Diesel cars and the environment

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Abstract. Signing of Kyoto Protocol in December 1997 in addition to the UN Framework Convention on Climate Changes has changed the automotive industry development priorities. Since that time the environmental requirements that are of paramount importance in the modern world, pushed the economic indicators to second place. Over the last twenty years, there has been rapid development of diesel engines both for passenger cars and for trucks. Engines capacity has significant increased; exhaust emissions faced a sharp decreased due to the reduction of NO_x and soot for the most part. There was a significant reduction of noise level and fuel consumption; the reliability of engines has improved, as well as maintenance intervals have increased, especially for truck engines.
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Introduction

Designing a new engine, a German engineer Rudolf Diesel 's intention was to create an efficient, convenient and easy motor capable displace steam engine with its dangerous and cumbersome steam boiler and a low coefficient of performance (COP). The secret of the success of his development was to self-ignition of the fuel mixture. This very property remains the main one in diesel engine today. At first, diesel engines were installed only on trucks, where the reliability and efficiency are needed primarily, while the size, weight and comfort can be sacrificed; but in 1929 the first car with diesel engine was produced. Diesel engine has been constantly improving for more than one hundred years [1]. The pressure was increased; separate combustion chambers system was replaced by the direct injection. Technical breakthrough was made by the introduction of high-pressure axial piston pump of distribution type for the direct diesel injection under the pressure of about 1000 bar directly into the cylinder, thus ensuring efficient combustion [2]. In the late 1990s, the engines were equipped by the several varieties of direct injection systems, which included radial piston dispenser pump, pump-injector unit technology, and Common Rail system. All these figures are very closely connected with the quality and precise fuel dosage, which in turn depends on the reliable operation of the fuel system. As a result, the engine power has increased and fuel consumption and emissions have decreased [3].

The main part

Diesel engine counts more than 120 years history, but only in recent years the development of its construction has been going rapidly. Modern motors are much more advanced than they were 10-20 years ago, most of them is equipped by charging-turbine set with air intercooling, many of them has liter capacity more than 37 kW / liter (50 hp / l) [4]. Modern diesel engines are very close to gasoline engines on the parameters of noise and reliability, while keeping their advantages in efficiency and specific characteristics. Today the diesel has a broad scope, a large range of facilities and a high efficiency up to 50%, which cannot be achieved by any other type of engine, so it cannot be replaced (see table 1).

Table 1. Diesel engines max efficiency

Volume l / cyl	1800	20	2	0.5
Frequency min^{-1}	60	1000	2000	4500
Capacity kW / l	2	20	30	55
Capacity kW	21600-32400	4800-6400	360-480	165-220
Maximum effective efficiency	52%	48%	45%	41%

Due to the development of electronics, the progressive changes in the fuel supply to the injectors of diesel engines have been implemented.

The main feature of the Common Rail system is that the fuel is supplied into all cylinders under the constant pressure, allowing up to eight injections per cycle. Thus, it is possible to realize the complex laws of fuel supply, demanded by the engines with undivided chamber [5]. Fuel economy is about 10-15%; capacity has increased up to 40%; emissions of nitrogen oxides and carbon have been significantly reduced, as well as noise level (10 dB reduction).

Second birth of pump-injector unit allowed increasing the injection pressure up to 205 MPa, and in the run up to 250 MPa. One uses a small pre-injection with fuel dose equals to 1-2 mm^3 for soft and clean operation; the fuel injection takes place in

dependence on the speed of the camshaft rotation. The combination of the ultra-high pressure injection and other parameters of the diesel working process made it possible to reduce the content of nitrogen oxides in the exhaust.

"Siemens" Concern patented piezoceramic injector, which runs four times faster than the previous ones. One managed to create a 280-ply piezoceramic, expandable to 80 microns in just 0.1 ms; that is enough to affect the needle nozzle with a force equals to 6300 N. At the same time, the voltage of the vehicle electrical system is used for control.

