COMBUSTION ENGINES – ENVIRONMENTAL MENACE

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INTRODUCTION

Air pollution is a serious problem in XXI age as a result of civilization development and industrialization processes. About 60% of air pollution in the atmosphere air comes from car combustion engines. Vehicles with sparkle ignition engine (ZI) and Diesel engine (ZS) are a source of harmful solid gas substances emission. One of the effective environmental protection ways, confronted with the real threat carried by motorization, is full execution of requirements as to emissions of exhaust gases and noise, during periodical technical investigations in stations of vehicles control as well as introduction of road control as to the emission of pollutants.

Requirements in this field are passed in the decree of the Minister of Transport and Sea Economy from the 7th of November 1994 concerning the technical condition and surveying of vehicles in Poland, the Journal of Laws No. 116, 1994 and the Journal of Laws No. 155 from 1996 as well as the decree of the Minister of Transport and Sea Economy from the 17th of March 1993, the Journal of Laws No. 21, 1993.

The present paper discusses in detail the existing threat for the environment from mechanical vehicles, technical state investigations methodology for vehicles and sample results in a chosen vehicles group.

THREAT FOR NATURAL ENVIRONMENT

Pollution of the natural environment means contamination of water, soil or air. Air is not only an indispensable for life processes oxygen container, but it is a part of natural environment, affecting the state of human health. Clean atmospheric air as a mixture of gases is illustrated in Fig. 1. Fig. 2 presents the frequent gas pollutants of air.

Constantly growing concentration of The above mentioned chemical compounds and limitation of the possibility of their assimilation result in climatic change and disturbances of natural phenomena on the Earth. Fig. 3 below presents global emissions of pollutants, involving both natural and anthropogenic emissions proportions as parts of main sources of air contamination.

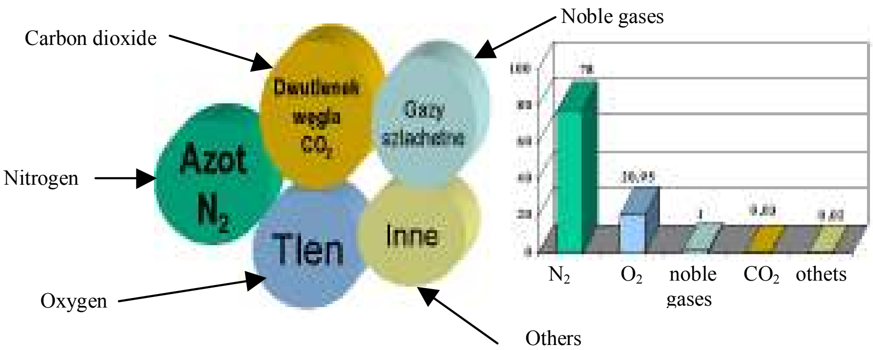
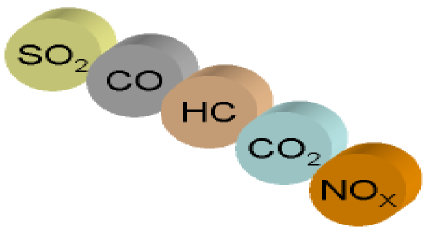


Fig. 1. Composition of clean atmospheric air

- sulphur dioxide
- carbon monoxide
- hydrocarbons
- carbon dioxide
- nitric oxide



- hydrogen sulfide
- carbon disulfide
- ammonia
- organic solvent and mineral acid vapour

Fig. 2. Gas pollution of air

Most of carbon monoxide and sulphur dioxide have been produced as a result of human activity, which results in general pollution of air.

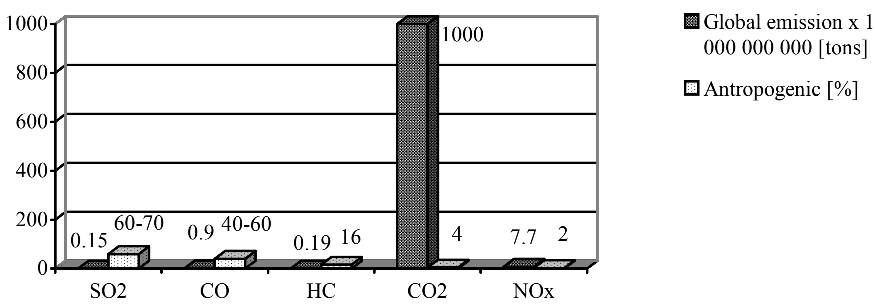


Fig. 3. Global pollution emissions

Neutralization of harmful chemical compounds is a distinct element of environmental protection, where forests and soil are main recipients of pollution. Possibility of assimilation of some chemical compounds was presented in Fig. 4.

