PRESENT STATE AND PERSPECTIVES OF ENVIRONMENTAL POLLUTION CAUSED BY VEHICLES

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Abstract: The paper brings forward the study of systems which reduce the amount of modern pollution coming from vehicles which are destined for transportation. The technical and construction characteristics of vehicles are presented as well as the tests which they undergo for the assessment of their efficiency. It is necessary to test emissions in order to verify if the pollution norms written in the operation and maintenance book of the vehicle are respected as well as to ensure an optimum operation of the motor and of the environment.

Key-words: norms, reduce emissions, lambda sensor, catalytic converter, EGR, scr.

1. GENERAL CONSIDERATIONS

When the motor of a car is running, several types of gases and particles are emitted, having therefore a negative impact on the environment. A special interest is born by carbon dioxide, a greenhouse gas; hydrocarbons – a dozen of volatile organic compounds, some of which are known as cancerous agents, nitric oxides, sulphur oxides, as well as suspended powders, minute solid particles such as metals and smut. Other health affecting emissions and which create the smog include ozone and carbon monoxide. The good news is that, although the number of cars on the roads has increased, air quality today is better than it used to be in the 70s, due to the laws brought into force during that period. In fact, lead emissions from vehicles have been completely eradicated due to the elimination of lead petrol.

Car emissions may affect the environment in several ways. Cars emit greenhouse gases such as carbon dioxide, which contributes to global warming. Some of the polluting substances found in air and suspended powders emitted by cars are laid

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on the ground and end up in surface waters reaching therefore the food chain; these substances may also affect the respiratory, immunity and neurologic systems of animals; nitric oxides and sulphur oxides have a major contribution to acid rains which modify the pH of water bodies and soil.

1.1. Polluting emissions verification norms. SIE vehicles running on petrol, LPG or CNG

When *emissions are not limited by a perfected regulation system*, such as a three component catalyser managed by the lambda sensor, the following verifications are carried out:

- Visual inspection of the exhaust system, in order to check if it is complete and in a satisfactory state and there are no leaks;
- Visual inspection of all the emissions' regulating equipments installed by the producer, in order to check if it is complete and in a satisfactory state and there are no leaks.
- After having brought the engine to normal operating parameters, considering the recommendations of the producer, the concentration of the emissions of carbon monoxide (CO) and hydrocarbons (HC) is measured, with the engine idle running and the gear stick in neutral (in the case of automated gearboxes, the gear changing stick shall be put in "Neutral" or "Park" position).
- The maximum admissible CO content in exhaust fumes shall not exceed the following values:
  a) For vehicles produced up to 1986: CO (cor): 4.5% in vol.;
  b) For vehicles produced after 1987: CO (cor): 3.5% în vol.
- The maximum admissible HC content in exhaust fumes shall not exceed 1000 ppm.
- HC measurements are not carried out for vehicles which run on LPG or GNC.
- The control of engines running both on petrol and LPG or GNc shall be made for both operating solutions.
- This type of verification is not carried out for hybrid vehicles and for two-cycle engine vehicles.

If *emissions are controlled by a perfected regulating system*, such as three component catalyser managed by the lambda sensor, the following verifications are carried out:

- Visual inspection of the exhaust system, in order to check if it is complete and in a satisfactory state and there are no leaks;
- Visual inspection of all the emissions' regulating equipments installed by the producer, in order to check if it is complete and in a satisfactory state and there are no leaks.
- Determining the efficiency of the emissions' regulating system by

measuring values of the lambda sensor and the CO and hydrocarbons emissions in the exhaust fumes. For each of the two tests the engine is brought to normal operating conditions, according to the producer of the vehicle.