One of the way to improve the fuel economy and environmental parameters is a conversion on work on gas [6]. It should be noted that the diesel engine cannot work using gas only; "clean gas" diesel is impossible even from theoretical point of view, because its auto-ignition temperature is much higher (about 700° C vs. 320-380° C in diesel fuel).

The simple version is an adaptation ordinary diesel to run on a mixture of diesel oil and methane, it is so-called gas-diesel engine. In this case, the work requires feeding the 15-30% of normal portions of the diesel fuel into the cylinders at the end of the compression stroke, the so-called seed portion, which always burns completely. Operating in this mode with 70-85% portion of natural gas as the fuel, a typical black smoke, which is usual for diesel engine, disappears completely. Moreover, the gas diesel has an increased resource and the service life of oil in comparison with the conventional diesel engine. At the same, time the noxious emissions such as soot, hydrocarbons, CO, benzopyrene, nitrogen oxide, etc. come down to 90%. In this case, a good economic efficiency combines with the unique indicators of exhaust emissions.

Another way is more radical. The fuel equipment of the diesel engine should be dismantled, and then the gas equipment (HBO) should be installed. One mounts the spark ignition system with microprocessor control and ignition angle corrected by lots of parameters. The system allows the conversion of diesel engine to gas engine, using a natural gas (methane) or liquefied petroleum gas (propane-butane) as a fuel. The engine is derated, the compression ratio is lowered. The result is a forced gas engine with a slight increase in fuel consumption in comparison with a diesel engine. As for power, gas engine would not disgrace the diesel, but its maximum torque is slightly shifted to higher turnover, so the shift control will differ from diesel mode. The advantage of this method is an excellent economic performance and maximum environmental benefits. Accordingly, the environmental indicators were optimal; the air emissions have decreased up to 90%. However, the disadvantage of this method is that the gas engine cannot run on diesel fuel, and returning the engine to diesel mode is possible, but very expensive task, the costs incurred are generally comparable to the cost of an engine overhaul.

Conversion of the diesel cars into gas powered with their relatively low fuel consumption is not advisable, since the payback period of additional equipment spread over 6-7 years, with an annual mileage of 15 thousand km. From an economic perspective, the most profitable is to set auto gas system on heavy diesel vehicles, medium and light trucks and public transport. The usage of both natural gas and liquefied petroleum gas, solves two global problems:

- The cost of transport decreases twice (in average);
- Use of gas reduces the amount of harmful emissions into the atmosphere.

In May 2012, EU countries, the members of the UNECE Convention "On Transboundary Air Pollution", included the black carbon (or soot), as a component of particulate matter. Black carbon is known as a short-term climatic factor, as it has a strong influence on the process of global warming, 680 times greater than CO2, so the need to reduce its emissions today is a major challenge in the fight against climate change (see Table 2).

Table 2. Standards for particulate emissions

	Vehicles weighted more than 3.5 tons Regulation number 49 on the UNECE		Cars Regulation number 83 on the UNECE	
	Adoption year	Allowable rate, g / kW • h	Adoption year	Acceptable standards for particulate emissions in g / km
Euro - 3	2000	0.1		
Euro - 4	2005	0.02		
Euro - 5	2008	0.02	2009	0.05
Euro - 6	2013	0.01	2014	0.05

The considerable changes in the reliability of environmental indicators were introduced [7]. Vehicle mileage for which the environment requirements are to be supported increased to 160 thousands km (80 thousand km Euro 4). This means that during the certification tests of new cars one must provide significantly greater margin with respect to the emission limit values than was required previously.

The rules # 83-06 and # 83-05, which came into force on December 9, 2010, contain the requirements of Euro 5. Comparing the limiting values of the Euro-5 and Euro-4 Regulation № 83-05 for diesel engines, we can make the following conclusions:

- CO – requirements are identical;
- NO_x – Euro-5 requirements are tighten by 30%;
- THC + NO_x – Euro-5 requirements are tighten by 23–24 %;

• Dispersed particles – Euro-5 requirements are tighten by 5÷12 times in dependence of the vehicle type.