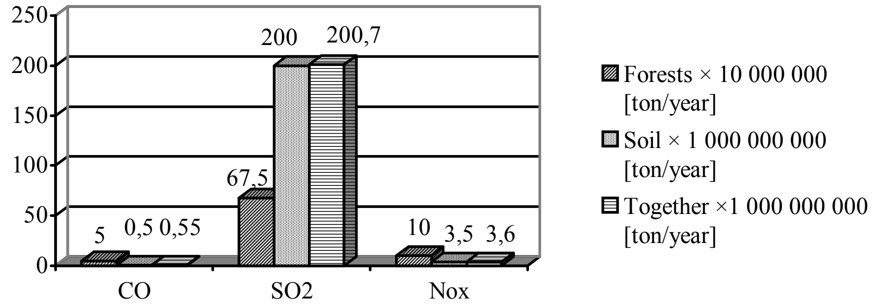


Fig. 4. Ability of pollution absorption through forests and soil

As it results from the analysis of Fig. 3 and 4 the ability of absorption of carbon monoxide and nitrogen compounds through soil and forests is insufficient in relation to their annual emission. According to UN experts, in order to reduce the greenhouse effect, which results in the disorders of weather all over the world (violent hurricanes, long droughts and dangerous storms), we need to reduce the emission of carbon dioxide (CO_2) by 60%. It is the task for the developed countries, whose occupants make up 23% of the earth population and are responsible for 75% of the world emission of CO_2 and other harmful gases. A relative sum of the emitted atmospheric pollution value per head in some sample countries is illustrated by Fig. 5 (average value in the world = 1,0).

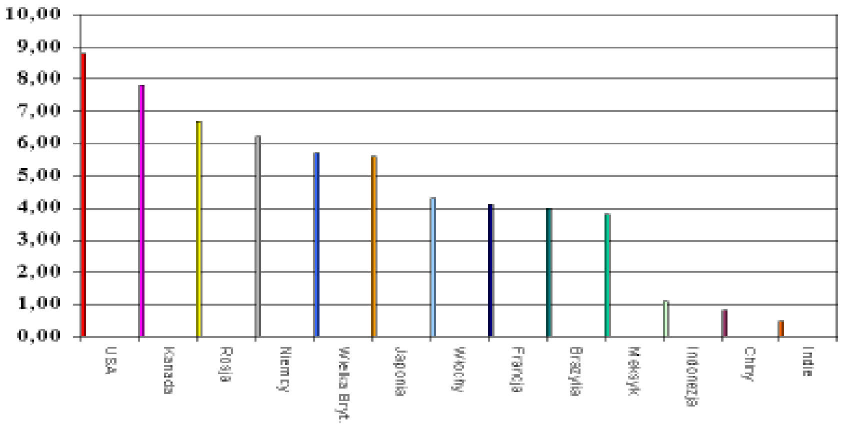


Fig. 5. Value of emitted atmospheric pollution in chosen countries

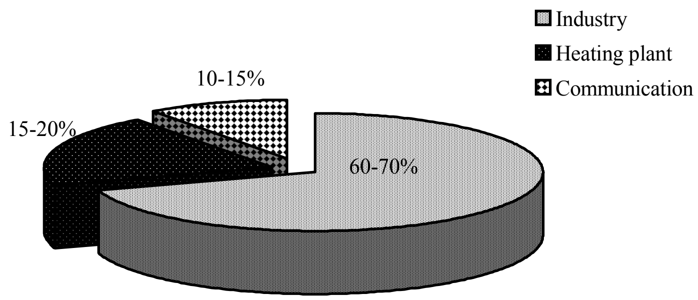


Fig. 6. Sources of air pollution in Poland

THE PARTICIPATION OF TRANSPORT SERVICES IN ENVIRONMENTAL POLLUTION

Vehicles emit combustion gases which are produced as a result of abrasion of brakes tyres and road surface. The country annual estimations of emission levels of harmful substances from all the vehicles, machines and devices driven by combustion engines were introduced in Fig. 7.

