke oil pump in order to realize the two – stroke lubrication system. Carburetor and DI – System without oil only fuel. The oil pump was fixed on the external side of the engine, this pump having an important role in assuring a minimal friction loss in the cylinder when Ethanol fuel mixed with Gasoline was used and also by using pure Ethanol.

The types of fuels used are:

- Super gasoline
- Super gasoline mixed with Ethanol (15 volume parts gasoline – 85 volume parts Ethanol)
- Pure Ethanol (E 100)

The modifications brought to the cylinder were made in time and 2 types were prepared:

- Compression ratio = 8:1
- Cylinder with increased compression ratio (9:1)

The combustion process in the spark ignition engine is described in the next charts and diagrams. Figure 1 shows the combustion process as it occurs in the original cylinder and in the higher compression (hc) cylinder using the carburetor as fuelling system and Super Gasoline as fuel.

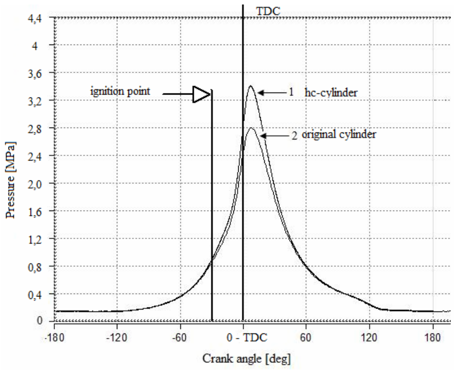

Figure 1 - Carburetor – hc-cylinder (1) and Carburetor – original cylinder (2)

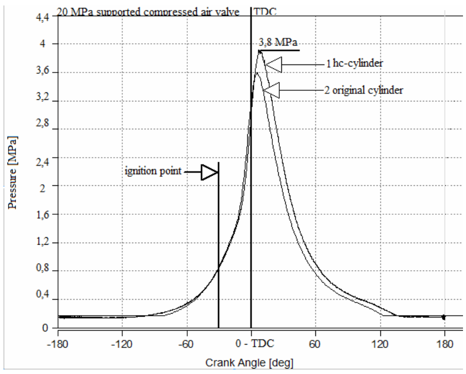

Figure 2 - Direct Injection – hc-cylinder (1) and Direct Injection – original cylinder (2)

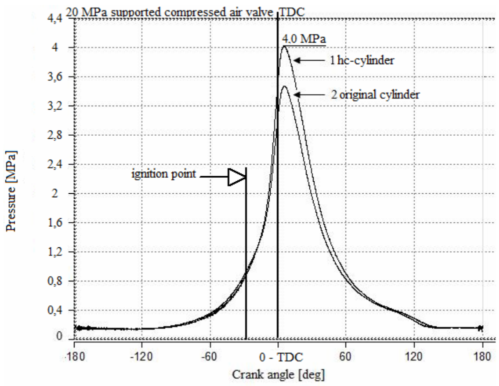

Figure 3 - DI – hc-cylinder E85 (1) and DI – original cylinder E85 (2)

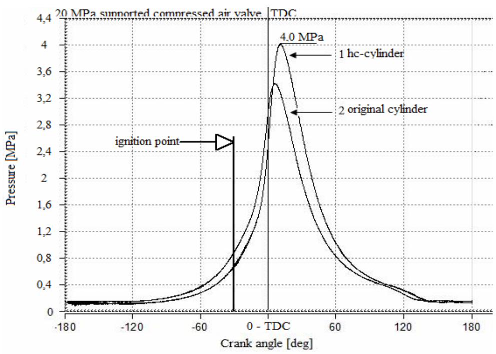

Figure 4 – DI – hc cylinder E100 (1) and DI – original cylinder E100 (2)

Figure 1 shows the pressure curves of the original and hc – cylinder using the carburetor as fuelling system and super gasoline as fuel. It can be seen that the pressure rises in the case of the hc – cylinder. The ignition point is at -43^{o} crank angle degrees. The combustion is similar to the original cylinder due to the fact that the ignition timing was left constant.

