STUDIES AND EXPERIMENTAL RESEARCH CONCERNING THE PERFORMANCES OF THE INTERNAL COMBUSTION ENGINE, CONTROLLED OVER THE POWERTRAIN CONTROL MODULE

PhD. Eng. Ioan **HITICAS, „Politehnica" University of Timisoara, Romania,**
idhiticas@yahoo.com
Prof. Dr. Eng. Danila **IORGA, „Politehnica" University of Timisoara, Romania,**
diorga@mec.upt.ro
Conf. Dr. Eng. Liviu **MIHON, „Politehnica" University of Timisoara, Romania,**
liviu.mihon@mec.upt.ro
Eng. Emanuel **RESIGA, „Politehnica" University of Timisoara, Romania,**
tm8bnz@gamil.com
PhD. Eng. Narcis **URICANU, Euromaster Tyre and Service Timisoara Romania,**
narcis.uricanu@yahoo.com

***Abstract** — the paper present how can be controlled a road vehicle through a powertrain control module, a type of ECU, programmable ECU (Electronic Control Unit), when we want to increase the performances of the engine, compared with the standard performances of the engine. The programmable ECU is a control system which replaces the ECU from the vehicle and is able to manage, better than the standard ECU, the behaviour of the spark ignition engine on increasing the performances. Sports cars need to obtain the best performances from them engine, the specific regimes at which them must function impose certain limits which will be achieved during the competition. Nowadays the vehicles designers and engineering, working for the production cars, have adopted many solutions from the race cars area, due to the advantage offered by these elements (lightweight materials, fasts responses, high speeds) and system like programmable ECU. To obtain more power on the engine, we have to find and applied the best solution concerning the internal combustion processes and the consequences concerning the exhaust. This papers present who can be increased the performances of the spark ignition engine through the air-flow ratio, controlled by the programmable ECU and with the sensors help, like water temperature sensor, intake air temperature sensor, throttle position sensor, lambda sensor.*

Keyword: internal combustion engine, performances, powertrain (engine) control unit, lambda, ARF.

Introduction

Today's road vehicles are used for many things, like arriving at time somewhere, carrying passenger or different object, but one thing it's sure: we need them today more than in other times and we count on them. For this reason, automotive designer and engineering are working continuously to find new solutions for the needs of today's drivers. Safety and comfort, these are two goals what must meet abundantly our cars. Close collaboration between the fields of mechanical, electronic, materials, and others areas, have led to today's vehicles, which offer safety and comfort, and one of these results is and the programmable ECU. What is a programmable ECU? It's an electronic control unit [1] designed to increase the performances of the engine by controlling the sensors of the vehicle, taking into account the inputs – air and fuel, and the parameters – temperature and pressure, which are set during the tested in real time. His target is to control the fuel injection of the spark ignition engine, controlling and the intake air temperature, coolant temperature, heated oxygen, the injection timing, and much more elements (fuel pomp, ignition, power, fast idle valve, sensor ground).

Analysing these advantage offered by the programmable ECU [2], we decided to realise the parameterization of a thermal engine with spark ignition, vehicle used for competitions at international level. To be useful this new system applied to our engine, first we realised the motor tuning, which involves the mechanical elements like intake manifold, exhaust manifold, turbines, box gear and other elements, which were replaced with other with high performances, situation which requires it. After we made the replacement of mechanical elements, we start to analyze the wiring diagram, to make all the new connections between the vehicle sensors and programmable ECU.

Technical Data

When we talk about thermal engine [6], [7] we have affront us more elements, but two elements are very important: fuel and air. The fuel is an important element without the thermal engine will not function. The first fuel used as energy power it was the diesel and the gasoline. After the oil crises, in years '70, engineers started to find new energy sources and they found the alternative fuels, biodiesel and the alcohols (used as additives for gasolines). The new concepts applied to the production cars, namely the electric cars, which are using the batteries, are steel too expensive for most of us. Thermal engine are steel for us a subject who keep the attention of the automotive engineers and designer. The second element is the air, taken from the atmosphere, necessary element for the burning process and which must be controlled on temperature and pressure across the intake process.

