INERT CATALYST IN COMPERSION IGNITION ENGINE - VOC'S EMISSION

Anna Janicka[1], Wojciech Walkowiak[2], Włodzimierz Szczepaniak[1]

Wroclaw University of Technology
[1]Institute of Environmental Protection, [2]Institute of Machine Design and Operation
Wybrzeże Wyspiańskiego 27, 50-370 Wroclaw, Poland
e-mail: anna.janicka@pwr.wroc.pl, wojciech.walkowiak@pwr.wroc.pl
wlodzimierz.szczepaniak@pwr.wroc.pl

Abstract

The volatile organic compounds (VOC's) are significant group o air pollution emitted during fuel combustion in diesel engines. This research work is continuation of research where the influence of an inert catalyst on toxic emission from a self-ignition engine has been investigated. In particular volatile organic compounds VOC's emissions which are known to have mutagenic and carcinogenic properties, have been studied. The experimental results show that implementation of catalytic coating on chosen elements of diesel engine causes change of percentage participation of particular compounds in their sum and decrease of their concentration. The analysis of chosen compounds (benzene and formaldehyde) shows that the modification which was proposed causes increase of concentration of those substances when engine works in specific conditions, what is connected with change of engine exhaust toxicity and decrease in PAHs concentration, what is connected with toxicity decrease in exhaust gases.

In particularly research work stand, the comparison of total VOC's concentration with and without catalytic coating, the comparison of benzene concentration, the comparison of formaldehyde concentration, the comparison of toxicity level with and without catalytic coating are presented in the paper.

Keywords*: combustion engine, inert catalyst, VOC's, compression ignition engine emission*

1. Introduction

The volatile organic compounds (VOC's) are significant group o air pollution emitted during fuel combustion in diesel engines. Because a fact that most of VOC's are listed as being toxic a problem of reduction of their concentration in diesel engines, exhausts is considered necessary to be solved. In atmosphere, because of ultraviolet radiation, VOC's can be able to formation into secondary pollutions (photochemical reactions) [1].

In group of VOC's the most toxic and common in human environment are particularly [1]:

- Benzene – the simplest organic compound in group of hydrocarbons. Because of its high volatile and able to commutation (in some conditions) in atmospheric air, benzene is one from the most toxic industrial poisons. It is known from its mutagenic and carcinogenic properties. Benzene is absorbed mainly from respiratory system and alimentary canal. Benzene and its metabolites (i.e. phenol) are able to fixation with liver proteins, bone marrow, kidney, blood, muscles and lien proteins. It cause devastation of nervous system and bone marrow (causes leukaemia),
- Formaldehyde (methanol) – the simplest organic compound from aldehydes. It is formed during incomplete combustion of substances with contain carbon. In normal conditions formaldehyde is a gas which has very characteristic, suffocating odour. It is known as toxic, hazardous and mutagenic substance,
- Acrolein – even in low level of concentration in air causes eyes and respiratory system irritations. It is known as very hazardous even deadly, compound.

2. Experiment

A modified 1,9 TDI self-ignition engine (diesel engine) was employed as a research engine. An engine modification was application of platinum-rhodium coating on engine glow plugs. Conventional fuel (commercial diesel oil) was used as engine fuel. Two characteristic engine loads: idle run and 150Nm, were chosen.

As an emission control system platinum-cerium catalytic filter was applied. VOC's emission control was a main aim of the present investigation. Simultaneously CO, NO and smoke level was controlled. A scheme of research work stand – engine test house – is presented in the figure 1.

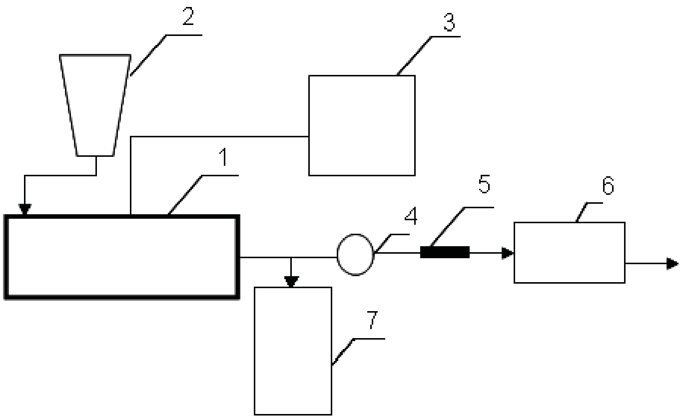

Fig. 1. Research work stand: engine test house. 1 – engine with a break, 2 – fuel reservoir, 3 – NO, CO and smoke level analyzers, 4 –formaldehyde absorber, 5 – tube with active coal, 6 – exhaust gases uptake system, 7 – engine control system

VOC's samples were up-taken by tubes with active coal (ex. prepared). Formaldehyde was up-taken by special absorption bulb with distilled water.