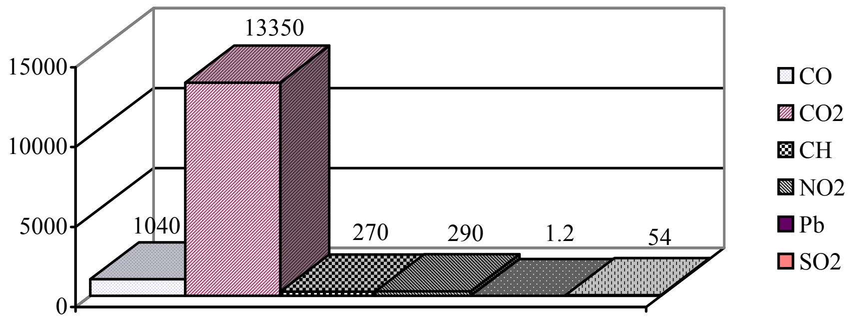


Fig. 7. Influence of transport services on air pollution, in thousand tons

The level of pollution produced by cars and other means of transport depends on many factors, such as:

- intensity and fluency of movement,
- engine construction,
- use of afterburners and filters,
- kind of fuels,
- technical state and conditions of vehicles' exploitation.

Table 1. Quantitative composition of combustion engine gases with sparkle ignition engine (ZI) and Diesel engine (ZS)

Engine gases composition	Measurement unit	Engine	
		Sparkle ignition	Diesel
Nitrogen	% of capacity	74-77	76-78
Oxygen	% of capacity	0.3-8.0	2.0-18
Steam	% of capacity	3.0-5.5	0.5-4.0
Carbon dioxide	% of capacity	5.0-12.0	1.0-10
Carbon monoxide	% of capacity	5.0-10.0	0.01-0.5
Nitric oxide	% of capacity	0-0.8	0.002-0.5
Carbohydrates	% of capacity	0.2-3.0	0.009-3.0
Aldehyde	% of capacity	0-0.2	0.001-0.009
Gas black	% of capacity	0-0.04	0.01-1.1

In Table 1 an average quantitative composition of combustion engine gases was introduced with division into sparkle ignition engine (ZI) and Diesel engine (ZS).

CRITERIA OF POLLUTION ASSESSMENT

Measurement of the toxicity degree of a vehicle's sparkle ignition engine's exhaust gas is carried out during technical check-out of vehicles. In Poland in accordance with the decree of the Minister of Transport and Sea Economy from the 7th of November, 1994 about exhaust gases of cars with sparkle ignition engine (ZI), the measure indication of carbon monoxide on idle gear should not exceed:

- 4.5% (bike 5.5%) for first time registered vehicles before 1st October 1986,
- 3.5% (bike 4.5%) for first time registered vehicles before 1st July 1995,
- 3.5% (bike 4.5%) for vehicles equipped into engine cubic capacities below 700 cm3 for first time registered before 31st of December 1996.

For vehicles registered after the 30th of June 1995 – cars 0.5% (CO); 100 ppm (HC) measured on idle gear of engine, bikes 4.5% (CO).

For engine speed from 2000-3000 r.p.m.:

- car – 0.3% (CO); 100 ppm (HC); combustion air factor (λ) 0.97-1.03,
- bike – does not concern.

In accordance with the decree of the Minister of Transport and Sea Economy from the 17th of March, 1993 about the technical condition and surveying of the vehicles equipped with Diesel engines (ZS) the following pre-cautions should be taken: fogging of exhaust gas, measured at free acceleration of engine in range on idle gear rotatory speed till maximum rotatory speed, expressed in form of coefficient of light absorption should not exceed:

- 2.5 m^{-1} for unsupercharged engines,
- 3.0 m^{-1} for supercharged engines.

This decree is valid since 1st of May, 1993 and it involves all the vehicles equipped with this engine type.