- Emissions at the outlet of the exhaust pipe – limit values
- The maximum admissible CO content of the exhaust fumes shall not exceed the following values:
  a) Measurements made for an idle run , with the clutch on and the gear lever on zero (in the case of automated gearboxes it should be on “Neutral” or “Park”): the maximum admissible CO content in the exhaust fumes shall not exceed the value CO (cor): 0.5% in vol. For Euro 3 and 4 vehicles; id shall not exceed the value CO (cor): 0.3% în vol. For Euro 5 and 6 vehicles;
  b) Measurements made for an accelerated idle running motor, at least 2000 revs/min and maximum 3000 revs/min, with the clutch on and the gearshift on zero (in the case of automated gearboxes it should be on “Neutral” or “Park”): the maximum admissible CO content in the exhaust fumes shall not exceed the value CO (cor): 0.3% in vol. For euro 3 and 4 vehicles; it shall not exceed the value CO (cor): 0.2% in vol. For euro 5 or 6 vehicles
- Lambda: 1±0.03
- The maximum admissible HC content of the exhaust fumes for an accelerated idle run 100 ppm.
- HC measurements are not carried out for vehicles which run on LPG or GNC.
- The control of engines running both on petrol and LPG or GNC shall be made for both operating solutions.
- For vehicles equipped with an onboard diagnostics system (OBD), the correct operation of the emissions’ control system may be verified by reading the OBD and checking that it operates accordingly instead of carrying out the measurements according to the specified requirements.
- This type of verification is not carried out for hybrid vehicles.

1.2. Making a diagnostic according to the pollution degree

Polluting emissions:

- For the polluting emissions it is recommended to measure the regulated polluters such as carbon monoxide (CO), nitric oxides (NOx), non methane hydrocarbons (NMHC) and suspended particles (SP). In order to carry out a technological comparative assessment, it is not required to measure the emission of SP for vehicles which meet the requirements regarding the EPA 2007 or later emissions, considering the efficiency of the particles filter, while the extremely low level of SP emissions of synthesis vehicles. This exclusion is not applied for technologies conceived to reduce the emissions of SP. Total hydrocarbons (THC) may be measured instead of NMHC (for diesel engine vehicles, for example, 2% is subtracted from the measured THC in order to obtain the NMKC).

- For greenhouse emissions (GES), it is recommended to measure the level of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N2O).
- For natural gases vehicles, it is imperative to measure the emissions of CO_2, CH_4, N_2O
- The performance criterion is the percent improvement (decrease of emissions), correlated to the basic absolute values, meaning that the improvement percentages need to be presented in the context of the initial value. For instance, a reduction of NOx 00:11 - 00:10 g / CP-h means a reduction of 9%, but it is practically minor in the context of the initial value, which is already quite low.

2. THE IMPROVEMENT OF THE POLLUTING EMISSIONS OF SIE

2.1. Controls and interventions

It is well known the fact that the supply system operates in a depression while the global parameter that characterises its operation is the pressure above and below the fuel filter.

The fuel cap needs to ensure the bond with the environment in order to avoid the appearance of the depression in the fuel tank, which may have negative effects on the aspirated fuel flow.

The strainer of the tank needs to ensure a primary filtering of the fuel to avoid the rapid clogging of the fuel filter.

The connection pipes should have no fissures or deformations.

The fuel filter shall be replaced periodically, or whenever it may be needed.

The lack of tightness of the system leads to the loss of pressure having negative effects upon the motor and the degree of pollution.

A global appreciation parameter of the technical state of the motor is the compression pressure, the value of which gives a general image on the degree of wear and pollution of the motor. Determining the compression pressure is made with the help of a specialised device (compression tester or compression graph) keeping in mind certain measurement conditions. The values of the read pressures for each cylinder of the motor as well as the difference between their maximum and minimum value need to be comprised between the limits set by the producer. On the contrary, it is necessary to intervene on the engine level in order to re-establish the corresponding technical state. Moreover, special attention is to be given to the blocking control of the distribution and the thermal al range at the valves.

