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THE EFFECT OF INNER CATALYST APPLICATION ON DIESEL ENGINE PERFORMANCE

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Abstract

This paper presents the results of the initial researches on platinum-rhodium inner catalyst application in one-cylinder compression-ignition engine (SB 3.1 type). According to recent researches [2-6] the active factor in an engine combustion space impacts on a combustion process. It is suspected that a catalyst i.e. a precious metal, affects the fuel combustion process by catalyzing the fuel-air combustion reaction (prior-combustion reactions what is correlated with shortening of combustion delay period).The researches was carried out in Division of Motor Vehicles and Internal Combustion Engines at Wroclaw University of Technology. The catalyst was put onto the engine valves surface. As a catalyst support a plasma-sprayed zirconium ceramic was used. The researches proved that the platinum-rhodium active factor on zirconium thermal barrier coating (TBC) placed into combustion chamber (inner catalyst) effects on the diesel engine performance. The impact of the inner catalyst seems to be advantageous for ignition delay. The active ceramic on the engine valve surface caused increase of in-cylinder maximum pressure and temperature values.

Keywords: internal combustion engine, active coating, catalytic fuel ignition, pressure diagram

1. Introduction

Nowadays, research on improvement of engine fuel combustion process has been increasing due to an increase in the price of diesel oil and increase in the environmental concerns. A great deal of research has been conducted on modification of the engine construction, using biobased-fuels and fuel addition including catalytic elements [1].

Williams and Schmidt [2] during their research on catalytic oxidation of liquid hydrocarbon fuel using rhodium as active agent, have analyzed the parameters of fuel-air mixture autoignition. The authors have observed that even minimal addition of rhodium to a reactor simulating internal combustion engine conditions (with some restrictions referring to real engine because the reactor worked in adiabatic conditions) causes improvement in chosen parameters of the combustion process. One of Williams and Schmidt suggestions is that the active agent put into combustion space causes start of complex chain reactions and the phenomena is related with shortening of time of chemical autoignition delay.

Mello, Bezaire and Sriramulu [3], in their researches have investigated influence of catalytic coating inside of a compression-ignition engine fueled with natural gas (DI-NG) on autoignition delay. The authors have proved that the catalyst coating in combustion space may improve the engine efficiency.

Based on references [2 – 6] it is possible to conclude that modification of combustion space by catalytic active agent implementation may, with significant probability, causes shortening of fuel-air mixture autoignition delay time in the internal combustion engine.

It is suspected that the active agent i.e. a precious metal affects the fuel combustion process by catalyzing the fuel-air combustion reaction, especially prior-combustion reactions what is correlated with shortening of combustion delay period.

The researches on an active ceramic application inside the combustion chamber of the internal combustion engines have been provide in Division of Motor Vehicles and Internal Combustion Engines at Wroclaw University of Technology for last few years. The inner catalyst is a solution based on implementation of active factor on chosen engine elements (glow plugs, piston and engine valves) to improve the combustion process [5,6].

Thick plasma sprayed thermal barrier coatings (TBC) is used as a catalyst support. zirconium, yttrium-stabilized ceramic, because of its special properties, is well known, suitable for thermal and hot corrosion protection material which is often use for diesel engines applications. In addition, they represent potential solutions to increase the engine efficiency, in terms of higher combustion temperature and reduced cooling air flow, and to reduce the fuel consumption [7].

The aim of this research was analysis of the effect of the platinum-rhodium inner catalyst on diesel engine performance.

2. Experiment

The researches was carried out in the Division of Motor Vehicles and Internal Combustion Engines laboratory of Wroclaw University of Technology. A one-cylinder SB 3.1.type diesel engine was employed as the research engine. The lay-out of the engine test bed is presented on figure 1.

