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INFLUENCE OF THE ELECTRONIC CONTROL UNIT ON OPTIMIZATION FUNCTION OF THE COMPRESSION IGNITION ENGINES POWERED WITH BIOFUELS

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ABSTRACT: This paper study the influence of parameters in the electronic control unit ECU on the functional optimization of a compression ignition engine fuelled with biofuels in various concentrations by computer simulation. To obtain this objective a model in the AVL Boost software for a single cylinder engine has been made, was implemented an element ECU with fuel injection control by loading the input maps on each drive channel. Following the computer simulations was studying the optimization of fuel injection by ECU parameters to obtain the same results from the combustion process for each type of biofuel use. Engine performance was evaluated based on the quantity of heat released obtained from the combustion process in the cylinder, comparing the properties of mixtures of fuels used in the simulation. To increase the quantity of heat released from the combustion process was commissioned by ECU parameters increasing the quantity of fuel injected with increasing the bio component quantity by enlarging the injection time.

KEYWORDS: electronic control unit, rate of heat release, cylinder pressure, starts of injection, computer simulation

INTRODUCTION

In the context of recent European Union directives requiring increased use of biofuels blended with fossil fuels in power compression ignition engines, in this paper we studied the influence of the ECU parameters to optimize the fuel injection [16].

Currently, research in this area is channeled predominantly to study the influence of biofuels on functional parameters of compression ignition engines in terms of data limitations for physico-chemical properties of biofuels relative to the construction of the motor system. A new line of research is related to the correlation influence on functional parameters of the engine ECU.

The ECU system is a complex of electronic modules used in the operation of the vehicle for command and control of parameters. The operating principle of the ECU system is input data, data processing, delivery date, or IPO (Input - Process - Output) [2]. To register the values are available sensors for measuring a physical characteristic such as speed, pressure, temperature, etc. This value is compared or calculated with a default value stored in the ECU. If the measured value and the value stored in the ECU do not match, the electronic control module adjusts the value of a physical process, so the actual values measured correspond with the nominal dimensions programmed into the ECU. To change the values of the particular parameters are used actuators [1].

The software architecture of the ECU system used in compression ignition engines is presented in figure 1. Software components covering aspects of the hardware input/output I/O are grouped into hardware abstraction layer HAL, contained in the standard software platform OSEK/VDX [14].

Units of input - output I/O needed to communicate with other systems via data bus are excluded from the HAL abstraction layer. The software platform includes software components in higher level layers which are used in communication with the ECU communication network, or with the tools, devices and diagnostic testing. These software components provide a standardized interface of application API (Application Programming Interfaces) interfaces that support various applications made by car manufacturers [11, 12].

The standard OSEK/VDX provides open application programming interface - API, which used the facilitate design of real-time operating systems. This standard defines a module for core application (Kernel) it is a real-time interface between software and hardware that can be implemented in various software models in memory modules on 8-bit or 16-bit [15]. OSEK is the German standard for open systems and the corresponding interfaces for automotive electronics (Offene Systeme für die und Elektronik im Deren Schnittstellen Kraftfahrzeug) and VDX is a French standard for communication between system components (Vehicle Distributed Executive).

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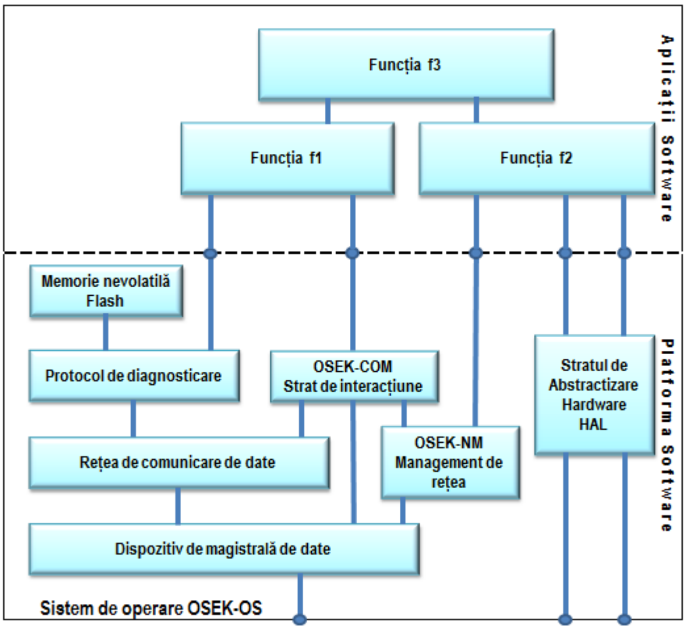


