APPLICATION OF MECHATRONICS IN UNDERGROUND MINING ELECTRIC LOCOMOTIVES TRANSPORT

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Abstract: *This paper introduces the mechatronic system – a mining locomotive for underground transport. It is presented as a mechatronic system that makes it possible to implement an integrated approach to integration of heterogeneous elements. Discussed are the electrical drive, measuring subsystem, control subsystem, transmission of data concerning the locomotive state. A system for reading the location of each locomotive is proposed that is essential for preventing accidents. Due to severe operating conditions it is necessary to receive updated information about the state and the location of the locomotive. The information system allows for keeping statistical data of all accident and emergency situations. The aim is to extend the service life of the locomotive, to reduce emergency repairs and avoid accidents.*

Keywords: MECHATRONICS, UNDERGROUND MINING, ELECTRIC LOCOMOTIVES

1. Introduction

The locomotive transport is a key element in the transportation system of underground mines. It is involved with the intense flow of heavy earth masses and is used for horizontal or slightly inclined transportation of various mining materials, humans and machines. It has relatively complex organization of the movement and operates in harsh and severe environments. The representation of the mining locomotive as a mechatronic system makes it possible to use a composite approach to integration of heterogeneous elements [1][2][5]. Given that it is operated in comparatively harsh conditions and in order to overcome them, its basic functional units have a high degree of interconnection. The following main components may be derived – mechanical, electrical drive, measurement and control, transmission and logging of information about the locomotive state. The location information about each locomotive is crucially important for mining operations optimization and for avoiding accidents. Due to the severe operating conditions it is necessary to continuously receive updated information about the status of the locomotive and the rail track. The information system allows for keeping statistics of all pre-emergency and emergency situations. The goal is to extend the service life of the locomotive, to reduce emergency repairs and to avoid accidents.

2. Problems with the operation of the mining locomotives

There exist a number of requirements for the locomotive transportation in underground mines which concern the specifics of the operating conditions and the safety of staff.

In underground mines of Bulgaria they are mainly used two types of electric locomotives (Table. 1) (Fig. 1).

Table 1: *Basic characteristics of some types of contact electric locomotives used in underground mines in Bulgaria.*

Type	Weight, kg	Traction, kg	Velocity, km/h	Voltage, V	Number of motors
7KR	6500	1430	11	250	2
10KR	8300	1790	11	250	2

Fig. 1 *Contact mine electric locomotive of type 10KR.*

The place inside those locomotives is highly constrained, both for the staff and for the electric drive and the control hardware (Fig. 2) [4].

Fig. 2 *Common view of the traction locomotive and placement of the electric motors.*

The following problems can be distinguished:

2.1. During operation, under the load of rock pressure, deformations can occur that lead to frequent breaks or shifts in the electric wiring.

2.2. Inadmissible deformations along the track due to erosion by flowing water or partial collapse. This can lead to rolling over of the train composition.

2.3. Obstacles on the track or in the area of movement of the train composition. It is possible that a rock mass, a construction element or other massive object fall on the rail tracks.

2.4. Presence of dust or dirt on the track rails, which affects the friction and deteriorates the motion, especially during starting or stopping modes of the train.

2.5. The light in underground mines is poor or completely absent, so due to limited space and reduced visibility the potential obstacles and irregularities are hardly noticeable.

2.6. Limited autonomy due to the manual control mode and the fixed power wiring.

2.7. Starting and control of electric motors using a rheostat that is associated with increased losses, lack of smoothness, a small speed range control, presence of mechanical contacts, and hence sparks.

3. The mining locomotive as a mechatronic system

In order to solve the problems discussed above, the electric mining locomotive can be viewed as a mechatronic system (Fig. 3) [1].

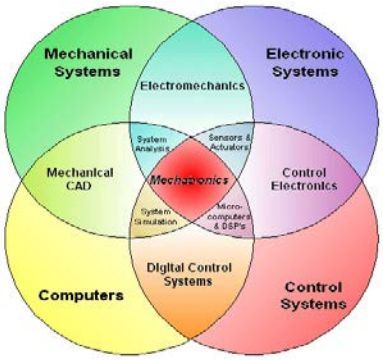

Fig. 3 *Elements of the mechatronic system.*

The mechatronic system is a heterogeneous structure, including elements of the mechanical design individually or in aggregate, power and control electronics subsystems, electric, measurment and information subsystems.

In order to avoid accidents the measurement subsystem for reporting movement-related parameters and emergency situations is crucially important. Backing up the data from these measurements helps to improve the mathematical models thus improving the operating conditions and the system as a whole.

The following stages can be derived:

3.1. Synthesis of the mathematical and simulation models.

It is relatively hard and in many cases even impossible to conduct experiments in a real environment. That is why a proper mathematical model is needed that provides an oppoprtunity to reproduce all working modes – both normal and emergency, thus shortening the overall design time to production of the entire system. During the simulations most of the potential problems can be seen and removed and other functionalities can be improved by tuning subsytems and adding sensors.

3.2. Requirements about the measurement and information subsystem

The measurements are directly related to the estimation of the state of the rail tracks and the locomotive itself. The following sensor types are appropriate for this purpose:

- strain gages – used for measurement of strain forces in the mining wagon and avoiding overloads;

- accellerometers – used for determining accelerations and reducing the sharpness of movement;

- inclinometers – used for measurement of tilt in order to avoid rolling over of the train composition;

- ultrasound transducers and optical sensors (for example lasers) – used in sensing obstacles on the rail tracks;

- cameras – for ensuring ability for autonomous work.

The information part of the system includes channels and means for transmitting the collected data to the surface. For that purpose the most commonly used devices are modems that transmit modulated signal via the power line. These data contains information about the locomotive state and the rail track.

3.3. Requirements regading the electrical drive system.

The main problems here are associated with the starting or stopping modes of the train. Because of the peculiarities of the rail track it is necessary to control the torque so as to ensure good traction, avoid slipping of the wheels and be able to overcome the obstacles encountered. The operation of the electric locomotives is characterized by frequent start, stop and change in braking torque. Therefore, particular attention should be paid to dynamic mode control. A number of companies are working towards the implementation of semiconductor converters for motor control.

3.4. Control system requirements.

In terms of improving the reliability two main approaches can be used - reducing the number of failures of various system components or admission of failures given that they are not fatal. [3] This affects both the performance of the locomotive itself and the live and health of workers.

4. Conclusion

All the elements that are typical for the mechatronic system are well present in the electric locomotives used in underground mines.

The application of microelectronics and microprocessor technology increases the productivity, safety and reduces emergency and operating costs. It allows for the implementation of complex control algorithms and continuous monitoring of the state of the locomotive.

In view of the low qualification of staff, the use of mechatronics allows for minimizing the human factor.

The collected sensor data can be used to enhance the mathematical models.

All these problems can be solved by analyzing the electrical locomotives as a mechatronic system.

5. References

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