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ASSESSMENT OF EXHAUST EMISSIONS BY ANDORIA 4CTi90 COMPRESSION IGNITION ENGINE

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Abstract

Compression ignition engines are a major source of air pollution in big cities and the cause of smog. Therefore, it seems appropriate to quantify emissions of toxic components of combustion gases by compression ignition engines.

In the paper, it was presented emission measurement results of selected components of exhaust gases such as CO, CO_2, HC, O_2, NO_x, by indirect injection compression ignition engine. The object of the study was Andoria 4CTi90 engine. The research was carried out at the AVL engine test bench. Measurement results were shown in the form of external and load characteristics. It was interesting to compare the emissions of individual exhaust components of the 4CTi90 engine with the contemporary direct injection engine. The measurements carried out at the Department of Automotive Engineering at the West Pomeranian University of Technology in Szczecin on the Fiat 1.3 JTD Multijet engine showed that the emissions of the considered exhaust gas components in conditions of external characteristics, for the rotational speed of 4000 1/min, were much higher than the Andoria engine. The study assumed the measurement of hydrocarbon emissions, however, within almost the entire range it was zero. Only for the speed of 4000 min^{-1}, the meter showed values slightly higher than zero. The authors believe that it would be interesting to compare the exhaust emissions of the 4CTi90-1BE engine and the ADCR engine.

Keywords: *exhaust emissions, external characteristics, compression ignition engine, indirect injection*

1. Introduction

Exhaust gas toxicity is currently the most important parameter determining the use of an internal combustion engine to drive the car. In modern cars, both spark ignition and compression ignition engines are used. In the past, a clear division of internal combustion engines was observed – the compression ignition engines were used only in trucks, while the engines with spark ignition in passenger cars and trucks. Currently, compression ignition engines are used in all types of vehicles. The increasing number of used compression ignition engines makes it necessary to assess the exhaust emissions of these engines. The popular view is that compression ignition engines are a major source of air pollution in big cities and the cause of smog. Therefore, it seems appropriate to quantify emissions of toxic components of combustion gases by compression ignition engines.

2. Research object

The research object was the 4CTi90-1BE compression ignition engine. The engine has been used to drive vans, off-road cars and mini-buses since the 1980s. During this time, many modernization projects, mainly involving the change of fuel supply systems, have been found. In the first, the in-line pump was replaced with an injection pump and the second was based on the use of a Common Rail system. The selection for this type of engine was dictated by the number of still operated engines in Lublin, Daewoo, Honker, LDV Convoy and many other cars, and quite good reviews about this engine [1]. The basic parameters of the tested engine are the following:

Tab. 1. Basic parameters of 4CTi90-1BE [2] engine

Number of cylinders	-	4
Cylinder capacity	dm^3	2.417
Cylinder diameter	mm	90
Piston stroke	mm	95
Power rating	kW	66
Rated rotational speed	1/min	4100
Maximum moment	Nm	195
Maximum moment torque speed	1/min	2250
Injection system	-	Indirect into the swirl chamber
Timing gear system	-	OHV, with camshaft in the cylinder head
Injection pump	-	Bosch rotary pump
Spray nozzle type	-	Pintlenozzle
Turbocharger type	-	High-speed, with exhaust gas release valve

The 4CTi90 engine was upgraded to ADCR in 2007. It is characterized by the increased engine displacement of 2636 dm^3, obtained by increasing the cylinder diameter up to 94 mm and the use of Common Rail direct fuel injection. The engine modernized this way met EURO-4 exhaust emission standards and after 2011 – EURO-5, while the base engine met EURO-3 exhaust emission standards. Particularly noteworthy is that the 4C90 engines are a Polish design developed for vans. The undisputed strengths of this engine include, among other things: a refined design, development opportunities already planned at the design stage and prototype research carried out with the drawing up of conclusions and bringing amendments [1].

3. Research

The research was carried out in the Laboratory of Construction and Operation of Motor Vehicles and Internal Combustion Engines of the West Pomeranian University of Technology in Szczecin at the AVL DYNOPERFORM 160 measuring station. The MAHA MDO 2 smoke meter and the IMR1500 exhaust gas analysers from ATUT and CAP 3201 from Capelec were used to measure exhaust gas emissions. The research consisted in determining the engine operating parameters (P_d, T_{tq}) and the emission values of individual exhaust gas components for different rotational speeds and loads. During the study, the following were measured.