Figure 1. ECU system architecture (OSEK/VDX) [5]

The ECU with exhaust emissions control system resulting from the combustion process includes engine control system and transmission control system. This type of systems is used to ECU electronic control modules, mechanical and hydraulic control in a real-time algorithm [6].

To reduce the development and production costs of real time operating system (RTOS), ECU unit and control modules, European consortium AUTOSAR for vehicle manufacturers develope a common vision for the software architecture basic site covering these two software components [8].

COMPUTER SIMULATION MODEL

Simulation software tools have become indispensable for the development and optimization of research related to the operation of internal combustion engines.

A computer simulation was performed using a model built in AVL Boost software for a single cylinder engine AVL 5402. In this model was implemented an ECU element for fuel injection control with input map loaded on each drive channel (figure 2).

Engine research AVL 5402 is a four stroke engine with common rail injection equipped with a Bosch CR1 of 1600 bar with three injections per cycle (pilot injection, main injection and post injection). The injection management system is the type AVL RPEMS (Rapid Prototype Electronic Management System). This system is equipped with a Etas ETK 7.1 ECU unit, whose parameters can be modified via software Inca-PC and allows full access to the injection parameters: start of injection SOI, duration of injection DOI and pressure in the common rail PRAIL [10].

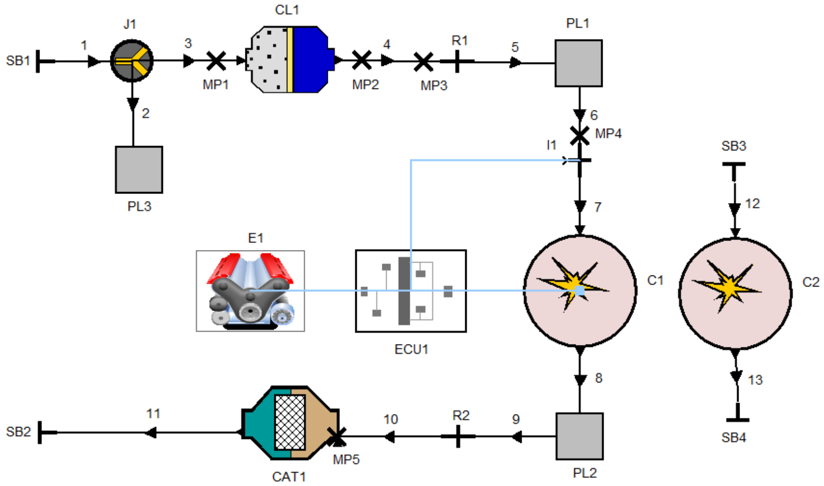
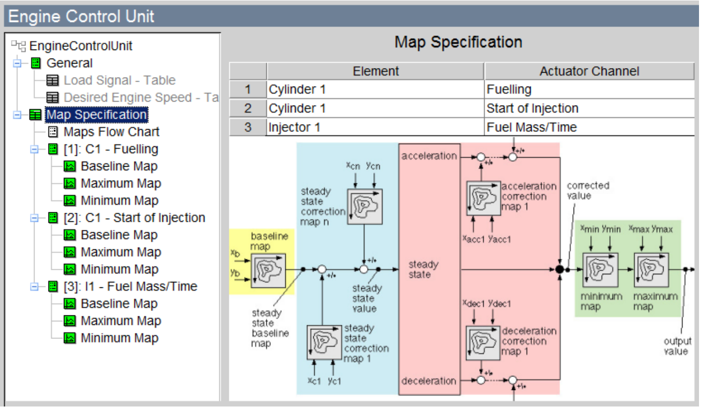


Figure 2. The 5402 AVL engine with ECU unit
SB1 - SB4: System Boundary, 1-13: Pipes, J1: Junction, MP1 - MP5: Measuring Points,
R1 - R4: Restrictions PL1 - PL3: Plenum, I1: Injector, C1: Cylinder engine used in the simulations,
C2: Cylinder image for C1 used for charging the experimental results, CAT1: Catalyst,
ECU1: Electronic Control Unit, E1: Engine element.

