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Journal of Engineering And Technology Research , 2013, 1 (1):7-15

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Influence Of The Control Unit Generation On Exhaust Emission In A Vehicle

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ABSTARCT

The paper presents a researchers on a popular model of car vehicle, equipped with a conventional petrol engine. During the study, exploitation map of car's engine was changed which allows for the fulfillment of the following European emission standards. The tests were performed on a chassis dynamometer, while using gas analyzers, paralled connected with the dynamo meter .In addition, to check the concentration of compounds such as hydrocarbons ,were used chromatograph *technique was also used. In addition ,the paper presents the story of the legendary Polish production enginein the light of emission standards.*

INTRODUCTION

Engine K-16 which is tested on field of exhaust gas emission is supply by simultaneously multi point injection system called Rover MEMS (Modular Engine Management System). It was developed by Rover and Motorola and it appear at 1989. It was developed for many years, it has modular building and thanks to this it can work with different Rover engines with MPI and SPI systems after little changes. Version 1.2 is desired to non- catalyst engines, version 1.3 works in closed loop with lambda sensor and exhaust emission control. Engine which will be tested has ECU in version 1.6 which characterized working in closed loop and catalytic converter, but still with ignition distributor and old type stepper motor controlling idle speed [6].

The MEMS ECU is designed to work in three main areas: ignition, fuel system and idle speed. The correct ignition dwell and timing for all engine operating conditions are calculated from data provided by crankshaft angle sensor and manifold air pressure. Main engine load sensor is MAP, CAS delivers information about rotational speed of crankshaft and its angle position. Basic ignition

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timing is stored in 3-dimensonal map, and after it are applied corrector factors. Main of them is temperature of engine from CTS, minor correction is done on the base of ATS and TPS signal. The basic air fuel ratio data is also stored in 3-dimensional map and the engine load and speed determined length of pulse steering injectors. ECU use to estimate all parameters speed/density method, what meant that engine will draw in a fixed volume of air per revolution. Of course the pulse duration is corrected by influence of ATS, CTS, TPS and also of battery voltage. During acceleration additional pulses are provided at 80º crankshaft intervals to enrich mixture. When engine is operating on idle speed, ECU use other special map for idle. Speed of engine during warm- up and hot running is controlled by stepper motor, however small adjustments are done by advancing and retarding the timing [1,3].

MATERIALS AND METHODS

The engine on which measurements were done, is K- series engine from MG Rover company. It history began on the beginning of 80`s. It was introduced as a power plant to Rover 200 in 1988. It was very modern construction in those times. What is very interesting, it was creating using CAD/CAM technique and FEM technique to optimize noise and vibration characteristic [6]. Second important thing was that low pressure sand casting technique was implemented in volume production. Characteristic for this K-series is its layer building and that whole block is made from aluminium. Generally we find 2 types of head: with 8 and 16 valves. K-series has several variants of engine displace: 1,1L (8 and 16 valves version), 1,4L (8 and 16 valves version), 1,6L and 1,8L (only 16 valves) and variety V6 configuration. During several years of implementing K-series family to cars from Rover group, risen many variant of power of those engines, depend from type of fuel supply, electronics used to control and also turbo charging or using VVC (Variable Valve Control).
At the beginning of 90`s, in Poland after fall the communist political system, polish company manufacturing passengers car FSO, started to redesign its old construction cars to fulfilled new expectations. Flagship car of that times was Polonez , which was designed based on Fiat 125p in 1976-78, after 15 years of production, had many old fashion technical solutions [7]. Thanks to opening of borders, polish constructors had the possibility to buy licenced and technology from West Europe. They decided to implement to Polonez modern and powerful engine from K-series. It was a great change, with comparison with old engines from Fiat, which had between 65 and 87HP and were not economical and durable [4].