The laboratory analysis contains two analytic methods: calorimetry (formaldehyde marking according to directive PN-71/C-04539) and chromatography. Gas chromatograph Hewlett-Packard 5890 with FID detector and capillary column (HP-5, 30 m, 0,53 mm) was used for quantity and quality analysis. The chromatography conditions were: column temperature (110 ºC), dozers (150ºC) and detectors (150ºC).

Tab. 1. The Recommended Maximum Concentration Limit (RMCL) and Relative Toxicity Coefficients for chosen VOC's

compound	RMCL $\mu g/m^3$	Relative toxicity coefficients
Acrolein	10	2
Benzene	20	1
Acetic aldehyde	20	1
Butanol	50	0.4
Formaldehyde	50	0.4
Hexane	100	0.2
Toluene	100	0.2
Ethylbenzene	100	0.2
Xylene	100	0.2
Propione aldehyde	300	0.06
Acetone	600	0.033
Oktane	1000	0.02
Heptane	1200	0.0166

For exhaust gases toxicity estimation relative toxicity coefficients was applied. The coefficients were related to the most toxic compounds which were detected: to benzene and acetic aldehyde. The Coefficients was determined based on Recommended Maximum Concentration Limit (RMCL) settled for particular compound (Dz. U. 88.55.355).

Table 1 shows the relative toxicity coefficients for chosen substances.

3. Results

To analyze applied engine modifications effectives (inert catalyst applied on research engine glow plugs) a comparison of two engine work states was performed. The comparison concerns total Volatile Organic Compounds concentration when engine was working with and without designed inert catalyst (Figure 2).

The comparison shows that total Volatile Organic Compounds concentration was on higher level when engine was working with catalytic coating application on engine glow plugs in case of 100Nm and 250Nm engine loads during its work on lower (1800 r.p.m.) and higher (2500 r.p.m.) rotational speed. In case of other engine loads a of total VOC's concentration was observed (50% decrease for engine loads 150Nm and 200Nm and 1800 r.p.m. rotational speed, and insignificant decrease for 200Nm and 2500 r.p.m rotational speed).

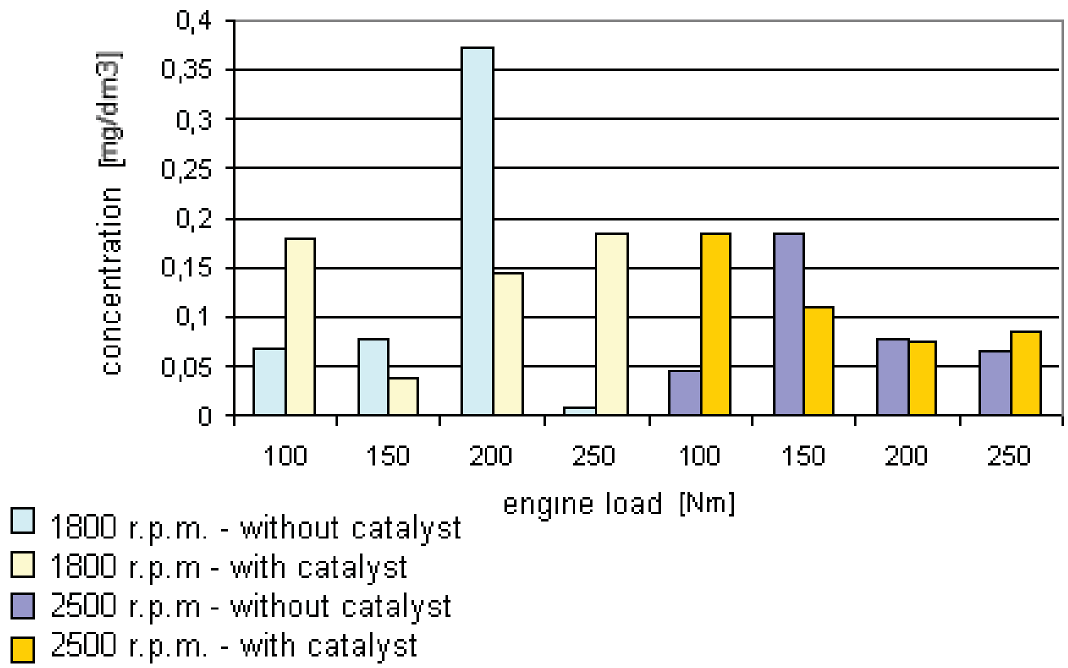

Fig. 2. The comparison of total VOC's concentration for two engine states: with and without catalytic coating on the glow plugs, on for engine loads and two rotational speeds

During a comparison analysis of benzene concentration (Figure 3) a significant increase of total VOC's concentration (from 10% up to 70%) was observed in case of engine work with inert catalyst application (except two phases of engine work: 1200 Nm/1800 r.p.m. and 150 Nm/2500 r.p.m. – in those cases the insignificant (from 10% up to 20%) concentration decrease was observed).