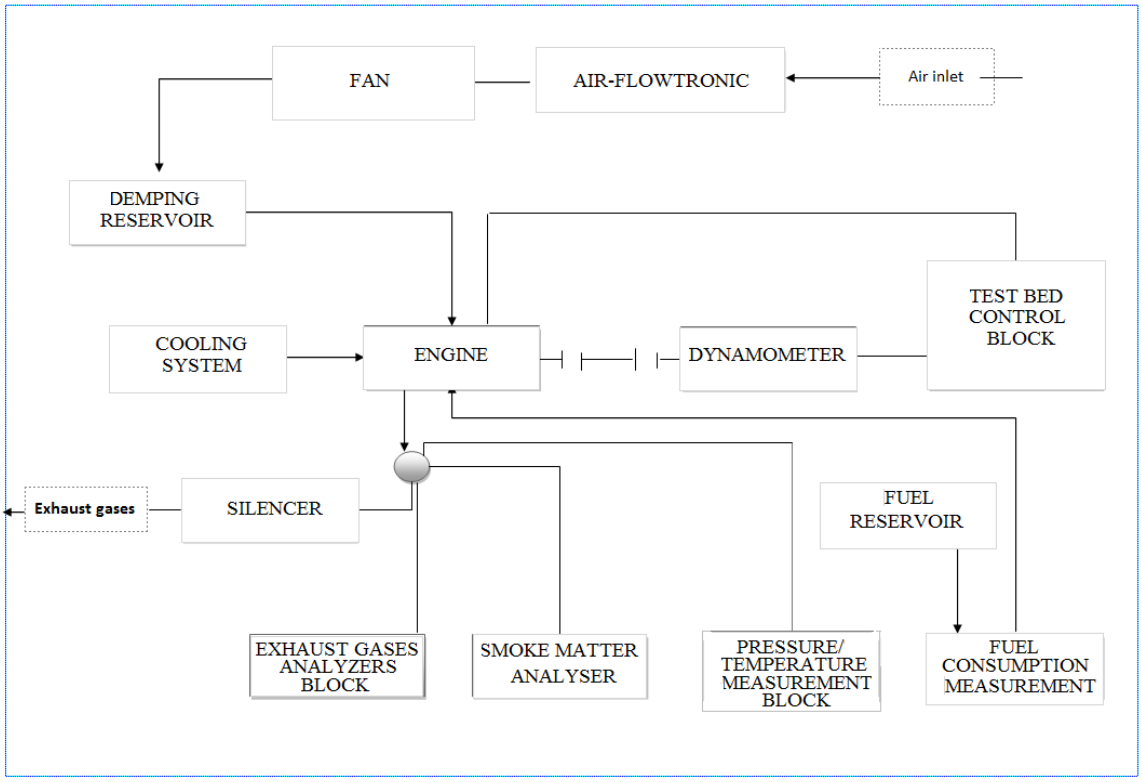

Fig. 1. The lay-out of the research test bed

The test bed was equipped with in-cylinder pressure and temperature measurement system. The system for data register and acquisition based on measurement channel with piezoelectric sensor, impulses amplifier, oscilloscope and software for signal processing software. Each pressure diagram has been averaging of 600 to 800 diesel engine cycles.

The engine modification was platinum-rhodium application on the engine valves surface. Plasma-sprayed, zirconium ceramic coating was used as a catalyst support. The ceramic coating acted simultaneously as a thermal barrier caused a local temperature increase.

The direct signals was put into several mathematical transformations connected with signal filtering and measurement channel calibration to eliminate potential disturbances. In the signal filtering process the signal aggregating method and average values weighting method were used.

The methods error was estimated as 0,01 MPa for range 0 to 5 MPa and 0,03 MPa for range 0 to 10 MPa. The difference in error level is an effect of signal transformations on values of pressure for various signal amplifications in the amplifier and the oscilloscope.

The tests were done for chosen engine speeds: 1200 rpm, 1400 rpm and 1600 rpm and crank angle degrees of fuel injection advance: 20 deg, 23 deg and 27 deg in crank angle. Two states of engine work were studied and compared: without and with inner catalyst. Average real operational engine load, 47,7 Nm, was chosen for pressure diagram analysis for each engine speed.

3. Results and discussion

Some results of the researches are presented on diagrams (fig. 2 - fig. 12) and in the tables (tab. 1 – tab. 3).

When engine run without the modification the combustion pressures measurements indicate typical performance for the engine type, comparable to producer data, what is shown on the figure 2 and 3.