Number for cylinders: 4
Capacity: 1396cm2
Firing order: 1-3-4-2
Stroke: 79mm
Bore: 75mm
Timing: DOHC, hydraulic tappet
Main bearings: 5
Compression ratio: 1:10
Maximal power: 103HP (76kW) at 6000rpm
Maximal torque: 127Nm at 5000rpm [3,4]

The engine used in the FSO Polonez is the most powerful version of 1,4l K-series engine. It has multipoint injection, controlled by Rover MEMS 1.6, 2 camshaft which steer 16 valves, 4 for each cylinder. It characterised by layer construction, all parts are connected together by stretch bolts. Thanks to aluminium and steel have different thermal expansion, during warming of engine, all parts are compressed stronger, especially the head gasket. It is important to not charge engine strongly, until it has proper temperature, otherwise it risk head gasket failure. Also overheating is very dangerous for gasket, that is why it is important to keep proper temperature of coolant fluid [5].

RESULT AND DISSCUSION

First step was mounting car on the dyno stand. It must be done very carefully, because belts carry all forces which car acts to the stand. Next step was warming up engine, because measurements with oil temperature below 80ºC are improper, emission of toxic substances is much higher than in normal condition. Also catalytic converter must have high enough temperature for correct working, what is important that this temperature is increasing with level of wear and age of it. This part of tests was realized by program implemented in dyno device, which allow us to load car with determined value, in this situation is used dynamic brake which convert torque to losses in Eddy currents. Then was checked condition of engine by measuring of power output. First test was done for ECU with number MKC103610 which fulfill requirements of norm Euro 2. Then ECU was changed for another with number MKC101610 which fulfill norm Euro 1 [7, 8]. During measurements were following parameters of environment:

- temperature of environment: 21,8ºC
- temperature of intake air: 22,2ºC
- humidity: 43,1%
- atmospheric pressure: 1013,2hPa
- vapour pressure: 11,3hPa
- oil temperature: 78 ºC.

Tab. 1. Results of performance engine with two types of ECU [7]

	MKC103610	MKC101610
P-norm	96,7 BHP	103,8 BHP
at:	5795 rpm	6065 rpm
	159,5 km/h	168,1 km/h
M-norm	121,1 Nm	124,7 Nm
at:	4995 rpm	4480 rpm
	137,5 km/h	124,1 km/h
P-engine	98,6 BHP	105,3 BHP
P-wheels	70,4 BHP	74,4 BHP
P-losses	28,2 BHP	30,7 BHP