Figure 2 shows pressure traces of the original cylinder and the hc – cylinder using the direct injection as fuelling system and Super Gasoline as fuel. It can be noticed that the combustion process is similar to the original cylinder and the pressure rises in case of the hc-cylinder. Milling the cylinder changes the compression ratio and determines also a small outlet and overflow timing change.

Figure 3 shows the pressure traces as they occur in the original cylinder and in the hc-cylinder using the direct injection as fuelling system and Ethanol 85 as fuel. It can be seen that increasing the compression ratio and using E85 the pressure increases up to 40 bar, this means also that the torque increases. We can observe that the combustion process is similar to the original cylinder due to the fact that the direct injection was manually regulated so that maximum torque is achieved with minimum emissions.

Figure 4 shows the pressure traces of the original cylinder and in the hc-cylinder using the direct injection as fuelling system and Ethanol 100 as fuel. In this case we can observe that from -60^{o} crank angle degrees, 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 also up to 40 bars.

Fuel type	**Super Gasoline**			
Fuelling system	**Carburetor**			
Cylinder type	**original**			
Measured emissions type	HC	CO	CO_2	NOx
Unit	ppm	g/kWh	g/kWh	ppm
Engine speed: 6000 rpm	15045	275	431	89
Max Torque (Nm) at 6000 rpm	4.279	4.279	4.279	4.279
Cylinder type	**hc – cylinder**			
Measured emissions type	HC	CO	CO_2	NOx
Unit	ppm	g/kWh	g/kWh	ppm
Engine speed: 6000 rpm	13644	229	360	257
Max Torque (Nm) at 6000 rpm	4.224	4.224	4.224	4.224

Table 2 – Emissions and torque comparison between the original and hc – cylinder using the carburetor and super gasoline

Fuel type	**Super Gasoline**			
Fuelling system	**Direct Injection**			
Cylinder type	**original**			
Measured emissions type	HC	CO	CO_2	NOx
Unit	ppm	g/kWh	g/kWh	ppm
Engine speed: 6500 rpm	3239	169	266	930
Max Torque (Nm) at 6500 rpm	4.502	4.502	4.502	4.502
Cylinder type	**hc – cylinder**			
Measured emissions type	HC	CO	CO_2	NOx
Unit	ppm	g/kWh	g/kWh	ppm
Engine speed: 6500 rpm	2097	243	381	586
Max Torque (Nm) at 6500 rpm	4.697	4.697	4.697	4.697

Table 3 – Emissions and torque comparison between the original and hc – cylinder using the direct injection and super gasoline

Fuel type	**E85**			
Fuelling system	**Direct Injection**			
Cylinder type	**original**			
Measured emissions type	HC	CO	CO_2	NOx
Unit	ppm	g/kWh	g/kWh	ppm
Engine speed: 6000 rpm	2153	312	491	215
Max Torque (Nm) at 6000 rpm	4.675	4.675	4.675	4.675
Cylinder type	**hc – cylinder**			
Measured emissions type	HC	CO	CO_2	NOx
Unit	ppm	g/kWh	g/kWh	ppm
Engine speed: 6000 rpm	6473	325	512	229
Max Torque (Nm) at 6000 rpm	4.732	4.732	4.732	4.732

Table 4 – Emissions and torque comparison between the original and hc – cylinder using the direct injection and E85

Fuel type	**E100**			
Fuelling system	**Direct Injection**			
Cylinder type	**original**			
Measured emissions type	HC	CO	CO_2	NOx
Unit	ppm	g/kWh	g/kWh	ppm
Engine speed: 6000 rpm	2068	398	627	160
Max Torque (Nm) at 6000 rpm	4.767	4.767	4.767	4.767
Cylinder type	**hc – cylinder**			
Measured emissions type	HC	CO	CO_2	NOx
Unit	ppm	g/kWh	g/kWh	ppm
Engine speed: 6000 rpm	4920	428	675	329
Max Torque (Nm) at 6000 rpm	4.838	4.838	4.838	4.838

Table 5 – Emissions and torque comparison between the original and hc – cylinder using the direct injection and E100