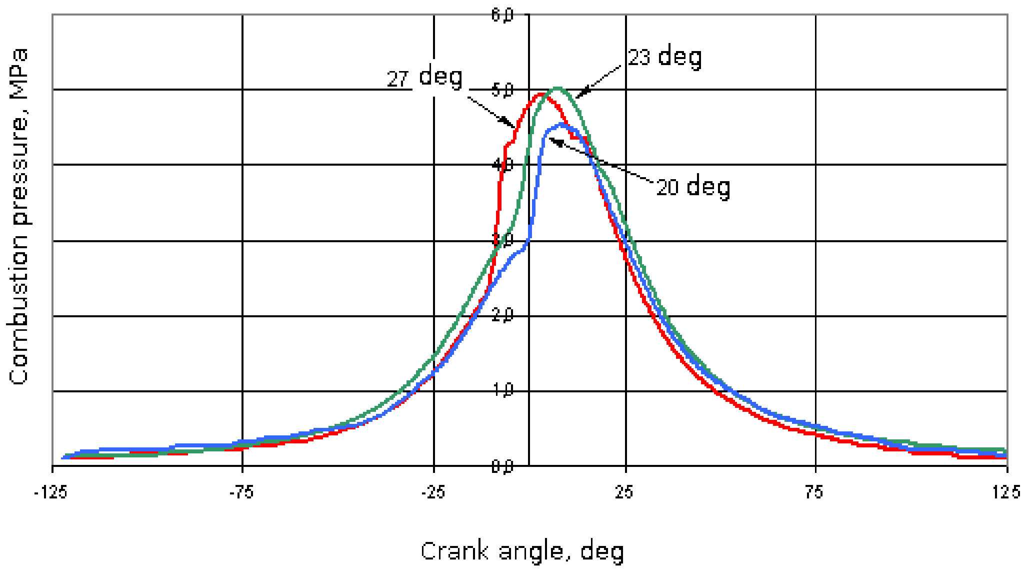

Fig 2.The pressure diagram for various fuel injection advances, engine without catalyst; engine speed: 1200 rpm

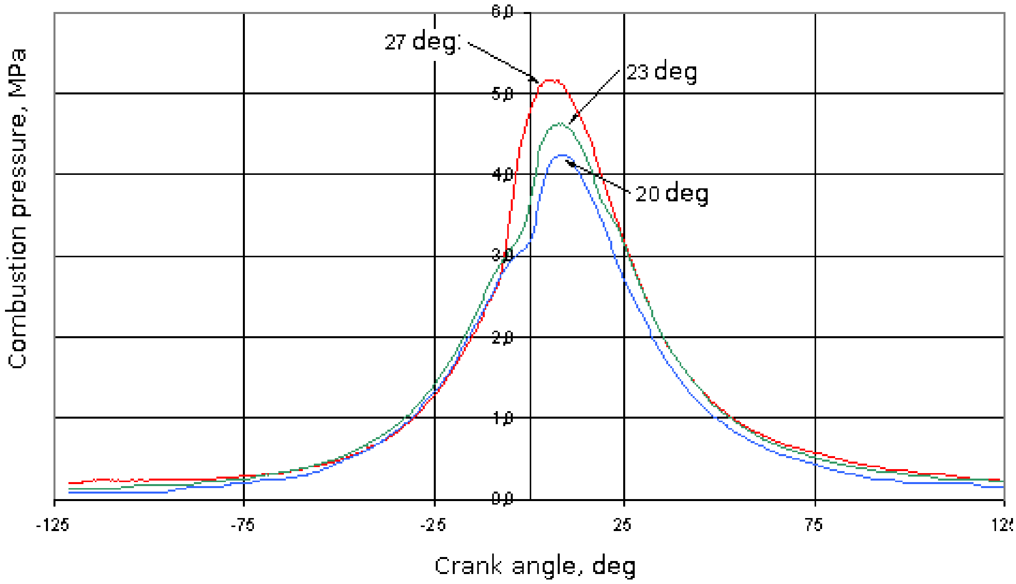

Fig 3. The pressure diagram for various fuel injection advances, engine without catalyst; engine speed: 1600 rpm

Higher values of maximum pressure was measured for higher angle for different fuel injection advances (higher for 27 deg of crank angle than 20 deg). Higher values of crank angle causes faster combustion ignition.

After catalyst application insignificant changes was observed (fig. 4 and 5) but the tendency of engine pressure performance is comparable to basic state: the higher crank angle degree the higher maximum pressure values are observed (the higher crank angle degree the faster combustion ignition and higher pressure to crank angle ratio dp/dα).

