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SELECTED POSSIBLE APPLICATIONS OF NANOMATERIALS IN AUTOMOTIVE INDUSTRY

Michał Ciałkowski, Michał Giersig, Antoni Iskra, Jarosław Kałużny, Maciej Babiak

Poznan University of Technology
ul. Piotrowo 3, 60-965 Poznan, Poland
tel.:+48 61 6652705, fax: +48 61 6652204
e-mail: jaroslaw.kaluzny@put.poznan.pl

Abstract

The nanotubes and nanotechnologies are relatively new areas of science and engineering practice. This article should be concerned as a review of the selected nanotechnology applications in the automotive industry. The applications were divided into groups in respect of implementation advance level. Special attention was devoted to innovative nanomaterials application in areas where taking advantage of their unique features is possible. Authors presented the catalytic converter for combustion engine exhaust system application in which the nanotubes were used in order to increase the contact area of exhaust gases with catalytic layer. In the paper preliminary results of proposed catalytic reactor conversion ratio were presented and future directions of development were discussed.

1. Introduction

The automotive industry has its own specificity due to which it can be distinguished on the background of other branches of industry. The cars are characterized by a fact that for more than one hundred years a process of their improvement takes place on a way of evolution and during this period the detailed design solutions are developed while their general design characteristics and functionality are kept unchanged. In fact a modern car is not so different from its prototype as, for instance, modern TV or telephone sets in comparison with their prototypes developed a few dozen years ago. In case of domestic appliances their design improvement process causes that though their original functions are maintained the construction and the way of operation of the former and current versions in some cases are different. However, paradoxically, basing on the above it should not be concluded that the motor industry is characterized by a certain conservatism which provides an artificial barrier for modern technologies and solutions. Though such a barrier really exists, however, it results from the specification of a final product – which due to that improvement process lasting for more than one hundred years – is difficult to be improved in a simple way, and due to large serial production where each modification must be well ransomed by a large investment. At the same time it is worth notifying that large serial production of cars does not only create a certain barrier for the application of new materials, but it is also a driving force which gives bonuses to more effective solutions which are cheaper than the previous ones being used so far.

Nanomaterials are characterized by some especially advantageous mechanical properties unattainable for conventional materials, however, their scale of applications in the motor industry is limited by their high prices, availability in industrial amounts and instability of properties of the individual lots of products.

2. The selected examples of well proved applications of nanomaterials in the motor industry

The motor industry applies the profitable features of the polymer-nanomaterial composites to a relatively large extent. Such plastics are already in current production on an industrial scale, and their advantages are as follows:

- increased rigidity free of loss in impact strength;
- dimensional stability;
- barrier effect improvement;
- increased thermal stability and fire resistance;
- good optical properties (filler particles with a diameter size smaller than visible light wave length make no barrier for them);
- limitations of the surface defects of products,
- increased crystallization ratio in relation to the original polymer [4].

The dashboards and body panels made of polymer composite materials have a higher resistance for scratching and surface damaging. A possibility of using the barrier properties of the nano-composites for building the fuel tanks is especially profitable. The nano-composites on a PA base are used as an inner layer in the multilayer blowing of fuel tanks while their outer layers are made of PE-HD.

Montmorylonit (MMT), which ensures good barrier properties, is used in another form for improving the characteristics of varnish coating being used for cars especially in order to increase their mechanical resistance [4].

The next group of nanomaterial applications, especially interesting one, has been found in the tribology field, in main nodes of friction of the piston engine. The Schaeffler Company developed a new technological line making possible the use of nanomaterial top layers in cylinder bearings and highly loaded elements of the driving gear systems. [9]

In the project presented in [10] a top layer of the engine cylinder surface, deposited by plasma spraying, in the AL-cylinder block engine was used. The obtained nanomaterial cylinder bearing surface gives a profitable alternative for a standard solution with a cast iron sleeve insert and makes reduction in friction losses and mass of the engine possible. Some examples of tribologic applications of the thermoplastics strengthened by nanomaterials are presented in [1].

Only the most significant domains of applications of nanomaterials in the motor industry with regards to the production scale were presented above. In a wider context those domains could be divided in a following way:

- bodies and elements of the load carrying structure if vehicles;
- engines and power transmission systems;
- varnish coating and other;
- chassis mechanism and brakes;
- tyres;
- lubricants and operation media;
- electric and electronic equipment elements;
- engine exhaust system and exhaust gas cleaning systems [8].