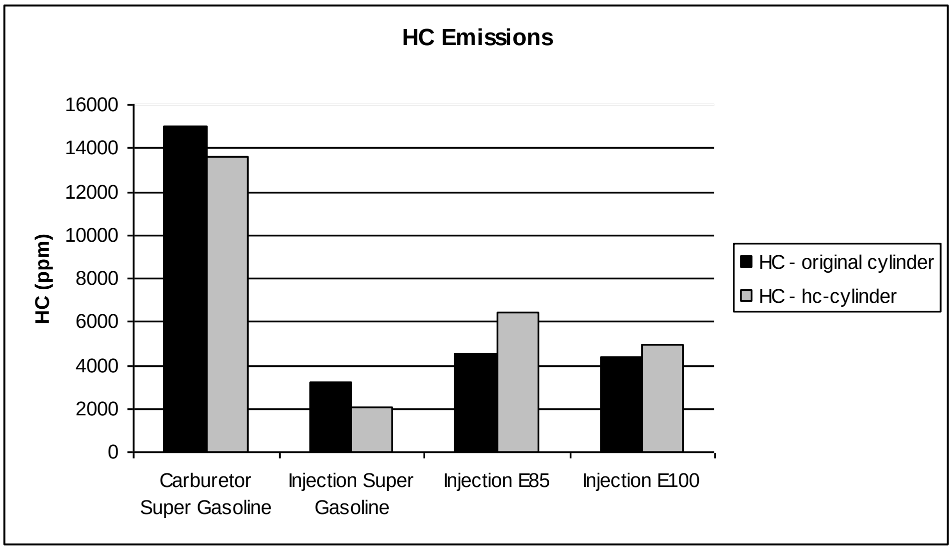

Figure 5 - HC Emissions

Figure 5 shows that by using direct injection instead of the conventional fuelling system the HC emissions are dramatically reduced. In case of the original cylinder it can be observed that the HC emissions are reduced furthermore by using Ethanol blends extended to using pure Ethanol fuel. Lambda has a value of 0.933 in case of the injected super gasoline.

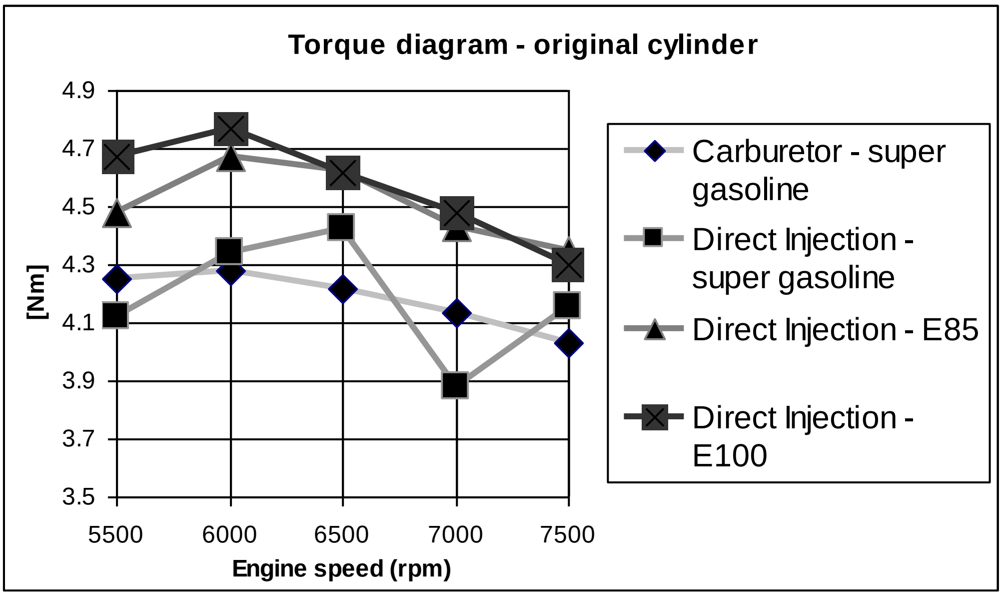

Figure 6 – Torque diagram

Figure 6 shows that the 2-stroke Otto-engine reaches maximum torque between 6000 rpm and 6500 rpm's. In case of the carburetor the maximum torque is achieved at 6000 rpm, the direct injection's maximum torque point is at 6500 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 4.7 [Nm] in comparison with super gasoline which reaches a maximum value of 4.5 [Nm] at 6500 rpm.

