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GAS EMISSION OF A SPARK IGNITION ENGINE WITH PROGRAMMABLE ECU

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ABSTRACT: The evolution of engine performances of our today vehicles involves some "prices" from us, as drivers, also as car manufacturers. Between power and engine gasses evolution must be "an agreement": if we would like to have low gas emission for our engines, do not expect to achieved top of vehicles performances; also, if we would like to achieve high performances with our cars, we must know that is possible, but the evolution of exhaust species won't be all the time in normal values. Below we present the evolution of exhaust species, CO, CO_2, O_2, HC and NO_x for our tested vehicle, namely Renault 5, car equipped with a programmable ECU, which was installed with the purpose to obtain higher curves of power and torque. The question was concerning the exhaust species. The article offer, to the engineering of the fields, the conclusion of our team, after theoretical and experimental research: the engines equipped with programmable ECU's can offer very good performances, but the gas emissions are not always in normal values. The main factor is the traction of the vehicle and the drivers.
KEYWORDS: spark ignition engine, programmable ECU, gas emission, performances

INTRODUCTION

Safety, power and low emission are the request from our vehicles. The differences between vehicles are made by the car project, which will take into consideration the drivers demands. As the industry and technology start to go on with very big steps, almost all this demands can be achieved.

Our team prepared a vehicle to offer more power, namely Renault 5, car designated for racing. It was a spark ignition engine, turbocharged. We decided to mounted on stand alone ECU, prepared to adjust the sensors limits in order to major the values from the power curves, namely a programmable ECU.

This ECU is one of the on-board ECU, connected with the ECU of the engine and which can be commanded from a little board [1], mounted inside the engine, like on the image.

Figure 1. Commands board for programmable ECU, inside the vehicle

The logical scheme for position of the programmable ECU is presented below. The advantage offered by this system is by controlling the limits of the sensors involved in spark ignition engine evolution and in performances evolution [8], [9]. The main two elements needed by the engine to work very well is air and fuel, but this mixture, as it is well known, must achieve some proprieties, like a specific temperature, a specific pressure, and so all the parameters involved in burning process can proved the energy need by the engine to run properly.

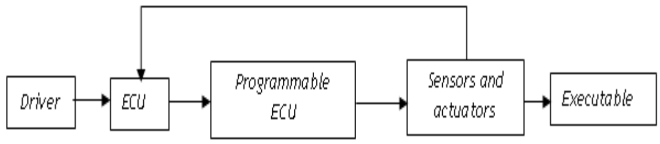

Figure 2. Block scheme for programmable ECU position

Some of the sensors involved in ECU programming are rpm sensor, lambda sensor, EGT sensor, manifold absolute temperature sensor (MAT), manifold absolute pressure sensor [2], [3], [4].

Our question was about the exhaust. How the exhaust species are after this new system was mounted on the engine? Do are better or not?

TECHNICAL DATA

One of the most important sensor was oxygen sensor, lambda. Lambda value is a ratio between two parameters, namely AFR and AFR_{stoech}.

$$\lambda = AFR / AFR_{stoech} \qquad (1)$$

where AFR is Air Fuel Ratio.

The AFR values can varies from maximum to minimum with consequences for burned mixture inside the combustion chamber [5], [6], [7] and also in exhaust.

As it is know from scientific literature AFR is:

$$AFR = m_{air} / m_{fuel} \qquad (2)$$

where: m_{air} - the amount of air needed for mixture
m_{fuel} - the amount of fuel needed for combustion mixture

Equivalence between AFR and excess air ratio λ can be done using the table below:

Table 1. Lambda to AFR conversion

Lambda	AFR	Lambda	AFR	Lambda	AFR
0.6	8.82	0.81	11.9	1.02	15
0.61	8.97	0.82	12.1	1.03	15.1
0.62	9.11	0.83	12.2	1.04	15.3
0.63	9.26	0.84	12.4	1.05	15.4
0.64	9.41	0.85	12.5	1.06	15.6
0.65	9.56	0.86	12.6	1.07	15.7
0.66	9.7	0.87	12.8	1.08	15.9
0.67	9.85	0.88	12.9	1.09	16
0.68	10	0.89	13.1	1.1	16.2
0.69	10.1	0.9	13.2	1.11	16.3
0.7	10.3	0.91	13.4	1.12	16.5
0.71	10.4	0.92	13.5	1.13	16.6
0.72	10.6	0.93	13.7	1.14	16.8
0.73	10.7	0.94	13.8	1.15	16.9
0.74	10.9	0.95	14	1.16	17.1
0.75	11	0.96	14.1	1.17	17.2
0.76	11.2	0.97	14.3	1.18	17.4
0.77	11.3	0.98	14.4	1.19	17.5
0.78	11.5	0.99	14.6	1.2	17.6
0.79	11.6	1.00	14.7		
0.8	11.8	1.01	14.9		

Technical data from the tested vehicle are:

- year of manufacture 1989;
- turbocharged;
- displacement of 1721 cc;
- power 89.5 kW at 5400 rpm;
- torque 175 Nm at 3300 rpm;
- Compression ratio being 8.1: 1.

