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AUTOMATED TWO - REGIME AND VISUALLY FORCED STABILIZATION OF MECHATRONIC SYSTEM OPERATION

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ABSTRACT
Analyzing exploitation work of highly sophisticated mechatronic systems in extreme exploitation conditions, it was found, that oft the existing level of the installed control does not provide completely stable, sure and reliable system operation in the extreme conditions. According to this the work presents a highly sophisticated mechatronic system with added elements for an automated two-regime and visually forced stabilization for mechatronic system operation. Experimental investigations and installation of named system were implemented on a high sophisticated mechatronic system (dumper trucks with payload capacity 120 t) in RMU "Banovici" what significantly increased safety and reliability of system operation.
Key words: mechatronic system, automatization, control, stabilization.

1. INTRODUCTION

The subject of this work are own research and experiences about the machines in the mining field (Brown coal mine "Banovići" – (RMU "Banovići")), where in operation is high productive equipment in coal exploitation, for loading the shovels (bucket capacity cca 21 m^3) and for transport dump trucks (payload 120 tons). Material transport in open pit mining process is an essential operation phase, as regarding the share in the product cost as in the achieving production tasks. Ever present the requirements to increase the transport volume in open pits resulted the manufacturing high – productive diesel electric dump trucks with payload of 170 tons. The improvement in driving system construction had a long development way connected with general technological development worldwide and manufacturing technology development that contributed to the improvements in truck driving systems.

2. COMPLEX MECHATRONICAL SYSTEMS

One of the most frequent complex mechatronical system we have mostly oft to deal with is a motor vehicle. The origin of the motorized vehicles is connected with the need to mechanize the human and animal work in the moving and load transport. The mechanization of these works was the first step in the motor vehicle development. Meanwhile and a series of other works has been mechanized: starting engine, steering direction, braking (stopping) the vehicle and others. To perform all these activities the human energy was used. In the further vehicle development the most of these activities were mechanized and at end the mechatronic was applied, as in the transmission system, necessary to overcome the rolling resistance as also in other motor vehicle systems. The main requirements and reasons for this development were on one side to increase the comfort for operator and passengers and on other side, specially considering the system automation, the need with increased speed and correct performance of operation to increase the system exploitation effectiveness. Every work or system, be it a production of material goods or service, could be presented in a block-diagram as in the Figure 1.

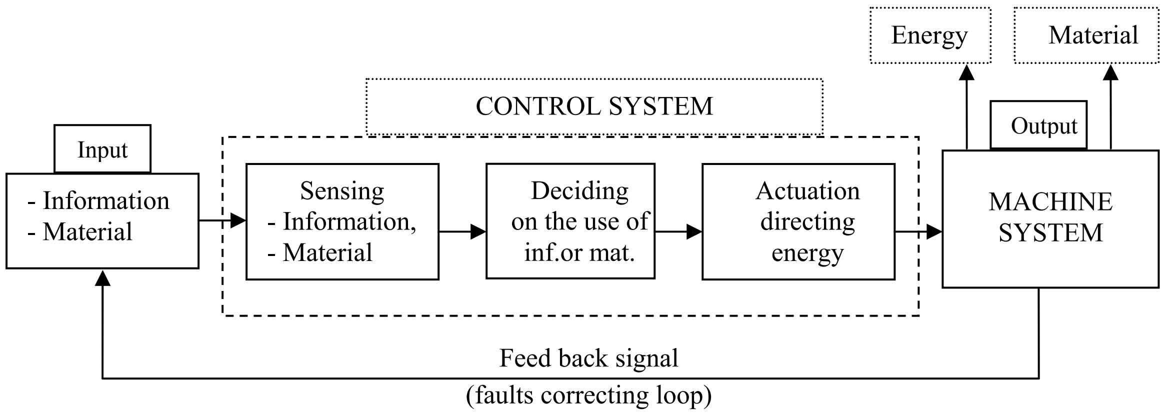

Figure 1. Block-diagram for operation process or system

As discussed above, one of the most complex mechatronical systems are diesel-electric dump trucks "LH M-120" used for coal and overburden discontinuous transport in the coal open pits of RMU "Banovići". These trucks are equipped with US produced "Cummins" engines as the main source of energy that drives the excitation and main generator of direct current supplied to parallel connected electric motors installed in rear truck wheels [1,2,3]. In the last period, more frequently the damages and fires occurred on the engines of these trucks. Therefore, it was necessary to find out an automated safe operation of the diesel engine and to prevent so called overcharge on them and whit it the fire occurrence. To find out easier the solution for this problem it is necessary to know that every production, system respectively, has three essential elements: input, control system and output.

The input presents an information or material in the form of a requirement what should be produced, in which form and on which way.

The output is a useful work or a product which is an effect of energy. The most part of energy is spent at output.