A decrease of concentration level for half of engine phases was observed in case of formaldehyde (mainly for lower rotational speed) (Figure 4). The decrease was ranging from 5% to 60% depending on engine work phase. In other cases a increase of formaldehyde concentration was observed even to 40%.

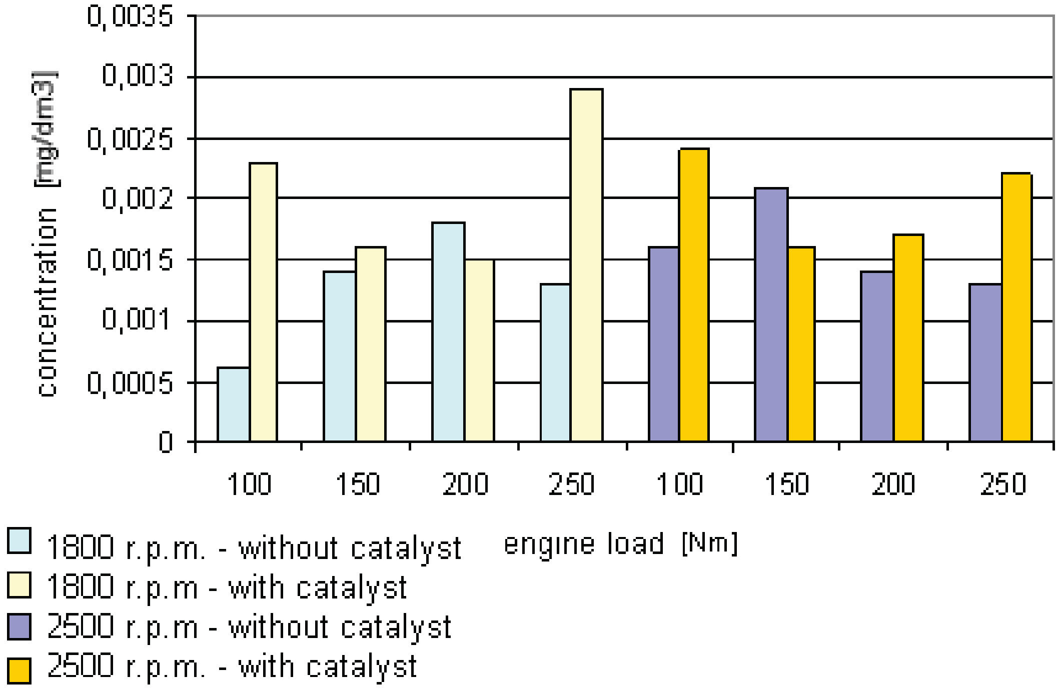

Fig. 3. The comparison of benzene concentration for two engine states: with and without catalytic coating on the glow plugs, on for engine loads and two rotational speeds