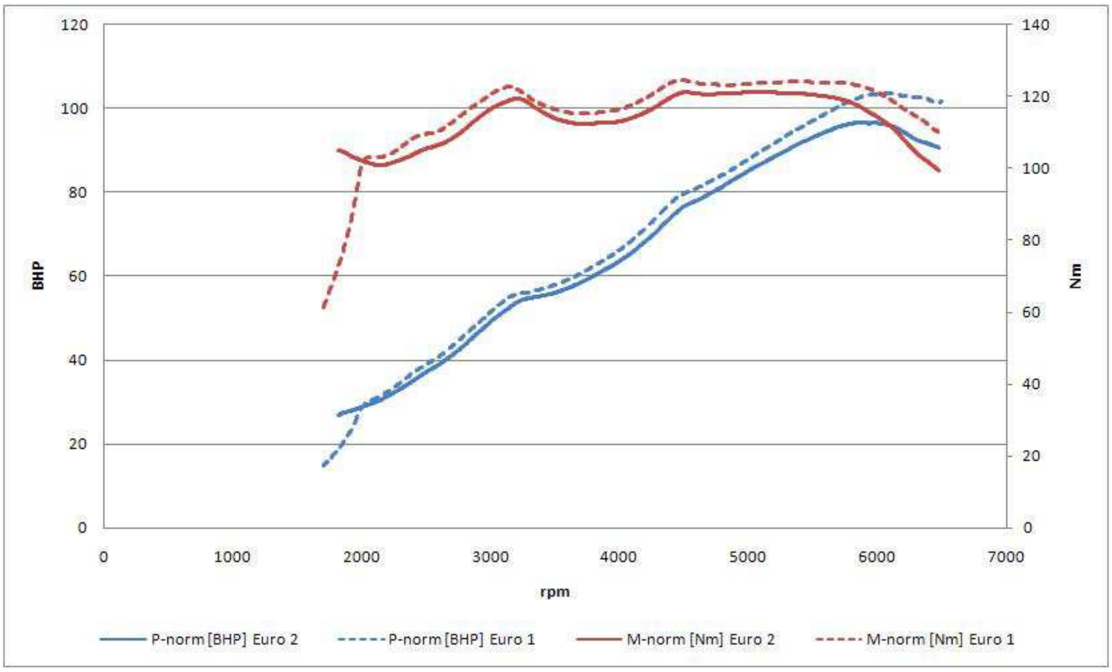

Fig. 2. Comparison curves of power and torque for two ECU [7, 8]

Results are in line with expectations. Engine has value of power and torque oscillating around nominal parameters (103 BHP, 127 Nm). The ECU which fulfill norm Euro 1 had better performance than ECU with Euro 2, what was result of more preciously map of injection and timing to reduce emission of toxic substances in exhaust gases. Also range of rotation speed when maximum performance appears is consistent with data given by producer – maximum torque at 5000rpm, maximum power at 6000rpm. Big surprise is behaviour of curves below 2000rpm, output power and especially torque is rapidly declining in comparison with performance engine with ECU MKC103610. It causes that accelerating from idle speed, driving car especially in urban traffics and manoeuvring with very little opening throttle is very difficult.

General purpose of dynamic charge test was to gain information about emissions with a different load on the engine – different speeds. Parameters which device records during test are: CO, O_2, HC, lambda coefficient, power losses in brakes, and rotational speed of engine, all of them are presented in time domain. Unfortunately measurement of NO_x was impossible because of lack of additional NO_x sensor. Registration this parameters were done for rotational speed 3000rpm, 4000rpm, 5000rpm and 6000rpm. The dyno has option to maintain set value of engine speed, when it is rising, brakes increase its roll resistance to set speed on the same level. Time of recording data was about 30 second – it is necessary to stabilize emission. For speed 3000rpm and 5000rpm were also done measurements of volatile organic compound. For lower speed it last required 20 minutes, how required parameters of device, for higher speed test lasted only 10 minutes, because of a problem with oil temperature. Engine does not have oil an radiator and oil temperature was rising up to dangerous level so test was stopped. To keep comparable conditions, research for second ECU for 5000rpm also was shortened to 10 minutes. This same investigation was done for second ECU for all speed. The results for each test are presented below.

