Possibility to Increase Biofuels Energy Efficiency used for Compression Ignition Engines Fueling

Calin D. Iclodean[1], Florin Mariasiu[1]

[1]Technical University of Cluj-Napoca, ART dept., Bdul. Muncii 103-105, Cluj-Napoca, Romania

Abstract **–The paper presents the possibilities of optimizing the use of biofuels in terms of energy efficiency in compression ignition (CI) engines fueling. Based on the experimental results was determinate the law of variation of the rate of heat released by the combustion process for diesel fuel and different blends of biodiesel. Using this law, were changed parameters of the engine management system (fuel injection law) and was obtain increased engine performance (in terms of energy efficiency) for use of different biofuel blends.**

Keywords **– Biofuels, energy efficiency, injection pattern, diesel engine, heat release.**

1. Introduction

Biofuels represent an opportunity to replace (partial or total) in the near future supply of fossil fuels used in vehicles with internal combustion engines.

In terms of performance it was found that biodiesel can be use in existing compression ignition engines without major problems or technical adjustments. Investigation showed that biodiesel burns much cleaner than diesel fuel. From point of view of energetic efficiency, biodiesel has about 80% of the energy potential of diesel fuel, but it considered when biodiesel is blended with diesel in proportions of up to 20%, the blends behave identical to diesel fuel [1, 2].

Regarding environmental protection, biodiesel pollute much less than diesel, with significant reductions in the quantities of pollutants, except higher levels of NOx (up to 10 %) [2] . In case of accidental spillage into the environment , biodiesel is harmless to the area because it is biodegradable.

Studies and research have shown that pure biodiesel can reduce engine life (by lubricating oil contamination), but this reduction may be offset by the cost to implement means to reduce emissions. Currently there are additives (chemically and/or biodegdegradables) that are added to the blends to reduce engine wear when using biodiesel. Experiementele made by Hofman in 2002 [3] showed that B20 blends reduce engine life as much as useof diesel fuel, but, instead generates lower emissions than when using diesel fuel and lower deposits (burn products from combustion process) in the engine [2] .

By volumetric combination of biofuels with diesel fuel in various concentrations to obtain biodiesel blends (B10, B20, B50), biodiesel can be used in compression ignition engines fueling, without ny technical restrictions. Biodiesel contains no sulfur and aromatics which presents an advantage over diesel fuel, reducing emissions resulting from the combustion process. Blends of biodiesel reduces emissions of CO, HC and particulates but increases NOx emissions compared to diesel fuel used to power a compression ignition engines [4, 5].

The results of experimental investigations and confirmed by other researchers in the field of biofuels [4,6,7], shows that in the injection process biodiesel blends there are some differences related to the phenomenon of self-ignition delay of these blends and diesel fuel. This delay (with immediate influence of combustion process efficiency) is due to the higher viscosity of which has biodiesel, which increases the injection pressure [4].

One method of evaluating the performance and quality of fuel used in IC engine power is determining the amount of heat released from combustion process. In simulations with different proportion of biodiesel blends by various researchers [3, 6, 8, 9], wasshown that exist a decrease in the heat released from biodiesel burning due to low calorific value. Thus, in general, it was found that pure biodiesel (B100) has only about 80% of the energy potential of diesel fuel. When mixture of biofuel to diesel fuel is in amounts of less than 20%, blends have been found to have properties similar to those of diesel fuel [2, 6].

The energy efficiency of an internal combustion engine is directly related to the value (amount) of heat released inside the cylinder, during fuel combustion process. The maximum heat released in the cylinder is increase with the concentration of biofuel in the blend and decrease with increasing of engine speed.

Variation of maximum heat released in the cylinder is due to the effect of the rate of oxidation (or burning velocity) in the early stages of self-ignition and combustion of the fuel processes.

Maximum heat release decreases with increasing of engine speed due reduced efficiently process of biofuel particles mixture with the air quantity available inside the combustion chamber (due to intake process).

