

MONITORING AND CONTROL OF THE CONDITION OF BTO (EXCAVATOR - BELT CONVEYORS – DUMPER) SYSTEM TRANSPORT LANES

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Abstract: In the domain of industrial automation, facilitating the smooth movement of goods and materials through various stages, conveyor belt systems represent the backbone of production lines and so-called internal transport. As a special interest in the efficient functioning of transport systems, and for the reason of continuous work without breaks and continuous exploitation of the necessary significant driving forces, the issue of improving the efficiency and optimizing the operation of conveyor belts or belt conveyors arises. The paper presents the possibilities of creating a system for monitoring and controlling conveyor belts of the BTO system, as well as discovering potential causes of problems and errors in work, with the help of the data collection process and expert knowledge and identification of system abnormalities. At the same time, the data collected by system monitoring should be converted into knowledge, which can be interpreted and efficiently exploited, and on the basis of which automatic data analysis and reuse of expert knowledge for decision-making is possible. By the way, the development of these types of intelligent monitoring and control systems for cases of conveyor belts is still in the early stages of development, so the realization of such systems, as highly reliable and automated due to their complexity, places such research in the focus of future research development projects.

Keywords: conveyor lanes, monitoring, sensors, BTO system

MONITORING I KONTROLA STANJA TRANSPORTNIH TRAKA BTO (BAGER - TRAČNI TRANSPORTERI - ODLAGAČ) SISTEMA

Rezime: U domenu industrijske automatizacije, olakšavajući nesmetano kretanje robe i materijala kroz različite faze, sistemi transportnih traka predstavljaju okosnicu proizvodnih linija i unutrašnjeg transporta. Kao poseban interes, iz razloga neprestanog rada bez pauza i kontinuirane eksploatacije neophodnih značajnih pogonskih snaga, nameće se pitanje unapređenja efikasnosti i optimizacije rada transportnih traka ili tračnih transportera. Rad prezentuje mogućnosti kreiranja sistema monitoringa i kontrole transportnih traka BTO sistema, kao i otkrivanja potencijalnih uzroka problema i grešaka u radu, procesima prikupljanja podataka ekspertskih znanja i identifikacije abnormalnosti sistema. Pri tome, podatke prikupljene monitoringom sistema treba konvertovati u znanje, koje se može interpretirati i efikasno eksploatisati, a na osnovu toga je takodje moguća automatska analiza podataka i ponovno korišćenje ekspertskih znanja radi donošenja odluka. Treba napomenuti da je razvoj ovakvih vrsta inteligentnih sistema monitoringa i kontrole za slučajeve transportnih traka, još uvek u ranoj fazi razvoja, pa realizacija ovakvih sistema, kao visoko pouzdanih i automatizovanih usled njegovih kompleksnosti, postavlja ovakva istraživanja u žižu budućih istraživanja razvojnih projekata.

Ključne reči: transportne trake, monitoring, senzori, BTO sistem

1. INTRODUCTION

In the world, the largest part of electricity is still obtained from coal (for example, in Serbia, 62% of all electricity production capacity is in coal-fired thermal power plants). Regardless of attempts to switch to the so-called green energy from renewable sources, it is expected that in the coming decades, the center of gravity of further increases in electricity production capacity will be on thermal power plants.

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For the transport of coal and tailings in surface mines, transport systems of conveyor belts are used, as part of the so-called BTO system [1].

Due to continuous work without breaks (24/7), the question of improving the efficiency and optimizing the operation of conveyor belts or belt conveyors arises as a special interest, and the monitoring and control of the conveyor belt system is a special chapter of the efficient operation of thermal power plants. In fact, in the domain of industrial automation, conveyor belt systems represent the backbone of production lines, with conveyor belt sensors, being an integral part of the safety and optimization of these systems, as sophisticated devices designed to monitor and regulate the working dynamics of conveyor belts. By providing real-time data on speed, alignment and other critical parameters, sensors of conveyors belt and system enable operators to achieve optimal performance levels, significantly increasing safety and productivity in industrial environments. Also, sensors not only ensure a smooth and efficient flow of goods and materials, but also play a key role in protecting machines and labor from potential accidents and breakdowns, thus directly contributing to minimizing downtime and maximizing production.