In the EU countries, the new restrictive norms of emissions were issued on the 1st May, 1993. These norms limit the emission of harmful gas substances included in exhaust gases, called commonly – EURO3:

– current norm related with toxic components emission for cars equipped into sparkle ignition engines (ZI). Emission (g/km): CO – 2.3; HC – 0.2; NO_x – 0.15;

– current norm related with toxic components emission for cars about payload till 3500 kg, equipped into Diesel engines (ZS). Emission (g/km): CO – 0.64; HC + NO_x – 0.56; PM – 0.05;

– current norm related with toxic components emission for cars about maximum authorized payload above 3500 kg, equipped into Diesel engines (ZS). Emission (g/kWh): CO – 2.1; NO_x – 5.0; HC – 0.7; PM – 0.1.

To check and control the toxicity of exhaust gases components for sparkle ignition engines we use exhaust gas analysers. Measurement of CO, CO_2, HC takes place as an over-exposure infrared radiation of exhaust gas, meanwhile over-exposure O_2 by electrochemical method. Revolution counter is connected into ignition cable and heat sensor of oil temperature is connected to the place of vehicle oil level measure. The analyser is adapted to work in the temperature from +5 to +40°C at relative humidity till 90% and atmospheric pressure 1000 hPa ± 25 hPa.

Set of exhaust gases emission soot level in Diesel engines (ZS) complies smokemeters:

– filtration smokemeters,
– light obscuration smokemeters.

EXAMPLES OF ENVIRONMENT POLLUTION RESULTS

To check the level of environmental pollution by mechanical vehicles, research was carried out. It referred to a group of 150 vehicles equipped with sparkle ignition engines (ZI). It considered 50 vehicles in each category of exhaust gas emission norms. Results of these investigations were presented in Fig. 8.

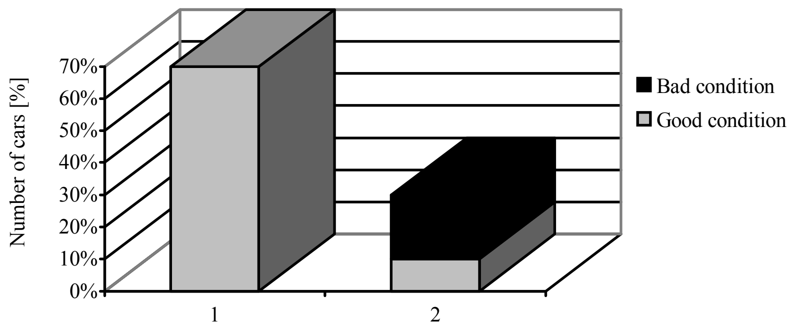


Fig. 8. Results of investigations of vehicles registered before 1st of October 1986

As the results of the research showed, 70% of the vehicles from the studied group will pass the technical chec-out in the permitted range of CO emission, however 30% will not be admitted to roads. However, small regulations are admitted at the Vehicle Control Stations, for a group of 2-10% vehicles could have adjustments made as to arrangement of air-fuel components or exchange of the air filter. However, 20% cannot be driven within the area of The Polish Republic.

Comparison of toxic emissions of CO by Polish and foreign vehicles was the next stage of the investigation, and the results were presented in Fig. 9.

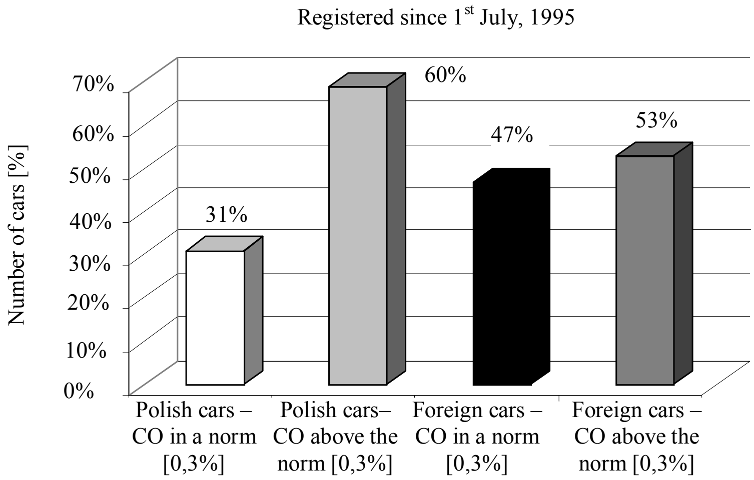


Fig. 9. Content of CO for Polish and foreign vehicles after 1st of July 1995

In wider investigations except CO, composition of air-fuel components were measured and presented in Fig. 10.

