INERT CATALYST IN COMPERSION IGNITION ENGINE - PAHS EMISSION

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Abstract

In this research work the influence of an inert catalyst on toxic emission from a self-ignition engine has been investigated. In particular polycyclic aromatic hydrocarbons (PAHs) 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 decrease in PAHs concentration, what is connected with toxicity decrease in exhaust gases.

The inert catalyst application (active coating on research engine glow plugs) is very advantageous for decrease of total polycyclic aromatic hydrocarbons (PAHs) concentration in engine exhaust gases, especially on idle running. The applied modification of engine combustion space causes significant decrease of exhaust toxicity. Because of high effectiveness in PAHs concentration and toxicity decrease it is recommended to continue the researches and extend them by various physical-chemical modifications of catalytic layers.

The paper research work stand containing engine test house, engine with a break, fuel reservoir, NO, CO and smoke level analyzers, filter, tube with active coal, exhaust gases uptake system and engine control system. The PAHs concentration marked in idle running diesel engine in two states of engine work, PAHs concentration marked in diesel engine and the total PAHs concentration in engine exhaust gases and PAHs toxicity in engine exhaust gases for two engine loads are presented in the paper.

Keywords: *inert catalyst, PAHs, compression ignition engine emission*

1. Introduction

One of the main anthropogenic sources of PAHs emission is motorization, especially compression ignition engines. The researches of International Agency for Research on Cancer (IARC) prove that some compounds from polycyclic aromatic hydrocarbons group are toxic for live organisms and causes damages of adrenal glands, lymphatic, circulation and respiratory systems [1]. Because of carcinogenic properties and common occurrence in human environment benzo(a)pirene is accepted as PAHs indicator. In relation to benzo(a)pirene, Nisbet and LaGoy determinated Relative Carcinogenic Coefficients (RCC) for particular polycyclic aromatic hydrocarbon (table 1) [2].

The most effective method of PAHs removal from exhaust gasses is using catalytic converters in vehicle exhaust systems.

The complicated problem of polycyclic aromatic hydrocarbons catalytic transformation had been investigated since few last years. Although some researches prove that the effectiveness of catalytic PAHs removal from engine exhaust is very high (in relation to their sum) [3], a problem of PAHs generation on catalytic converter is known [4].

As combustion catalyst of hydrocarbons are applied precious metals like platinum, palladium, ruthenium, rhodium or oxides such metals as manganese, chrome, cuprum.

Tab. 1. PAHs Relative Cancirogenic Coefficients [2]

no.	PAH	RCC
1	benzo(a)pirene	1
2	benzo(a)antracene	0,1
3	indeno(1,2,3-c,d)pirene	0,1
4	antracene	0,01
5	chryzene	0,001
6	naphtalene	0,001
7	acenaphtylene	0,001
8	acenaphtene	0,001
9	fluorene	0,001
10	phenantrene	0,001
11	pirene	0,001

The hydrocarbons combustion proceeds according to reaction [4]:

$$C_nH_{2n+2} + (3n+1)/2\ O_2 \Longrightarrow nCO_2 + (n+1)H_2O.$$

The catalysts contain platinum and palladium are more active in full hydrocarbons oxidation, especially aromatic hydrocarbons, than catalysts contains oxides such metals as: Cu, Mn, Cr, Fe, Co, Sn, Ni, Zn.

In case of peculiarly toxic polycyclic aromatic hydrocarbons interpretation of catalytic oxidation base on two phases: reactions cause formation of carbonyl compounds which next react to formaldehyde, carbon dioxide and water according to reactions [4]:

$$C_nH_{2n+2} + (O) \Longrightarrow [C_{n-1}H_{2n-1}COO] \xrightarrow{(O)} n(HCOOH),$$

$$(HCOOH) + O_2 \Longrightarrow CO_2 + H_2O + (O).$$

Williams and Schmidt [5] during their researches on catalytic oxidation of higher alkanes using rhodium as active agent, have analyzed the parameters of autoignition. The authors have observed that making even minimal addition of rhodium to a reactor which simulates engine conditions (with some restrictions referring to real engine conditions because the reactor worked in adiabatic conditions) causes increase effectiveness of higher alkanes removal. One of Williams and Schmidt suggestions is these that active agent which is put into combustion space causes start of complicated chain reactions, which is related with abbreviation of time of chemical autoignition delay what is connected with exhaust toxicity decrease.

