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Ecological Aspects of Electronic Diesiel Control

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Summary. The article presents the simulation of damage to the engine power (EP) system components and to verify the impact of damage on toxic components emission. The other aim of the article is to simulate the failure of two sensors (the rail pressure sensor and the flow meter), which directly affect the toxicity, and to analyse signal paths during simulated damage. Simulation studies were conducted using the Oliver D60 ophthalmometer following the free acceleration method. Studies included driving a Toyota Avensis powered by 2.2D-4D diesel engine with 2AD-FTV designation and recording of thirty signals in the EP engine control system. The results will allow to correct the exhaust gas composition model.

Key words: exhaust emission, electronic diesel control, OBD system, simulation studies.

INTRODUCTION

The growing number of cars in the world and the resulting pollution of the natural environment have lead to increased pollution-related restrictions. Emission measurements in passenger vehicles are carried out during homologation tests on the chassis dynamometer, during road tests in actual road conditions and at vehicle inspection stations. The latest test results on public roads show that for some exhaust components emissions are up to several percent higher for gaseous compounds and particulate matter compared to emissions from the test bench. The above observations suggest the necessity to carry out emission tests in road conditions. The European Union, the United States and Japan have introduced exhaust emission standards, limiting the toxicity of individual components (Figure 1). Emissions are related to the operating conditions of internal combustion engines, especially at variable dynamic states [5,8,13].

Introduction of On-Board Diagnostics (OBD) emission and diagnostic standards has tightened the requirements for emission control systems of toxic components [10,12,16]. Modern OBD systems must recognise and record the erroneous indications of circuits associated with the emission of toxic exhaust components and damage to the vehicle's electrical system. The occurrence of damage is recorded and memorised by the OBD system in the form of error codes [9,11].

The basic requirements of OBD standards for toxicity include:

- assessment of the efficiency of the catalyst by measuring the oxygen content of the exhaust gas,
- monitoring the fuel supply system,
- control of the exhaust recirculation system,
- identification and location of the non-combustion process (ignition failure).

Analysis of the electrical system is reduced to checking the continuity of the measuring network, the shortbacks of the sensor signal circuit or the supply circuit of the actuator to the ground or to the power source. An electrical performance test has included a comparison of the voltage from the sensor with the reference given by the manufacturer and the upper and lower limits. A signal falling short of the permissible minimum or exceeding the corresponding maximum is a symptom of damage to the sensor. For actuator tests, the object of measurement is the current flowing to the actuator, whose value is a diagnostic parameter of its technical condition. Electrical validation tests enable the detection of the most common electrical faults in the operational practice, and their positive result is a necessary but not sufficient condition to assess the performance of the tested components. After a long period of operation, the measuring and operating elements are subject to natural wear, which affects the metrological properties of these elements [1-4].

The aim of this article is to simulate damage to the engine power (EP) system components and to verify the impact of damage on toxic components emission. The second aim of the article is to simulate the failure of two sensors (the rail pressure sensor and the flow meter), which directly affect the toxicity, and to analyse signal paths during simulated damage.

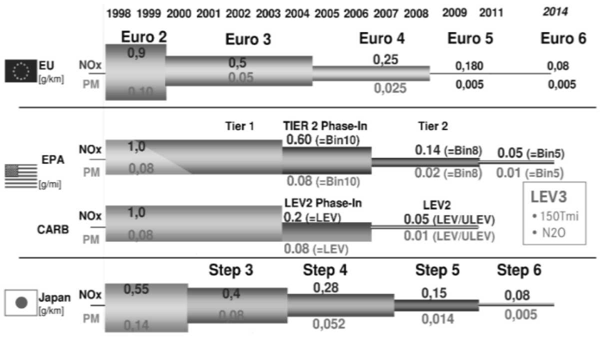

Fig. 1. Emission standards in the world

EXPERIMENTAL SIMULATORY TESTING OF ENGINE TOXICITY

The measurement of exhaust smokiness makes it possible to assess the effect of the type of damage on the concentration of soot in the exhaust gas. Exhaust smokiness is the result of the presence of particulate matter (soot) and other components. With soot content of 100-300 (mg/m^3), exhaust smokiness becomes visible. Black smoke appears at a concentration of about 500 (mg/m^3). Smoke measurement devices, called opacimeters, use the phenomenon of absorption of visible radiation (light) in the gases. At the time of measurement, light absorption in a continuous exhaust gas stream containing soot particles is used. At one end of a measuring chamber of a certain length a light source is placed, and at the other a photoelement. The exhaust gas in the measuring tube absorbs light, which changes the current flowing in the photoelement. These changes are read on an electric meter scaled in conventional units of the degree of smoke emission. Measurement accuracy is influenced by the temperature and pressure of the gases that should be kept within certain limits [6,7,14,15]. The degree of light absorption is determined by the absorption coefficient A (1):

$$A=(\Phi_0-\Phi)/\Phi_0\ [\%] \tag{1}$$

where :

Φ_0 – intensity of input light stream

Φ – intensity of the light stream after passing through the exhaust gas in the measuring chamber.

