THE IMPACT OF AUTOMOTIVE CATALYTIC CONVERTERS ON REDUCING EMISSIONS INTO THE ATMOSPHERE

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Abstract

This study explores the profound impact of automotive catalytic converters on mitigating atmospheric emissions, aiming to comprehensively analyze their mechanisms, classifications, merits, and drawbacks. The research focuses on the efficiency of catalytic converters in reducing the emissions of harmful substances, including hydrocarbons, nitrogen oxides, and carbon monoxide – major contributors to air pollution with adverse effects on both human health and ecosystems. Special attention is given to technological innovations and advancements in catalytic converter design aimed at enhancing their effectiveness while minimizing negative environmental consequences.

The study's to quantitatively assess pollution levels emitted by vehicles equipped with operational catalytic converters, drawing a comparison with those without catalytic converters. The methodology involves the use of instruments such as the automotive scanner ELM 327 version 1.5 and the gas analyzer "ГАНК-4" for precise measurements and analysis. The comprehensive comparative analysis seeks to highlight the strides achieved by automotive catalytic converters in actively mitigating atmospheric emissions.

In the introduction, the study underscores the significant role of automotive transportation as a primary contributor to atmospheric pollution, releasing nitrogen oxides, hydrocarbons, carbon monoxide, and particulate matter. To address these environmental challenges, catalytic converters are employed, utilizing precious metals like platinum, palladium, and rhodium to catalyze chemical reactions that transform toxic gases into less harmful or inert substances. However, the study acknowledges the drawbacks associated with catalytic converters, including high costs, wear and tear, potential effects on engine performance, loss of activity, and the risk of secondary pollution.

The study provides a detailed examination of catalyst composition, highlighting the use of ceramic or metallic honeycombs with micro-layers of reactive metals. Modern catalytic converters are described as three-component systems, with each element addressing specific pollutants.

In conclusion, this research contributes valuable insights into the multifaceted aspects of automotive catalytic converters, offering a balanced assessment of their positive contributions to reducing atmospheric emissions and the challenges associated with their implementation. By conducting a quantitative analysis of pollution levels and a comprehensive comparative evaluation, the study aims to contribute to ongoing efforts in developing more efficient and environmentally friendly catalytic converter technologies.

The objective of this study is to scrutinize the operational principles, classifications, merits, and demerits of automotive catalytic converters. Additionally, a comprehensive evaluation will be conducted to gauge their influence on the surrounding environment. The primary objective is to quantitatively assess pollution levels emitted by vehicles equipped with operational catalytic converters, juxtaposed with those without catalytic converters. Furthermore, the study aims to conduct a comprehensive comparative analysis of the strides achieved by automotive catalytic converters in mitigating atmospheric emissions.

Keywords: Automotive Catalytic Converters, Atmospheric Emissions, Air Pollution, Nitrogen Oxides, Hydrocarbons, Carbon Monoxide, Precious Metals, Environmental Impact, Technological Innovations, Comparative Analysis, Catalyst Composition, Three-Component Systems, Engine Performance, Secondary Pollution, Environmental Challenges.

Utilized Instruments:

Automotive scanner ELM 327 version 1.5, gas analyzer "ГАНК-4"

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Introduction:

Automotive transportation stands as a primary contributor to atmospheric pollution through harmful emissions, adversely impacting human health and ecosystems. Among these emissions, nitrogen oxides, hydrocarbons, carbon monoxide, and particulate matter pose significant threats. To mitigate air pollution from vehicular exhausts, specialized devices known as catalytic converters are employed. Catalytic converters possess the capability to transform toxic gases into less harmful or inert substances through chemical reactions occurring on the surfaces of precious metals such as platinum, palladium, and rhodium. While catalytic converters prove effective in combating atmospheric pollution, they are not without drawbacks, including high costs, wear and tear, subsequent engine performance effects, loss of activity, and secondary pollution [1].

The cornerstone of the catalyst comprises ceramic or metallic honeycombs. Depending on the model, a micro-layer of palladium and rhodium or iridium is applied to the honeycomb walls. These metals exhibit elevated chemical reactivity. Regarding deposition, a portion of the exhaust engages in a chemical reaction. Some elements resulting from fuel combustion are bound.

Modern catalysts are three-component systems:

The first element binds nitrogen oxides.

The second eliminates some unburned fuel elements, primarily carbon monoxide.

The third element is a sensor, analyzing gases at the catalyst's exit, with data transmitted to the onboard computer.

Manufacturers claim a service life of 100-150 thousand kilometers for the neutralizer. However, practical issues may arise even with lower mileage, especially in metropolitan areas where frequent traffic congestion is commonplace.

Depending on usage patterns, the replacement of the catalytic neutralizer may be scheduled every 3-7 years. In the event of catalyst-related issues, prompt replacement is imperative. Optimal resolution entails the installation of an authentic neutralizer. All substitutes and deceptive imitations may precipitate an expedited engine failure, render the acquisition of a diagnostic certificate unattainable, and additionally impose an undue burden on environmental sustainability [2].

Functional Assessment of the Automotive Catalyst:

To scrutinize the performance of automotive catalysts, we resolved to conduct an emissions analysis on three vehicles utilizing the "ГАНК-4" gas analyzer. The "ГАНК-4" gas analyzer is a portable automatic device with forced sample extraction designed for measuring the concentration of chemical substances and providing readings of physical factors in ambient air, occupational environments, enclosed living spaces, industrial emissions, ventilation discharges, and technological processes. Its purpose is to safeguard the environment, ensure occupational safety, optimize technological processes, and uphold the sanitary-epidemiological well-being of citizens [3].