Mello, Bezaire and Sriramulu [6], in their researches have investigated influence of catalytic layer inside of a self-ignition engine feed by natural gas (DI-NG) on autoingnition delay. The authors were trying to solve problem of time of autoignition delay abbreviation which is related with higher hydrocarbons emission. During the researches Mello, Bezaire and Sriramulu [6], have observed satisfactory effects of toxic emission reduction on higher loads of engine condition, but when engine idle running the effects was very insignificant. The suggestion of the authors is that physical-chemical modification of catalyst layer may improve its effectiveness.

Based on literature data [4 – 8] it is possible to conclude that modification of combustion space by making addition of active agent (catalyst) may, with significant probability, causes abbreviation of autoignition delay time.

2. Experimental

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.

PAHs 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.

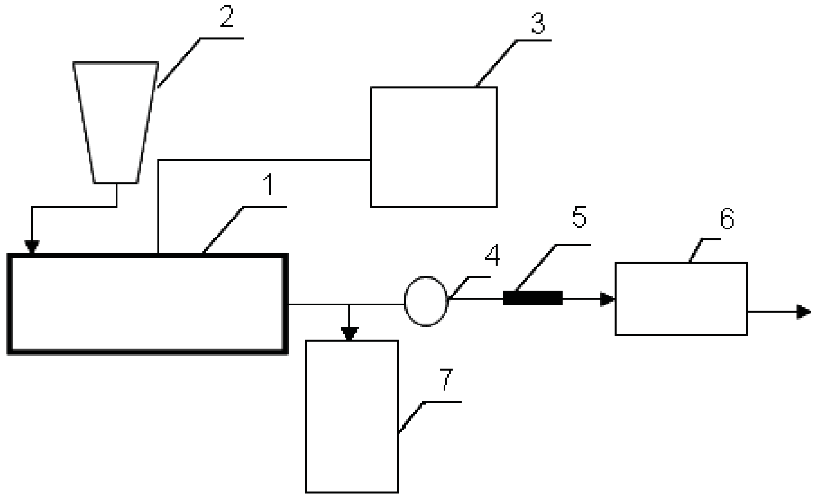

Fig. 1. Research workstand: engine test house. 1 – engine with a break, 2 – fuel reservoir, 3 – NO, CO and smoke level analyzers, 4 – filter, 5 – tube with active coal, 6 – exhaust gases uptake system, 7 – engine control system

In connection with low level of PAHs concentration in exhaust gases PAHs analytic method based on few important stages: uptake stage, research material recovery, sample purification and enrichment, chromatography analysis. Because of unstable parameters of engine work (pressure and temperature jumps) PAHs samples was uptaken by tubes with active coal, type SKC-lot 120, (gas phase) and by Staplex TF AGF 810 filters (PAHs adsorbed on particle matter) [12]. According to new analytic recommendations Solid Phase Extraction was used for sample purification. 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 calibration was made by attested mixture of 16 model samples (according to EPA, USA). The temperature was programmed in the range 60 – 280 ^{o}C with 15 deg/min increase.

For estimation of exhaust toxicity Nisbet and LaGoy Relative Carcinogenic Coefficients (RCC) was used (Table 1).

3. Results and discussion

In result of the research work, which aim was PAHs marking in exhaust 1,9TDI engine, six from possible 16 hydrocarbons was detected: acenaphtylene, acenaphthene, fluorene, phenanthrene, fluoranthene and pirene.

The results of measurements are shown in the table 2.

The analysis of two states of engine work was performed. In the first state the engine was working without any modification and in the second state with inert catalyst application (Figures 2 and 3).

For both states, the reduction of amount of detected hydrocarbons and decrease of their concentration level was observed (except acenaphthene which concentration increases when engine was working with inert catalyst).