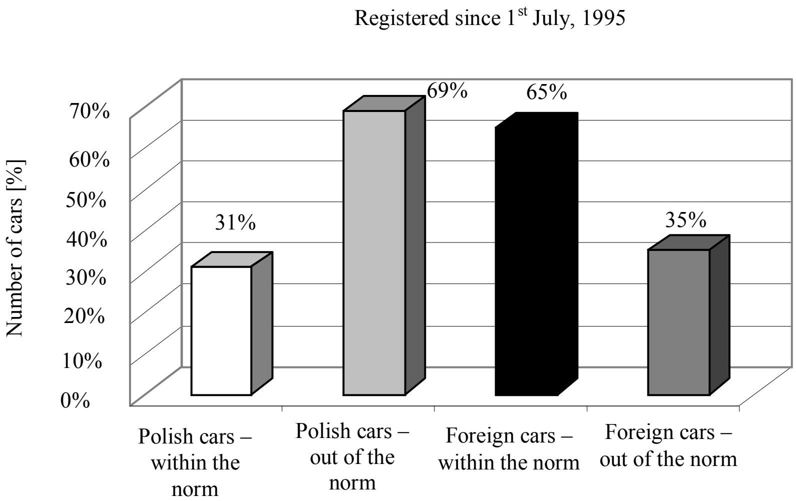


Fig. 10. Content of λ for Polish and foreign vehicles after 1st of July 1995

Summing up the results of the studied vehicles, all the dependencies were taken down and proportions of the part of vehicles were counted, which fulfilled all the conditions simultaneously, i.e. content of CO, HC, as well as combustion air factor λ. Results of this were introduced on fig. 11.

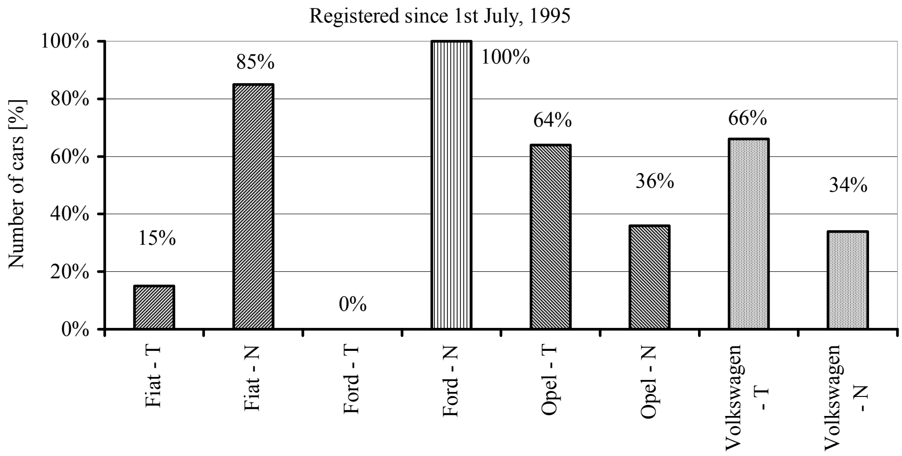


Fig. 11. Results for vehicles mark registered after 1st of July 1995

Analysing proportional part in every group, the best results were shown by the vehicles of Volkswagen make, showing the smallest emission per vehicle. The second in turn came Opel with a small loss; the third Fiat; however Ford showed the largest emission of exhaust gases. Generally we should stress, that the received results are unfavourable and they testify to great damage to the environment from the cars on our roads.

WAYS OF FIGHTING WITH EXCESSIVE EMISSIONS

Exhaust gas cleaning should lead to the maximum decrease of harmful components in car exhaust gases. The exhaust gases toxicity limitation is possible by proper support of an engine's technical state and proper control of the following systems: timing gear, ignition, supply, exhaust and airing of crankcase. They are necessary conditions, however insufficient to the fulfilment of the present requirements of the natural environment's protection in the European Union. Further reduction of harmful components emission in the exhaust gases from spark ignition (ZI) engines was possible with the help of **catalytic reactors**, (mistakenly called exhaust gases catalysts). Catalytic reactor is a ready to use aggregate in tin casing with properly placed catalyst, presented in Fig. 12.