The unit of smoke is assumed to be the absorption coefficient *k*, which is dependent (2):

$$k=(1/l)\ln(1/1-A)\ [m^{-1}] \tag{2}$$

where:

l – measuring system length

The limit values of smoke emission for compression-ignition engines are set in accordance with paragraph 9, passage 1, point 3 of the regulation of the Minister of Infrastructure of the 2015 year on the technical conditions of vehicles and the scope of their necessary equipment:

$k= 2,5\ m^{-1}$ for aspirated engines

$k= 3\ m^{-1}$ for supercharged engines

$k= 1,5\ m^{-1}$ for vehicles manufactured after June 30, 2008.

The relationship between the soot concentration and the absorption coefficient *k* and smoke emission according to Bosch DB and Hartridge DH is shown in Figure 2.

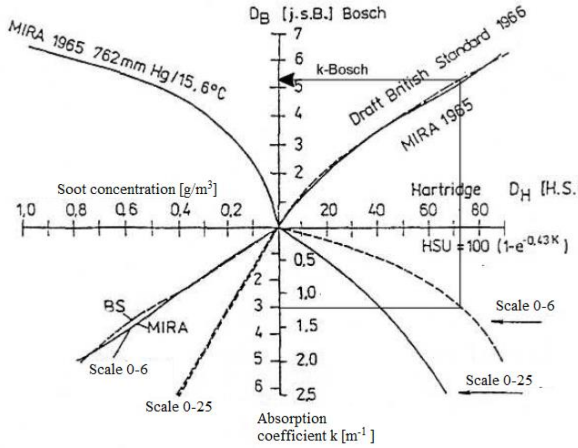

Fig. 2. The relationship between the soot concentration and the absorption coefficient *k* and smoke emission by Bosch DB and Hartridge DH.

Simulation studies were conducted using the Oliver D60 ophthalmometer following the free acceleration method. Measurement of smoke emission is carried out by increasing the rotational speed from the idle speed to maximum speed, at full dose of fuel for the unloaded motor. The object of the research was a diesel engine with a capacity of 2000 cm^3, power 150 HP, equipped with supercharging and a common-rail system.

The study was conducted for five simulated defects:

- Failure no. 1 – smoke measurement with a locked injector on cylinder 1 (blocked spray tip).
- Failure no. 2 – smoke measurement with a faulty sensor the charged air temperature (circuit breaker).
- Failure no. 3 – smoke measurement with a faulty solenoid valve (valve locked)
- Failure no. 4 – smoke measurement with a leaky supercharger

- Failure no. 5 – smoke measurement with a damaged HFM5 thin-layer air flow meter.

For each failure, eight smoke measurements were performed for which an average value was calculated. The results of the measurements are shown in Table 1.

Table 1. Comparison of exhaust smoke measurements

Type of failure	Unit	No. measurement								Average
		1	2	3	4	5	6	7	8	
Locked injector on cylinder 1	k [m^{-1}]	3,66	1,05	0,67	0,69	0,50	0,24	0,22	0,41	0,93
	%	79	36	25	26	19	10	9	16	28
Faulty sensor the charged air temperature	k [m^{-1}]	1,38	1,17	0,70	0,69	3,36	1,10	0,62	0,65	1,21
	%	45	39	26	25	76	37	23	24	37
Faulty solenoid valve	k [m^{-1}]	0,87	0,54	0,56	0,64	0,60	0,68	0,72	0,76	0,67
	%	31	21	21	24	23	25	27	28	25
Leaky supercharger	k [m^{-1}]	3,92	2,25	1,38	1,17	0,88	1,16	1,38	1,94	1,77
	%	81	63	45	39	31	39	45	57	50
Faulty air flow meter	k [m^{-1}]	4,89	3,77	3,77	3,77	3,75	3,68	3,80	3,73	3,90
	%	88	80	80	80	80	79	80	80	81

The coefficient of smoke is over 3 k [m^{-1}] for faulty air flow meter.

EXPERIMENTAL RESEARCH IN THE CONTROL CIRCUIT

Experimental studies included driving a Toyota Avensis powered by 2.2D-4D diesel engine with 2AD-FTV designation and recording of thirty signals in the EP engine control system. The data were recorded when driving with the diagnostic connector attached to the tester.