Hydrocarbons in exhaust gases

The emission tester checks general content of hydrocarbons in exhaust gases, without dividing them for individual compounds. It amount is given by unit ppm (parts per million). Graphs below present amount of HC in time domain, with demonstration value of speed. On some charts it is possible to observe behaviour of engine during transient states of increasing or decreasing rotational speed.

After changing numerical data to chart, characteristics were more clear. After analysing them, is possible to notice some conclusion. First of all, time of measuring HC content for 4 and 6 rpm was to short, values did not manage to stabilize, what is visible on chart for 3 and 5 rpm. On the beginning of every test appear high peak of amount of hydrocarbons. Before each measurement, engine worked some time on idle speed. Temperature of exhaust gases were low, many HC did not burn completely in combustion chamber, also temperature of catalytic converter was lower than required to proper afterburning. Most of them settled on walls of exhaust manifold and exhaust pipe. During increasing speed of engine increased also flow of gases, which caused blowing of HC from all exhaust system. After some seconds, when catalytic converter reached demanded temperature to fully conversion HC, they amount significantly decrease. However the final level of them was higher for 3 rpm than for 5 rpm. It was result of lower temperature of all system, which caused not completely burning of HC, for 5 rpm they practically did not exist. For 3 rpm they stabilised on average level 8ppm for ECU with Euro 1 norm, and 15ppm for ECU with Euro 2 norm. For speed 4 rpm they archived average level respectively 11 and 20ppm. During measurements for 6 rpm, they did not manage stabilize at all, results would be on the same level as for the 5 rpm, but values of them during test still were decreasing, reaching final value respectively 7 and 12 ppm. Chart below presents function of emission of HC in load domain. Values for 6000 rpm must be treated like howler, and should be ignored. Curves should have last points on level as for 5000rpm.