Tab. 2. Values measured during research

Measured values	Symbol	Unit
Rotational speed	n	1/min
Power output	P_d	kW
Torque	T_{tq}	Nm
Fuel consumption	B	g/s
Infrared radiation absorption rate	k	m^{-1}
Carbon monoxide emissions	CO	% vol
Carbon dioxide emissions	CO_2	% vol
Hydrocarbons emissions	HC	ppm
Oxygen content	O_2	% vol
Nitrogen oxides	NO_x	ppm
Excess-air ratio	λ	-

4. Study results

The results are presented graphically in the form of load characteristics:

– CO, CO_2, NO_x, k as the engine torque function,
– CO, NO_x, k as a function of the excess-air ratio.

Figure 1 shows the dependence of carbon monoxide emissions on engine torque at various engine speeds. It can be seen that the emission of carbon monoxide for light loads was the largest. In the range of medium loads, it decreased and increased slightly with increasing load.

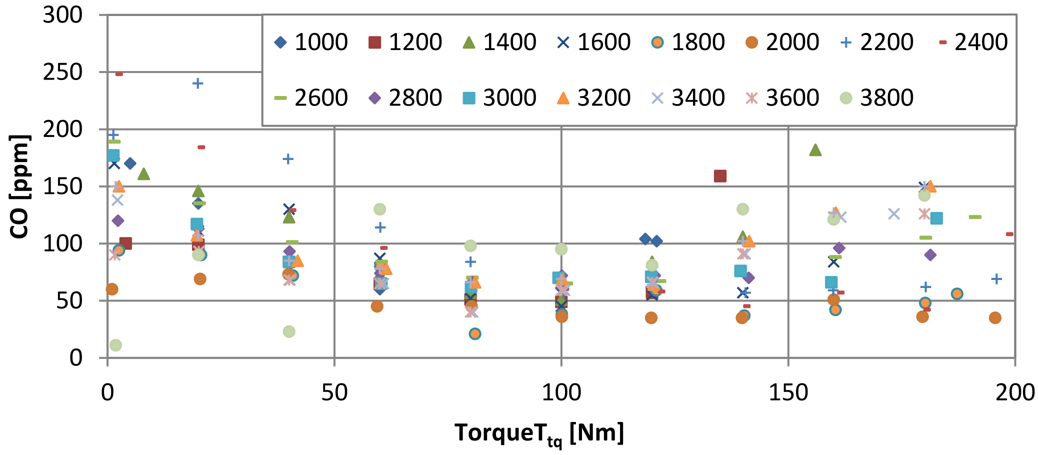

Fig. 1. Dependence of CO emissions on load

Carbon dioxide emissions (Fig. 2) increased along with increasing load, while for low loads the impact of rotational speed was small. The influence of rotational speed increased along with the load increase.

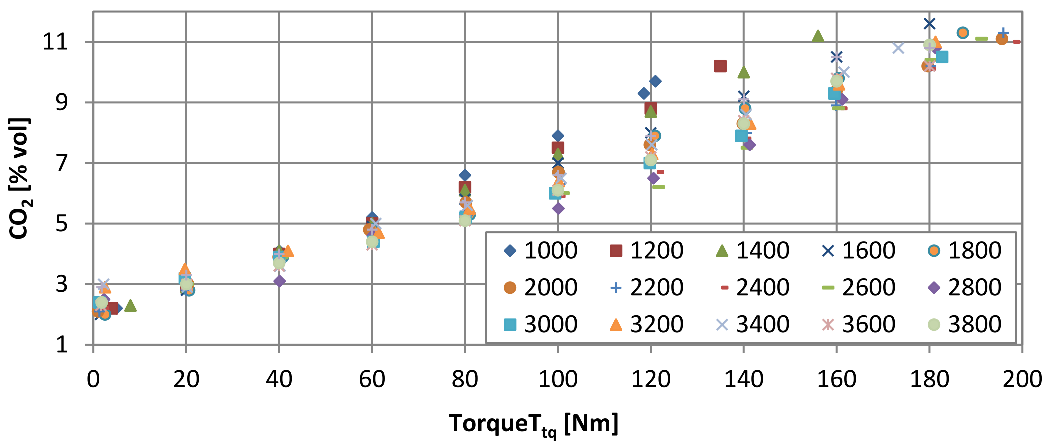

Fig. 2. Dependence of CO_2 emissions on load

In the case of nitrogen oxides, an increase in emissions with an increase in load up to about 75% of the nominal load can be observed, followed by a slight decrease in emissions. In this case, it is not possible to see the orderly effect of rotational speed on emissions.