ECU element introduced into the simulation model was used to manage all the functions of an electronic engine control maps and allows loading control fuel injection (figure 3).



	Element	Actuator Channel
1	Cylinder 1	Fuelling
2	Cylinder 1	Start of Injection
3	Injector 1	Fuel Mass/Time

Figure 3. Element ECU and maps specifications

Baseline Map contains the reference values for steady state, values shall be compared with the values provided by the sensors (x, y) and after applying adjustments on the coefficients from correction maps will generate output values that are transmitted to the actuators channel.

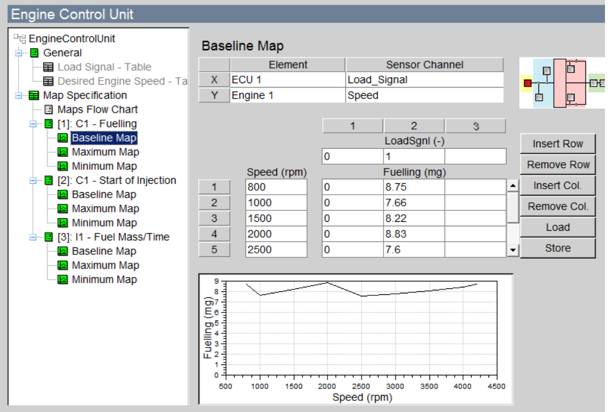
Parameters controlled by the ECU which was connected to actuator channel are:

- Fuelling [mg] mass of fuel injected into the cylinder (figure 4(a));
- Start of injection SOI [°CA] the moment when the fuel injection was starts. Conditions applied to this parameter are important for minimizing emissions and maximizing the fuel economy (figure 4(b));
- Fuel Mass/Time [kg/h] fuel flow injected per time unit (figure 4(c)).

Different values of engine speed which is performed simulations causes the ECU to calculate the load signal using proportional, integral and differential gain control with speed deviation from the set value [9]:

$$l_s = p(n_{des} - n) + i\int_0^t (n_{des} - n)dt + d\frac{d}{dt}(n_{des} - n)\ [-]; \qquad (1)$$

where l_s - engine load [-], p - proportional gain [1/RPM], i - integral gain [1/RPMS], d - differential gain [s/RPM], n - engine speed [RPM], n_{des} - speed desired [RPM].

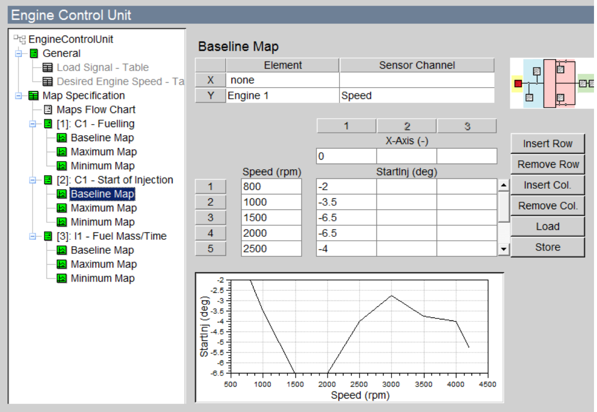


Baseline Map

	Element	Sensor Channel
X	ECU 1	Load_Signal
Y	Engine 1	Speed

		1	2	3
LoadSgnl (-)		0	1	
	Speed (rpm)	Fuelling (mg)		
1	800	0	8.75	
2	1000	0	7.66	
3	1500	0	8.22	
4	2000	0	8.83	
5	2500	0	7.6	

