SELECTED ISSUES REGARDING IN-CYLINDER CATALYTIC COATING

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Abstract. The problem of harmful components emissions lies at the basis of current motorization development and legislative action aimed at reducing the air pollution caused by road transport. From the internal combustion engines ecological properties point of view, solutions that would limit the formation of harmful compounds in the combustion chamber are desirable, e.g. by shortening the ignition delay time. One of the technical solutions available to reduce the amount of impurities present in the combustion chamber is the catalytic coatings implanted on the engine components – the glow plug, cylinder head or piston
Keywords: catalytic coating, combustion chamber, emissions, ICE

1. Introduction

The problem of harmful components emissions lies at the basis of current motorization development and legislative action aimed at reducing the air pollution caused by road transport. The most significant changes include the expansion of the current type approval test to include the RDE (Real Driving Emissions) test performed in real vehicle driving conditions. These actions are intended to adjust the type approval procedure to reflect the actual vehicle operation to the fullest extent possible.

The regularly tightened limits for harmful components emissions imposed on motor vehicle manufacturers force the application of new methods to reduce the amount of pollutants in the exhaust gases. The solutions observed in the last dozen or so years, that allow meeting the type approval tests requirements, are mainly related to advanced exhaust aftertreatment systems – the use of catalytic converters, particle filters and selective catalytic reduction technology. All of these technical solutions concern the treatment of the exhaust gases that have left the internal combustion engine, and they do not contribute to limiting the formation of harmful compounds. From the internal combustion engines ecological properties point of view, solutions that would limit the formation of harmful compounds in the combustion chamber are desirable, e.g. by shortening the ignition delay time. One of the technical solutions available to reduce the amount of impurities present in the combustion chamber is the catalytic coatings implanted on the engine components – the glow plug, cylinder head or piston [2].

2. Methodology of catalytic surfaces coating

One of the most important properties of catalytic surfaces is the service life, which depends mostly on their application technique [1, 5]. One of the most popular and easiest methods is the plasma spray method, which dates back to the fifties of the twentieth century. Plasma spraying is usually carried out under ambient conditions – APS (Atmospheric Plasma Spraying). Depending on the type of sprayed elements or chemical compounds, the conditions for the formation of the catalytic layer may vary [6].

Plasma spray coatings typically consist of high melting point materials such as metal oxides and carbides, as well as pure metals, metal alloys and mixtures:

- ceramic coatings – aluminum oxide, chromium oxide, and zirconium oxide coatings,
- cermet coatings – mixtures of ceramic and metal materials with different chemical and phase compositions,
- metal coatings - tungsten and molybdenum coatings, as well as alloy coatings of cobalt, chromium or nickel etc. [6].

From the perspective of the catalytic coating life, ion implantation is a superior solution to plasma spraying, indicated as a solution with high future potential [3]. The use of this method, however, involves a greater financial cost. Ionic implantation is mainly used to improve the usable properties of implanted materials. The material-based process itself is based on the use of high dopants kinetic energy. Dopant atoms are ionized in the ion source and then accelerated in the electric field to the energy of a few hundred kilovolts. The formed ion beam is directed at the surface of any material. The ions are introduced (implanted) into the substrate surface to a depth of about one micron. The kinetic nature of this process means that practically any material can be doped with any element. The biggest advantage of the ion implantation method is the lack of adhesion problems between the material and the modified layer. This is because there is no boundary between the substrate and the implanted material. The process itself does not involve the addition of a material layer, but rather the structure modification of the existing substrate surface [4].

The ion implantation method also has its limitations, mostly due to its inability to work with complex shapes. Structural changes with the doping material only affect the layer directly within the ion beam. In addition to the inability to modify complex geometric details, the relatively low penetration depth and high cost of implantation can be considered as the main disadvantages [4].

3. Catalytic surfaces applications

The study by Zu and Ladommatos [2] concerned the emissivity assessment of a platinum-rhodium-plated internal combustion engine. The researched object was a single-cylinder SI engine. A 0.15 mm thick catalyst layer was applied in the process of plasma spraying. Hydrocarbon and nitrogen oxide concentrations (Fig. 1-4) were measured at full engine load, constant crankshaft rotational speed of 1500 and 2000 rpm, and variable air to fuel ratio (Φ).