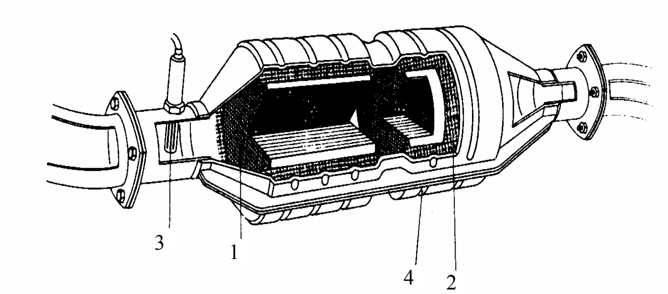


Fig. 11. Building of three functional catalytic reactors: 1 – ceramic monolith with catalytic layer, 2 – elastic braid from wire, 3 – combustion air factor sensor, 4 – casing from stainless sheet metal

A substance taking part in a chemical process of a different substance is a catalyst, accelerating or giving a desirable direction, although it itself does not undergo any chemical transformation. A catalyst transforms harmful exhaust gas components into harmless components, which concerns: hydrocarbons (CH); carbon monoxide (CO), which become oxygenated, creating harmless relationships CO_2 and H_2O, meanwhile nitric oxides Nox after a reduction decompose into N_2.

A cordierite is a material on which a catalytic substance settles, crystalline mass from magnesium oxide MgO, aluminium oxide Al_2O_3 as well as silicon dioxide SiO_2. Magnesium – aluminium silicate stands out with small thermal expansibility at large heat resistance.

Currently two kinds of carriers are used:

- ceramic – made from cordierite,
- metal – got through twist thin, shapen heat-resistance foil.

Temperature becomes essential in the selection of catalyst carrier material, because in exploitation it is constantly situated in hot exhaust gases. Currently applied ceramic catalytic carriers are in form of a cylinder about circular section or oval, in form of monolith from 8000 oblong tubes about square section infatuated alternatively. Active surface carries out 15-25 m^2, however thickness of sectional sides is 0,15 mm. Metal carriers in result of the small thickness of channel sides 0,05-0,07 mm at their equal number, have an isolated surface from 20 to 30% larger from ceramic carriers. This characterizes larger working effectiveness as well as smaller resistances of flow of exhaust gases through better geometrical and physical character in comparison with ceramic. Besides, metal carriers have best thermal conductivity and they are more resistible to thermal shocks and mechanical shocks as ceramic carriers, but they are expensive and so far they are used only in luxurious cars. Settling of ceramic monolith (catalyst) was the most important part in a catalytic reactor considering his small resistance to hitting and mechanical burdens. Durability of a catalyst amounts from 80 000 to 150 000 km.

Diesel engines (ZS) emit small amount of carbon dioxide (CO_2), poisonous carbon monoxide (CO) and none burned carbohydrates (HC). The main problem is emission of nitric oxides NO_x which are responsible for acid rains, as well as most important thing, solid particles of soot (PM) connected with hydrocarbons and sulphur). Solid particle (PM) remind micro balls about diameter 0,1 to 1 micron. These microscopic elements have to be filtered out. Creating of these microscopical elements closely depends on combustion process, but also on quantity of gas oil and concentrations of sulphur. To decrease the content of hydrocarbons and carbon monoxide in Diesel engines' (ZS) exhaust gases, only oxidizing catalysts are applied. Here, carbon monoxide and hydrocarbons react with oxygen contained in exhaust gas and they are transformed into carbon dioxide and water steam. A serious problem in case of Diesel engines (ZS) exhaust system is a decrease of solid particles (PM) emission, emitted alongside with exhaust gas in form of soot. The so far used devices serve as passive stoppers, resulting in mechanical stopping of particles by the so-called soot filters placed in final sections of exhaust systems. They require periodical exchange or cleaning.

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SUMMARY

The present paper presented the essential problems concerning the limitation of vehicles exhaust gases toxicity degree from sparkle ignition engines as well as emissions of solid particles from Diesel engines exhausts. Advice and present tendencies were described in limitation of the levels of these emissions. Ways of limiting solid particles emission were presented as well as the latest devices reducing this emission. There is no doubt, that in the coming years Diesel engines, thanks to the latest solutions (Common Rail, FAP system, solid particles filter etc.) will be progressively replacing sparkle ignition engines.