We know that the spark ignition engine works on optimal conditions if the AFR (Air/Fuel Ratio) is closer to the ideal value, which is the stoichiometric ratio, 14.7:1. This ideal situation was made for the octane (choose this element due to his proprieties).
Lambda number is ratio between a give AFR and the stoechiometric AFR [1]:

$$\lambda = \frac{AFR}{AFR_{stoch}} \quad (1)$$

The given AFR can be found in the following table for some of the fuel. [11]

Table1. *Equivalent air/fuel ratio*

Air/Fuel Ratio Equivalents					
Lambda	**Gasoline**	**Propane**	**Methanol**	**Ethanol**	**Diesel**
0.70	10.3	11.0	4.5	6.3	10.2
0.75	11.0	11.8	4.9	6.8	10.9
0.80	11.8	12.5	5.2	7.2	11.6
0.85	12.5	13.3	5.5	7.7	12.3
0.90	13.2	14.1	5.8	8.1	13.1
0.95	14.0	14.9	6.1	8.6	13.8
1.00	***14.7***	***15.7***	***6.5***	***9.0***	***14.5***
1.05	15.4	16.5	6.8	9.5	15.2
1.10	16.2	17.2	7.1	9.9	16.0
1.15	16.9	18.0	7.4	10.4	16.7
1.20	17.6	18.8	7.8	10.8	17.4
1.25	18.4	19.6	8.1	11.3	18.1
1.30	19.1	20.4	8.4	11.7	18.9

The AFR is also a ratio between masses of the air and fuel [3]:

$$AFR = \frac{m_{air}}{m_{fuel}} \quad (2)$$

So, if we have a rich mixture, then we can affirm the compression ratio as 12.5: 1. This means:

$$11.0:1 \;/\; 14.7:1 = 0.75 \quad (3)$$

$$AFR \;/\; AFR_{stoech} = \lambda$$

The oxygen sensor will manage the AFR ratio, also the λ number. This sensor is useful concerning the volumetric efficiency. The volumetric efficiency, η_V, [3] is “one of the most important parameter for the evaluation of the running regime of the engine. The volumetric efficiency is the ratio between the pressure in the cylinder/combustion chamber and the pressure in the intake manifold.” [4]

The oxygen sensors have a different trigger point for stoichiometric compared to a narrow band sensor, and the opposite “slope” to the voltage curve as showed in the following figure. It can be observed the best power area concerning the air fuel ratio. [11]

