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Development of a Design Technique for Installing Internal Combustion Engines on a Locomotive Using System Engineering Methods

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Abstract

The article presents an example of application of system approach methods to create a method of designing the installation of internal combustion engines on locomotives. The work is directed on development of the universal technique, allowing to reduce design terms as much as possible and to exclude errors arising at this process. Advantages of creation of the structured process with use of engineering of requirements and creation of the structurally functional scheme of a final product are shown.

Keywords: locomotive, systems engineering, requirement, function, stakeholder, design, subsystem, interfaces

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1. Introduction

For a long time, the global industry has been using rail transport for its needs as the main means of transporting heavy and bulky goods. At present, its production is actively developing all over the world. One of the important and large niches in this market is the production of railway locomotives. The design of each locomotive includes a power unit that performs the function of converting mechanical energy into electrical energy for its subsequent transfer to the traction electric motors of each wheel pair of the locomotive. The power unit consists of an internal combustion engine and a generator that converts the engine torque into electrical energy. Different locomotives use different power sizes and other technical characteristics of engines.

In the modern world, with high competition in this market, the customer focus of any manufacturer is one of the main advantages compared to other market participants. Most often, customers of railway equipment have extensive experience of working with this equipment, and as a consequence, their preferences to work with certain manufacturers. Manufacture of locomotives with similar characteristics, but with different equipment, depending on the needs of the Customer, is an important task for the successful presence in the market of production of railway equipment. At present, the company, of which I am an employee, is mastering the design of modular locomotives. The principle of locomotive design, in which all the units located on the frame of the locomotive, are enclosed in separate modules (frames) that allow for their rapid replacement with minimal downtime of the locomotive. Also, this method assumes acceleration of the design process due to modularity of the design (clear and visually assembled).

However, even with the modular scheme of the locomotive, regardless of the type and characteristics of the engine, it takes time to design its installation in the locomotive. Without a clear structural scheme, this process often takes quite a long time. Also, the likelihood of forgetting or missing something at the design stage increases significantly. And the cost of an error in the design leads to significant economic and time costs, when it is detected at the stage of pilot operation of the locomotive. In this article I have considered methods of system approach to creation of a method of designing of the given process, allowing to accelerate and minimize errors as much as possible.

2. Results and Discussions

At the beginning of this task it is necessary to consider the internal combustion engine as a "black box" system [1] (fig. 1). The engine is part of the locomotive and is therefore a subsystem of the locomotive. It is necessary to create the list of requirements shown by the given supersystem directly to the engine. These requirements can be found in the locomotive specification. Most often all requirements of stakeholders are reflected in the given document, but at presence of time resources, and also competences and possibilities of employees necessary for this purpose, carrying out of works on definition of requirements of not considered stakeholders or additional requirements for successful realisation of the project will be unequivocally not superfluous at the given work. It is necessary to supplement this list with the requirements of national standards, which are not detailed in the existing terms of reference, but which are also referenced in it. As a result, we have a complete list of engine characteristics and functions, which will need to be verified and validated afterwards [2-3]. Some of these requirements are already being verified at this stage, after requesting the engine specification from the manufacturer and comparing it with the required parameters.

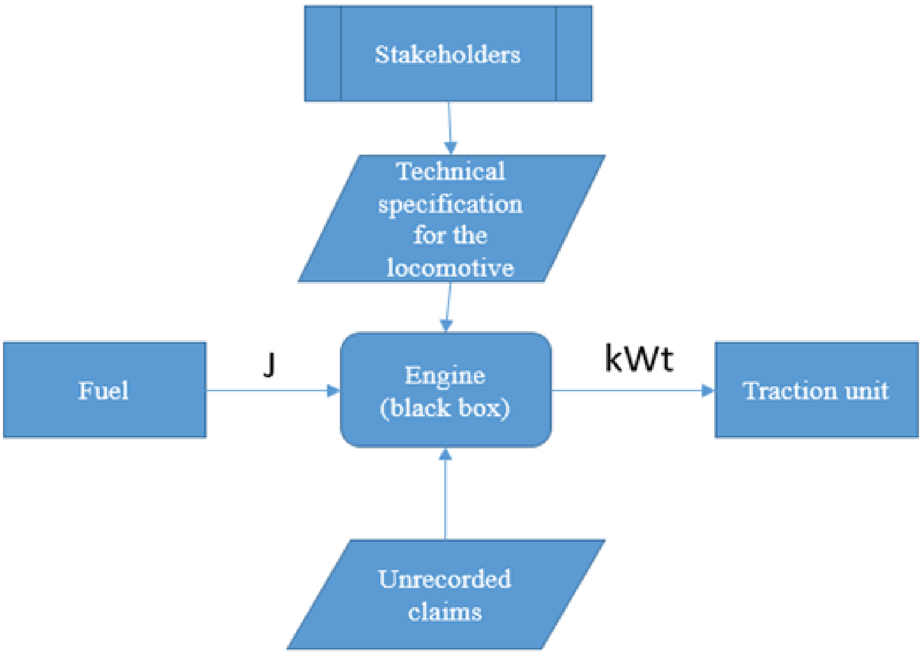

Figure 1: The functional scheme of the engine from the point of view of consideration in the form of a ”black box”