Figure 4(a). Fuel mass flow map

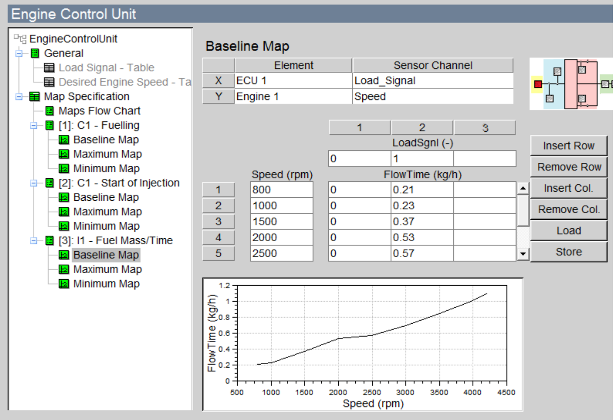


Baseline Map

	Element	Sensor Channel
X	none	
Y	Engine 1	Speed

		1	2	3
X-Axis (-)		0		
	Speed (rpm)	StartInj (deg)		
1	800	-2		
2	1000	-3.5		
3	1500	-6.5		
4	2000	-6.5		
5	2500	-4		

Figure 4(b). Start of injection map



Baseline Map

	Element	Sensor Channel
X	ECU 1	Load_Signal
Y	Engine 1	Speed

		1	2	3
LoadSgnl (-)		0	1	
	Speed (rpm)	FlowTime (kg/h)		
1	800	0	0.21	
2	1000	0	0.23	
3	1500	0	0.37	
4	2000	0	0.53	
5	2500	0	0.57	

Figure 4(c). Fuel injected map

RESULTS AND DISCUSSIONS

After defining the ECU parameters according with data to table 1, were running a series of simulations using diesel fuel. Values determined were maximum cylinder pressure, rate of cylinder pressure, maximum heat released and the rate of heat released by the combustion process.

Table 1. Simulation results using diesel fuel

Speed [RPM]	Fuel [Kg/h]	Air [Kg/h]	Fuel Injection [Kg]	Pressure max [Pa]	Rate of Pressure [Pa/°CA]	ROHR max [J/°CA]	ROHR [J/°CA]
800	0.21	10.40	8.75e-006	6,369,000	592,342	55.48	0.5431
1000	0.23	11.87	7.66e-006	6,126,000	577,868	43.69	0.4758
1500	0.37	20.61	8.22e-006	6,269,000	604,109	40.51	0.5102
2000	0.53	30.85	8.83e-006	6,342,000	629,893	35.16	0.5468
2500	0.57	34.19	7.60e-006	6,076,000	614,769	37.81	0.4692
3000	0.70	43.42	7.78e-006	6,084,000	621,745	36.47	0.4784
3500	0.85	51.98	8.10e-006	6,305,000	643,051	28.45	0.4976
4000	1.01	60.72	8.42e-006	6,350,000	646,241	24.75	0.5123
4200	1.10	65.33	8.73e-006	6,352,000	646,142	25.21	0.5336

Simulations have been repeated using various biofuels in the diesel fuel blend (B10, B20, B50 and B100). The main properties of diesel fuel and biofuels used for the simulations are shown in table 2.

Table 2. Properties of biofuels

Properties	Diesel	B10	B20	B50	B100
Lower Heating Value [KJ/Kg]	44.800	42.270	38.040	34.240	30.620
A/F Ratio [-]	14.70	14.29	14.07	13.40	12.29
Density [Kg/m^3]	834	848	856	880	884
Carbon/Total Ratio [%]	86.20	85.37	82.24	81.33	76.05
Oxygen/Total Ratio [%]	-	1.21	4.47	5.55	11.14
Molar Mass [g/Mol]	226	282	254	271	276

Engine performance was evaluated based on the amount of heat released obtained from the combustion process in the cylinder, to compare the influence of fuels mixtures used in the simulation. It was obtained an amount of heat released from combustion which was reduced in the increasing concentration of organic component concentration because biodiesel has a lower specific heat and higher density than diesel fuel.

To increase the amount of heat released from combustion was changed the parameter values for injection, fuel injected increasing with the organic component in the mixture.