The dependence of exhaust gas opacity on the load (Fig. 4), determined by the absorption coefficient of infrared radiation by the exhaust gas, indicates that the value of the absorption coefficient increases as the load increases. For low rotational speeds, the absorption coefficient is the smallest, the average rotational speed range promotes an increase in the absorption coefficient k, and however, for the range of higher rotational speeds, the absorption coefficient decreases again.

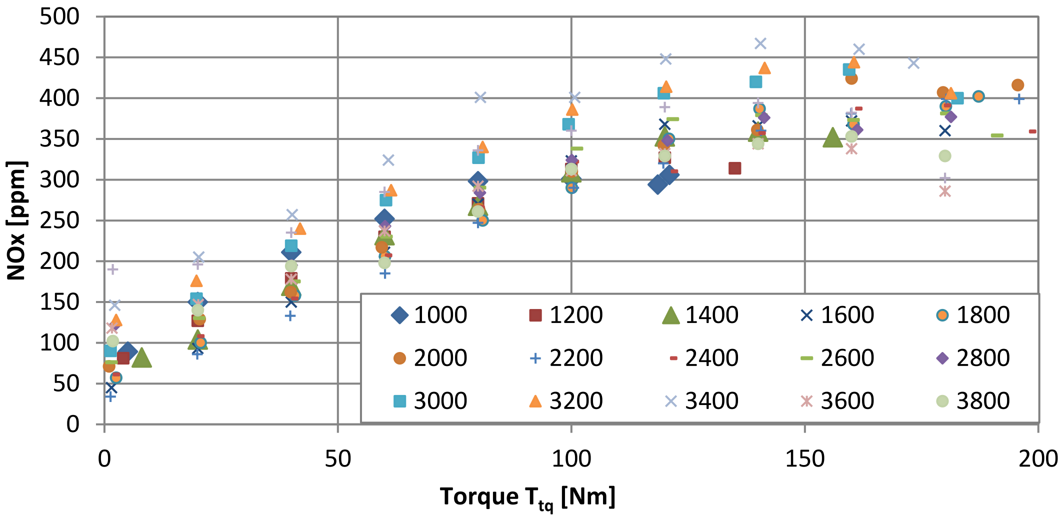

Fig. 3. Dependence of NO_x emissions on load

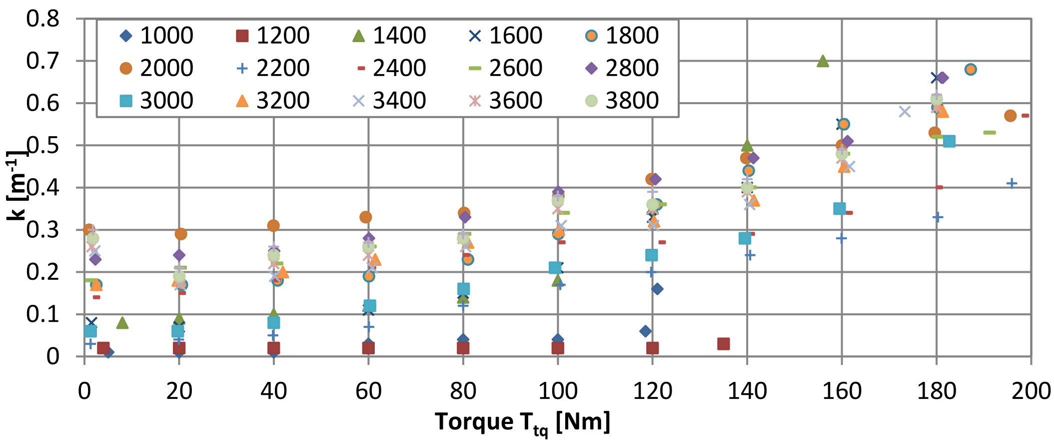

Fig. 4. Dependence of coefficient k on load

The subsequent figures show the dependence of emissions of carbon monoxide, nitrogen oxides and absorption coefficient on the excess-air ratio coefficient for engine speeds ranging from 1000 to 4000 1/min. When discussing the characteristics, it should be remembered that the lower values of the excess-air ratio correspond to higher loads and as the excess-air ratio increases, the load decreases.