The next step is to consider the engine as a white box system (fig. 2). The performance of the engine, to meet the necessary requirements of its supersystem ”locomotive” is also determined by the performance of its life-supporting systems, such as fuel supply system, cooling systems, exhaust systems, requirements for the site for the installation of the engine, vibratory supports, and so on. We define the functions of the system and make some structural and functional scheme of the engine, with certain interfaces, which gives us the first visual representation of the principle of its structure and operation.

Having a clear structural and functional diagram of the engine, we have the opportunity at the next stage to create a list of requirements for each engine subsystem and interfaces from the engine system to them. Also, this list should be supplemented with the requirements of regulatory documents for these products installed in the territory of the state where the operation of the future locomotive is envisaged. As a result of this action, we have the minimum necessary, and, at the same time, the most comprehensive lists of requirements for each interface system. The received lists are transferred to the persons or structures responsible for the design of each particular system. Thus, it allows you to set the task for designers as clearly and clearly as possible, eliminating the need for them to independently seek out what, how and why it is necessary to design. The

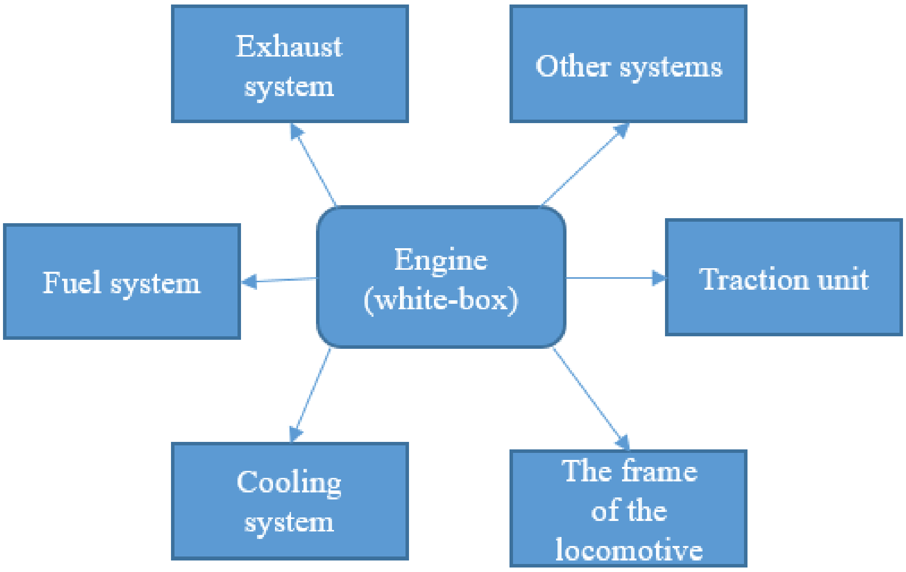

Figure 2: The functional diagram of the engine from the point of view of consideration in the form of a ”white box” to determine the requirements for service systems and interfaces.

undeniable advantage of this stage is also the possibility of the most visual verification and validation of these requirements, which undoubtedly leads to a reduction in the number of possible errors.

When assembling a prototype of a locomotive, at present, there are often errors associated with the interaction of adjacent offices in the design of nodes that are in close proximity to each other because of a very dense layout. Quite often it turns out that certain access requirements for equipment maintenance or repair are not taken into account, and so on. To solve this problem, our company is implementing a system of locomotive design using a basic control structure. It is created at a stage of the technical project and represents, 3D model in the CAD-program consisting of the elementary geometrical figures (a cube, the cylinder etc.): base control structures of separate knots and units. On each knot or the unit the certain vital space which is calculated before the beginning of designing is allocated. Also, this model takes into account the areas necessary for the operation, maintenance and repair of units. As decomposition progresses, the control structure of each individual node is broken down into its subsystems and the structures are transferred directly to the designers of these systems. Thus the maximum simplification of visualisation of that space in which it is necessary to contain a design of system, and accordingly elimination of the further errors is reached.

Thus, it is possible to draw a conclusion that, following the given technique, process of designing becomes more clearly, faster and easier, and the percent of the errors made thus is reduced to a minimum, at the expense of accurately put problems for each participant.

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