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THE IMPACT OF ACTIVE CERAMIC COATING IMPLEMENTATION ON GASOLINE ENGINE EXHAUST TOXICITY

Anna Barbara Janicka, Wojciech Walkowiak, Agnieszka Sobianowska-Turek

Wroclaw University of Technology
Institute of Machine Design and Operation, Emission Research Laboratory
Wybrzeże Wyspiańskiego 27, 50-370 Wroclaw, Poland
tel.: +48 71 3477918, fax: +48 71 3477918
e-mail: anna.janicka@pwr.wroc.pl
wojciech.walkowiak@pwr.wroc.pl

Abstract

One of the ways for toxic emissions reduction from internal combustion engines, beside external Exhaust purification systems and alternative fuels, is direct intervention into engine combustion process. The inner catalyst application, in form of ceramic active coating applied inside of combustion chamber, is one of the examples of that kind of solution. The application of active coating inside of a compression-ignition engine (diesel engine) may have an important impact on several stages of combustion process: fuel cracking, fore-flame phase, combustion phase and secondary combustion phase. Investigations of such construction are very rare in the literature. The paper presents the results of the researches which aim was analysis of inner catalyst application impact on toxic emissions. As a catalyst platinum and rhodium was used. As a catalyst support and local thermal barrier a zirconium ceramic coating was used. The catalyst was located on the gasoline engine valves surface. The research was done in Emission Research Laboratory of the Division of Motor Vehicles and Internal Combustion Engines. The analysis was done according to European standard (EN ISO 16017-1: 2006) on gas chromatograph (Varian 450 GC) equipped in capillary column and flame-ionization detector (FID). The results of the researches proofed effectiveness of that solution on toxic emissions limitation.

Keywords: *inner catalyst, exhaust toxicity, internal combustion engine, exhausts toxicity*

1. Introduction

Volatile organic compounds are significant group amid 200 identified compounds in diesel engine exhaust (mainly aldehydes but also alcohols, ketons, esters, paraffin and aromatic hydrocarbons). In group of VOC's the most toxic and common in human environment are particularly: benzene, toluene and xylene (so called BTX group) [1, 2].

As an effective method for controlling the engine emissions of VOC's catalytic combustion has been proposed and developed. As combustion catalyst of hydrocarbons are applied precious metals like platinum, palladium, ruthenium, rhodium or oxides such metals as manganese, chrome, cuprum. The catalysts are usually deposited on monolith supports and placed into vehicle exhaust system as catalytic reactors. Their effectiveness is correlated with exhaust gases temperature and reaches the highest values when exhaust temperature is below approximately 523 and 573 K. When engine is idle running exhaust gases temperature is too low to ensure sufficient effectiveness of the catalytic reactor in reduction of CO and hydrocarbons (HC) [5].

In Division of Motor Vehicle and Internal Combustion Engines the researches on inner catalyst application have been provide since last few years. The active factor (catalyst is implemented into engine combustion space. The investigation was provided on diesel engine. A very high effectives in toxic hydrocarbon reduction was observed [3, 4, 6]. This phenomena is connected with improvement of combustion process (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) but also because of ceramic layer application which was used as a catalyst carrier but primarily as a thermo-isolating material (thermal barrier) to cause temperature local increase [5, 6].

This study concerns an experimental inner catalyst application in gasoline engine.

2. Experiment

A modified 1.6 gasoline engine was employed as a research engine. An engine modification was application of platinu-rhodium inner catalyst on engine valves. As a catalyst carrying zirconium ceramic layer was used. A scheme of the inert catalyst is shown in the Fig. 1.

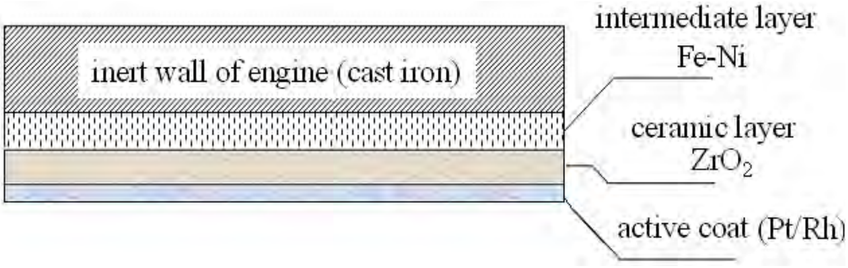

Fig. 1. Scheme of the inner catalyst

Conventional fuel (commercial diesel oil) was used as engine fuel. The characteristic points of engine work were chosen:

1. Engine speed: 1500 rpm engine load: 30 Nm,
2. Engine speed: 2000 rpm engine load: 40 Nm.

CO, NO, HC and 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 Fig. 2.

