EFFECT OF DIESEL ENGINE DECARBONISATION ON SELECTED EXHAUST VALUES

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In this article, the authors refer to the measurement of acoustic emission, where they found that this methodology can determine the combustion characteristics in the combustion chamber of the engine and thus it is possible to confirm a better combustion process and overall reduction of engine noise after decarbonization. The formation of diesel exhaust soot is also supported by the authors' paper, in which they describe how such soot is formed and what effect the addition of special mixtures to the combustion process has on the formation of such carbon deposits. The article uses BG technologies for deep engine decarbonization, including intake and exhaust parts. This technology is one of many on the market, but it was only with this technology that the authors managed to achieve the relevant results that this article will introduce to. For the test, we selected vehicles that had a problem to pass at the emission control.

KEYWORDS

decarbonisation; exhaust; measurement, EGR, DPF

1 INTRODUCTION

Reducing emissions from internal combustion engines is now the number one issue, as every world's leading carmaker strives to develop engines that can meet the European Union's high emission standards or are looking for innovative forms of energy for the movement of commercial vehicles, whether using newly developed green fuels from renewable energy sources, or focusing on electrifying their vehicle portfolio, where energy is obtained from batteries installed directly in vehicles.

In this article, the authors refer to the measurement of acoustic emission, where they found that this methodology can determine the combustion characteristics in the combustion chamber of the engine and thus it is possible to confirm a better combustion process and overall reduction of engine noise after decarbonization. Based on this article, we can hypothesize that after complete decarbonization of the engine, we could use the same methodology to measure acoustic emissions to confirm our claims that such a decarbonization process will both improve engine performance, reduce its emissions and, last but not least, eliminate its noise when operating in real conditions, which will significantly reduce the negative impact on the environment [Dong 2020].

The resulting soot in diesel engines is also supported by the authors' article, where they describe how such soot is formed and what effect the addition of special mixtures to the combustion process has on the formation of such carbon deposits. They deal with the change in the characteristics of the engine, but especially with the positive effects with regard to the elimination of emissions produced during the combustion of such special fuel mixtures. In this article, the authors also deal with the efficiency of combustion with a high level of exhaust gas recirculation, where they state several facts that correspond to the hypothesis that professionally decarbonization of the internal combustion engine has a significant impact on removing all hydrocarbon deposits in the engine, which will ensure more efficient engine operation and reduces the content of harmful substances in the exhaust gases [Sun 2020, Yesilyurt 2020].

Many scientific teams deal with the reduction of emissions produced by diesel engines, where they do not primarily deal with the cleaning of the engine from carbon deposits, but deal with special additives to conventional diesel, which should guarantee the reduction of emissions [Abdrabou 2020, Uslu 2020a]. Harmful emissions from internal combustion engines have a high share of greenhouse gas emissions and therefore directly pollute the environment [Piotrowska 2024, Jayabal 2020, Woo 2020, Tucki 2019]. The authors deal with the efficiency of diesel combustion and its optimization in this article, where the combustion process takes place at a high level of exhaust gas recirculation. It is this method, which has been used for many years in all diesel engines, that results in the formation of carbon deposits in the engine intake manifold in the part through which the exhaust gases are recirculated from the exhaust manifold back to the intake manifold [Sun 2020]. Many studies and scientific teams are involved in reducing emissions and thus indirectly the formation of carbon deposits in the engine, some of which have addressed the impact on engine performance and emissions when using diethyl ether and palm oil as diesel additives and injecting them gradually at different loads [Uslu 2020b, Huang 2020]. These bio-components, which are produced from renewable energy sources, may play a significant role in the near future in looking at the further development of the use of internal combustion engines [Saravanan 2020, Nanthagopal 2020]. One of the world's many scientific teams dealt with the blending of the bio-component - pentanol to standard diesel in various proportions and again monitored the effect of this additive on engine performance and emissions [Appavu 2020, Ahmadi 2019]. Experimental results have shown several encouraging results, where it has been shown that such an additive to diesel has, on the one hand, reduced engine power but, in particular, has improved exhaust emissions with a high percentage on the other side [Rosero 2020, Praveena 2020]. The right blend of standard diesel and such bio-components shows encouraging results in evaluating emissions from internal combustion diesel engines where such a blend has been used as a fuel [Thangavelu 2020, Taghavifar 2020]. Another category for diesel engines is the group of scientists involved in the production of pure biofuels from renewable energy sources, which could completely replace standard diesel as the primary fuel used in these types of engines [Alagulamai 2020, Uslu 2020b].