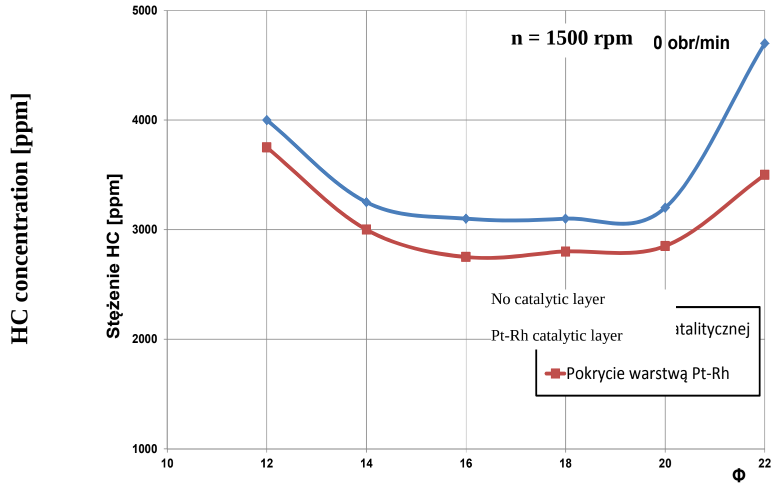

Fig. 1. HC concentration change at engine speed of 1500 rpm due to the effect of the catalytic surface

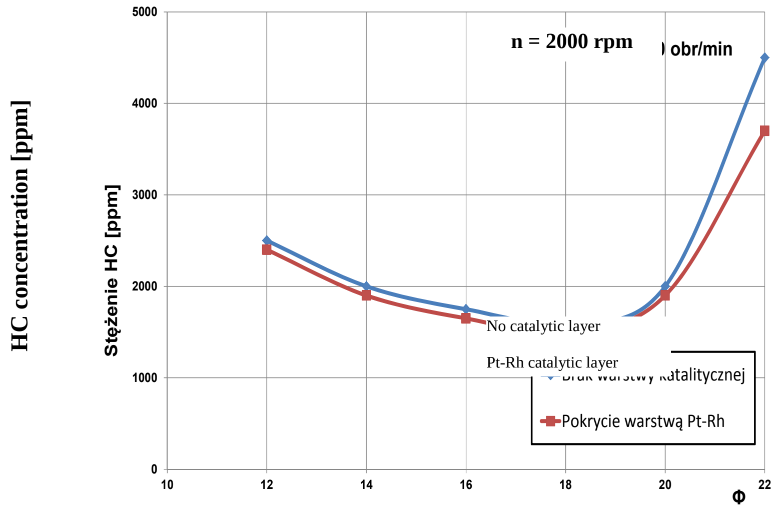

Fig. 2. HC concentration change at engine speed of 2000 rpm due to the effect of the catalytic surface

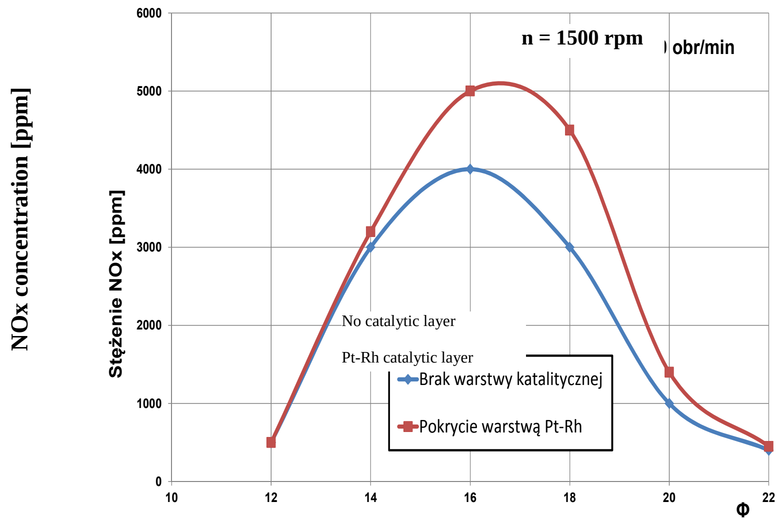

Fig. 3. NO_x concentration change at engine speed of 1500 rpm due to the effect of the catalytic surface

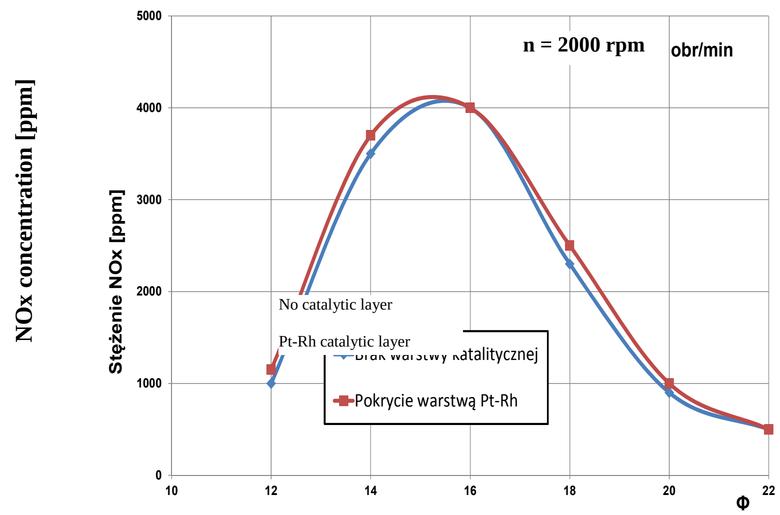

Fig. 4. NO_x concentration change at engine speed of 2000 rpm due to the effect of the catalytic surface

The obtained results indicated:

- a reduction of hydrocarbon concentration at engine speed equal to 1500 rpm by about 20% as a result of catalytic oxidation,
- slight decrease in hydrocarbon concentration at the engine speed of 2000 rpm,
- an unfavorable impact of the catalytic layer on the nitrogen oxides concentration at crankshaft rotational speed of 1500 rpm – average increase of 10%,
- No significant changes in the nitrogen oxides concentration at engine speed of 2000 rpm.