Tab. 2. Polycyclic aromatic hydrocarbons concentration [μg/dm^3] in diesel engine exhaust gases in two states of engine work

	PAHs concentration [μg/dm^3]			
	whidout catalyst		**with catalyst**	
engine load [Nm] / PAH	**5**	**150**	**5**	**150**
Acenaphthylene	0,00624	0,00518	n.d.*	0,00596
Acenaphthene	0,00496	0,00534	0,00757	0,03353
Fluorene	0,01184	0,00975	0,00562	0,00400
Phenantrene	0,03569	0,05432	n.d.*	n.d.*
Antracene	n.d.*	n.d.*	n.d.*	n.d.*
Fluoranthene	0,07039	0,03222	n.d.*	n.d.*
Pirene	n.d.*	n.d.*	n.d.*	n.d.*
total	**0,12912**	**0,10680**	**0,01319**	**0,04349**
toxicity	**0,00013**	**0,00011**	**0,00001**	**0,00004**

* - non detected.

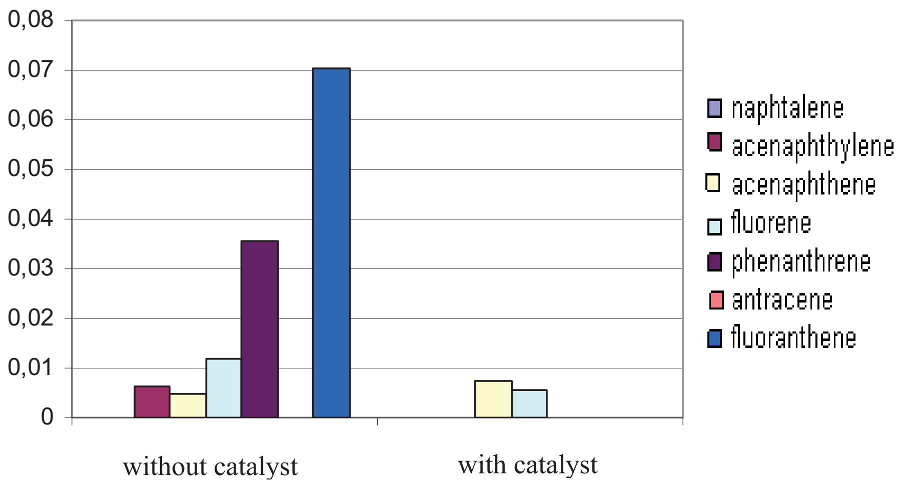

Fig. 2. PAHs concentration [μg/dm^3] marked in idle running diesel engine in two states of engine work

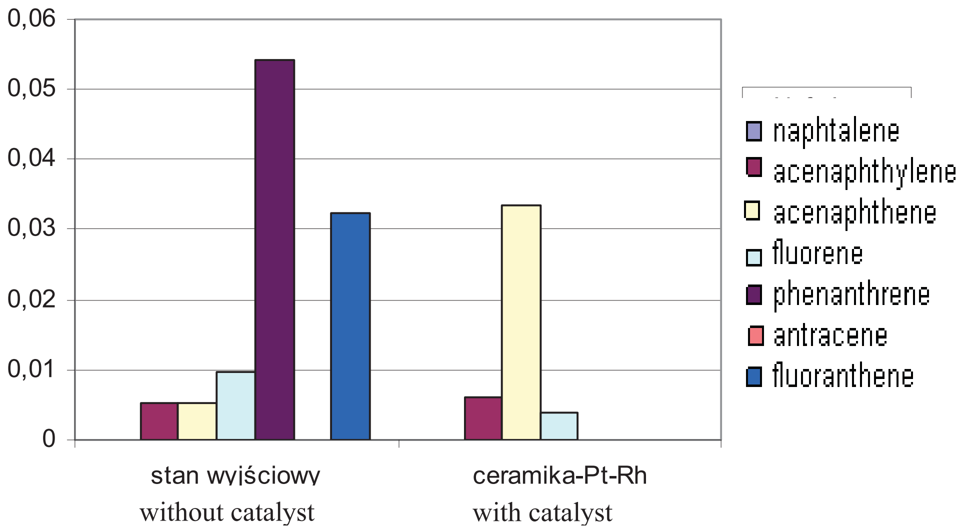

Fig. 3. PAHs concentration [μg/dm^3] marked in diesel engine (engine load: 150Nm)

The comparative analysis of states of engine work shows that inert catalyst application cause significant decrease of total PAHs concentration level especially on idle running conditions (about 90%) (Figure 4).