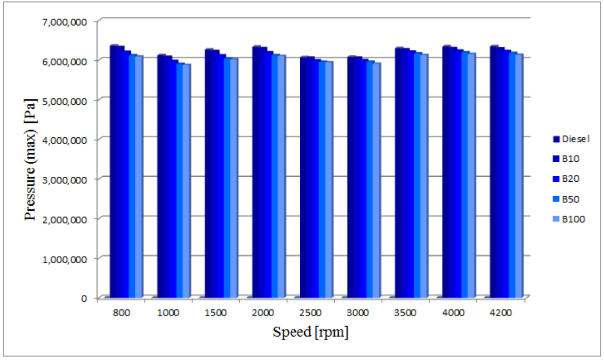


Figure 5(a). Maximum pressure in the cylinder

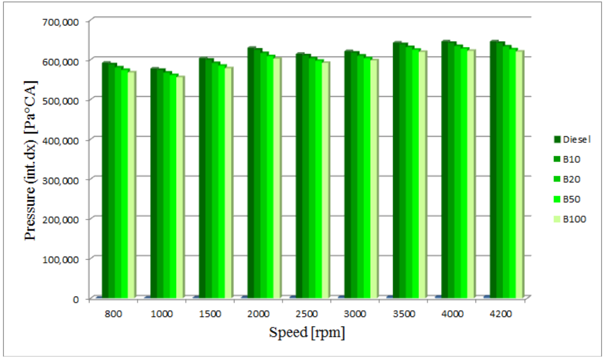


Figure 5(b). Rate of cylinder pressure

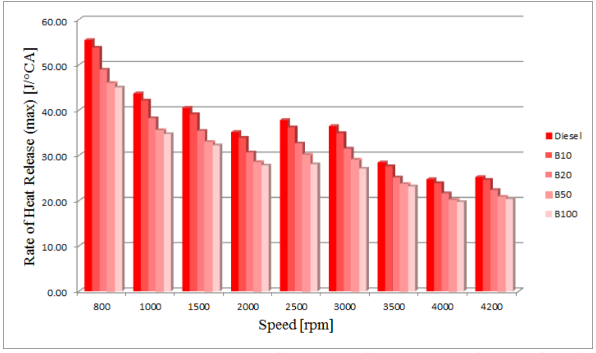


Figure 6(a). Maximum heat release in the cylinder

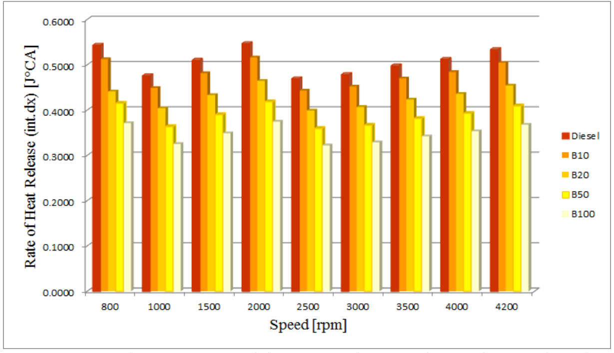


Figure 6(b). Rate of heat released in the cylinder

Figures 5(a), 5(b) presents the evolution of maximum pressure, the rate of cylinder pressure for different values of engine speed when using different mixtures from pure diesel fuel to pure biodiesel

(B100). Higher density of biodiesel blends reduces fuel losses during the injection process, which leads to the acceleration of the combustion process [7].

The evolution of the maximum heat released by the combustion process and the rate of heat released in the cylinder for different values of engine speed when using various biofuel blends is shown in figures 6(a) and 6(b).

Simulations have been repeated by changing the quantity of fuel injected for the model fueled with blended biodiesel. In the simulation model was implemented the law of injection iRate. This law determines the flow rate of fuel injection delivered by the injector. To increase the amount of heat released from combustion process fuel injected has been changed from ECU parameters as it results from table 3 [3].

Table 3. The quantity of fuel injected

Speed [RPM]	Diesel	B10	B20	B50	B100
	Fuel Mass Flow [Kg/h]	Fuel Mass Flow [Kg/h]	Fuel Mass Flow [Kg/h]	Fuel Mass Flow [Kg/h]	Fuel Mass Flow [Kg/h]
800	0.210	0.220	0.245	0.260	0.300
1,000	0.230	0.240	0.270	0.300	0.325
1,500	0.370	0.390	0.435	0.480	0.535
2,000	0.530	0.560	0.620	0.690	0.750
2,500	0.570	0.600	0.660	0.720	0.820
3,000	0.700	0.740	0.810	0.900	0.990
3,500	0.850	0.900	0.990	1.100	1.200
4,000	1.010	1.065	1.175	1.300	1.415
4,200	1.100	1.165	1.275	1.420	1.560

The simulation results obtained by increasing the quantity of fuel injected are shown in figures 7(a) and 7(b) and the value in table 4.