2 MATERIALS AND METHODS

Decarbonization is an innovative way of removing solid carbon deposits in the engine by chemical means, without the need for complicated and expensive mechanical intervention in the engine. The parts of the engine through which hydrocarbon substances (fuel, oil) pass are often clogged with carbon deposits by the action of high temperatures. These carbon deposits most often form on the intake and exhaust valves, injectors, in the combustion chamber, which results in a decrease in compression ratios and thus a reduction in engine power. Clogging of the injectors increases fuel consumption, causes the engine to run erratically, the engine to knock and the engine to start badly [BG 2024]. Another very easily observable benefit of decarbonizing the engine is its reduced noise during operation. Complete decarbonisation of the engine removes all deposits in the engine that can cause such noise and the engine runs more smoothly, which also has a significant positive effect on the overall engine noise. The first sign that the engine is clogged with hydrocarbon deposits is its increased smokiness and a noticeable decrease in car performance. Hydrocarbon deposits are most often caused by a very simple cause. With direct injection engines, especially diesel engines, high operating temperatures are achieved in the combustion chamber area, where at the same time the injectors lose the ability to be cleaned by a mixture of air and fuel. This opens up space for the formation of carbon deposits on the injection nozzles. Sediments at the injection nozzles are most often found at their tips, where they have ideal conditions for formation. If the tip of the injector is clogged with carbon deposits, this has a significant negative effect on the dosing and atomization of the fuel in the combustion chamber (Figs. 1 and 2). Improper fuel metering and poor atomization significantly affects engine operation, smooth fuel combustion and, last but not least, it increases the overall corrections of fuel injection doses in individual cylinders, which significantly increases vehicle consumption (Figs. 3 and 4).

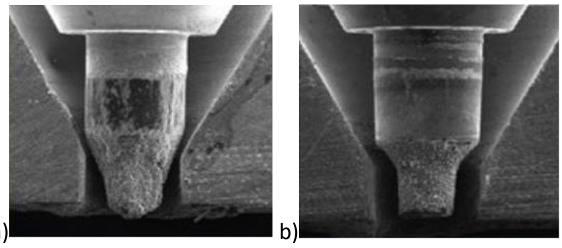
a) b)

Figure 1. Injection nozzle a) clogged with carbon b) after cleaning [BG 2024]

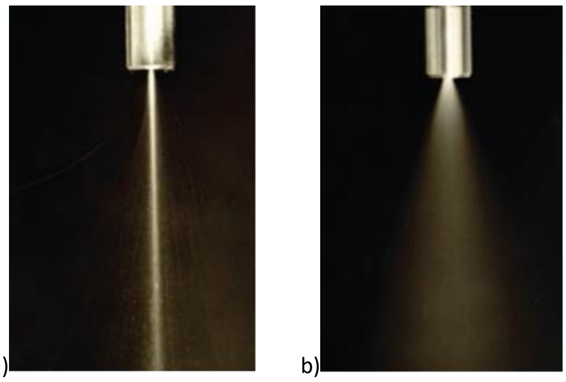
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Figure 2. Fuel injection in case of a) clogged nozzle b) after nozzle cleaning [BG 2024]