The control is the third essential system element. The control, in general, involves three basic functions: sensing (to receive or acknowledge the information, the material), deciding (how to use information, material) and actuation (to direct the energy).

2.1. Diesel engine - energy transformer

Knowing that a motor vehicle for its function uses a series of specific technique fields: pneumatic, hydraulic, electric, electronic, etc., and that the main "source" of energy on a vehicle is its engine, it was naturally that the engine was the first system whose elements were firstly mechanized and automated. Mechanical energy from the engine is not used only to prevail the rolling resistance but also for other needs: activating systems, assemblies and elements, prevailing the resistance of operation of special devices on the vehicle and for others. The engine role on the vehicle is to transform the fuel chemical energy into mechanical energy. It is mostly used for the basic function of the vehicle as a hauler, as a working machine respectively. The mechanical energy output emitted by the engine depends basically on two parameters: fuel quantity supplied to the engine and on the engine efficiency. Therefore the engine torque, as a measure for the energy emitted by the engine, is regulated through the position of the device regulating the fuel quantity. As the product of the torque and of the number of revolutions present the power:

$$P = C \cdot M \cdot n \qquad \text{... (1)}$$

where: P= power, C=constant, M=torque, n=revolution number it means that the power is a complex output of the engine.

All processes in the engine have the complex characteristics because they are mutually connected and are a result of many influencing factors. In an access to a complex system the investigator should to adopt a definite number of first order impacts for the analysis. These are his determinant factors. Other factors are for this investigator of second-rated importance and could be treated as random ones.

As is previously said, the basic input into engine is the fuel quantity per cycle. It directly regulates the mechanical energy output from the engine. However to transform fuel chemical energy into mechanical energy it is necessary, in addition to fuel, also to supply into engine the air to produce a chemical reaction, an oxidation relatively.
It is used to say that regulating the power output of a gasoline engine is qualitative and of diesel engine is quantitative (because the fuel-air ratio changes). The coefficient of the air surplus (that is ratio of really sucked air to really stoichometric necessary) at gasoline engines scarcely changes and at diesel engines changes in very broad limits when the load changes or when supplied fuel to the engine changes. The question is how to regulate the fuel supply to the engine, considering that obtained energy could destabilize the system, or change the balanced work regime of the engine.

2.1.1. Destabilization of the diesel engine work

The change in a balanced work regime of the engine could be caused by changed characteristics of vehicle resistance moment (M_R) or by changed characteristics of engine torque (*Me*). M_R could be changed by a steeper road grade and *Me* could be changed by a changed quantity of injected fuel. The change in a balanced work of the truck diesel engine is frequently caused by change of the characteristics of the engine torque *Me*, by change of fuel injection. The engine without load with extern speed characteristic of torque at maximal injected fuel quantity develops maximal revolution speed, such high revolution speed (not allowed) of the engine increases the inertial forces of rotating and translation masses of the engine. At engines with engine mechanism elements' larger masses at high revolution speeds, the inertial forces could reach the values introducing the strains considerably higher than critical, that are the causes of big damages on diesel engines.
This occurrence is frequent on diesel engines on dump trucks LH M-120, that, because of high pressures in cylinders, have considerably larger masses of moving parts compared to gasoline engines. Therefore diesel engines are regularly equipped with automatic limiters of maximal revolution speed – so called one-regime regulators of number of revolution. However oft it is the case that at these engines it is not possible to have a stabile work at minimal revolution speeds – at so called idling. This is almost regular case in engine work periods after the start when the engine temperature regime is not yet stabilized. Therefore diesel engines with higher power, with larger masses need an additional installation of so called two-regime regulator, that, in addition to limit maximal engine revolution speeds, has also to provide a stabile work at idling regime.

2.2. Automated two -regime and visually forced system stabilization

The engine on a vehicle presents the first mechatronical system on which the mechanization and automation were applied. The complete vehicle performances depend on the engine function performances, its economy and reliability. The vehicle influence on the environment and its pollution mostly is determined by output engine parameters and these by the characteristics of all assemblies which are more or less automated. A balanced engine work regime at any time is determined only by an adequate energy quantity necessary to the vehicle to perform its functions. If these energies are characterized by the effective torque *Me* and rolling resistance M_R, the condition of a balance shall be

$$Me = M_R \qquad \text{... (2)}$$

Neglecting an unevenness of the revolution speed due to the cyclic engine work the revolution speed remains constant all the time till the balance exists. According to this, the solution of the problem is in the two-regime regulation of fuel injected quantity.
Installation of an automated two regime regulator and a forced actuator (man operator) to regulate the quantity of the fuel injected to the engine are applied for diesel electric engines for dump trucks LH M-120 used in RMU «Banovići».
By this regulation the work stabilization of diesel engines is completely achieved for any extreme exploitation conditions (limited maximal revolutions for extreme temperatures and engine loads) of the diesel engine (Figure 2).