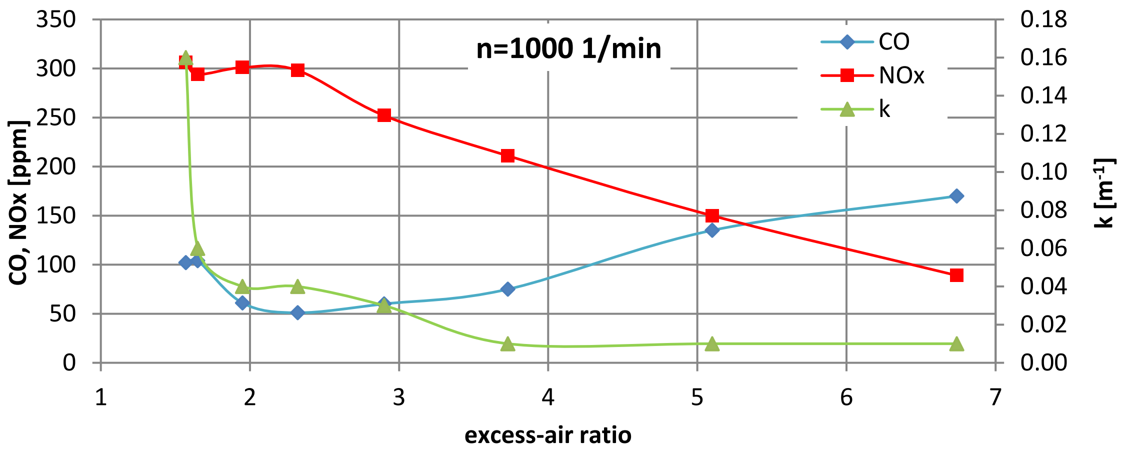

Fig. 5. Dependence of CO_2, NO_x, k emissions on λ excess-air ratio at the engine speed of 1000 1/min

For a rotational speed of 1000 1/min (Fig. 5), the carbon monoxide emission at an excess-air ratio in the range from about 0.7 to about 2.3 decreased from 100 ppm to 50 ppm. With an increase of λ to approximately 6.7, the emission increased linearly to about 160 ppm. For nitrogen oxides, at λ = (1.7 – 2.3) their emissions were relatively constant and reached a value of about 300 ppm. With the increase of λ from 2.3 to about 6.7, NO_x emissions decreased almost linearly to values below 100 ppm. Opacity of the exhaust gas, expressed as the k absorption coefficient, decreases rapidly for λ from 1.3 to about 3.0, after which the k value is set at about 0.01 m^{-1} in the range of λ from about 4.0 to about 6.7.

At a rotational speed of 1600 1/min (Fig. 6), the lines of the considered exhaust gas components emissions are similar in nature as at 1000 1/min. There are also slight differences in values. Only an increase in emissions of carbon monoxide and nitrogen oxides can be observed to about 370 ppm for the lowest values of the excess-air ratio. Also, for the lowest values of excess-air ratio, the carbon monoxide emissions increased slightly to 150 ppm. A more regular course of the k absorption coefficient line and its several times higher values can be observed. For small λ, there has been an increase from about 0.16 m^{-1} to 0.65 m^{-1}. For high λvalues, the absorption coefficient k increased from 0.01 m^{-1} to almost 0.10 m^{-1}.

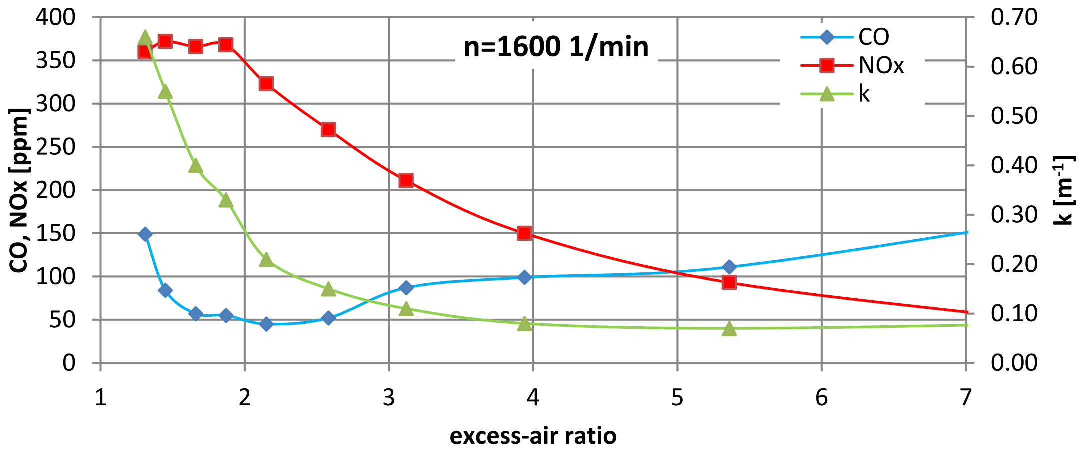

Fig. 6. Dependence of CO_2, NO_x, k emissions on λ excess-air ratio at rotational speed of 1600 1/min