The mixture of fuel injected into the combustion chamber with air available have particularities that depend on the operating parameters of the engine, therefore the homogeneity of the mixture decreases with the engine speed and consequently, the time available to achieve the complete combustion of the air-fuel mixture.

Results from experimental researches [10] are partially confirmed by physico - chemical characteristics of biofuelblends, which have a lower calorific value but a density and a viscosity higher than diesel fuel. The higher density of the biofuels injected in the combustion chamber determines the injection of a smaller volume of fuel in the case of biodiesel compared to diesel fuel [6, 10].

The presence of oxygen in biodiesel chemical structure, improves the combustion process of the mixture and the amount of heat produced per engine cycle, with immediate influence on the energy parameters of the engine (indicated efficiency); and in this way, compensate the relative energetic difference (expressed by calorific value) between mixtures of biodiesel and diesel fuel [2, 10].

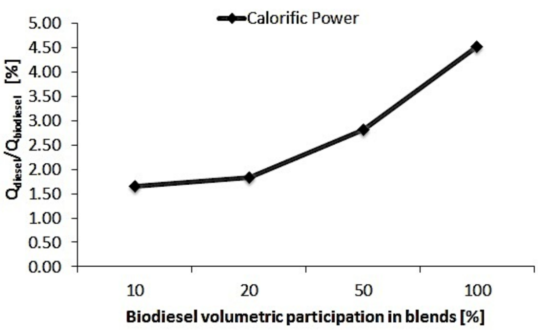

Figure 1. Relative difference of fuel calorific power by volumetric participation of biofuels in blends with diesel

From Figure 1 it is noted that the maximum difference of calorific power between the B100 biodiesel type and the diesel fuel is 4.52%. It also notes that in terms of heat released per cycle percentage, the maximum difference between the values obtained for those two fuels is only 3.20%.

The Rate of Heat Release(ROHR) in the cylinder during the combustion process, is an apparent size that can not be measured by conventional means because of mixture chemical composition permanent variation in the cylinder and thus it is calculated based on the pressure measured inside of combustion chamber.

The premises from which was started the research on optimizing the energy efficiency of biofuels for IC engines was based on identifying opportunities to increase the amount of heat released by changing injection parameters.

2. Material and method

To determine the ROHR value are necessary experimental determinations of the value of the pressure inside the combustion chamber resulting from burning process. After determining ROHR values, was identified the law of variation of the heat released relative to the volumetric participation of biofuel in the fuel blend.

The experimental apparatus used to determine the data required is a modern test stand for internal combustion engines AVL 5402 type. Technical data of the test stand are presented in Table 1. Biofuel blends used in experiments are rapeseed methyl ester (RME) based with physico-chemical characteristics presented in Table 2.

Table 1. Technical data of AVL 5402 engine

Parameter	Value
Type	Diesel, single cylinder
Bore [mm]	85
Stroke [mm]	90
Con rod length [mm]	138
Compression ratio [-]	17.5
Power [kW] @ 2200 rpm	6
Torque [Nm] @ 2200 rpm	23

Table 2. Biofuel blends physico-chemical characteristics

	Diesel	B10	B20	B50	B100
Heating value [MJ/kg]	42.63	42.15	41.61	40.03	37.54
Density [kg/m^3]	840.3	844.7	849.1	862.5	884.7
Viscosity [mm^2/s]	2.7	2.9	3.2	4.2	4.9
Cetanic no.	48	49	50	52	55
Carbon [%]	86.50	85.52	84.55	81.70	77.14
Oxygen [%]	0.00	1.13	2.26	5.56	10.84
Molar mass [g/mole]	208.9	215.5	222.4	245.6	294.8

AVL test bench offers the possibility to interfere with the engine management system by modifying the injection mapping of the electronic control unit (using the INCA software application). To optimize the amount of heat released from burning process were changed timing values for injection process, changing in this way the quantities of injected fuel (and also increasing the percentage of biodiesel in the blend) and also the injection process pattern. By modifying the injection process pattern was eliminated the negative effect of biofuels ignition delay characteristics [11,12].