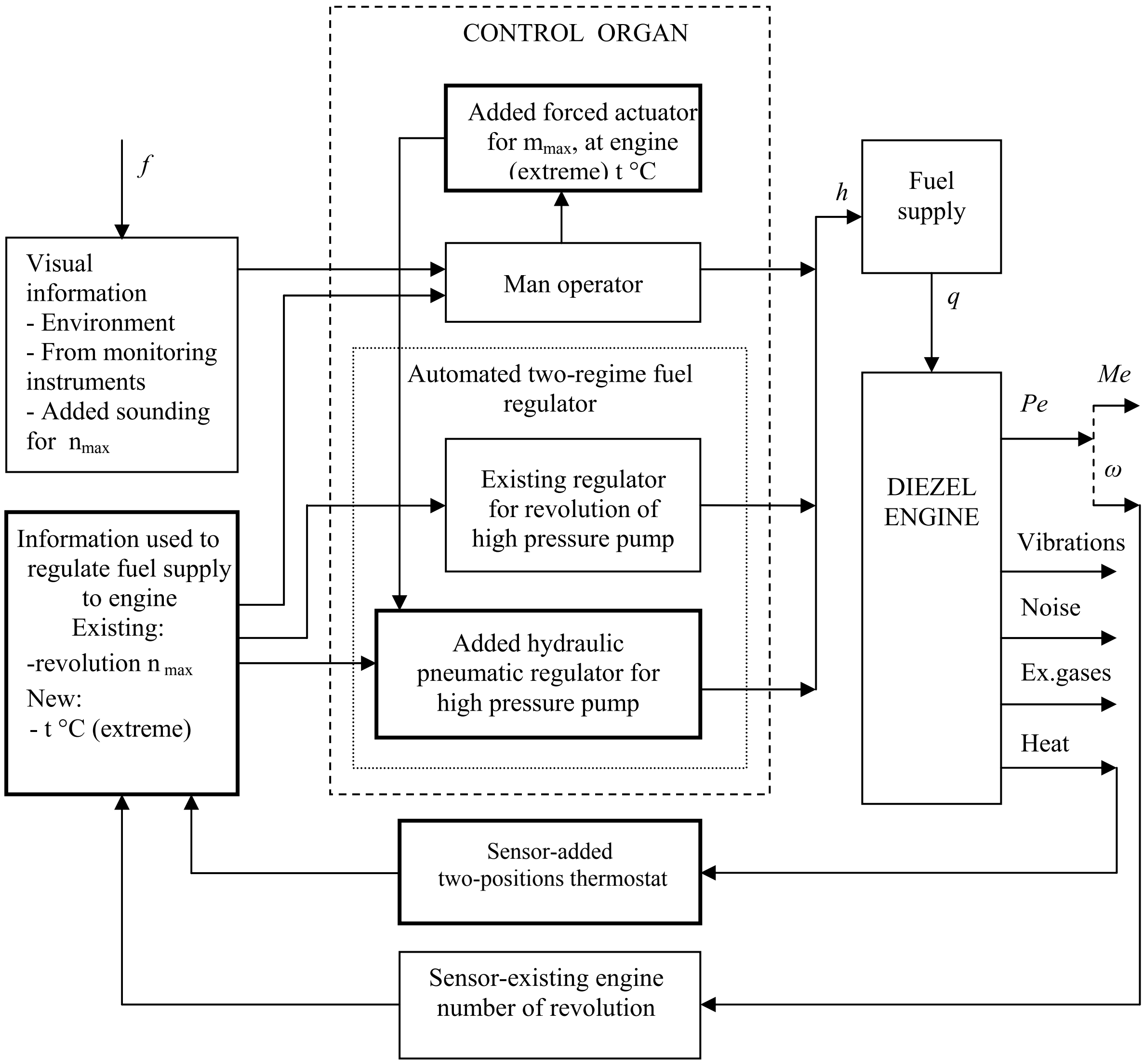

Figure 2. Automated two-regime and visually and forced diesel engine work stabilization

The successful control of engine input and output quantities indirectly depends on the fulfillment of dynamic basic tasks of the engine automatic control. One-regime and two-regime regulators have to limit maximal revolutions and to assure the stabile engine work under extreme system work conditions.

3. CONCLUDING CONSIDERATION

By installation of so called two-regime regulator which enables to change the injected fuel quantities at engine extreme work conditions avoided is the possibility of an increased fuel injection (so called overcharge). Indirectly it is possible to regulate output engine revolution speeds, inertial forces respectively, which are the cause of the strains considerably higher than critical and may be a possible cause of the damages on the engines with larger masses.

Installations of this regulator provides the higher efficiency of the diesel engine and analogously the system availability and productivity, longer lifetimes of the system components, less time for maintenance, etc.

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