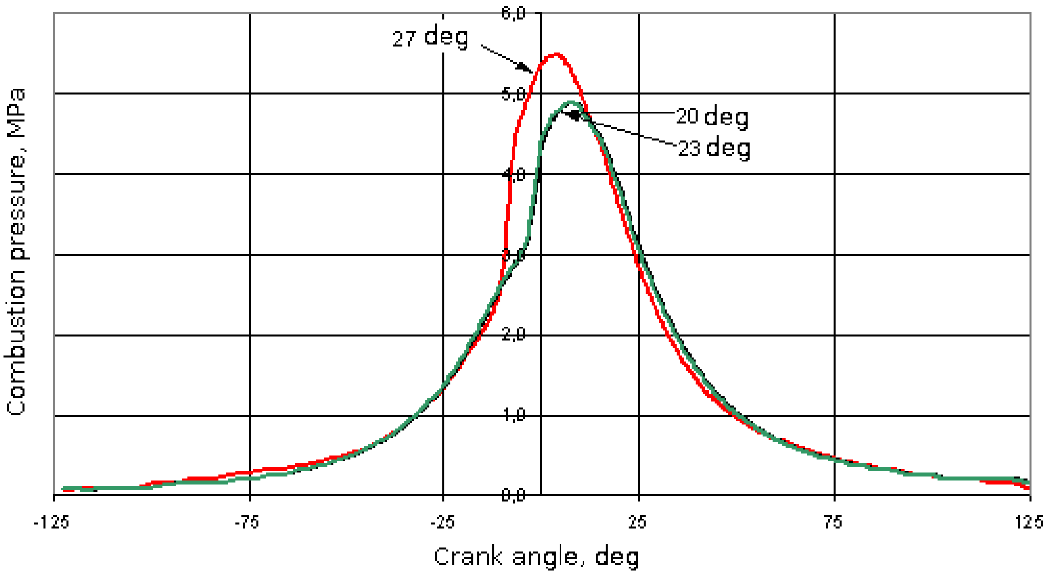

Fig 4. The pressure diagram for various fuel injection advances, engine with catalyst; engine speed: 1200 rpm

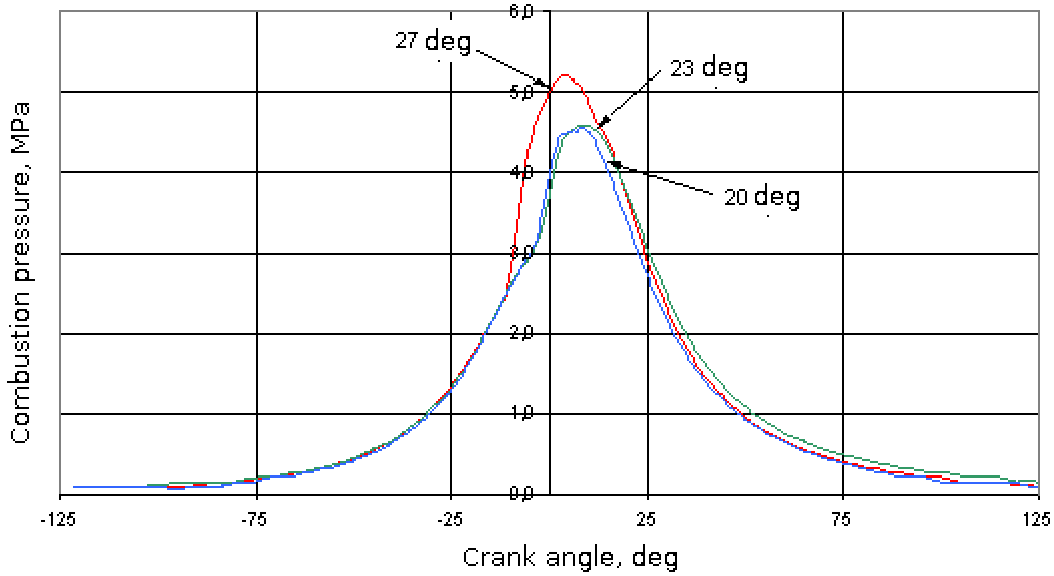

Fig 5. The pressure diagram for various fuel injection advances, engine with catalyst; engine speed: 1600 rpm

The comparison of the results shown on the figures 2 and 3 (engine without catalyst) with figures 4 and 5 (engine with active ceramic coating on the engine valves surface) shows that inner catalyst application caused higher maximum pressures in combustion chamber and faster combustion ignition was observed. Ratio dp/dα of the fuel combustion process were comparable for both states of engine work. Maximum pressure values was decreasing while engine speed was increasing.

The maximum in-cylinder pressures for both engine states on each analyzed engine speed are presented in table 1.