Due to imperfect tightness of the piston-segments-cylinder ensemble, the casing of the motor accumulates a considerable amount of un-burnt gases, which together with the oil vapours mix and create an extremely polluting chemical agent. Moreover, the pressure created in the engine case forces the elements which create tightness and deteriorates them releasing harmful chemical compounds into the environment. In order to avoid all the previously stated facts, a re-suction system is therefore used, which has the role to catch up the gases of the engine case and introduces them back into the admission system of the engine by-passing the air filter. Oil vapours mixed with engine case gases shall be therefore separated through decantation and sent back into the oil tank of the engine. The malfunction of this system leads to the exaggerated increase of the degree of pollution of the engine. It is why it is imposed to maintain the cleanliness and tightness of the system.

The admission system of the engine may create pollution problems if it is not maintained correspondingly. It is why it is imposed to maintain the cleanliness and tightness of the system.

The air filter of the admission system needs to be replaced periodically, not respecting this set of rules leads to the increase of fuel consumption and the degree of pollution of the engine due to the clogging of the filter.

The fumes' exhaustion trajectory needs to be tight sealed and needs to present no deformations or blows which may render more difficult the exhaustion process.

2.2. Emissions' reduction methods used in transportation

Fumes emissions which are limited by law are carbon monoxide (CO_2), hydrocarbons (HC), nitric oxides (NO_X) and particle (PT or PM). Carbon dioxide is also added to this list (CO_2), a limitation which imposes the decrease of the specific fuel consumption.

Methods for the reduction of emissions are therefore divided as follows:

- active, fight the creation of emissions by optimising combustion – the combustion procedure, supercharging and intermediate cooling of admission air, reducing oil consumption and sulphur contained in the fuel;
- passive, their purpose being the retention and oxidation of particles after they are created in the combustion chamber – post-treatment of burnt gases, particles filters;
- In the case of CO and HC polluters as well as the organic soluble fraction of particles, the passive methods for the reduction of emissions are identical as for the ICE using thus oxidation catalysers.

In the case of SIE, the homogenous air-fuel mixture is found in a narrow range around the stoichiometric ratio, while the burnt gases may pass though the trivalent analytic converter, being possible, simultaneously, the oxidation reaction of CO and HC, as well as the reduction of NO_X. Recently, passive methods for the treatment of burnt gases have been developed, based on catalytic reactions for the reduction of NO_X. The active reduction of NO_X is considered to be difficult due to the three compromises it generates: fuel consumption, CO_2, particles. The two main factors which influence the combustion are taken into consideration: the temperature of the combustion chamber and the local O_2 concentration.

The increase of temperature in the combustion chamber is equivalent to the increase of temperature of the warm source, according to the second principle of thermodynamics and implicitly of the thermodynamic efficiency for a process which is considered ideal; qualitatively, the increase of temperature in the combustion chamber leads to the decrease of fuel consumption and O_2 and CO_2, favouring the production of NO_x. The decrease of NOx using passive methods was achieved though the development of catalytic treatment techniques of exhaust gases of diesel engines: the methods are thus divided into:

- Non-selective reduction, **NSCR** (Non-Selective Catalytic Reduction);
- Selective reduction, **SCR** (Selective Catalytic Reduction).

For the production of the number of particles the particles filters are used.

3. DEVICE FOR THE REDUCTION OF POLLUTING EMISSIONS OF THE ICE

In order to reduce the polluting emissions of ICE, together with the constructive modifications of the actual engine, a series of devices were realised which contribute significantly for the legal programmed norms to be met.