Therefore, if we can get closer to the values for λ on 11.5-12.00 using a programmable engine control unit, it means that we will have an increased performance of the car.

EXPERIMENTAL RESEARCH

For determining the exhaust species and them evolution during the measurements, we mounted the vehicle on the test bench, MAHA LPS 3000. The vehicle was fixed on the roller; air fan was also connected - for air resistance and for simulating the real situation from the road - and the probe was mounted on the tailpipe.

Figure 2. Tested vehicle on Dyno

The equipment for measuring the emission of the exhaust species allows us to monitor all the species on the same window, very helpful for experimental research. The engine speed also can be monitored on the same window. A very important element was the lambda coefficient [10], [11], which allows following the quality of the combustion mixture, around the stoechiometric values.

Figure 3. MAHA MET 6.1 exhausts analyser

Figure 4. Exhaust gas prove

Figure 5. Clamp for RPM detection

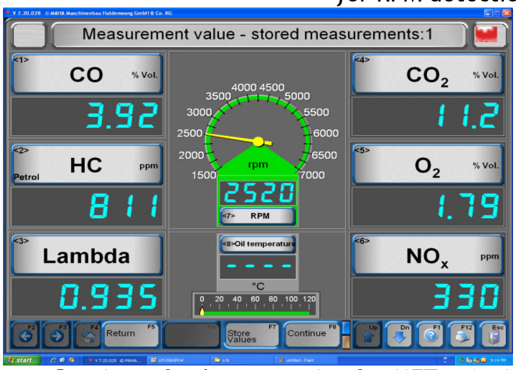

Figure 6. Preview of exhaust species for MET 6.1 window

Exhaust species measured with Maha analyser, MET 6.1, were recorded using dedicated software, namely Eurosystem, than were stored in tables. To monitor the evolution of all exhaust species [12], we run on Dyno with different loads, starting from 0 N and finishing with a load by 2000 N. On this paper we will present two cases, namely for load by 200 N and 2000 N.

Table 2. Exhaust values for 200N load

n [rot/min]	CO	CO_2	O_2	HC	NOx	Lambda
1480	4.65	10.1	2.08	453	168	0.936
1940	4.72	10.4	1.94	413	293	0.931
2020	4.21	10.6	1.84	523	309	0.933
2520	3.92	11.2	1.79	811	330	0.935
3080	0.94	13.8	1.23	169	481	1.024

Table 3. Exhaust values for 2000N load

n [rot/min]	CO	CO2	O2	HC	NOx	Lambda
1600	3.25	11.8	2.3	404	213	0.993
2050	2.56	12.4	2.04	492	301	0.999
2920	1.05	13.1	2.16	168	707	1.068
3120	2.01	12.9	1.74	198	639	1.015
4040	0.9	13.6	1.15	126	927	1.025

Exhaust species for tested vehicle running on 200 N loads:

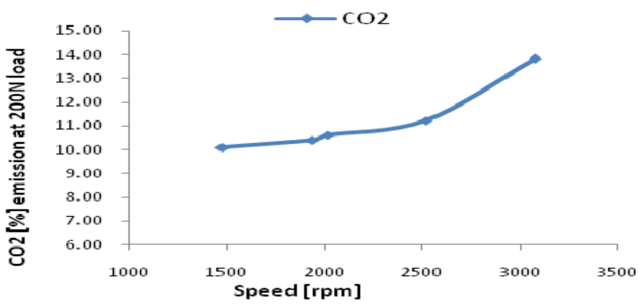

Figure 7. CO_2 [%] emission according with engine speed

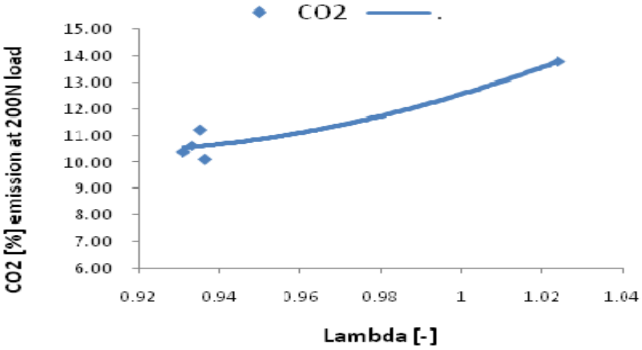

Figure 8. CO_2 [%] emission according with lambda

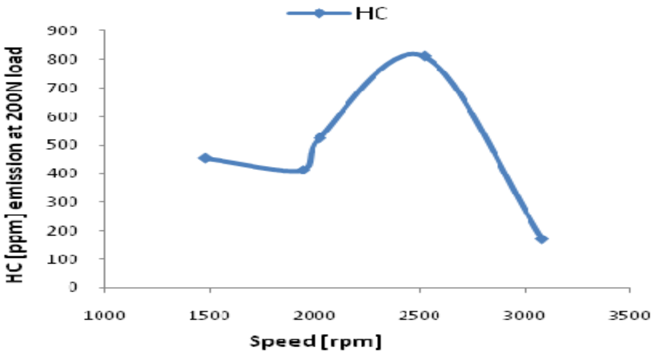

Figure 9. HC [ppm] emission according with engine speed

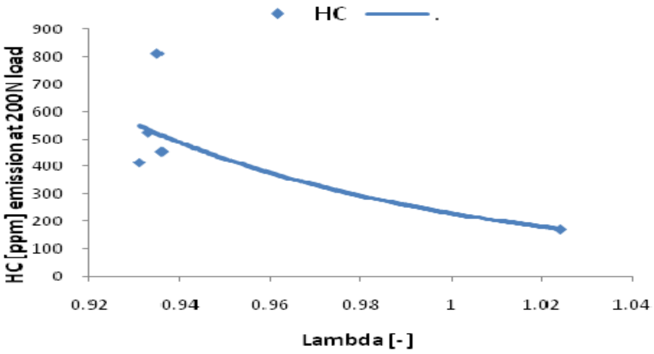

Figure 10 HC [ppm] emission according with lambda

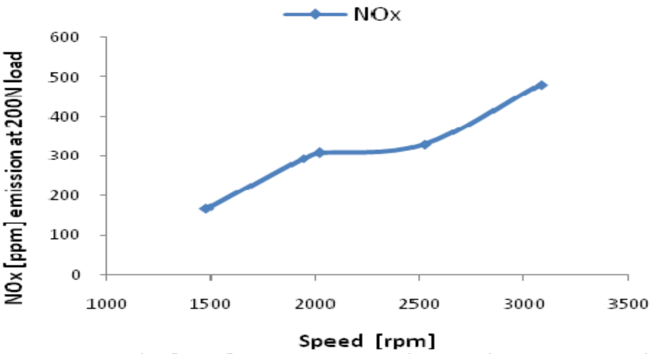

Figure 11. NOx [ppm] emission according with engine speed

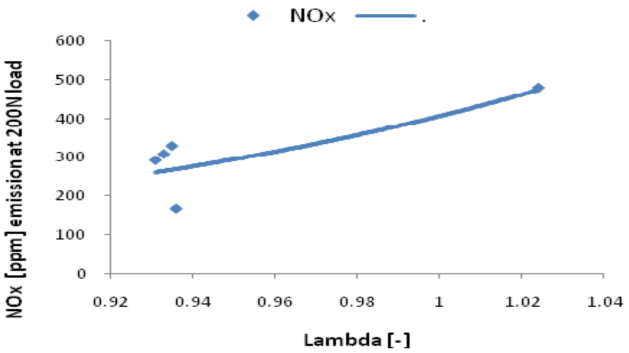

Figure 12. NOx [ppm] emission according with lambda

Exhaust species for tested vehicle running on 2000 N loads:

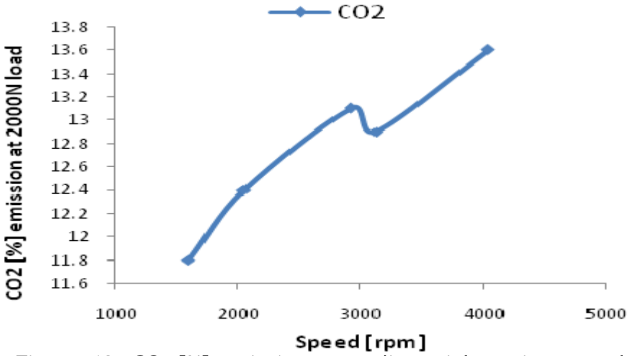

Figure 13. CO_2 [%] emission according with engine speed

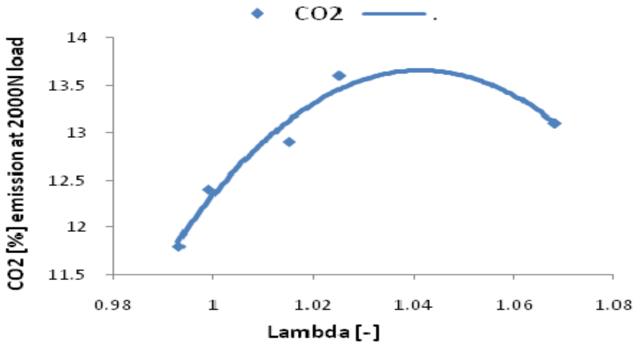

Figure 14. CO_2 [%] emission according with lambda

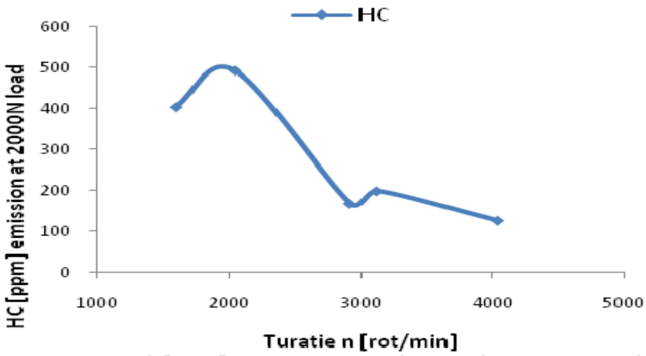

Figure 15. HC [ppm] emission according with engine speed

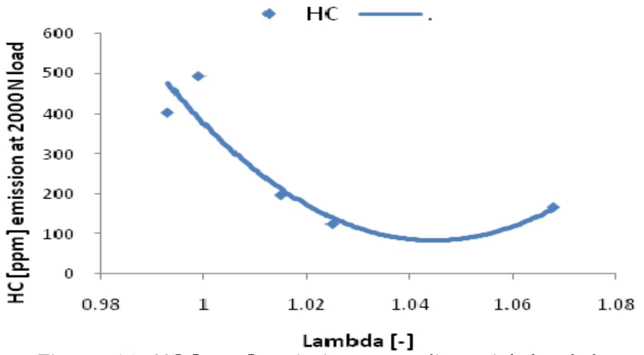

Figure 16. HC [ppm] emission according with lambda

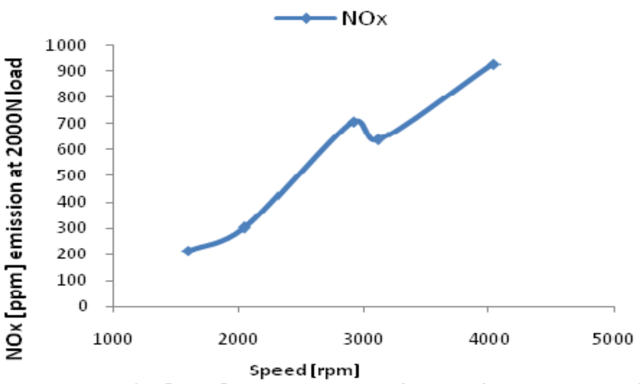

Figure 17. NOx [ppm] emission according with engine speed

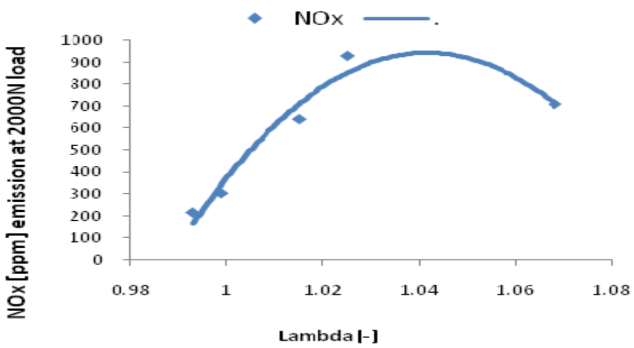

Figure 18. NOx [ppm] emission according with lambda

CONCLUSIONS

The comparison between these two cases, namely 200 N loads and 2000 N load for tested vehicle, completed with programmable ECU, make us to affirm the following conclusion:

- The engine behaviour was very good, especially because the vehicle was running on vehicle competition and there were no technical or software problems.
- The engine power curves presented high vales after the programmable ECU was mounted on the vehicle, also the AFR and lambda values achieved very good vales (lambda values at the top for this adjustments was 0.75, which means an AFR by 11.00).
- The exhaust species presented interesting values for both situation, and 200 N and 2000 N. The evolution of all the exhaust species presented ascending curves, on evolution, namely, for CO_2, and for NOx; for HC values, the curves present decreasing values, which is very good.

For future research, concerning the performances of the engine by programmable ECU is to obtain values for AFR between 12.50÷13.97, and for exhaust emission, situation very comfortable watching the fuel consumption and the behaviour of the engine. Also, future research concerning the programmable ECU is to use an alternative fuel, as isobutene, which takes into account the real problem about concentration of CO_2 from the atmosphere, concerning the apertures for the renewable energy from today.

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