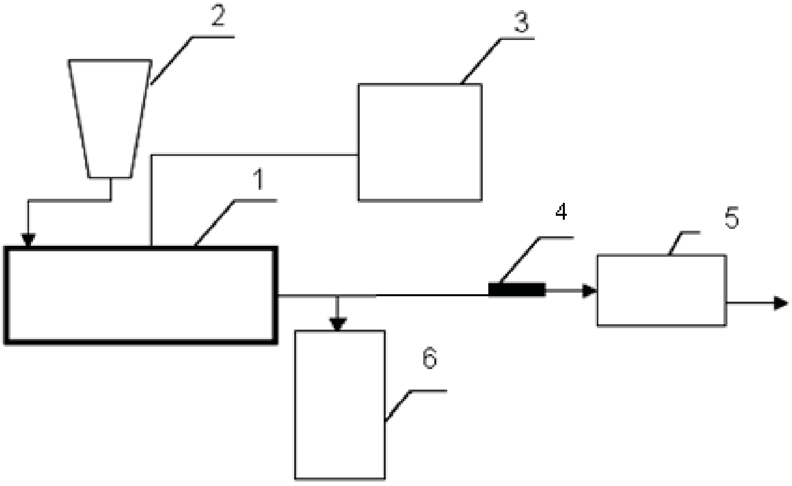

Fig. 2. Research workstand: engine test house. 1 – engine with a break, 2 – fuel reservoir, 3 – engine control system, 4 – tube with active coal, 5 – exhaust gases uptake system for hydrocarbons sampling, 6 – NO, CO and HC analyzers

VOC's samples were uptaken by tubes with active coal (SKC lot 2000). The analysis was done according to polish standard: PN – EN ISO 16017-1: 2006. The laboratory analysis of VOC's is based on gas chromatography. Gas chromatograph Varian 450 GC with FID detector and capillary column was used for quantity and quality analysis. The chromatography conditions were: column temperature (110°C), dozers (150°C) and detectors (250°C). The error of the analytic method is on 30% level and strongly depends on extraction stage.

3. Results and Discussion

The analysis of total concentration of volatile hydrocarbons indicates on high effectiveness of active coating inside gasoline engine on VOC's reduction in exhaust (over 50% in both points of engine work) (Fig. 3).

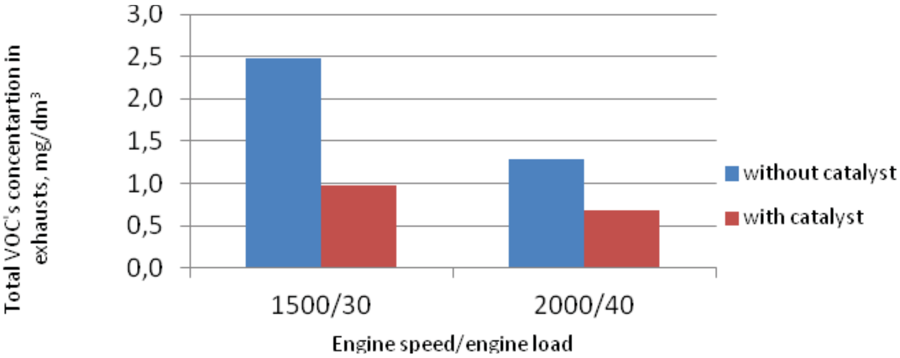

Fig. 3. Total VOC's concentration, mg/dm^3, in exhausts gases

The effect of catalytic factor is significant especially for lower engine speed and lower load what is very important because of the fact that lower combustion temperature causes higher hydrocarbons emission.

When engine was working on speed 1500 rpm and load 30 Nm following VOC's was identified: n-pentane, 2-propanol, benzene, toluene, etylobenzene, xsylene, cumene, propylobnzene, mesitylene (Fig. 4).

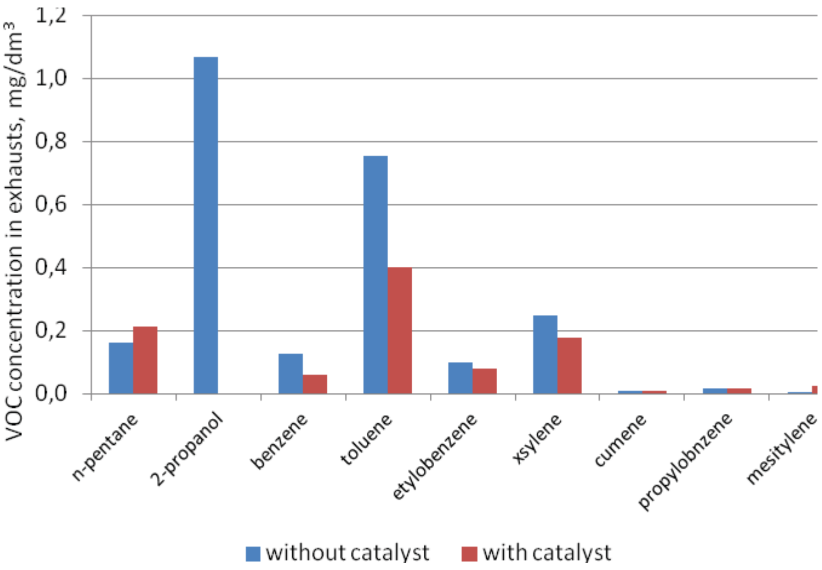

Fig. 4. VOC concentration, mg/dm^3, in exhaust gases; Engine speed: 1500 rpm, engine load: 30 Nm