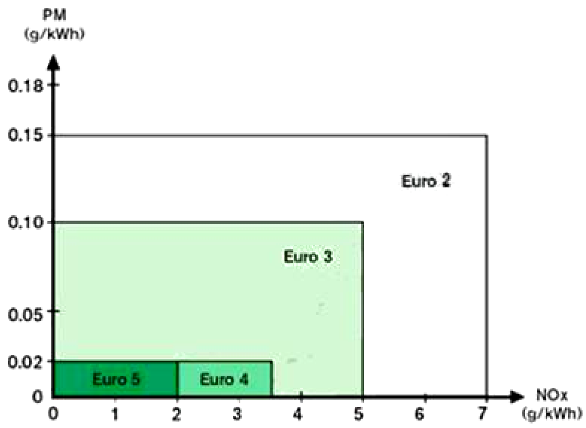

Fig. 1. European pollution normative

The hereto figure presents a diagram which indicates the measure in which the European norms reduce the NO_x and particles emission.

3.1. Catalytic converters

In order to satisfy the more and more rigorous norms concerning pollution, thermal engines have begun to be equipped with catalytic converters starting with the 80s. The construction of the **Catalyser** installed on these engines is similar to the previously presented one, the porous ceramic element being covered with a thin layer of platinum. Oxidation reactions of the carbon monoxide and un-burnt hydrocarbons take place inside at temperatures comprised between 200 and 350^{o}C and they are transformed in to CO_2 and water vapours – it is therefore a two way catalyser.

The oxidation of the sulphur in the fuel occurs above this temperature, process the result of which is sulphur dioxide and trioxide, two extremely harmful substances. After the catalyser, only in some cases, a sensor similar to the lambda sensor previously presented is brought forward, with the role of sending to the main computer data regarding the quality of the mixture. It represents the most spread solution for the reduction of polluting emission of the ICE, and have allowed for it to be comprised within the described parameters imposed by legislators in the field.

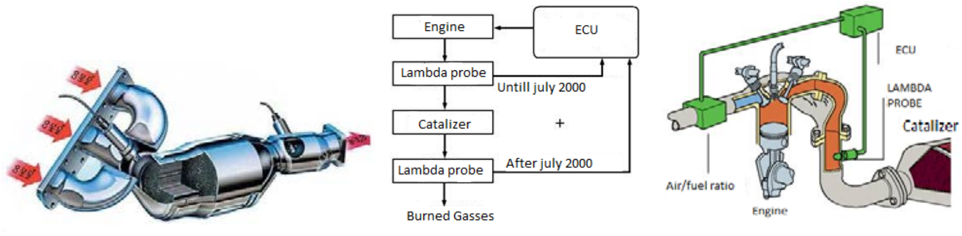

Fig. 2. Catalytic convertor

Catalytic converters are installed as close as possible to the engine in order to reduce heat losses and to ensure a rapid heating. There are two types of catalytic converters:

1. Two ways catalytic convertors used in ICEs
2. Three ways catalytic converters. SIEs no longer use two ways catalytic converters, but the three ways one.

3.2. The LAMBDA sensor

It represents the main sensor which allows correct mixture dozing. Together with the significant reduction of specific consumptions it ensures the optimum operation conditions of catalytic converters.

Figure 3 presents the sensor as a whole (a) and section (b).

The zirconium dioxide element, brought to a temperature of 300^{o}C, realises a potential difference between its interior side (which constant concentration environmental oxygen reaches) and the exterior one (which the oxygen of burnt gases reaches). The measure of the generated tension depends on the concentration of oxygen in the exhaust gases. Consequently, this tension is a precise indicator of the combustion of the motor, information taken over by the numeric calculation system. This, based on a series of programs, and on the data supplied by other sensor as well, commands the execution elements of the mixture dozing system.

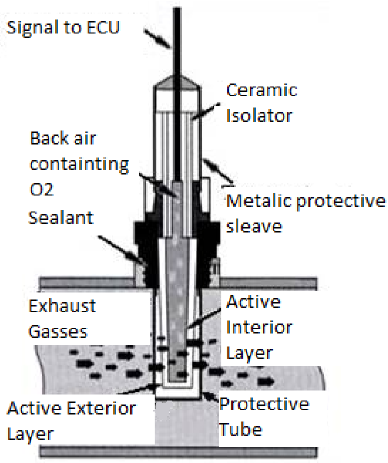

Fig. 3. Lambda sensor

1. is the connection cable to th process computer;
2. it is a series of holes through which environmental air into the zirconium dioxide element;
3. is the metallic protection case;
4. allows for it to be screwed to the exhaustion gallery, as close as possible to the outlet of burnt gases of the engine;
5. the part which resides in the burnt gases stream.