Tab. 1. The maximum in-cylinder pressure, MPa, for various engine speeds and both states of engine work

Crank angle fuel injection advance, deg	Maximum in-cylinder pressure, MPa					
	1200 rpm		1400 rpm		1600 rpm	
	Without catalyst	With catalyst	Without catalyst	With catalyst	Without catalyst	With catalyst
- 20	4,59	4,97	4,48	4,76	4,27	4,59
- 23	5,06	5,03	4,85	4,91	4,73	4,65
- 27	5,03	5,57	4,76	5,30	5,30	5,30

The values of crank angle fuel injection advance, presented in table 2, indicate on phenomena of inner catalyst impact on ignition delay. Combustion ignition is also function of engine speed: the higher engine speed the closer to TDC fuel combustion process starts.

Tab. 2. The ignition of the combustion process, crank angle before TDC, deg, MPa, for various engine speeds and both states of engine work

Crank angle fuel injection advance, deg	Start of the combustion process, crank angle fuel injection advance, deg					
	1200 rpm		1400 rpm		1600 rpm	
	Without catalyst	With catalyst	Without catalyst	With catalyst	Without catalyst	With catalyst
- 20	- 1,10	- 4,70	- 3,40	- 4,20	- 2,30	- 5,60
- 23	- 3,24	- 4,96	- 4,19	- 4,58	- 2,86	- 3,82
- 27	- 11,00	- 11,80	- 11,20	- 11,20	- 9,50	- 11,00

The changes in pressure to crank angle ratio (dp/dα), presented in table 3, show that for 20 and 23 degrees of crank angle before TDC, the ratio values are higher when engine worked with platinum/rhodium catalyst on the engine valves surface in comparison to state without the engine modification. Only for 27 deg of crank angle and the lower engine speed the relation was opposite. The phenomena needs to be explained in future researches.

Tab. 3. The ratio of dp to dα, MPa/deg, for various engine speeds and both states of engine work

Crank angle before TDC, deg	dp/dα, MPa/deg					
	1200 rpm		1400 rpm		1600 rpm	
	Without catalyst	With catalyst	Without catalyst	With catalyst	Without catalyst	With catalyst
- 20	0,43	0,43	0,33	0,33	0,25	0,32
- 23	0,29	0,47	0,20	0,47	0,31	0,35
- 27	0,64	0,36	0,84	0,75	0,57	0,64

The thermodynamic state of the medium in combustion chamber is determine by Three parameters: pressure, temperature and volume. Two of them: pressure and volume as direct parameters are known as parameters indicates direct on engine performance. The third parameter, temperature, in engine measurements is define by mathematical rules because pressure and volume changes are easier and more precise tool for temperature measurement than using direct sensor of this parameter. By using data of pressure value, state of engine work, engine speed and specific fuel consumption etc,. it is possible to get knowledge about the temperature behavior in the combustion chamber. The example of that estimation is presented on figure 6.

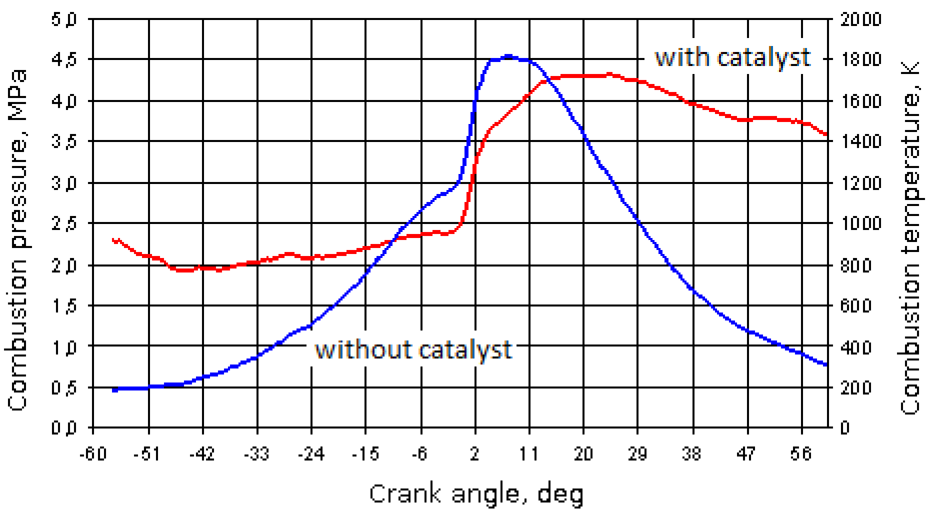

Fig 6.The in-cylinder pressures and temperatures versus crank angle (example)

In following figures (7 to 10) the in-cylinder temperatures values are presented versus various crank angle degrees.