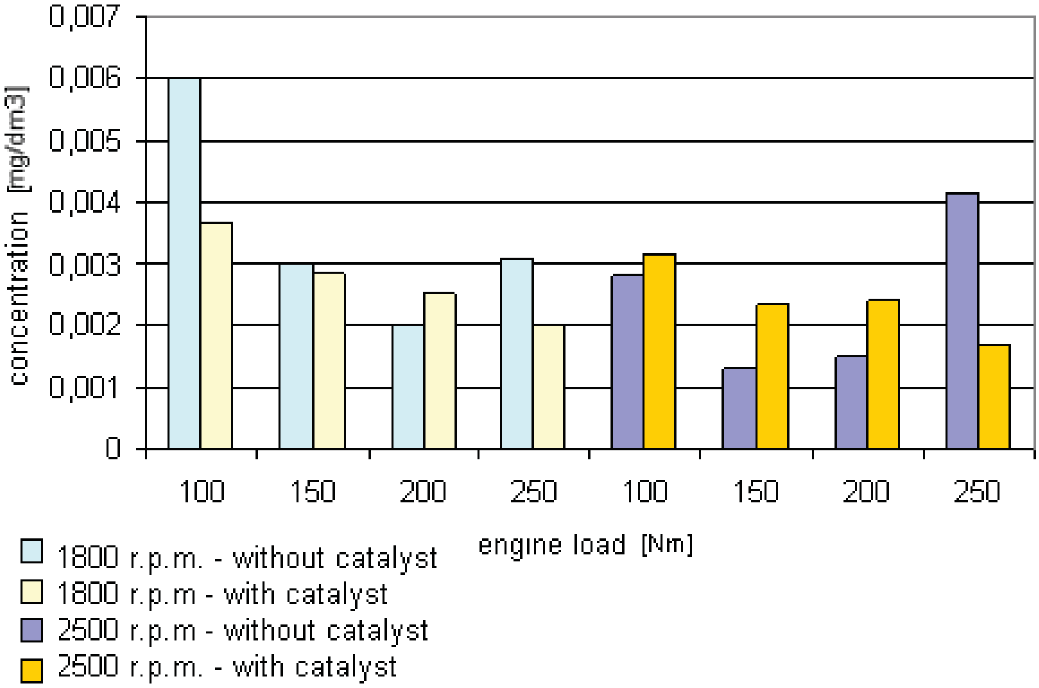

Fig. 4. The comparison of formaldehyde concentration for two engine states: with and without catalytic coating on the glow plugs, on for engine loads and two rotational speeds

One from the most important factors is toxicity of VOC's emitted with exhaust gases during engine work. A toxicity comparison analysis for both states of engine work (with and without active coating) shows that exhaust gases toxicity decrease when engine works with inert catalyst application (except two phases of engine work: 150Nm/1800 r.p.m and 250Nm/1800 r.p.m.). The decrease was ranging from 10% to even 80% (250Nm/2500 r.p.m.) (Figure 5).

The highest effectiveness in toxicity reduction was achieved for peripheral engine loads for each rotational speed of engine.

In case of medium engine loads, for lower rotational speed (1800 r.p.m.) an increase of toxicity level was observed and for higher rotational sped (2500 r.p.m.) reduction of toxicity level was insignificant.

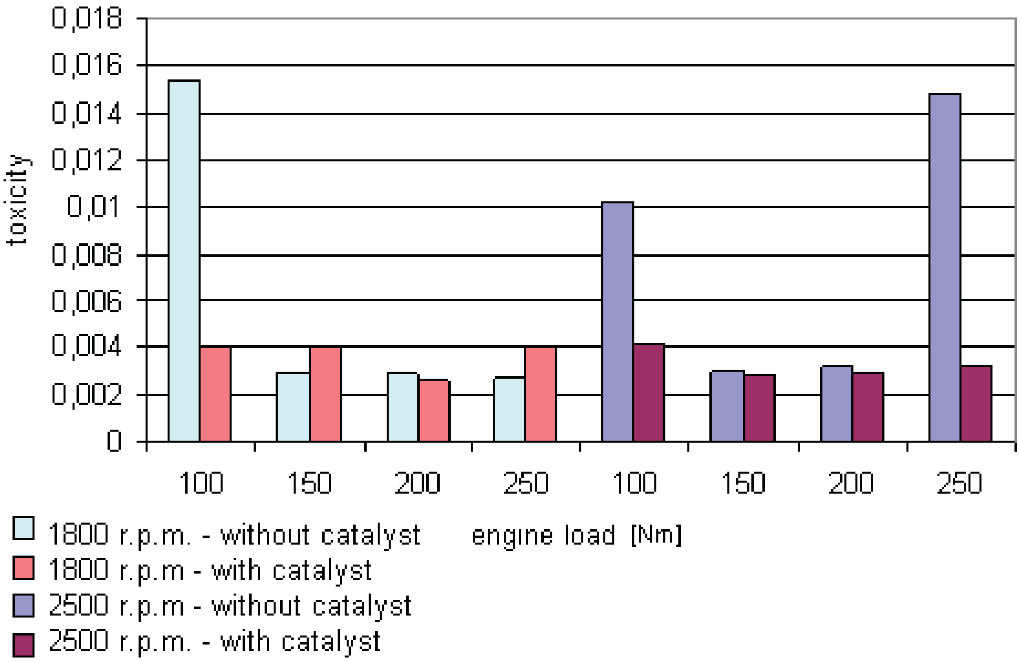

Fig. 5. The comparison of toxicity level for two engine states: with and without catalytic coating on the glow plugs, on for engine loads and two rotational speeds

4. Discussion

Although the inert catalyst application (catalytic coating on the glow plugs) in the compression ignition engine is generally advantageous for limitation of total Volatile Organic Compounds concentration and their toxicity for main phases of engine work which were investigated, in some phases the increase of those factors were observed. Because of this fact it is very important to continue the researches and extend them on physical-chemical modification of catalytic coating and diversified phases of engine work.

Literature

[1] Mendyka, B., Radek P., Wargacka, A., Czarny A., Zaczyńska, E., Pawlik, M., *Cytotoksyczność i mutagenność preparatów zawierających domieszkę estru metylowego oleju rzepakowego,* Medycyna Środowiskowa, 8 (2), 2005.