The problem of this sensor, if it is started cold, is the relatively increased heating time. Therefore self heating lambda sensors have been created, reducing the unwanted effects occurring on catalytic catalysers in case of cold starting.

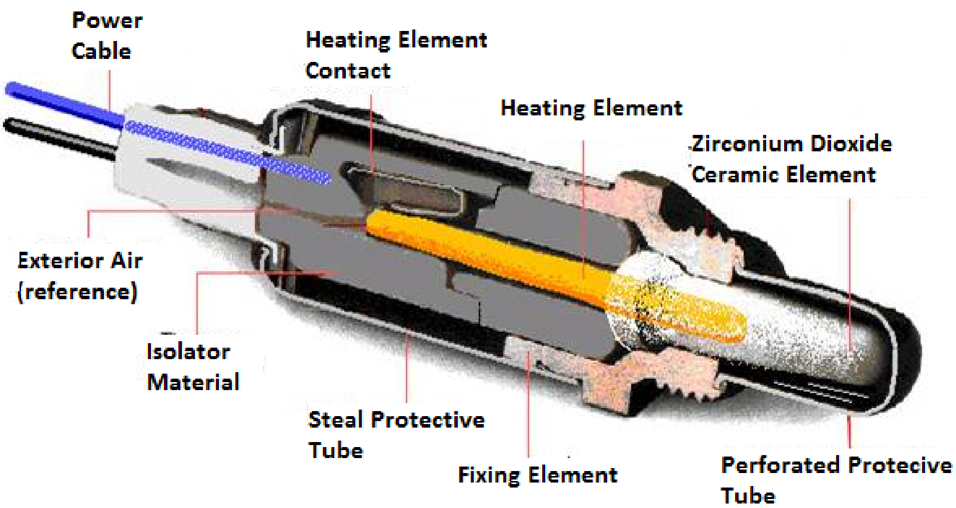

Fig. 4. Self-heating lambda sensor

The hereto figure brings forward the section of a self-heating lambda sensor. Actual generation Internal combustion engines are foreseen with two lambda sensors. The second sensor is placed after the catalytic convertors. It sends information to the main calculation unit which compares them to the ones of the main lambda sensor placed before the catalytic convertors. The main calculation unit may thus establish the measure in which the catalytic convertors meet the established parameters.

3.3. ECR and EGR systems

The use of the EGR system, apparently a cheaper solution, supposes the degradation of combustion which has direct effects on the fuel consumption and the performances of the engine. Also, it determines short intervals of oil change. This type of system implies minimum maintenance and does not require the injection of special additives. In order to meet the Euro 4 and 5 pollution norms, it requires a post-treatment of mechanical particles (particles filter). The major disadvantage consists of the fact that it does not allow for it to meet the Euro 6 pollution norms. The ECR system implies the use of a special installation which comprises the additive tank, the injection pump, the injector, the electronic command unit, the NOx sensor, elements which increase the production cost and require additional installation places. The special additive and the OBD (On-board diagnostics) monitoring the AdBlue level of the tank, the NOx concentration of the exhaust fumes and the entire operation of the system, is also added.