3. Possible domains of the new applications of nanomaterials in motor industry

Nanotechnology is commonly considered as a one of the key technologies of the 21st century and its special role results from some exceptional – mechanical, electric, thermal, and optical properties of nanomaterials – completely different from the properties of the conventional construction materials. Carbon nanomaterials form crystal lattices with an extremely limited concentration of defects. The crystal structure give them very high hardness and mechanical strength values which are at least by one order of magnitude higher than those in case of steel, at very high elasticity values. Such materials conduct electricity very well, they become superconductors in low temperature and they are resistant to high temperatures and due to their dimensions smaller than the light wave length forming the transparent surfaces is possible. The organized crystal structure created by carbon atoms arranged in a plane forming a side cylinder surface is a form of fullerenes called a nanotube. Organized crystalline structure made by carbon atoms at surface forming graphen is show on fig. 1.

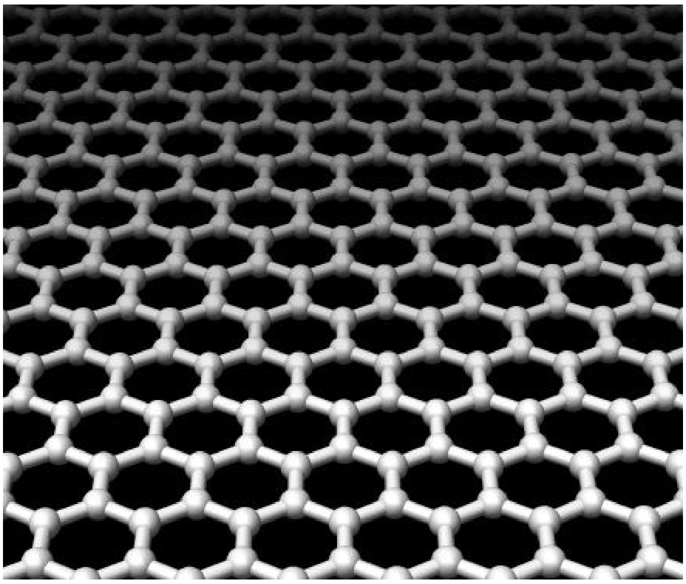

Fig. 1. Schematic structure of graphen

Nanotubes present a piezoelectric effect even after applying a relatively low voltage and the observed elongation is several times higher than in case of the quartz crystal pile supplied with a high voltage. Such a characteristic is especially desirable in case of building an actuator for controlling the nozzle needle. Moreover, nanotubes placed in vacuum can act as actuators (Young's modulus 1800 GPa) even under the conditions of very high temperature ranging up to 2800 °C [2, 6, 7]. The peculiar optical properties of nanotubes cause that their use in the car windscreen production, where they could play a role of the electric heating and windscreen deeming depending on the intensity of light, enters the car manufacturers' field of interests.

Some interesting examples of application of nanotubes for building the catalyst converters making the conversion of gases possible can be fund in the bibliography [3]. The authors of this paper think that it is advisable to test the usefulness of carbon nanotubes applied as a catalytic converter carrier in the engine exhaust systems. Ratio of solid area to solid volume increases as the solid size decreases. A nanotube considered as a cylinder with a diameter measured in nanometers is characterized by an especially advantageous solid area to solid volume ratio value and by the same it can be considered as a very attractive carrier of the catalytic layer of the converter by increasing its area of contact with the exhaust gases.

4. Carbon nanotubes in the catalytic converter applications

A standard design of the catalytic converter for clearing the exhaust gas from a car engine uses a ceramic carrier coated with an intermediate layer increasing its roughness and contacting with exhaust gas area. In case of the oxidation converter used in Diesel engines platinum is deposited on the intermediate layer which is the proper catalyst in a chemical meaning. The authors have built a test converter which is based on a standard ceramic carrier, on which nanotubes functioning as an intermediate layer are deposited and finally pointwisely platinum coated. Due to a limited diameter of 84 mm of the test converter, its carrier length of 20 mm and the density of ducts of 400 cpsi, only a fragment of exhaust gas stream is directed into the test converter. The nanotube test catalytic converter is developed by the Chair of Thermal Engineering of the Poznan University of Technology (PUT) within the international co-operation with Boston College in the United States of America and the Hahn-Meitner-Institut in Berlin in Germany. The typical view of our catalytic converter prototype is shown on fig. 2. The accurate information about carbon tubes growing process can be found in the K. Kempa's publication [5].