In case of 20 deg of crank angle (fig. 7 and 8), for both engine speeds, the higher values of temperature was observed for engine equipped with inner catalyst. Also ignition of the combustion process started faster. Simultaneously with engine speed increase the temperature of medium in the combustion chamber was increasing.

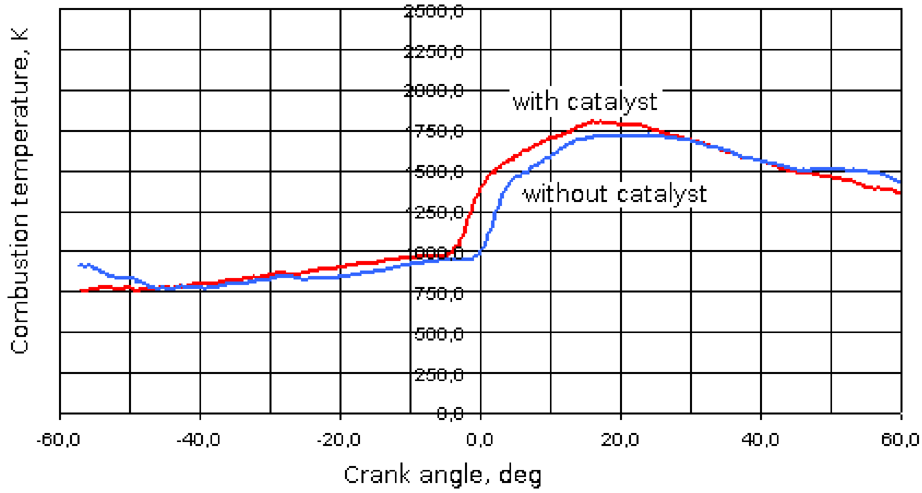

Fig 7.The in-cylinder temperatures versus crank angle for engine without and with inner catalyst application, engine speed: 1200 rpm, crank angle fuel injection advance : 20 deg

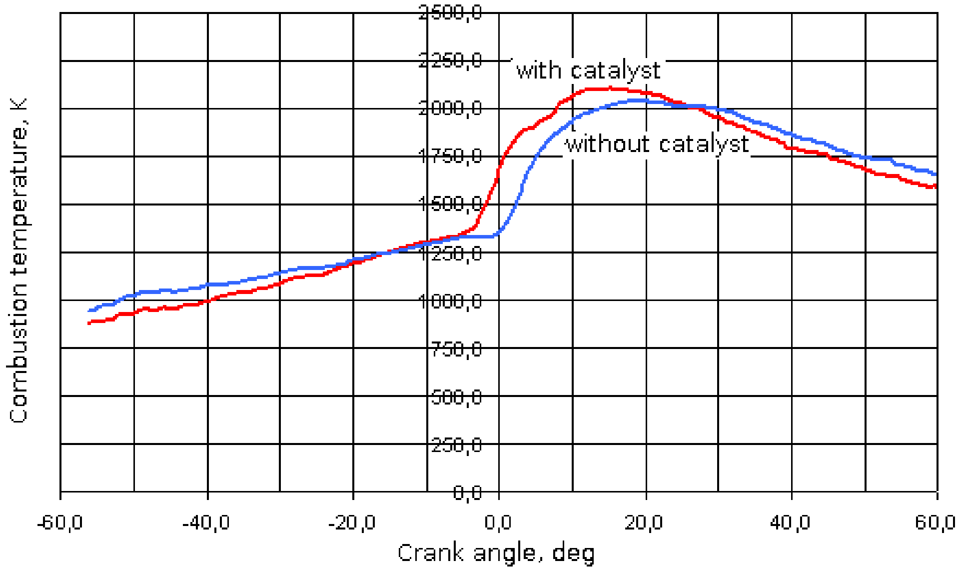

Fig 8.The in-cylinder temperatures versus crank angle for engine without and with inner catalyst application, engine speed: 1600 rpm, crank angle fuel injection advance: 20 deg

In case of 27 deg of crank angle various temperature states were observed (fig 9 and 10). When engine speed was 1200 rpm the engine with inner catalyst was achieving higher combustion temperatures than in basic state. The ignition of the combustion process was observed in comparable crank angle momentum. The opposite situation was observed when engine worked with the higher engine speed (1600 rpm). This phenomena could be explained by different behavior of the active agent placed in combustion space, depend on engine conditions and should be investigate in future researches.