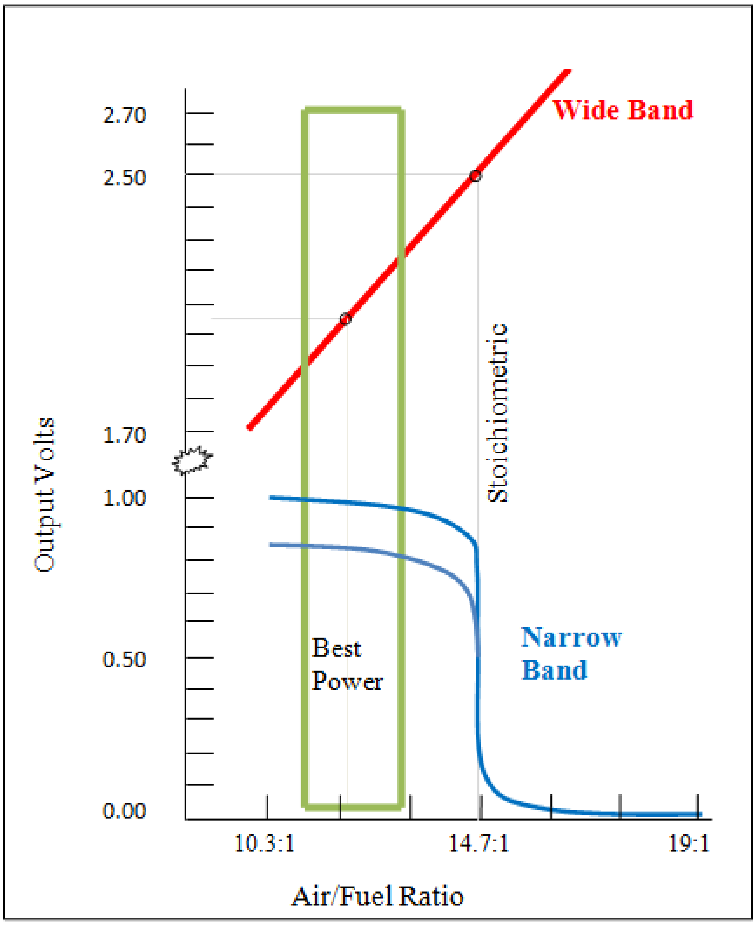

Figure1. *Oxygen sensor output – narrow and wide band [11]*

Experimental research

Our studies analysed the evolution of the AFR on a spark ignition engine, with gasoline as fuel, with target to obtain a value of the AFR, from the lambda sensor, closer to the ideal situation, when, due to these number, we will obtain the high performances from the engine.

The vehicle used for experimental research was a race car, involved in national and international competition. Vehicle Renault 5, 1721 cm^3displacement, 89.5 kW – maximum power at 5400 rpm, 175 Nm – maximum torque at 3300 rpm, 8.1:1 compression ratio [12].
The connection between the powertrain control unit and the engine sensors is possible through the OBD II plug, and a laptop which has the software used specially for this purpose [5].

Before to add this powertrain control unit on the vehicle [8], [9], which is an ECU tuning, we proceeded on the mechanical tuning on the engine, like replacing the exhaust pipe, intake manifold system, the gear box, the turbine, and other elements. After this mechanical replace, the followed element was the vehicle ECU, replaced with the new powertrain control unit, analysing the wiring diagram to make the new connection.

The advantage of this system is the possibilities to manage the sensors of the engine and to control them by setting the value limit, maximum and minimum values.

The below figure show us a general view of the software through we observe the evolution of RPM (crankshaft rotate per minutes), MAP (manifold absolute pressure), TP (throttle position), AFR (air/fuel ration), PW (pulse weight), Duty Cycle (injection timing), CLT (coolant temperature), MAT (manifold absolute temperature). On the right side of the windows we can manage the volumetric efficiency and the advance.