Further tests [2] measured hydrocarbon and nitrogen oxides concentrations according to the cooling fluid temperature (Figures 5 and 6).

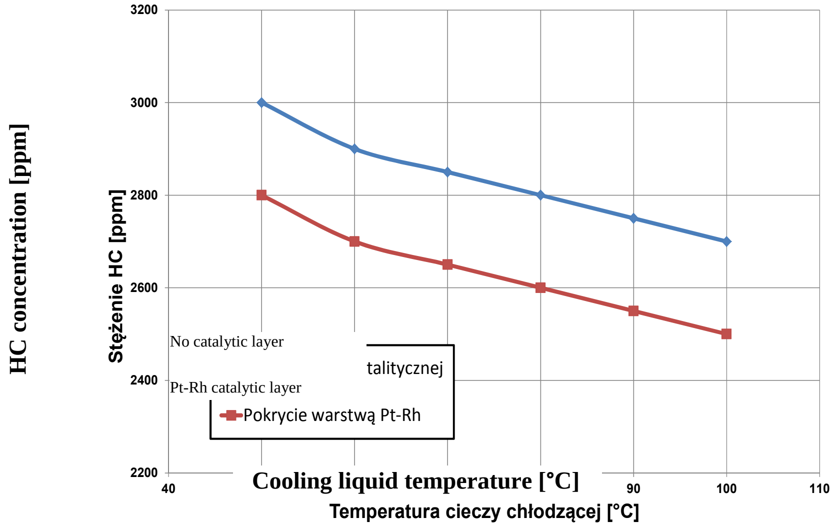

Fig. 5. HC emission change as a result of the catalytic surface at different coolant temperature values

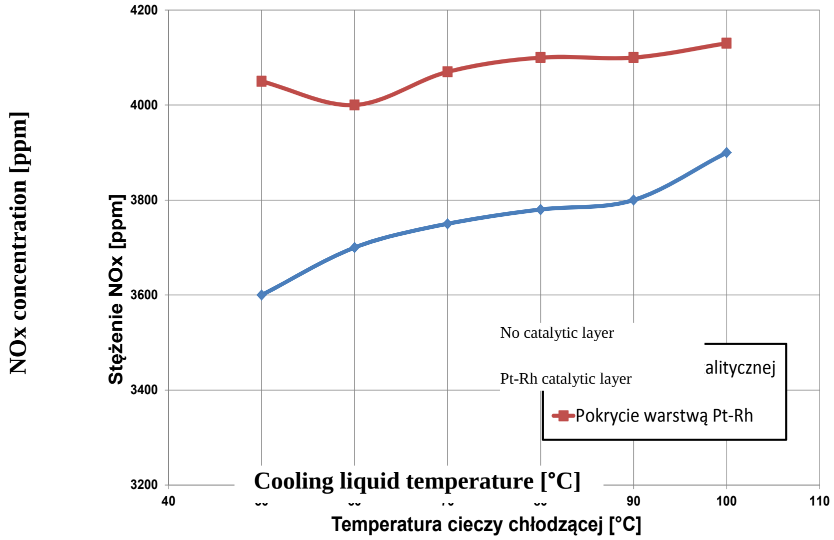

Fig. 6. NO_x emission change as a result of the catalytic surface at different coolant temperature values

The performed measurements revealed a linear relationship between hydrocarbon concentration and the coolant temperature. The use of a catalytic surface reduced the hydrocarbon concentration by about 10%. This indicates that the catalytic oxidation efficiency, resulting from the presence of a catalyst inside the engine, does not depend on the engine temperature. On the other hand, the concentration of nitrogen oxides increased due to the increase of the maximum temperature inside the cylinder, as a result of the catalytic processes. The intensification of the above phenomenon does not depend on the engine temperature.

4. Conclusions

Legislative changes and increasingly stringent emission standards result in the search for new technical solutions for limiting the harmful emissions from internal combustion engines. Apart from the use of advanced exhaust aftertreatment systems, it is necessary to seek solutions to limit the very formation of harmful compounds in the combustion chamber. Based on a performed review of the application of in-cylinder catalyst layers, it has been found that they are a technical solution that can effectively limit the formation of harmful compounds in combustion engines. The life span of a catalytic surface depends on its application technology. Plasma spraying is the most common and most readily available, but in the context of catalytic coating life it does not work as well as ion implantation, indicated as a high potency solution in this aspect.

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