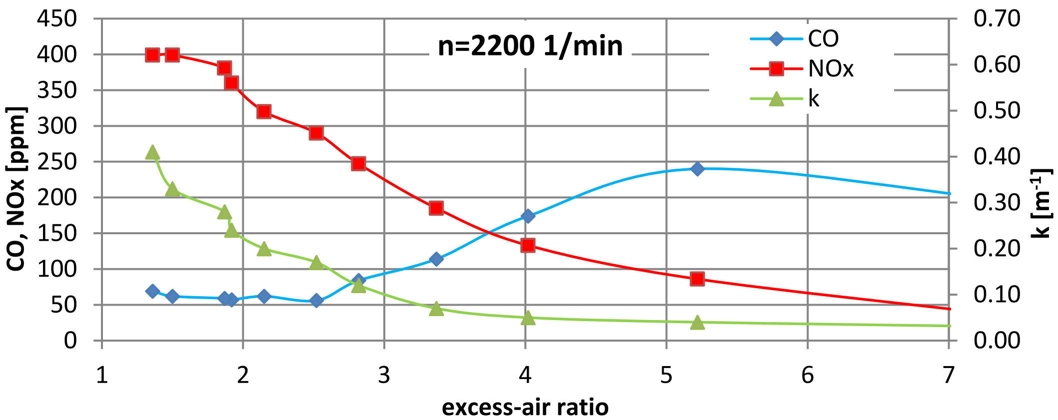

Fig. 7. Dependence of CO_2, NO_x, k emissions on λ excess-air ratio at rotational speed of 2200 1/min

As there are almost no differences between the characteristics shown in the other figures (Fig. 7-10) and in Fig. 5 and 6, their description would be very similar. Therefore, it is advisable to discuss only differences in particular characteristics. At a speed of 2200 1/min for the lowest absorption coefficient (about 1.5), the nitrogen oxide emissions increased to about 400 ppm. Emissions of other ingredients are almost unchanged. In the case of the highest (4000 1/min) rotational speed, the increase in emission values of almost all considered components is noticeable, especially in the range of high absorption coefficient values. NO_x emissions increased to about 150 ppm, CO was essentially independent of speed and ranged from 100 ppm to 200 ppm, the absorption coefficient k has reached the highest values, of up to 0.3 m^{-1} as well as for the speed of 3600 1/min.

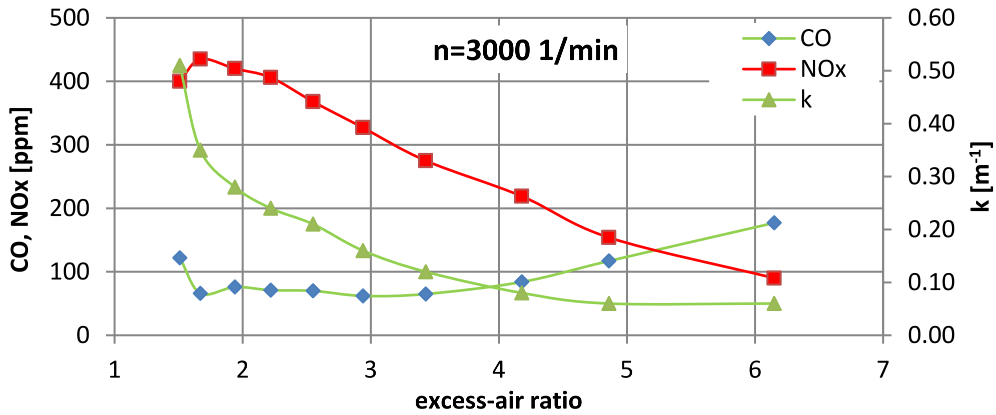

Fig. 8. Dependence of CO_2, NO_x, k emissions on λ excess-air ratio at rotational speed of 3000 1/min