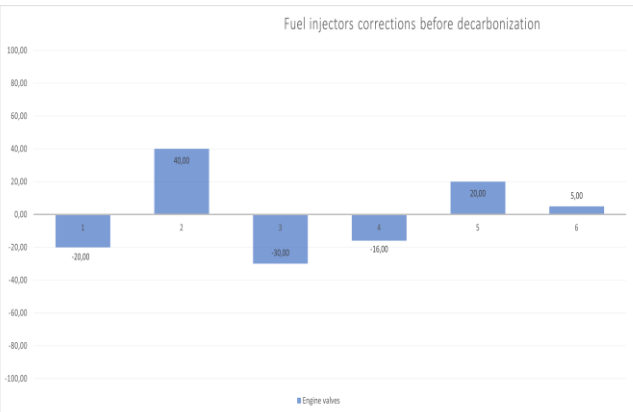


Figure 3. Corrections of injectors before cleaning

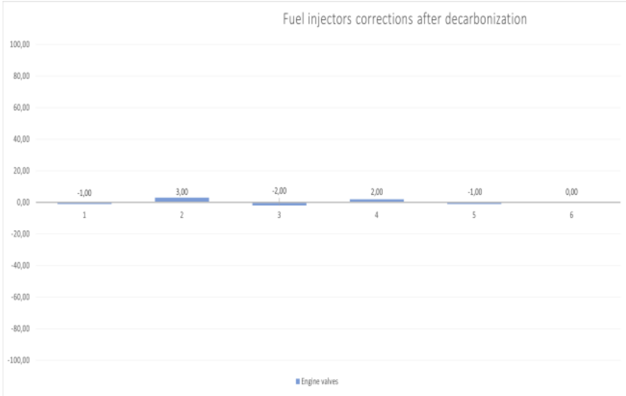


Figure 4. Corrections of injectors after cleaning

Intake and exhaust valves are usually endangered components in the deposition of carbon impurities, where these soots settle on the valve seats, which loses the valve's 100% seal functionality and thus loses compression pressure in the combustion chamber, resulting in direct power reduction and engine operation in non-ideal conditions (Fig. 5).

Figure 5. Valves before and after cleaning [BG 2024]

Another element that is affected by the high operating temperature is the oil itself, which loses its viscosity after reaching a certain operating interval, where it is unwanted burned and vented to the engine's intake tract, which causes carbon deposits in the engine intake manifold. The subsequent side effect of losing oil viscosity is often the elimination of the functionality of the piston rings, through which the oil itself enters the combustion chamber of the engine, which again leads through settling to settling of deposits in the intake manifold, increasing vehicle smokiness and last but not least the combustion process itself, which directly increases the content of harmful substances in the car's exhaust gases (Fig. 6).

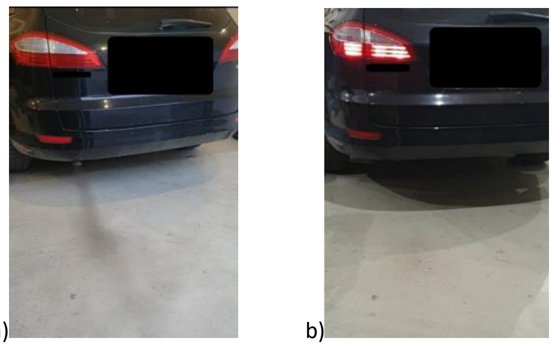
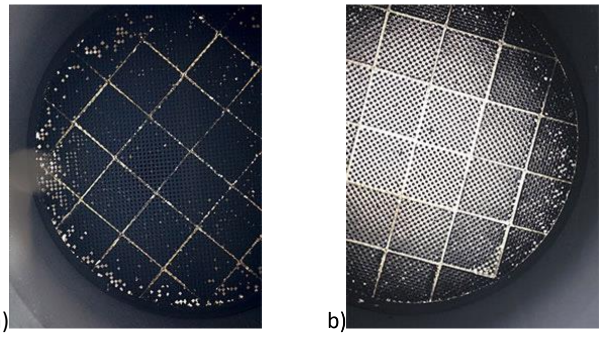

a) b)

Figure 6. Vehicle smokiness a) before cleaning, b) after cleaning

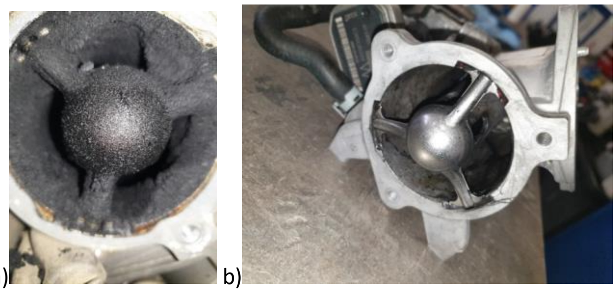
Poor fuel dosage and combustion processes outside ideal conditions cause exhaust gases to contain increased amounts of pollutants and unburned hydrocarbon particles, which in newer types of cars clog both the exhaust pipe itself and, in particular, the particulate filters.



a) b)

Figure 7. DPF filter a) clogged, b) after cleaning [BG 2024]

Under the right combustion conditions, it is these particulate filters that capture the harmful components contained in the exhaust gases, thereby reducing the proportion of pollutants in car exhaust gases. In a clogged engine, where these conditions are no longer ideal, the particulate filters themselves become clogged, resulting in immediate clogging and malfunctioning of the EGR valve on the engine, which is the most common cause of all problems in diesel cars that suffer from performance problems, frequent regeneration of DPF filters or complete engine inoperability (Figs. 7 and 8).