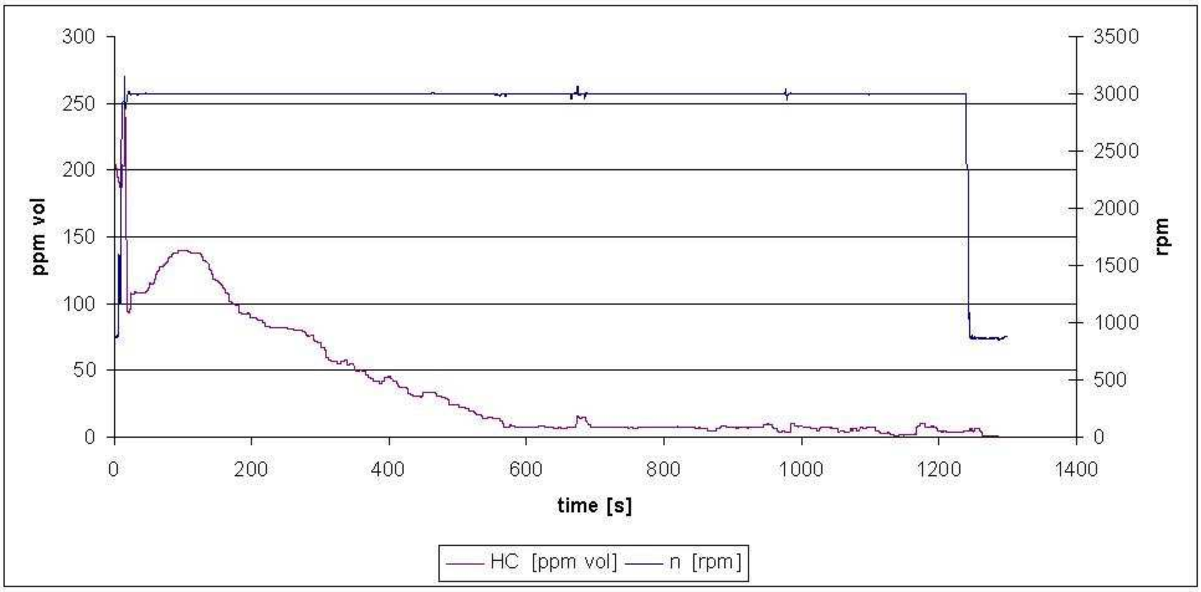

Fig. 3. Content of HC, 3000rpm, ECU with norm Euro 1

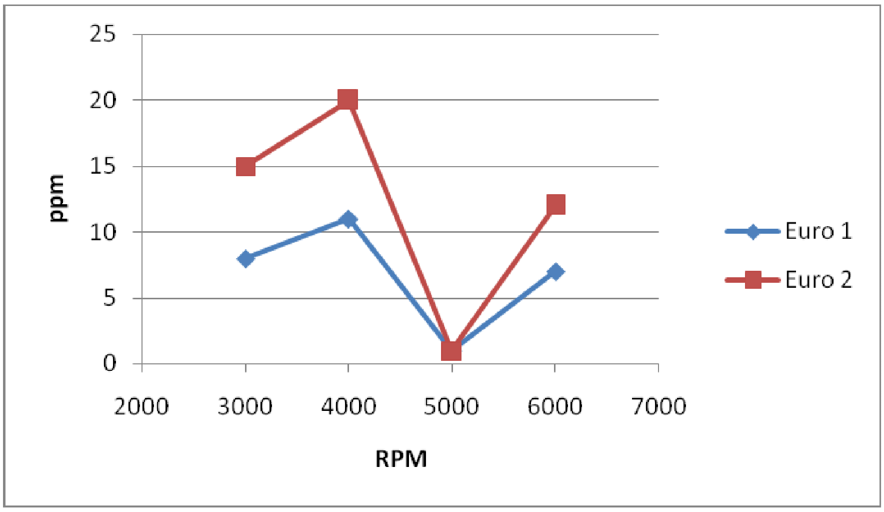

Fig. 4. Content HC in engine load domain

General view on this part research is different to expected. It follows that engine steering by ECU with norm Euro 2 produces on every measuring point more hydrocarbons than with ECU with norm Euro 1, what dose not agree with assumptions of norms.

Carbon monoxide and oxygen in exhaust gases

Amount of carbon monoxide and oxygen in exhaust gases is very strong connected together. It depends on lambda factor, which determine kind of mixture burning in chamber. This three values are presented on charts below. Procedure of registration all this data was the same like hydrocarbons. For better readability was added value of engine speed. It also allows observe characteristics of steering of mixture during transients states.

After analysing presented data on the charts, is possible to observe that content of CO and O_2 is independent form load and speed of engine. That is why impossible do draw chart of emission in power domain. Only if injection system maintains stoichiometric $\lambda = 1$, all oxygen is used to burn fuel, CO practically does not exist, because of completely combustion. It minimal quantity appears in consequence of dissociation CO_2 in high temperature, local heterogeneity of mixture and in case when engine work with full load and mixture is rich, but this case did not test in our research .

Even small change in value of lambda factor has great influence to amount of tested gases. When mixture is lean, excess of oxygen goes to atmosphere, when mixture is rich, catalyst can not convert CO to CO_2 because lack of oxygen to burning. Generally injection system in this engine has tendency rather to running on lean mixture. It is accordance with assumption of construction of engine – is designed to use mixture with excess of oxygen.