After inner catalyst application on engine valves concentration of most toxic, aromatic hydrocarbons (like benzene, toluene, xylene and ethylobenzene) was reduced. The reduction of aromatic hydrocarbon group is shown also on Fig. 4. Removal of n-propanol cause elimination of alcoholic group in the exhausts. Concentration of n-pentane, propylobenzene and mesitylene increase slightly.

During the engine work on higher speed and load (2000 rpm/30 Nm) n-pentane 2-propanol, benzene, 2-butanol, toluene, etylobenzene, cumene, propylobnzene and mesitylene was detected (Fig. 5).

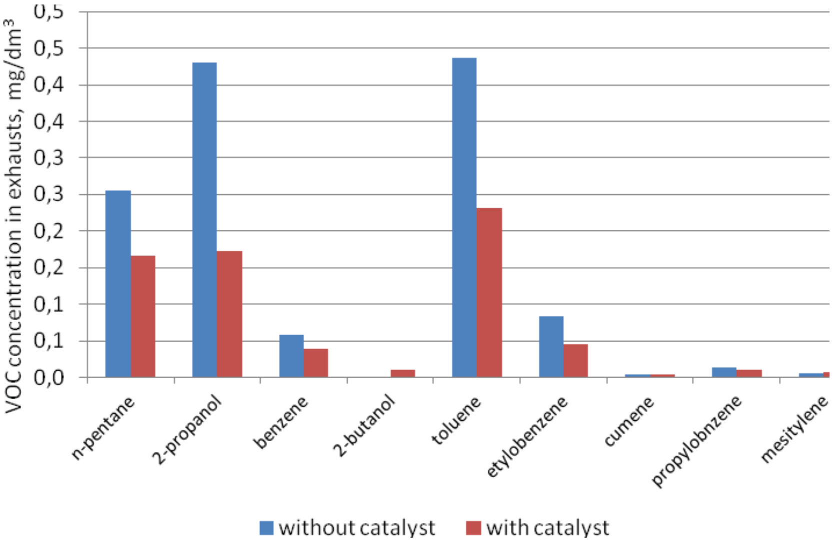

Fig.5. VOC concentration, mg/dm^3, in exhaust gases; engine speed: 2000 rpm, engine load: 40 Nm

Almost every compound concentration (except 2-butanol) from VOC's group was reduced after active factorimplementation into combustion space. Toxic aromatic hydrocarbons concentration was reduced about 40% (Fig. 6).

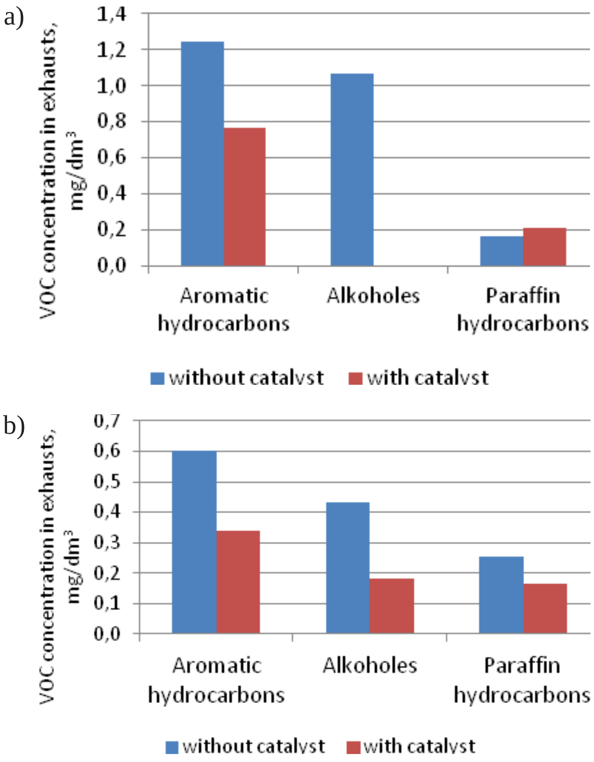

Fig. 6. Group share of VOC's identified in exhausts: a) engine speed: 1500 rpm, engine load: 30 Nm (on left), b) engine speed: 2000 rpm, engine load: 40 Nm (on right)

The catalyst application did not impact significantly on concentration of CO in exhausts (Fig. 7). The highest reduction of this compound concentration level was detected for lowest engine load on lower engine speed (1500 rpm/40 Nm).