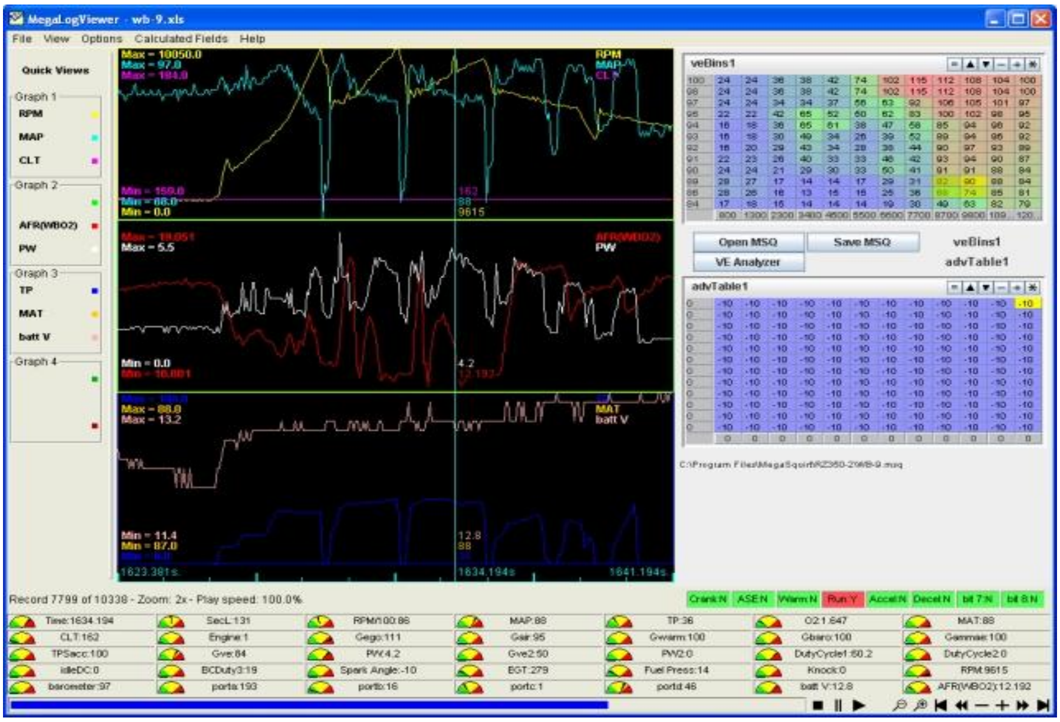

***Figure2.** – General view of software used for tuning*

The MAP sensor represents the absolute pressure in the intake manifold to determine the load on the engine and the consequent fuelling requirements. The MAP sensor values must be between 115 kPa and 250kPa and the engine will run properly.

TP is a voltage divider that gives information to the powertrain control unit about the throttle position, from which is calculated the rate of throttle opening for acceleration enrichment.

PW is a signal with a fixed frequency, which is turned on for part of the pulse, and is used to control the voltage to injectors.

Duty Cycle is used to describe the amount of time that the injectors are turned on, and to describe the "hold" part of the peak and hold injector drivers.

CLT and MAT are resistors whose resistance varies with temperature.

At the end of fixing all the additional sensors, we make the first vehicle test a real time, on the road, with constant speed, for a short distance, to eliminate the possible errors. When was set the value of the sensor, we proceeded to the vehicle tests, and below we present only the graph where is the AFR values.

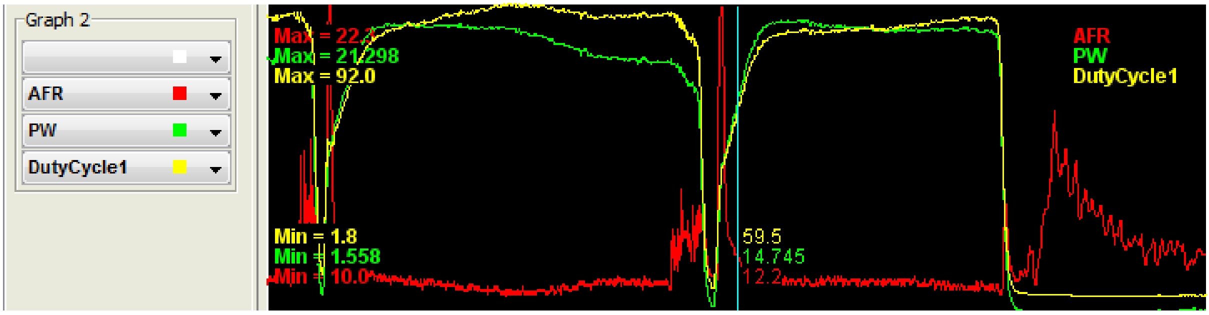

Figure3. *Evolution of AFR*

As it can be seen in the figure, the AFR value varies between 11.5 and 12.5, value 12.2 archived along our measurements is a very good value. It allowed us to increase the performances of the engine due to this ratio between air mass and fuel mass. The value of lambda is around 0.83, which is a very good ratio at 5000 rpm. The behaviour of the engine is very good and the fuel consumption is acceptable considering that is a rich mixture, comparing with poor mixture, when the AFR is around 16.6.

Conclusions

As conclusions we affirm that this powertrain control unit, programmed by our team, provided a very good behaviour of the internal combustion engine used for this purpose. We mention that the vehicle run on the completion race after these adjustments and won. The performances of the engine was increased, air fuel ratio, with his value 12.2, being our witnessing. Because on the race the vehicle must run at different regimes, we realised the best adjustments for this purpose.

As future research we will try to achieve better values of the AFR, like 13.5 to be inside the "best power" area. Also, we intend to use the powertrain control unit and for vehicle running with alternative fuels, like propane or ethanol, or other alternative solution, which offers a very good alternative to fossil fuels, taking into account the greenhouse effect, due to the high level of CO_2 concentration [10] on the atmosphere.

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