The recorded data were transferred to a computer and played back using the Intel Viewer 3.20. During testing, the following signals were recorded:

- load, vehicle speed, engine speed, accelerator pedal position, current in the VCM pump circuit (Fig. 3),
- fuel pressure output, actual fuel pressure, fuel pressure of the booster device, signal from the mass air flow meter, air pressure signal (Fig. 4),
- throttle position, throttle opening angle, throttle switch, EGR valve position, EGR valve adjuster (Fig. 5),
- injection dose, pilot 1 injection, pilot 2 injection, main injection, final injection (Fig. 6),
- injection correction, pilot 1 injection, pilot 2 injection, main injection, final injection (Fig. 7),
- position of the accelerator pedal (Fig. 8).

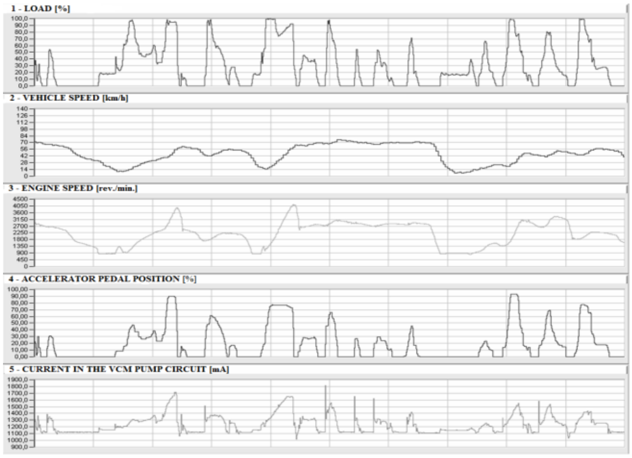

Fig. 3. The recorded signals as a function of time
(1 – load, 2 – vehicle speed, 3 – engine speed, 4 – accelerator pedal position, 5 – current in the VCM pump circuit)

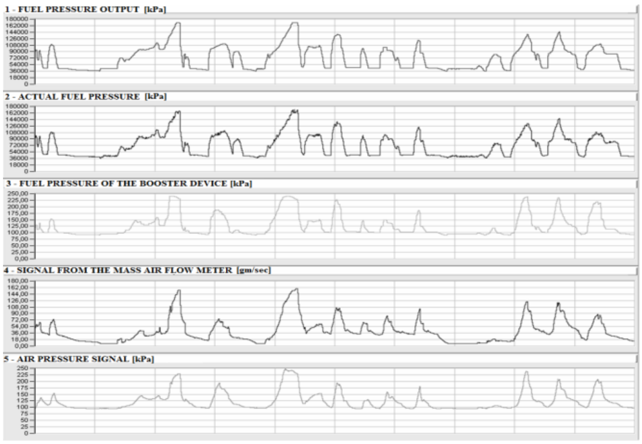

Fig. 4. The recorded signals as a function of time
(1 – fuel pressure output, 2 – actual fuel pressure, 3 – fuel pressure of the booster device, 4 – signal from the mass air flow meter, 5 – air pressure signal)

Fig. 5. The recorded signals as a function of time
(1 – throttle position, 2 – throttle opening angle, 3 – throttle switch, 4 – EGR valve position, 5 – EGR valve adjuster)

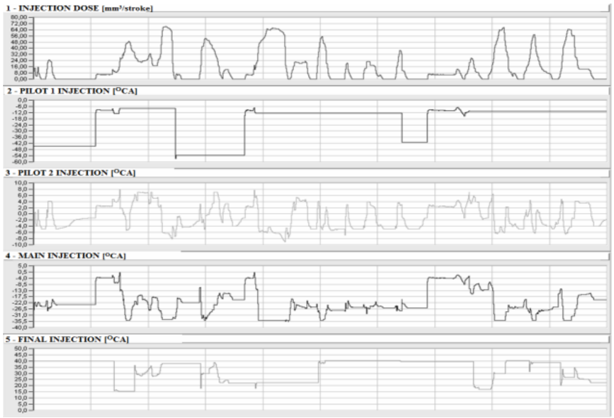

Fig. 6. The recorded signals as a function of time

(1 – injection dose, 2 – pilot 1 injection, 3 – pilot 2 injection, 4 – main injection, 5 – final injection)

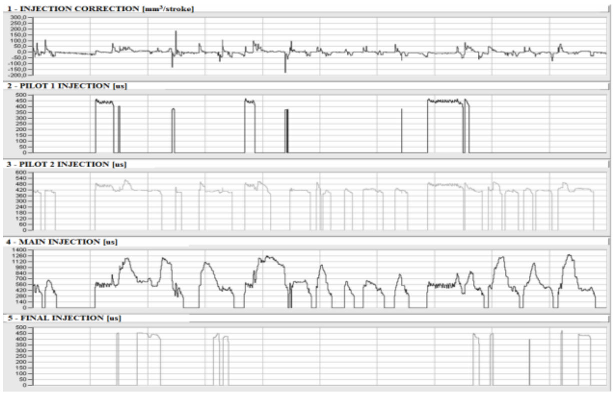

Fig. 7. The recorded signals as a function of time
(1 – injection correction, 2 – pilot 1 injection, 3 – pilot 2 injection, 4 – main injection, 5 – final injection)