Also in case of NO concentration in exhausts the impact of the inner catalyst was rather insignificant (Fig. 8). NO concentration strongly depends on combustion process temperature (thermal NO_x).

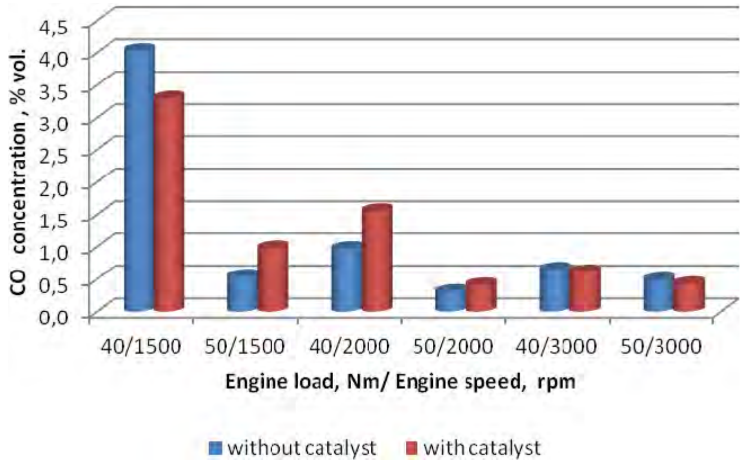

Fig. 7. CO concentration, % vol., in exhausts

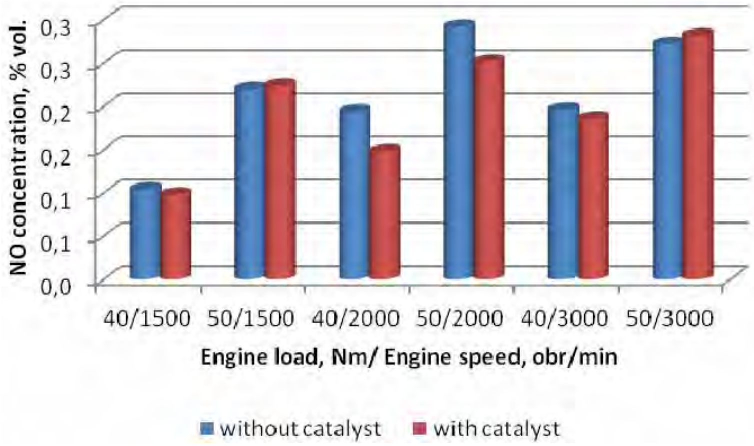

Fig. 8. NO concentration, % vol., in exhausts

The changes in level of concentration of total hydrocarbons (HC) show similar situation to results of chromatographic analysis for VOC's – high effectiveness (from 20% to over 60%) of the catalyst (Fig. 9).

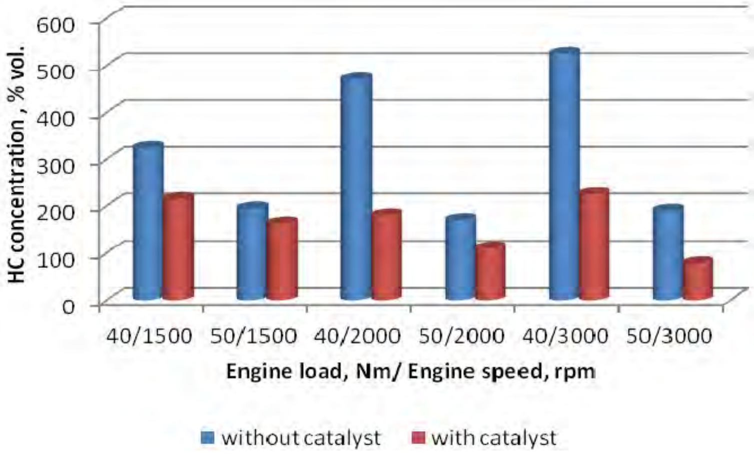

Fig. 9. HC concentration, % vol., in exhausts

Taking into consideration fact that according to the recent researches [1, 2, 6] hydrocarbons in the engine exhausts are the most hazardous, toxic, mutagenic and carcinogenic group of the substances, inner catalyst application seams to be good solution for toxicity reduction of engine exhaust.

4. Conclusions

1. The inner catalyst application in gasoline engine is very advantageous in reduction of total hydrocarbon concentration aspect.
2. The significant reduction of aromatic, volatile organic group (also BTX) concentration in the exhausts was observed as an effect of catalytic factor application in gasoline engine combustion space.
3. The results of the researches indicate that inner catalyst application causes decrease in exhaust toxicity.

References

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