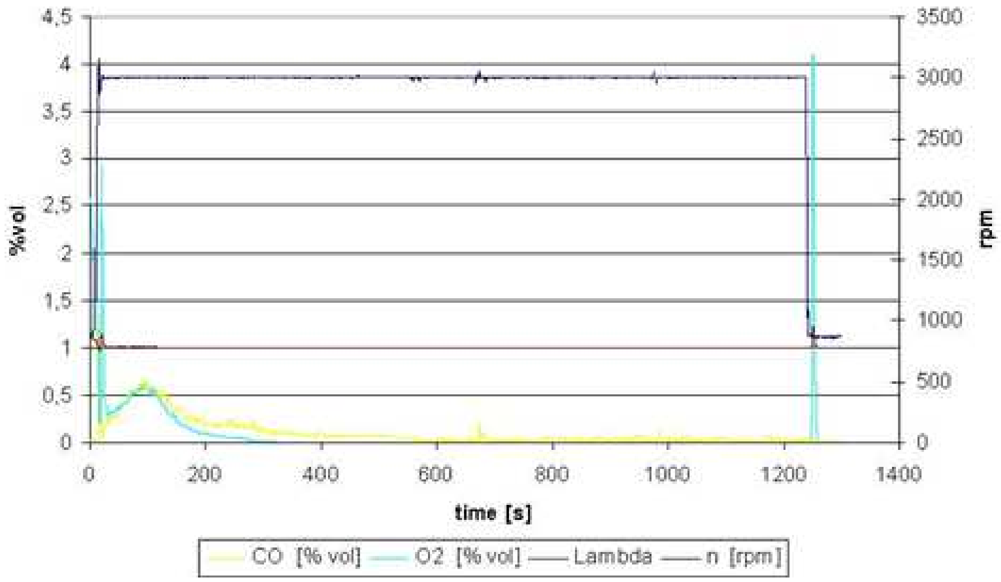

Fig. 5. Content of CO, O_2 and λ test at 3000rpm, ECU with norm Euro 1

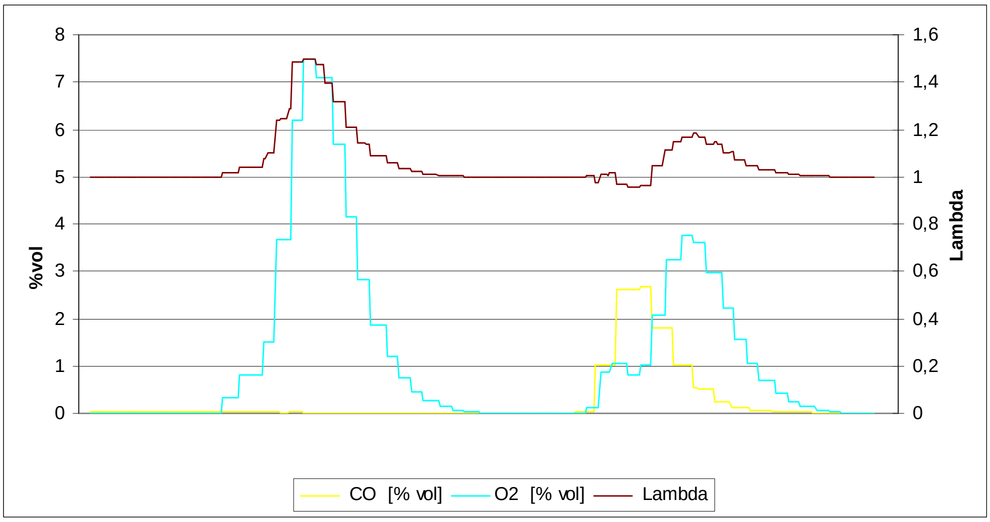

Fig. 6. Amount of CO and O_2 in exhaust gases in lambda function

Volatile Organic Compound in exhaust gases

Parallel to measurement did by emission tester, was got specimen of volatile organic compound to examination in gas chromatograph. Amount of gases was needed for test is approximately $10dm^3$, and it lasted 20 minutes. However, how it was said before, measurements for 5000 rpm was shortened to 10 minutes and $5dm^3$ of gas, because problems with oil temperature. It is mean that amount of individual components for results of 5000 rpm must be multiply by two to archive proper value. Sucked gases was going through active carbon, where VOC particles were gathered. This part of experiment was realised by automatic aspirator ASP-3 II. It ensure constant speed of flow independent of ambient conditions. Carbon specimen was tested in gas chromatograph Varian 450GC with flame-ionization detector and column VF-WAXms 30m x 0,25mm ID DF: 0,25 µm.

Measurement result is chromatogram, which must be analysed to obtain quantitative results. On base of chromatogram was done quantitative result of find compounds in exhaust gases. It was done 3 times for each specimen, and average value for every measurement are presented in last table. Only 4 compounds were in significant amount which where available to detect using this stand, but they allow to compare emission for different ECU and load.