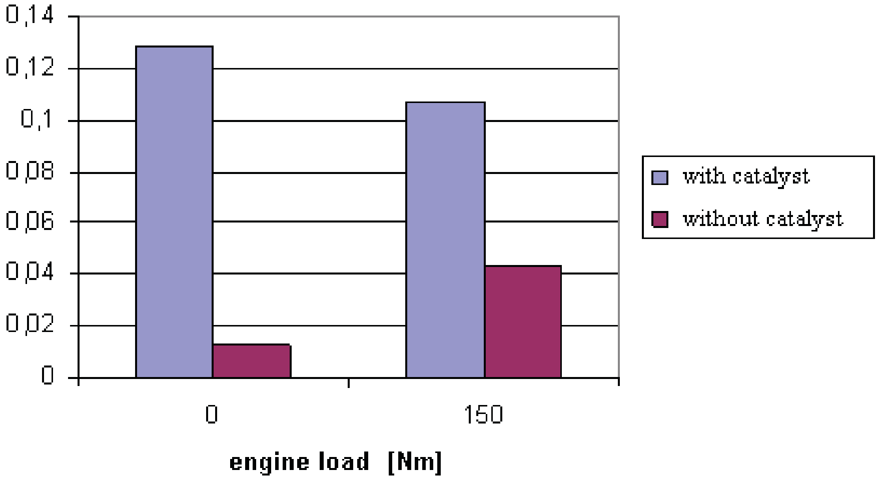

Fig. 4. Total PAHs concentration [µg/dm^3] in engine exhaust gases for two engine loads

An analogical situation is observed in toxicity analysis of engine exhausts (Figure 5).

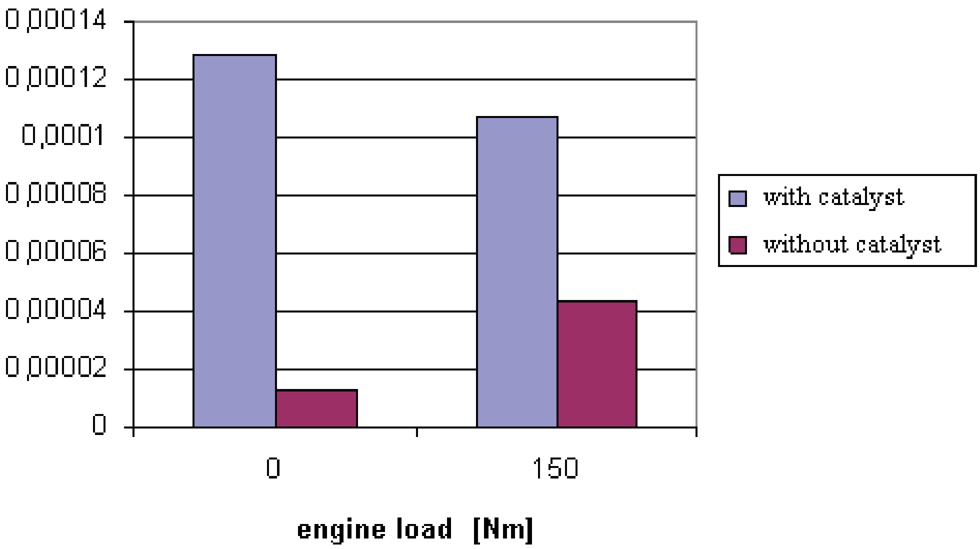

Fig. 5. PAHs toxicity in engine exhaust gases for two engine loads.

Inert catalyst application causes 60% decrease of total detected PAHs toxicity for 150Nm engine load and almost 90% for idle running.

4. Conclusions

1. The inert catalyst application (active coating on research engine glow plugs) is very advantageous for decrease of total polycyclic aromatic hydrocarbons (PAHs) concentration in engine exhaust gases, especially on idle running.
2. The applied modification of engine combustion space causes significant decrease of exhaust toxicity.
3. Because of high effectiveness in PAHs concentration and toxicity decrease it is recommended to continue the researches and extend them by various physical-chemical modifications of catalytic layers.

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