Limit values for Euro 5 are presented in Table 3.

Table 3. Euro 5 limit values

Category	Class	Control mass, kg.	Limit values				
			CO L1 (mg/km)	NO_x L4 (mg/km)	THC + NO_x L2 +L4 (mg/km)	PM L5 (mg/km)	P L6 (quantity/km)
M	-	All	500	68	180	4.5	6.0×10^{11}
N_1	I	RM ≤ 1305	500	68	180	4.5	6.0×10^{11}
	II	1305 < RM ≤ 1760	630	90	135	4.5	6.0×10^{11}
	III	1760 < RM	740	108	280	4.5	6.0×10^{11}
N_2			740	108	280	4.5	6.0×10^{11}

Note: Carbon monoxide - CO; Nitrogen oxides - NO_x; total hydrocarbons and oxides of nitrogen - THC + NO_x; Weight dispersed particles - PM; number of dispersed particles - P.

Since 2010 there has been started the development of requirements for additional systems to reduce emissions (particulate filters, selective neutralization SCR NO_x analyzers, etc.) installed on commercial vehicles and buses. To reduce the emissions from diesel vehicles it is proposed to start the work on equipping the urban public diesel buses by exhaust gas neutralizers. Allocation of public transport in a separate section is not random, because it plays a huge role in the sustainable development of cities, being one of the most socially significant areas [8, 9].

Unbalanced power impacts in aggregates and components of the car, external influences from pavement irregularities cause motion vibrations which are transmitted to the body and through the roadbed on roadside space. Vibration can be viewed from two components: the impact on the occupants (driver and passengers), the impact on the surrounding objects. We can distinguish general and local vibration by the method of transmission on person. The first vibration is passed through the supporting surface on the body, causing the whole body tremors. The second one is transmitted through the hands of man. The driver of the car is exposed to general and local vibration, while passengers and pedestrians, located next to the roadway, are exposed only to general vibration. Oscillations and vibrations are the result of vehicle discomfort to the occupants.

Currently, due to the need of serious improvement of the environmental situation the intensive researchers of hybrid vehicles large-scale application opportunities are hold [10]. However, there is a problem of electromagnetic radiation associated with a large number of electrical sources. Electromagnetic fields of high energy density have harmful effects on the human body and the environment. The degree of impact is determined by the amount of energy of electromagnetic radiation, frequency and wavelength. The problem is becoming increasingly important with the rapid development of transport, despite the fact that the car is a relatively low-power source.

It is necessary to mention the fact that the electric motor generates far less noise and vibration than engines, because the sound energy production process is a certain proportion of the total energy produced by machines. Noise exposure is one of the most common forms of harmful physical influence on the environment, which leads to worsen reaction, causes fatigue, and has an overall negative impact on human health. Road transport is a major source of noise, and the noisiest are considered to be the trucks with diesel engines 90-95dB. Therefore, finding ways and means to combat these negative impacts is a vital task now [11].

Conclusion

The developers of modern diesel engines faced with the difficult tasks. On the one hand, there are the requirements of technical perfection, such as power, reliability, traction performance, efficiency and low cost. On the other hand, there is a need to meet ever increasing stringent environmental requirements. Today there is no doubt that the diesel engine provides the power and dynamics corresponding to or even better than the other types of engines. Due to the turbochargers with variable turbine geometry, which are standard now, modern diesel engines show a high torque even at low revs. Modern vehicles running on diesel are quiet and economical. Exhaust treatment systems, such Denoxtronic, further reduce emissions of nitrogen oxides, allowing fit even the most stringent standards such as Euro-6.

Modern life is unimaginable without a large number of vehicles, so we need to make serious steps to reduce the negative impact of transport on air quality. Only complex implementation process, planning, organizational and technical measures can lead to improvement of the environmental quality.

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