Designing for Manufacturing of the Closed Control System for Cars Waste Gases Neutralization

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Abstract. The process of end-to-end digital design of the closed control system for exhaust gas neutralization of cars proposed by the authors is considered. Known catalysts with heating, but without heating control are not effective enough to neutralize harmful exhaust gases. The system includes measurement means of gas concentration, control unit and standard units of the vehicle catalysis exhaust system, communication devices, GPS/GLONASS as elements of this control system. The stages of end-to-end digital system design from digital modeling of functions, schematic, design solutions oriented on selected production technologies are considered. Full or partial digital design of technological and production processes is provided. The principal novelty is the use of catalyst controlled heating, as well as the creation of assign vehicle units of the system for serial production. A computer program has been developed that simulates the stages of digital electronics production for environmental monitoring systems. The computer program contains elements of the cyber physical systems concept. The computer program is designed to ensure the quality of design and production efficiency. The knowledge base was built as ontological approach for supporting and updating information about the system with the ability to extract knowledge at the request of users is proposed. The input information for filling the knowledge base is formed on the basis of conceptual and constructive knowledge, as well as databases containing information about the system elements. The description of the knowledge base, the results of the development, possible ways of development are given.

1. Introduction
The solution of the actual ecological problem of monitoring and minimization of harmful exhaust gases of cars on the basis of controlled catalytic neutralization was proposed in [1,2,3] in the form of a closed control system (CCS) of car exhaust gases (CEG). The creation of CCS is aimed at minimizing the harmful emissions of cars, such as carbon monoxide (CO), hydrocarbons (CₙHₘ), nitrogen oxides (NO, NO₂ ..., NOₓ), by bringing together modern technologies and spatial communication facilities for the catalyst control. In a number of works [4, 5, 6, 7] the electric heating of catalysts efficiency is experimentally confirmed. However, the catalysts with unregulated heating
are not effective enough to solve the actual problem, for example, for cold start modes and, if necessary, take into account external background concentrations.

CCS research have shown that global and local management of catalysis can create a system that not only minimizes harmful emissions to the atmosphere, but also controls vehicles in accordance with environmental norms in space and time. We offer CCS based on measurements of the concentration of emissions in one car, and in the flow taking into account background concentrations. The system implements local and global CEG neutralization technologies.

The article describes the end-to-end digital process of designing CCS CEG, ensuring its further production. The applied program, CAD/CAM tools, computer program, knowledge base, models and methods provide technical solutions for further production based on the accepted criteria. Previous researches are the basis for the design. The design process is carried out using the developed knowledge base (KB), which is based on the general principles proposed in [8] for KB "Control system "nature-technogenic". The mathematical models, results of the analysis and synthesis of CCS CEG, the element base, design decisions, means of interoperability contain in the same KB.

2. Object for design
The object of design is CCS for measurement and neutralization of exhaust gases, which is presented in Figure 1.

![Figure 1. Object for design.](image)
catalyst [1];
catalyst heater [2];
a sensor for the concentration of carbon monoxide measurement [3];
a sensor for the concentration of nitrogen oxides measurement [4];
a sensor for the concentration of hydrocarbons measurement [5];
feedback unit for neutralization control [6];
a wireless communication unit with a GPS/GLONASS receiver [6.1];
the wireless unit of the GPS/GLONASS transmitter with the catalyst heater control unit [6.2];
catalyst heater control unit [6.3];
block of indication harmful emissions of the car - for the driver [7];
the block of indication harmful emissions - for the dispatcher of technical supervision [8].

A computer program has been developed, which includes modeling the stages of digital production of electronic products for environmental monitoring and control systems in the production process, types of Geomonitoring systems, which are advisable to be designed as cyberphysical. The modules set out in the computer program contain elements of the concept of cyberphysical systems that are in demand for transport, as it implies the direct integration of computing resources into the physical processes of car exhaust, monitored and controlled. The computer program is designed for the gradual introduction of technological processes in the digital production of electronic products and contributes to ensuring the quality of design and production efficiency.
3. Design tools
The design process includes the sequential development of structural, electrical circuits, PCB design, development of design documentation, software, manufacture, Assembly and configuration of the prototype.

Figure 2 shows the simplified structure, the elements of the individual parts are omitted.

Figure 2. Structure of the Closed control system for one car waste gases measurement and neutralization.

The structure of the CSS development is carried out using tools such as Matlab, Solid Works. The CCS selected elements is carried out in the Knowledge Base (KB). The electric circuit that includes sensors, controller, measuring and transforming equipment, etc are developed in accordance with the CCS structural scheme. The structure of the KB is presented in figure 6.

The wiring diagram is performed using PCAD design tools. The results of the end-to-end design process are presented by a PCB file (Figure 3). Tools of Design for Manufacturing (DFM) provide resolution of discrepancies in accordance with the IPC standards the during this and subsequent processes. Such processes and the sub processes are Bill of Material Analysis, Component Library, Practical Rules, Validation, PCB Fabrication, PCBA Test Validation [9, 10].

Figure 3. PCB drawing.
Design and production of project documentation are carried out at the following stages of design on the basis of the developed structural and electrical circuits. CAD PRO-ENGINEER, AUTOCAD, ALTIUM were used for this purpose.

The fragment of CCS construction drawings is shown in Figure 4. The proposed version of the placement of the catalyst and the CCS elements behind the main silencer in the trunk allows you to maintain the existing design of the silencer without significant changes.

![CCS construction drawings](image)

Figure 4. Details of CCS construction.

Quality assurance at all stages of the life cycle includes the identification of inconsistencies and the development of management solutions. The corresponding technique is proposed in [11] and developed for end-to-end digital design and production.

In the case of designing for the production of CCS CEG at all stages of the applied four-phase cycle from the identification process of inconsistencies to the process of developing directions of solutions.

To support and update information on CCS developed a knowledge base (Figure 5) based on an ontological approach with the ability to extract knowledge on demand. Input information for filling the knowledge base of the WMS is formed on the basis of conceptual and constructive knowledge, as well as databases containing information about the elements included in the system.

The information and software structure description for formation of the knowledge base for CCS design performed using a diagram of data flows. Processes of formation of knowledge base of design of CCS are carried out by developers, and the application is focused on the user.

4. Conclusion. The CCS development
To communicate emission data, limiting concentrations values and transfer of control actions to CCS, it is proposed to use the GPS/GLONASS systems resources. Use of methods and means the Internet of things allows to convergence CCS functions and also identification and positioning functions for cars. The design of the proposed system is performed for a single car as a converting process and supplementing the primary digital CCS model. Further stages of monitoring, diagnosis, testing, maintenance also use the results the model transformation. The “Smart City” concept assumes minimization the cars exhaust gases at their mass use. In these conditions, in works of the authors, an assessment is made concentrations background harmful gases and consideration the emissions effect of each car.
Figure 5. The Knowledge Base’ Chart for CCS (UAV – Unmanned Aerial Vehicle, CAD – Computer-Aided Design, IDEFx – Integration DEFinition standards, DFD – Data Flow Diagram, UML – Universal Modeling Language).

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