a) b)

Figure 8. EGR valve a) clogged, b) after cleaning

All of the above mentioned factors, which arise in all types of internal combustion engines, can be easily avoided by professional engine decarbonisation, where machines developed for this process are used, which, through the action of thermo-chemical processes, are able to rid such engines of all carbon deposits in the intake manifold, combustion compartment, oil compartment and even the exhaust manifold, which returns the engine to its original parameters, when the fuel combustion process returns to optimum conditions, which significantly reduces the production of harmful emissions, reduces fuel consumption and vehicle noise. Subsequent regular maintenance of such engines can guarantee their trouble-free and environmentally friendly operation for the duration of their use.

3 RESULTS AND DISCUSSION

Cleaning of the engines was carried out using BG gears, which are directly designed to carry out such servicing. Measurement of the exhaust gas values was carried out with an industrial emission measuring device from Testo (Fig. 9).

Figure 9. BG cleaning devices and Testo ED [BG 2024, Testo 2024]

As a test sample for the experiment, we selected 5 different diesel cars of different make, year of manufacture and mileage. For all the test vehicles, the same parameters of the experiment were maintained, i.e., all the vehicles were professionally serviced for injector nozzles, professionally cleaned for intake manifold and engine oil change (Fig. 10).

For all vehicles tested, there was a positive result where we compared the exhaust emission values before and after the application of the service. All vehicles tested showed a reduction in emissions after cleaning, less smoke under acceleration, and most importantly quieter and smoother engine operation (see Tables 1 and 2).

Figure 10. Connection of cleaning machines to the engine

Table 1. Emission before cleaning

Emission values	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5
$\%CO_2$	2.12	2.85	3.89	2.11	4.57
$\%O_2$	18.6	18.05	17.8	18.12	17.32
ppm CO	125	292	367	162	193
ppm NO	105	101	306	150	270
ppm NO_x	106.5	112.6	311.3	154.3	279.9

Table 2. Emission after cleaning

Emission values	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5
$\% CO_2$	1.86	3.21	2.89	2.32	3.81
$\%O_2$	16.84	15.86	17.01	17.86	14.79
ppm CO	96	54	284	24	101
ppm NO	60	57	161	113	194
ppm NO_x	60.4	57.6	221.6	129.4	118.3

4 CONCLUSIONS

As a test sample for the experiment, we selected 5 different diesel vehicles of different makes, year of manufacture and mileage. The same parameters of the experiment were followed for all the test vehicles, i.e., all the vehicles were subjected to a professional service of the injection nozzles, professional cleaning of the intake manifold and engine oil change (Figure 10). These steps and the result of the research can serve as a basis for further experimental investigations. At the same time, this experiment established the principles of methodology determining the success of the experiment. When piston rings are cleaned of carbon, compression is restored, power is restored, and consumption is reduced. The level of emission reduction depends on the overall pollution, but after comprehensive decarbonization, it can be approached to the values that were in the new vehicle, as long as there was no mechanical damage to the internal parts of the engine, for example damage to the pistons from carbon and the like.

As part of decarbonization, the European Union has adopted a ban on the sale of passenger vehicles with internal combustion engines from 2035 [Rimar 2023]. However, the problem is the number of vehicles in the system that do not meet the latest EURO standards. These cars will not be withdrawn from circulation and are the biggest polluters from passenger transport. In Slovakia, over the past 4 years, the average age of cars has increased by almost 2 years to 12 years. This average age of cars is constantly increasing for several reasons. The main reason is the economy and the high prices of cars, which have risen by more than 50% in the last 5 years (Dacia Duster 2019 - €9990, Dacia Duster 2024 - €15790). With electric vehicles, the price is even higher, so it is necessary to focus on reducing emissions on existing vehicles on the road, which have the highest share of passenger transport emissions. It is therefore a huge benefit for reducing emission production that there are functional technologies that make it possible to significantly reduce engine carbonation. The decarbonization mentioned in this article works for both diesel and gasoline engines and can reduce the amount of CO2 in the air much faster than just buying zero-emission cars without restricting existing vehicles. After the deep cleaning in this test, all vehicles took part in the mandatory emissions inspection that must be carried out every 2 years without any problems.

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