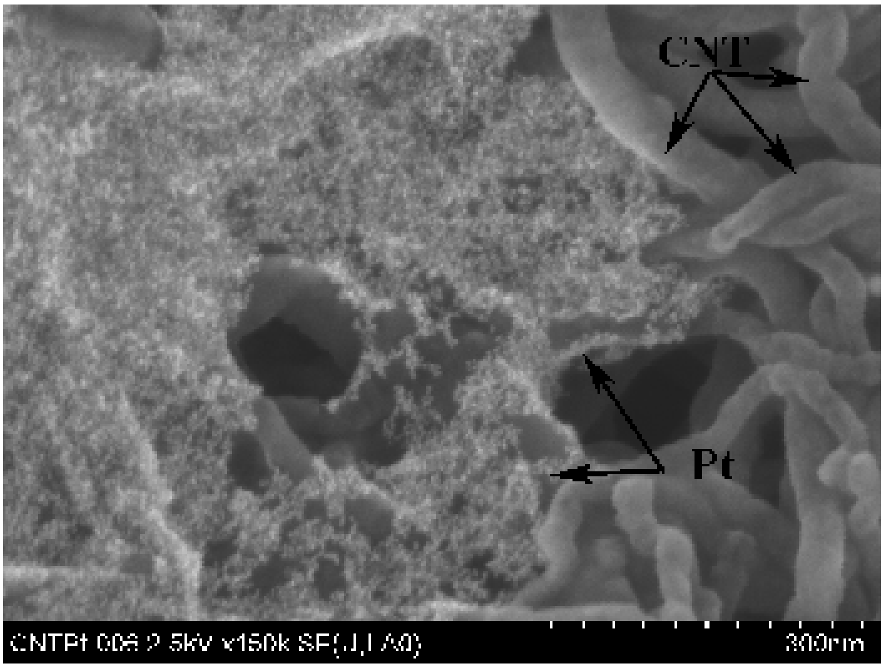

Fig. 2. Picture of carbon tubes (CNT) on the ceramic face and platinum nanoparticles placed on its surface taken with scanning microscope

Examinations of the conversion rate for selected toxic exhaust elements were carried out at the laboratory of the Institute of Combustion Engines and Transport of PUT. Volkswagen TDI engine of AXE code was used during the tests. It is a modern 5-cylinder, supercharged Diesel engine being currently mounted in Volkswagen Tranporter and Touareg cars, its swept volume is 2,5 dm^3, maximum output power is 96 KW and it fulfils the requirements of the Euro 4 exhaust emission standard.

The analysis of the exhaust gas components was carried out by the TESTO 360 exhaust-gas analyser. The concentration of toxic exhaust gas elements is measured by the NDIR method and electrochemical cells, and exhaust gas is delivered to the device via a heated gas line. The engine test stand with the Volkswagen TDI engine, TESTO exhaust – gas analyzer and test converter is showed on fig 3.

Obviously the developed test catalytic converter with the intermediate nanotube layer is not allowed to be considered as a completely functional device with characteristics which could enable it to be mounted in its present form in cars being currently produced. The exhaust gas conversion ratio and resistance of flow would have unacceptable values even if taking into consideration the limited dimensions of the carrier. However, it was the authors intention to find out whether the converter developed by them can work and to obtain the first conclusions.

Fig. 3. The engine test stand for examinations of the catalytic converter conversion ratio

The preliminary tests, the results of which are presented in Table 1, were performed for several engine operating points in the range of loads most often experienced in real operation. According to the assumed concept of examinations the exhaust gas stream after leaving the engine was separated into the fragments flowing through the test converter and the standard oxidation converter used by the engine manufacturer. The exhaust gas emission measurements concerning the CO and HC concentrations were taken before converters and at the same time behind the test converter and the standard one.

Tab. 1. Results of the preliminary engine tests

Engine operating point P	Engine rotational speed	Fuel dose	Exhaust gas temperature after turbine	CO before converter	CO after test/standard converter	HC before converter	HC after test/standard converter
-	[rev/min]	[mg/cycle]	[°C]	[ppm]	[ppm]	[%]	[%]
1	1800	25	467	135	56/7	0,053	0,040/0,041
2	2500	15	387	160	51/7	0,072	0,057/0,038
3	2500	10	282	333	183/6	0,102	0,081/0,039

5. Summary and conclusions

The unique properties of nanomaterials suggest that these materials are, at last potentially, able to revolutionize the technical solutions being in use so far, the motorization field including. It can be assumed that at the moment we are at the beginning of the process of the implementation of nanomaterials in the industrial automotive applications. In the aspect of the automotive design solutions nanotubes possess especially advantageous properties, and one of their possible application is an intermediate layer of the catalytic converter in the engine exhaust system. This paper presents some results of the preliminary measurements of the conversion ratio of the oxidation converter which was obtained by coating a ceramic standard carrier with a layer of nanotubes on which platinum particles with diameters ranging from 2.5 to 5 μm were pointwisely deposited. Thereby some characteristic of nanotubes was used, namely, their especially advantageous area/volume ratio allowing to enlarge an area of the contact of the catalyst, which is platinum, with exhaust gas. According to the authors' opinion the obtained results theoretically confirm the possible profits resulting from the described nanomaterial application and they present the first stage in the optimization process. The industrial use of the nanomaterial converter with the proposed construction solution is conditioned by a cost-and-profit calculation in comparison with costs of the conventional converters. However, in the presence of the observed intensive process of the reduction in nanomaterial production costs it is worth continuing studies on new fields of their applications.

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