To optimize the combustion process were modified injection parameter values using INCA application (aiming to obtain an increase in the amount of heat released from burning and to preserve the emissions within the limits imposed) by change in the amount of pilot fuel injection and advanced timing of pilot injection.The system ETAS ETK 7.1 was used to control the amount of fuel injected and the timing of injecting fuel into combustion chamber. Data acquisition were done using system was Indicom system and were processed and analyzed further using AVL Concerto software package.

3. Results and discussion

Following experiments on biofuel blends energy efficiency used the results regarding calculated values of RORH are presented in Table 3. The maximum value of heat release is increase with increasing of biofuel participation in the blend due to the concentration of more oxygen. But also, the maximum amount of heat release decreases with increase ofengine speed due to reduced efficiency of mixing process between biofuel and available air inside of combustion chamber.

On the basis of the obtained data (Table3) can be determine a specific law of variation of the heat released taking into consideration the proportion of biofuel in the blend (Eq. 1). This relationship is defined below and the graphical representation is shown in Figure 2:

$$\frac{Q_{diesel}}{Q_{biodiesel}} = 0.786 \times V_{biodiesel} + 0.645 \qquad (1)$$

, where ($Q_{diesel}/Q_{biodiesel}$) is the ratio of heat release distribution between diesel and considered blend [%] and($V_{biodiesel}$)is the volumetric participation of biofuel in the blend [%].

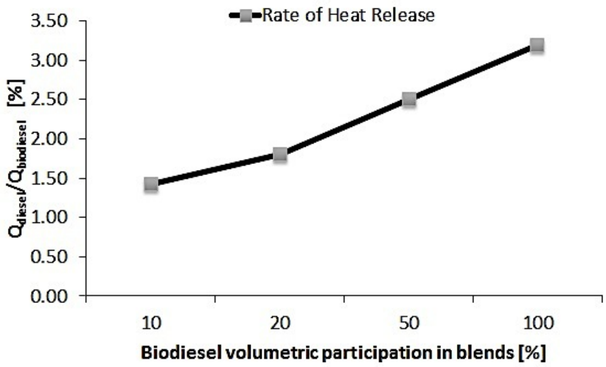

Figure 2. The variation law of the rate of heat release(ROHR) for biodiesel blends

Based on this law of variation of the heat released function of the proportion of biofuel in blend, and considering the premise from which we started, experimental researches were carried out based on changing injection process maps of electronic control unit. Thus, in order to optimize the amount of heat released from the combustion process are modified to the values of the injection times thus changing the values for the quantities and timing of fuel injected with the increase in the proportion of biofuel in the blend.

The initial injection parameters and theirmodifiedvalues are presented in Table 4only for B50 case (for brevity). The injection process pattern and graphical representations of injection maps (initially and modified) are presented in Figure 3 and respectively Figure 4.

Changing pattern of the fuel injection process was based on the following considerations:

- By increasing with 10% the amount of fuel injected in the pilot phase increases also the intensity of fuel diffusive combustion phase. Increasing the initial temperature of the combustion chamber (before the development of the main injection) creates better conditions for vaporization and mixing of the fuel injected and engine fluid (air + fuel vapor). Further, this will lead to more ignition nuclei of the mixture and influence the optimization of the combustion process [2, 6];
- Use an injection pressure of 10% higher in the main injection phase leads to better fuel vaporization of fuel injected. By increasing the injection pressure to eliminate the negative effect of higher density and viscosity of biofuels comparative to diesel fuel. The mixture process of air and fuel inside the combustion chamber takes place in a shorter time and promotes a faster combustion process. By achieving a faster

combustion process it's possible to reduce the amount of heat lost to exterior, through the walls of the combustion chamber (less available combustion chamber area for thermal transfer), the heat released from fuel combustion is more used to produce mechanical work.

Table 3. Calculated values of RORH [J/^{o}CA].