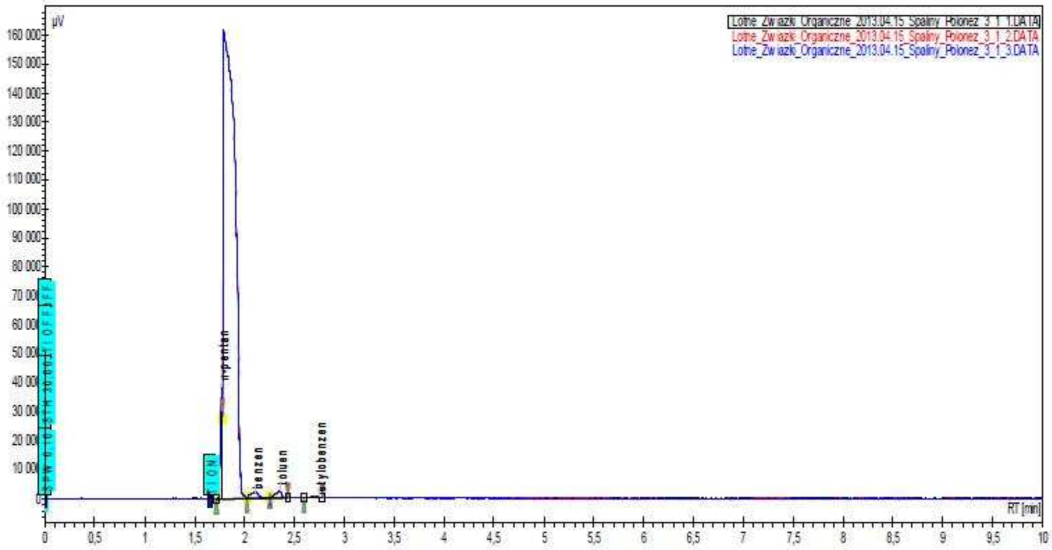

Fig. 7. Chromatogram for speed 3000rpm, time of gathering gases 20 minutes.

After analyse data gathered in this measurements, is possible to notice difference between ECU with norm Euro 1 and Euro 2. For medium rotational speed of engine, which is most often use during normal driving, emission of individual compounds for ECU with norm Euro 1 is average 20-30% higher. Also for this speed for ECU with norm Euro 2 there is no found ethylbenzene. For 5000rpm emission is nearly the same, but this time is a little higher for ECU fulfill norm Euro 2. It may be the result of a little lower temperature of combustion causing different injection time and timing. However, amount of all compounds is definitely lower for this speed, because of temperature of combustion, exhaust gases and catalytic converter.

Tab. 2. Average values of amount each compound for all tests

	Quantity [ppm]			
	Euro 1 3krpm	Euro 2 3krpm	Euro 1 5krpm	Euro 2 5krpm
n- Pentan	120,18	98,8	10,94	11,12
benzene	52,87	45,5	12,89	13,53
toluene	131,49	77,59	62,17	69,16
ethylbenzene	17,68	---	21,97	16,16

CONCLUSION

The aim of the research was planed and measured exhaust emission for chosen vehicle during dynamometer test and archived function of emission in power domain. The task was to check influence of engine load for forming toxic compound.

After literature survey and good theoretical preparation it was made several measurements. Firstly it was checked and confirmed good condition of engine and catalytic converter, what qualified it to further tests. For 3, 4, 5 and 6 thousand revolutions per minute was registered amount of HC, CO and O_2 in exhaust gases. Additionally for 3 and 5 rpm was checked quantity and composition of

VOC. Analyse of results shows that measurements was made with some mistakes. Time of measurements for 4 and 6 thousand rpm was too short to get real values of emission of HC. That is why chart showing emission in power domain is not agree with theory and practical observation. On this points high emission is caused by many residues of HC which were in exhaust pipe during working engine on idle speed. Only at the end of measurements values was going down to real level. Results are not in line with expectations, engine steering by ECU with norm Euro 2 have higher emission than with norm Euro 1. Presenting emission CO and O_2 on power domain is completely impossible, because of it independency from load. For this compounds have only influence lambda factor. VOC measurements show that for medium rotational speed engine steering by ECU with norm Euro 2 have lower emission level. But for higher speed, there is practically no difference. Problem with too high oil temperature in measurement for 5000 rpm causes that there is no real quantitative results, only qualitative. Results can not be compared with norms Euro, because they are defined emission on unit better suited to the real using of vehicles – in grams for one kilometre. Equipment on which test were done, does not allow to get results on this form, only shows percentage content of tested compounds. However research confirms main influence of temperature for forming HC, in higher temperature emission is lower, more particles are burned and catalytic converter has higher efficiency.

Research like this shows how difficult is measurement amount toxic compound emitting by vehicle during real condition. For it has influence so many factors, depending on construction parameters of engine, it mechanical condition and also external factors like type of ride and driving style. Also realisation this kind of work demonstrates toxicity measured compound, they health hazard and influence for environment. All this knowledge about preventing our atmosphere before degradation is very important especially nowadays, when amount of vehicle in the world is rising fast.

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