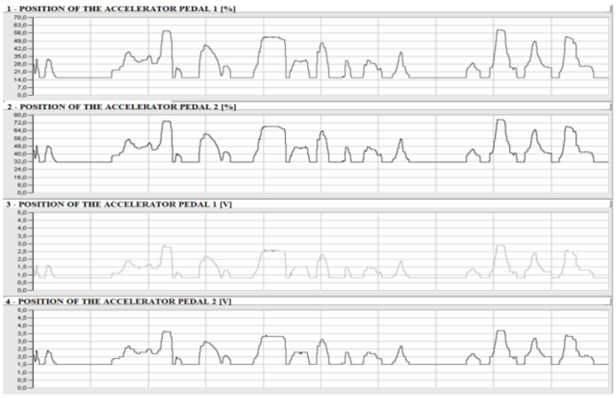

Fig. 8. The recorded signals as a function of time

(1 – position of the accelerator pedal signal 1, %;
2 – position of the accelerator pedal signal 2,%;
3 – position of the accelerator pedal signal 1, V;
4 – position of the accelerator pedal signal 2, V).

The study cycle included simulating damage of the air flow meter, EGR valve, throttle position sensor and fuel pressure sensor. The simulated damage of the air flow meter allowed the individual signals to be recorded at the idle speed of the engine. The results of the recorded signals are shown in Figure 9.

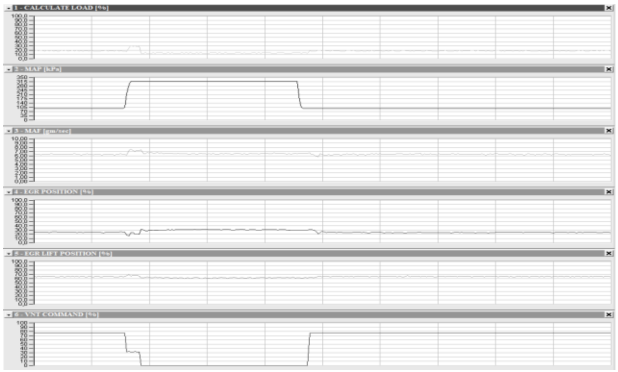

Fig. 9. Signal flow for a defective air flow meter
(1 – calculated load, 2 – manifold absolute pressure sensor, 3 – mass air flow meter, 4 – EGR position sensor, 5 – position EGR flip position sensor, 6 – VNT signal)

The second simulated failure was a break in the fuel pressure sensor circuit when the engine was running idle. The results of the recorded signals are shown in Figure 10.

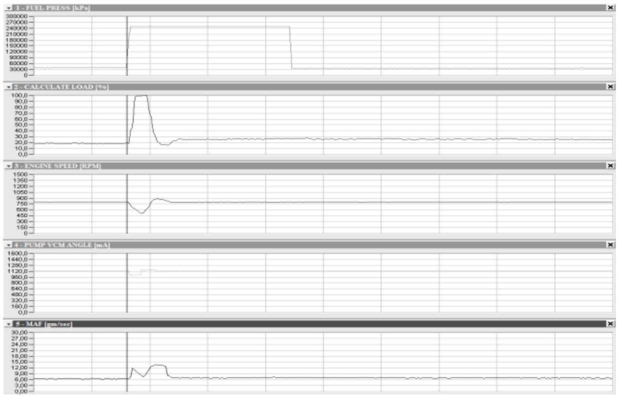

Fig. 10. Signal flow for a defective fuel pressure sensor (1 – fuel pressure, 2 – calculate load, 3 – engine speed, 4 – pump VCM angle, 5 – mass air flow meter)

CONCLUSIONS

The existing regulations on standards related to environmental protection are very strict and do not allow to determine the impact of damage to individual elements of the change in value of the individual components without special equipment. Previously conducted tests at vehicle inspection stations do not give full information about the cause of the failure of the EP control system.

Simulation of damage in the fuel path and the EP control gives the possibility to develop diagnostic patterns allowing to determine the diagnostic relations permitting to attribute to the symptom characteristics of a technical object. Determining the parameters of the EP state requires measurements of the parameters that affect the proper operation of the engine. To achieve the goal of diagnostic reasoning, it was necessary to simulate the selected defects and to analyse the signals that could be used to infer the EP properties.

Further research is being conducted to develop a model of the impact of individual quantities on the toxicity of exhaust gases. To achieve the result of the diagnostic procedure it was necessary to simulate the selected electrical faults in the sensor circuit that affected the EP control process. The obtained results will allow to correct the exhaust gas composition model.

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