Engine speed [rpm]	800	1000	1500	2000	2500	3000	3500	4000	4200
Diesel	0.520	0.455	0.488	0.525	0.451	0.462	0.481	0.500	0.519
B10	0.516	0.453	0.486	0.523	0.449	0.459	0.479	0.494	0.516
B20	0.511	0.448	0.481	0.516	0.443	0.451	0.469	0.485	0.504
B50	0.492	0.431	0.463	0.501	0.429	0.435	0.454	0.472	0.487
B100	0.464	0.407	0.437	0.471	0.405	0.414	0.431	0.446	0.464

Table 4. The injection parameters (initial and modified) for B50 case.

Engine speed [rpm]	Volume pilot inj. [mg]	Volume main inj. [mg]	Pilot inj. timing [°CA]	Main inj. timing [°CA]	Rail pressure [bar]	Pilot inj. duration [μs]	Main inj. duration [μs]
			Initial				
1000	1.20	10.63	-23.25	-2.25	416	229	682
1250	1.20	9.94	-24.50	-3.50	470	210	602
1500	1.20	9.38	-26.00	-4.50	493	202	562
1750	1.20	8.83	-29.25	-6.75	515	196	533
1900	1.20	8.50	-33.25	-8.50	528	194	518
2000	1.20	8.29	-34.50	-9.75	541	192	507
2250	1.20	8.17	-35.25	-10.25	564	190	501
2500	1.20	8.05	-36.00	-11.00	572	185	493
			Modified				
1000	1.32	11.69	-24.50	-2.25	458	252	682
1250	1.32	10.93	-25.75	-3.50	517	231	602
1500	1.32	10.32	-27.25	-4.50	542	222	562
1750	1.32	9.71	-30.75	-6.75	567	216	533
1900	1.32	9.35	-35.00	-8.50	581	213	518
2000	1.32	9.12	-36.25	-9.75	595	211	507
2250	1.32	8.99	-37.00	-10.25	620	209	501
2500	1.32	8.86	-37.75	-11.00	629	204	493