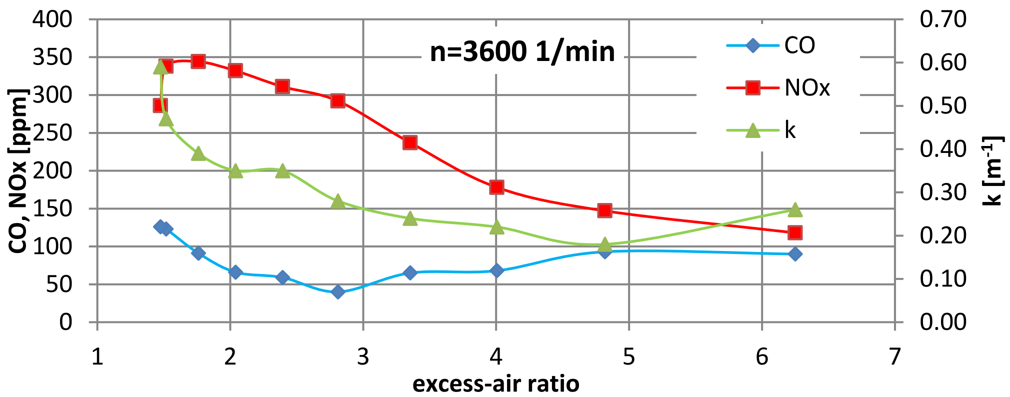

Fig. 9. Dependence of CO_2, NO_x, k emissions on λ excess-air ratio at rotational speed of 3600 1/min

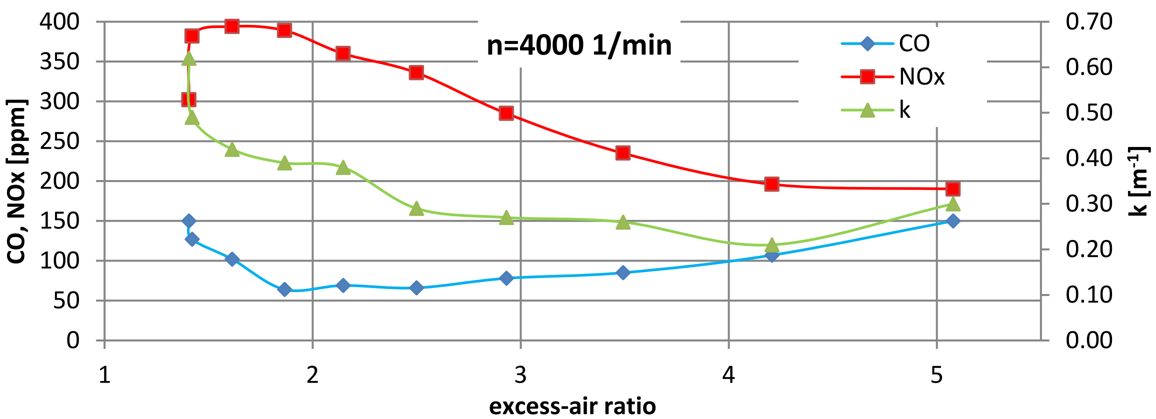

Fig. 10. Dependence of CO_2, NO_x, k emissions on λ excess-air ratio at rotational speed of 4000 1/min

5. Conclusion

The study involved a split-combustion engine where the injection was applied to the swirl chamber of Ricardo Engineering. Nowadays, in the age of domination of direct injection engines, research on such an engine may seem outdated, however, they are still quite commonly exploited and the authors considered it expedient to present and analyse the results of these studies.

It is interesting to compare the emissions of individual exhaust components of the 4CTi90 engine with the contemporary direct injection engine. The measurements carried out at the Department of Automotive Engineering at the West Pomeranian University of Technology in Szczecin on the Fiat 1.3 JTD Multijet engine showed that the emissions of the considered exhaust gas components in conditions of external characteristics, for the rotational speed of 4000 1/min, were as follows: $k=3.32\ m^{-1}$, $NO_x=1105$ ppm, CO=153 ppm, it is therefore much higher than the Andoria engine. The study assumed the measurement of hydrocarbon emissions, however, within almost the entire range it was zero. Only for the speed of 4000 $min^{-1,}$ the meter showed values slightly higher than zero. The authors believe that it would be interesting to compare the exhaust emissions of the 4CTi90-1BE engine and the ADCR engine.

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[1] Wojniak, A.,Wcisło, S., Harnas, M., *Silniki wysokoprężne dla motoryzacji*, Journal of KONES, Vol. 7, No. 1-2.

[2] ANDORIA, *Instrukcja obsługi, Silnik wysokoprężny 4CT90-1BE,* W.S.W., Andoria, 2000.