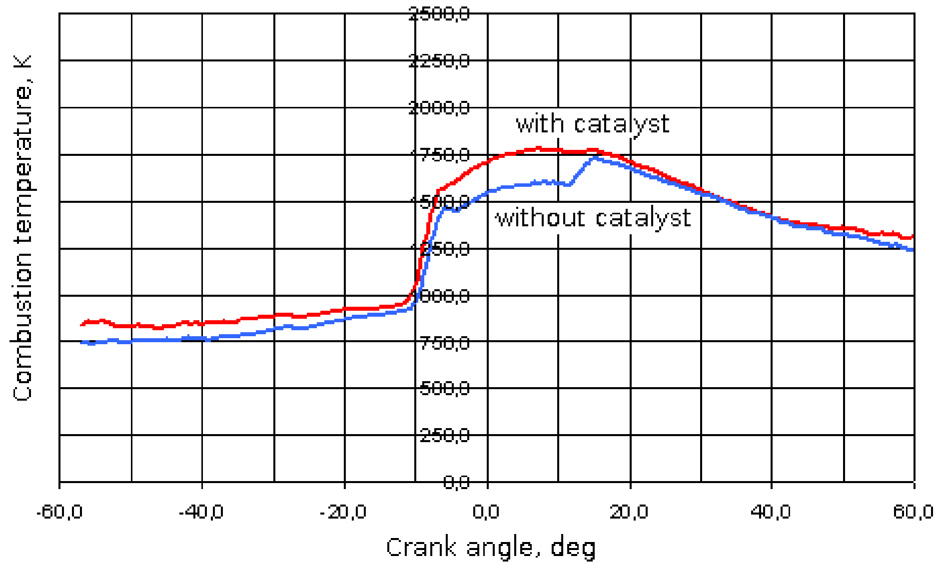

Fig 9. The in-cylinder temperatures versus crank angle for engine without and with inner catalyst application, engine speed: 1200 rpm, crank angle fuel injection advance: 27 deg

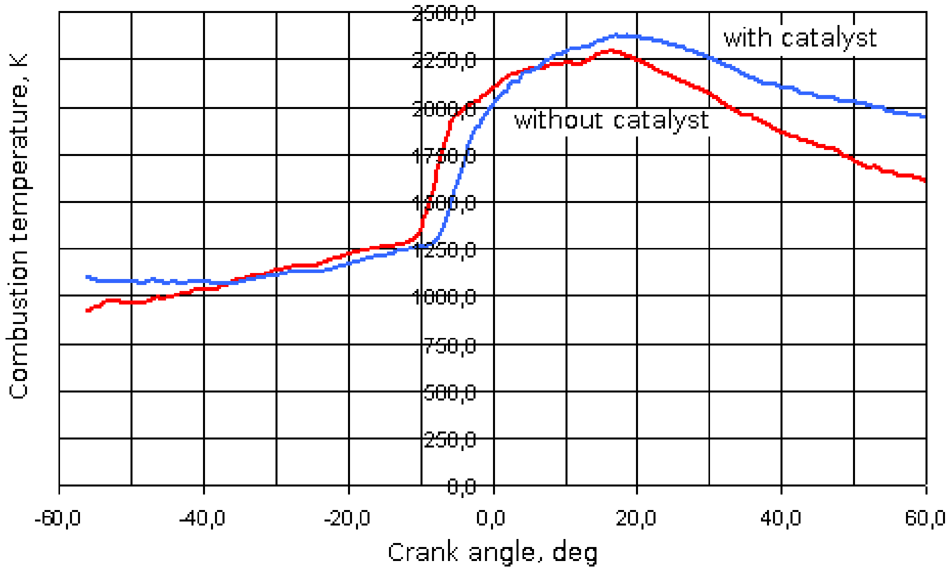

Fig 10. The in-cylinder temperatures versus crank angle for engine without and with inner catalyst application, engine speed: 1600 rpm, crank angle fuel injection advance: 27 deg

The maximum in-cylinder temperatures variation is shown on figures 11 and 12.