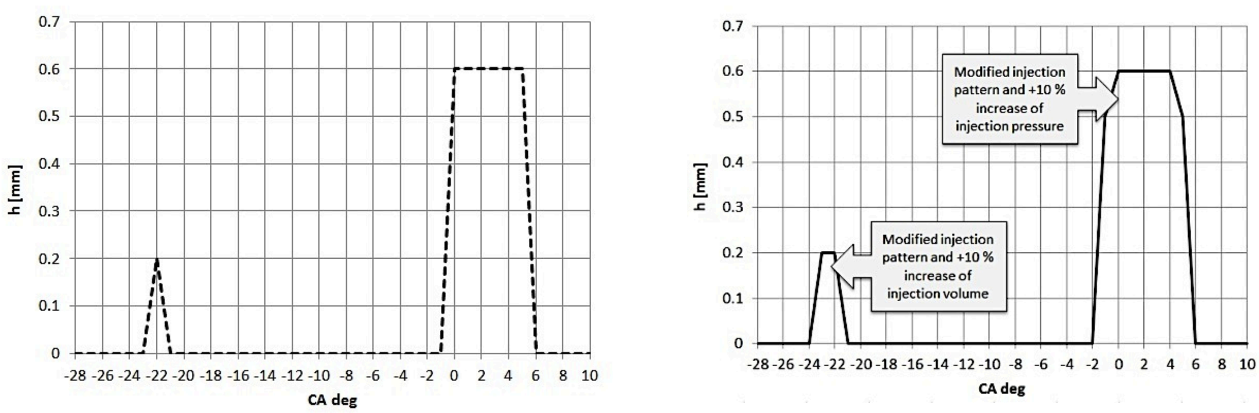

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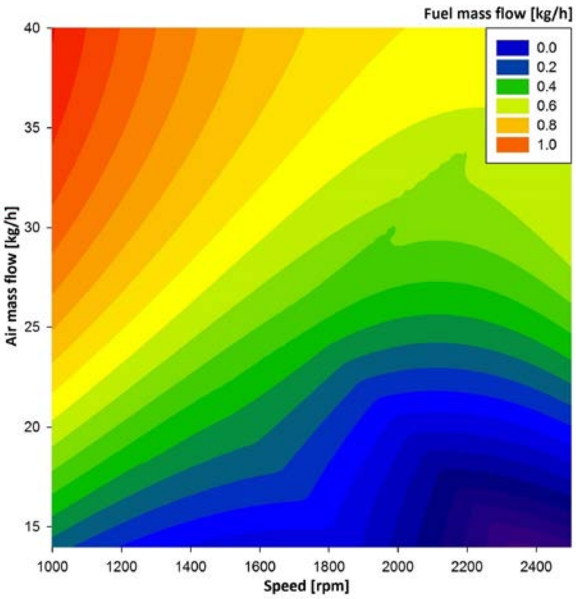
Figure 3. The injection process pattern (a-initial; b- modified; h- injector needle movement)



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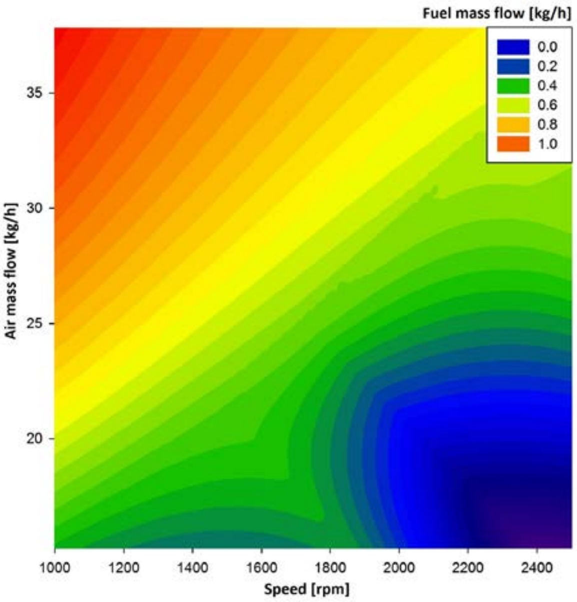

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Figure 4. The injection map (a-initial; b-modified) for B50 case.

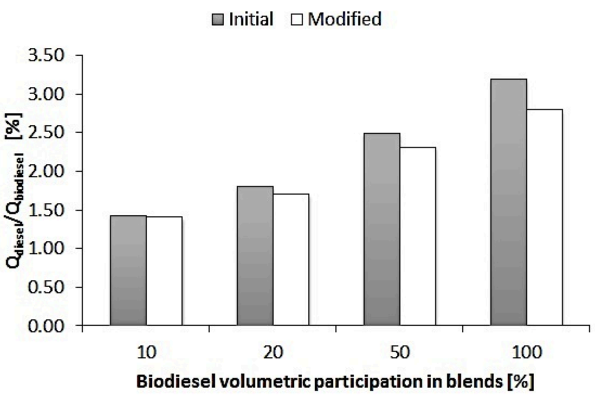

Figure 5. The variation law of the rate of heat release(ROHR) for biodiesel blends

Variation of the amount of heat released (emitted) in the process of burning (RORH) by changing injection parameters biofuels laws (by changing injection maps) is shown in Figure 5. Note that differences in the use of diesel fuel and biofuel blends are lower, showing an improvement in the energy efficiency of the combustion process. Considering the values of RORH ratio for diesel and biofuel, the improvement is between 1.23% for B 10 blendcase and 12.49% for B 100 blend case (average value is 6.51%).

4. Conclusion

This paper presents issues related to the possibility of improving the energy efficiency of the use of biofuels in CI engine power (by changing the fuel injection maps). Currently the engine management system (electronic control unit - ECU) contains maps to command injection process that are optimized for fossil fuels use.

The injection process must be correlated with the physical and chemical properties of biofuel blends, to obtain improve values of combustion process energetic efficiency. With mandatory demand to increase the percentage of biofuels in fuel blends to be use in internal combustion engines, it is necessary making studies and researches to optimize the processes related to the command and control issues the engine' management system.

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Corresponding author: Florin Mariasiu
Institution: Technical University of Cluj-Napoca, Automotive Engineering and Transports department.
E-mail: florin.mariasiu@auto.utcluj.ro