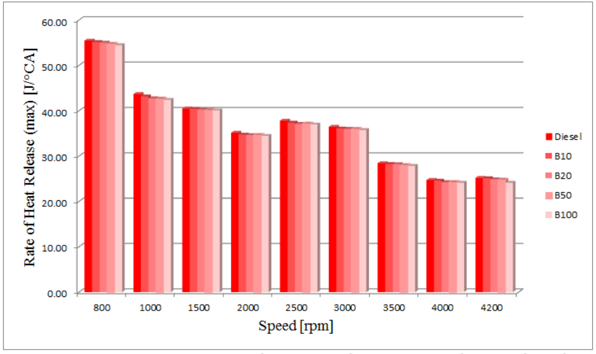


Figure 7(a). Maximum heat release in the cylinder

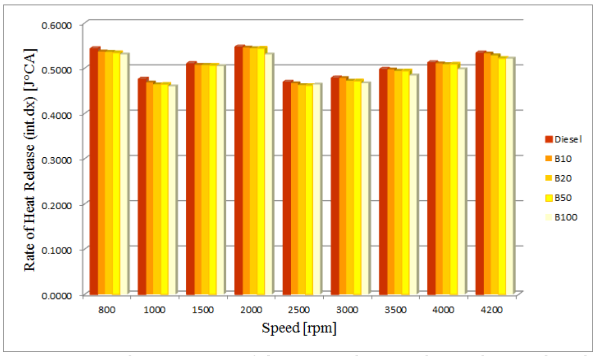


Figure 7(b). Rate of heat released in the cylinder

Table 4. Maximum value of ROHR using biofuels

Speed [rpm]	B10		B20		B50		B100	
	ROHR max [J/°CA]	ROHR [J/°CA]	ROHR max [J/°CA]	ROHR [J/°CA]	ROHR max [J/°CA]	ROHR [J/°CA]	ROHR max [J/°CA]	ROHR [J/°CA]
800	55.16	0.5369	55.03	0.5362	54.69	0.5340	54.46	0.5306
1,000	43.17	0.4685	42.75	0.4644	42.60	0.4643	42.41	0.4599
1,500	40.44	0.5074	40.30	0.5073	40.08	0.5062	40.07	0.5046
2,000	34.73	0.5458	34.65	0.5444	34.59	0.5439	34.48	0.5305
2,500	37.37	0.4667	37.12	0.4627	37.09	0.4615	36.98	0.4640
3,000	36.08	0.4783	36.01	0.4724	35.92	0.4716	35.74	0.4668
3,500	28.26	0.4973	28.23	0.4943	27.94	0.4939	27.84	0.4840
4,000	24.60	0.5108	24.25	0.5092	24.20	0.5089	24.12	0.4978
4,200	25.12	0.5326	24.91	0.5284	24.76	0.5215	24.13	0.5213

CONCLUSIONS

The main trend that underlies the development of compression ignition engines represents a compromise between reducing emissions and improving fuel economy, energy and environmental efficiency. This can be controlled by reducing combustion by the ECU system and its focus around TDC and pre-formed by increasing combustion mixtures and mixtures controlled.

A modern car integrates a growing number of electronic devices which increase the complexity and cost of development and production processes series. To reduce production costs of large vehicle auto set common standards consortia working to implement electronic systems and software architecture. These standards ensure reliability ECU models for different construction vehicles and therefore reduce production costs [13].

In the simulations it was found that the pure biodiesel (B100) have about 80% of the energy potential of diesel fuel. When biodiesel is blended 20% with conventional fuel, the blends behaves similar with the diesel.

In terms of environmental protection, biodiesel and biodiesel blends pollution emission are lower than using classic diesel fuel, with significant reductions of emissions except NO_x. Biodiesel fuel can be used in any compression ignition engines. He has excellent combustion properties leading to a combustion process without pressure curve sharp increase, good running engine and oxygen content of 11% produces smaller quantities of soot [4].

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