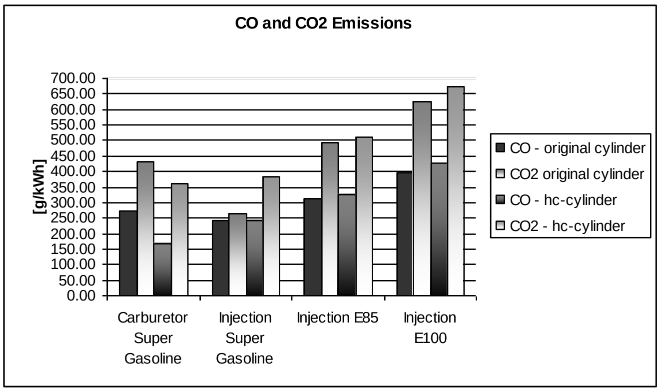

Figure 7 - CO and CO2 Emissions

In figure 7 it can be seen that the CO and CO_2 emissions drop significantly when changing the fuelling system from conventional to direct injection. The effect when changing to E85 is that the amount of CO and CO_2 increase. Using E100 in the hc – cylinder shows that CO emissions and CO_2 emissions are still increasing.

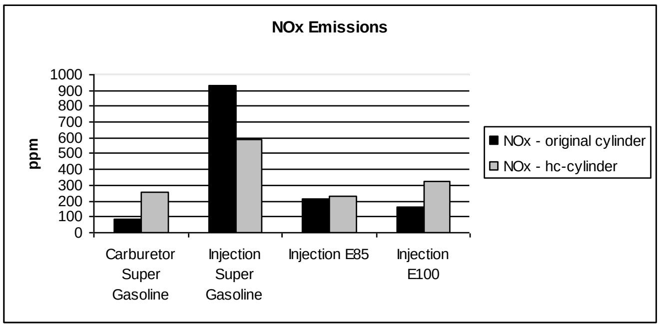

Figure 8 - NOx Emissions

In figure 8 it can be observed that the NOx emissions increase by using the direct injection and super gasoline, but this increase is a result of burning a slightly lean mixture. It can be seen that by using E85 in the original cylinder with direct injection the NOx emissions decrease. Furthermore NOx emissions drop also when using pure Ethanol in the original cylinder. The NOx Emissions were recalculated after the measurements due to the fact that Ethanol 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 which is 0,71.

CONCLUSIONS

Using advanced fuelling systems like the direct injection proves that not only the efficiency of the engine is increased but also the emissions are lower. The combustion process has a very good behavior in all cases due to the fact that the direct injection was manually regulated in order to achieve it. The pressure rises due to higher compression ratio and the torque reaches its peak when using E100 in the hc – cylinder. In order to gain torque from a spark ignition engine without bringing important changes to it, increasing compression ratio is one technical solution and the second solution is by using Ethanol blended with Super Gasoline (E85), which offers a more reliable combustion process than pure Ethanol. Working with Ethanol 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 to 1/3 in comparison with the standard fuelling system and they decreased further by using blended Super Gasoline with Ethanol or Ethanol in pure state. The air pressure was induced into the mixture (air – fuel) formation chamber of the direct injection system with a pressure of 4 – 5 bars. CO emissions dropped significantly by using the Direct Injection fuelling system in the original cylinder, nevertheless in the modified cylinder the CO Emissions dropped also. When using direct injection CO_2 emissions dropped also by 1/3. NOx emissions increased when using direct injection with super gasoline due to the fact that the engine worked with a leaner air-fuel mixture. It can be observed that by using ethanol and direct injection the NOx emissions drops in both cases, original and hc – cylinder. Overall using direct injection into the hc – combustion chamber leads to higher torque and lower emissions. Replacing conventional fuel with alternative fuel shows an improvement in torque and emissions decrease. Using ethanol and direct injection is an answer to have an improved motor behavior, a safer environment and human health.

ACKNOWLEDGEMENTS

This paper is supported by the Sectorial Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/6/1.5/S/6.

This paper is supported also by Karlsruhe Institute of Technology (KIT) – Institut für Kolbenmaschinen (IFKM).

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