For our comprehensive analysis, we selected three automobiles. The first, a Chery Tiggo4 Pro, is of the 2023 model year with a 1.5-liter engine. This vehicle, equipped with a catalytic converter, stands as the most recent in our lineup. The second automobile is an Opel Astra G, manufactured in 2002, featuring a 1.6-liter engine. Representing the oldest among the three, it holds historical significance. The final addition to our study is the Kia Rio, a 2013 model with a 1.6-liter engine, notably lacking a catalytic converter. This analysis aims to unveil the functional attributes of the catalyst after two decades of operation and discern any disparities between vehicles with and without this emission control technology. The outcomes of our examination are detailed in Table 1.

Table 1 - Chemical Substance Concentration Determination Using "ГАНК"

Substance	Formula	ПДК	Chery Tiggo	Opel Astra	Kia Rio
Carbon monoxide	CO	5.00	3.13 3.11 3.25	3.83 3.61 3.55	3.92 3.79 3.91
Nitrogen dioxide	NO_2	0.200	2.74 2.84 3.32	2.75 4.43 3.29	3.36 3.85 4.07
Nitric oxide	NO	0.400	0.00107 0.00192 0.00275	0.00250 0.00282 0.00322	0.00286 0.00314 0.00318
Carbon(Soot)	-	0.150	0.0146 0.0143 0.0153	0.0186 0.0208 0.0187	0.0210 0.0243 0.0226
Carbon dioxide	CO_2	3900	1100 1120 1460	3210 2800 2640	2960 2990 3110

The results of our analyses distinctly showcase the superior performance of the latest automobile model among the parameters measured. As for the vehicle lacking a catalytic converter, it exhibited suboptimal emission outcomes. Based on the analytical results, one can assert the enduring efficacy of catalytic converters in automobiles, even those two decades old.

In addition to emissions analysis, we opted to conduct tests on vehicles with catalytic converters using the ELM 327 automotive scanner. This device stands as a versatile automotive scanner employed for diagnosing vehicle systems. It enables users to read and analyze information related to various automobile parameters, encompassing engine status, error code retrieval, fuel efficiency, and more[4]. The emission test data is presented in Figures 1 and 2.

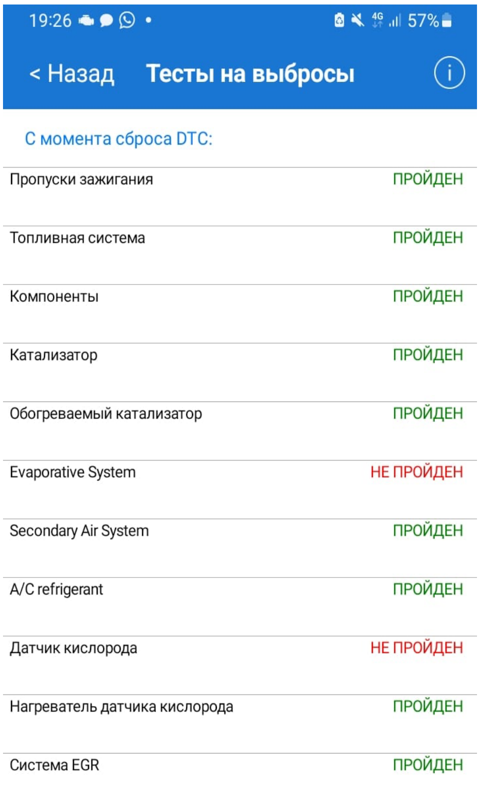

Figure 1- Result of Opel Astra G (2002 to)

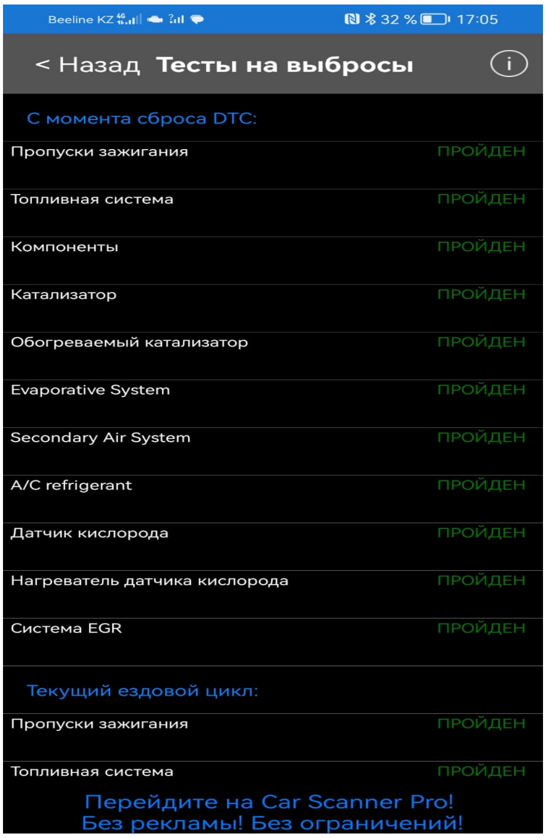

Figure 2- Result of Chery Tiggo 4 Pro (2023 to)

The illustration reveals a malfunction in the oxygen sensor heater of the vehicle with a two-decade mileage history. Drawing from the test outcomes, we can affirm that the wear and tear of the catalytic converter significantly influences the emissions released into the atmosphere.

In the culmination of our scholarly endeavor, we draw the inference that automotive catalytic converters play a pivotal role in curtailing the release of harmful substances into the atmosphere. All the data meticulously collected by our study attests to the substantial positive impact of these devices on the environment, contributing to the enhancement of air quality and the reduction of adverse effects on human health. Emphasis is placed on the imperative need for continued research and developments in this domain to elevate the efficiency of catalytic converters and contribute to the sustainable evolution of transportation infrastructure.

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