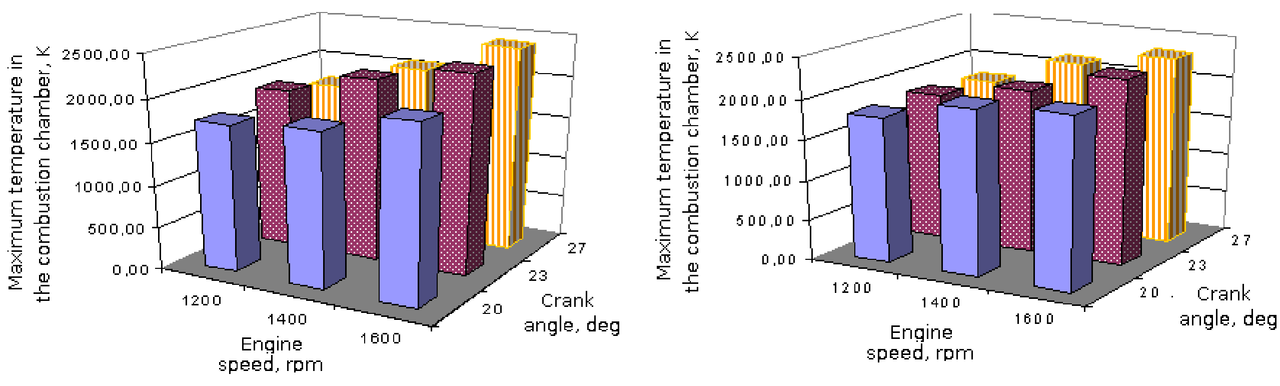

Fig 11.The in-cylinder temperatures versus crank angle and engine speed, without ((left) and with (right) inner catalyst application

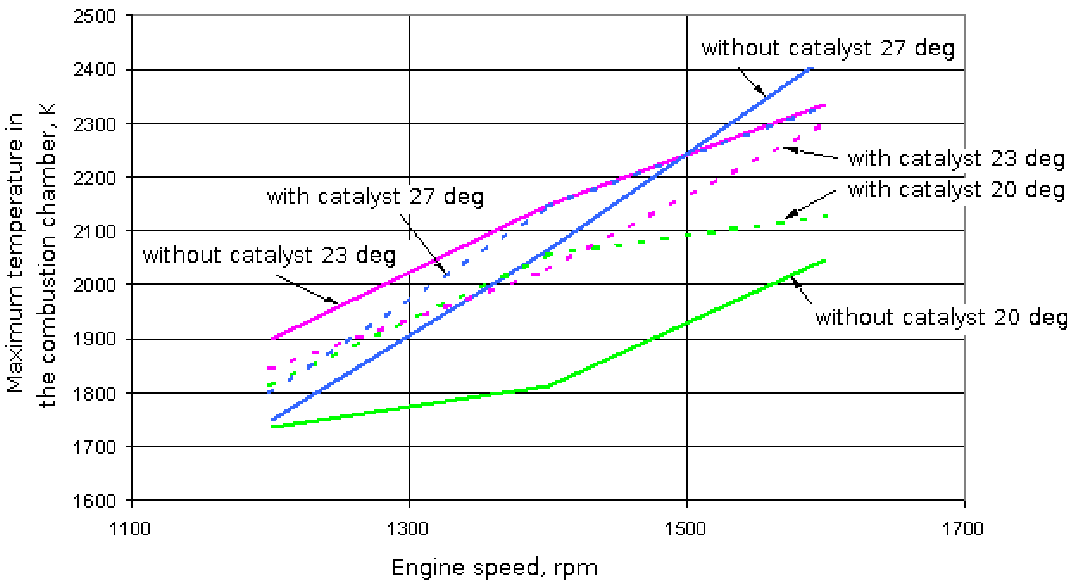

Fig 12.The in-cylinder temperatures versus engine speed, for both engine states (with and without catalyst) and various crank angle degrees

The results of in-cylinder temperature analysis indicates on effect of inner catalyst application on engine performance but trends of the engine parameters variations and their explanation should be investigate in the future research.

4. Conclusions:

1. The platinum/rhodium active factor on zirconium thermal barrier coating placed into combustion chamber (inner catalyst) effects on the diesel engine performance.
2. The impact of the inner catalyst seems to be advantageous for ignition delay.
3. The active ceramic on the engine valve surface caused increase of in-cylinder maximum pressure and temperature values.
4. To determine and explain trends of pressure and temperature values changes versus engine parameters the researches on inner catalyst application should be continue and developed.

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