In certain conditions, the NOx concentration exceeds 7 g / kwh, the AdBlue tank is empty or the system cannot monitor the emission of NOx during 50 hours of engine operation, the OBD reduces the power of the engine with 40% to prevent the emission into the environment of nitric oxides concentrations over the admissible limit. The NOx concentration monitoring system is active only when the following re conditions are met: the temperature of the environment is between -7 to +35 ^{0}C; the altitude is less than 1600 m ; the temperature of the cooling liquid is 70 degrees Celsius. The major advantage it brings is the reduction of fuel consumption with approximately 5%, as well as the possibility to use the engine in optimum conditions, leading therefore to maximum performances. In Figure 5 brings forward the diagram of a post treatment system which uses the SCR system. The system proposed by Bosch contains the following: catalytic oxidation converter – DOC, temperature transducer before the SCR, NOx transducer installed both before and after the SCR, AdBlue tank, transport module – ensures the transport of the AdBlue solution to the dozing module. These elements are interconnected through the electronic command unit.

The SCR systems have surfaced as a need for heavy vehicles, being the only efficient solution which is able to ensure for the vehicles to meet the Euro 4 standards onward. Therefore, beginning with 2002, it has been decided on a European level to use the NOx emissions reduction systems with AdBlue injection.

As it was estimated by ACEA, the big automotive producers, as a consequence of the results obtained with large vehicles concerning pollution, accepted the SCR system for their vehicles. Audi successfully uses a revolutionary pollution-removal system by post-treating the exhaust fumes, Figure 5, on their Q7 model. The exhaust fumes coming from the engine are first introduced into an oxidation catalytic convertor situated close to the engine. Hydrocarbons and carbon monoxide, here, are transformed into carbon dioxide and water. In the second step, the gases reach the diesel particles filter where they are eliminated from the gas flow and accumulated within the structure of the filter, which is regenerated at regular time intervals. Nowadays, both the catalytic converter and the particles filter are indispensable components of the standard exhaust system and post treatment on vehicles with diesel engines.

Fig. 5.a. The organisation of the post-treatment system of exhaust fumes for Audi Q7

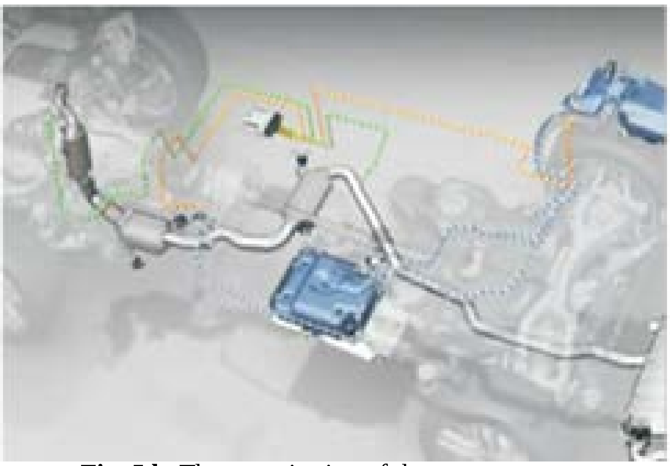

Fig. 5.b. The organisation of the post-treatment system of exhaust fumes for Audi Q7

4. CONCLUSIONS

The production costs of urea are mainly determined by the energetic costs and materials to which the cost of distribution is also added, the final price being determined by the distribution and necessary investments required for the filling stations to undergo. Moreover, it is to be reminded of the fact that the final price shall depend on market demand and how fast the SCR technology is introduced on the market. The AdBlue solution consumption represents 5% of the fuel consumption, while the fuel economy which the use of this solution makes possible, is related to the amount used. Therefore, the price of the solution should be smaller than that of the fuel, this aspect acting as an incentive to for the consumer to use. An ulterior motivation might be the reduction of taxes applied to vehicles equipped with SCR systems in order to partially compensate the additional investments made for the vehicle.

The major advantage of the use of SCR systems, besides the costs, consists in the fact that it allows for vehicles to meet with Euro 6 pollution norms. It is to me observed that AdBlue post treatment does not determine sacrifices from the point of view of performances and fuel consumption. Together with the additional costs introduced for the production of vehicles, SCR systems require special infrastructure, in the sense that it needs to build structures like conventional fuel supply.

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