2. CONVEYOR BELTS

Increased demands for coal production lead to greater transport needs, the so-called. belt conveyor systems, which will require an increase in the length and capacity of the belts, as well as the installed power of their drives. This of course means that the operation of the belt, and thus the system, without failure requires the correctness of the drive belt and rollers (which start and maintain the operation of the belt), which indicates the need for special attention in the area of maintaining the reliability of the belt and rollers at the highest possible level, that is, it can be said that monitoring and control of the condition of the belt and rollers are of vital importance in this domain [2], [3]. By the way, the conveyor belt, belt conveyor or conveyor consists of a core (frame) and a rubber casing (upper and lower supporting roll), and it can be said that it represents the most important part of transport systems (Figure no. 1). The rubber involucre of the tape protects the core from mechanical damage, and consists of upper and lower rubber lining and rubber protective edges. The belt conveyor has a simple construction and basically consists of endless rubber or plastic belts and two drums, one of which is the drive and the other is used to tighten the belt. And if they increasingly have an extremely large application in the so-called in internal transport, the importance of conveyor belts is often overlooked, because they are usually seen as a piece of equipment that does not cause problems and works for a long time without failure. In such systems, of course, continuous quality improvement is necessary, where as the basic material for the production of conveyor belts, most often rubber or similar products are used - the so-called. elastomers (high-copolymer materials based on natural or synthetic rubber), with wire mesh cores - tapes. The cores are elements that give the tape tensile strength, but also resistance to tearing and impact, as well as support for the load being transported, absorb the kinetic energy of the material during loading and provide the necessary stability when centering and guiding the tape over the rollers [4].

The bearing rollers are balanced - balanced and have roller bearings with permanent lubrication, while at the loading points, where there are devices for filling the tapes, the rollers are placed very densely and coated with soft rubber.

Mechanization in such production is most often organized into systems [5]:

1. BTO (excavator - belt conveyors - dumper) or
- 2.1. BTD excavator - belt conveyors - crushing plant and
- 2.2. BTU excavator - belt conveyors - loading.

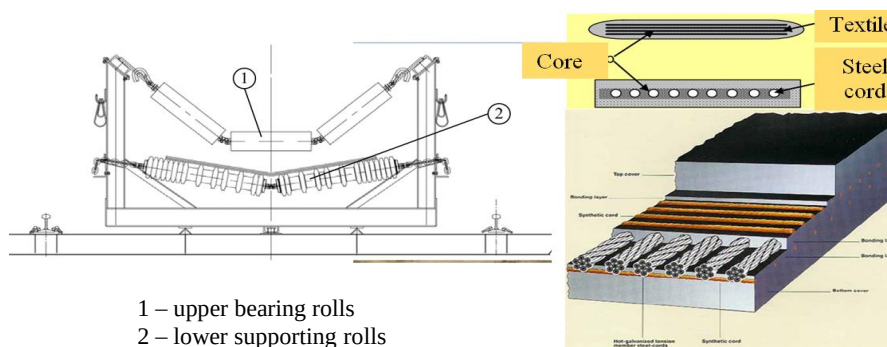


Figure 1 –Appearance and cross-section of a conveyor belt with a steel cord [5],[6]

It can be said that belt conveyors represent universal means suitable for continuous transport of bulk materials, with relatively low energy consumption and low noise level, simple installation, as well as good transport possibilities over long distances and relatively low maintenance and exploitation costs [2], [3], [7], [8]. On the other hand, it should be noted that the tapes are sensitive to chemical influences and high temperatures, as well as to frequent physical damage during the transport of rough materials with sharp edges, with application limitations due to possible reasons of high slopes, as well as the lack of a part for catching the load [4], [8].

3. MONITORING OF THE CONVEYOR LANE SYSTEM

The aim of the paper is to illustrate the possibility of monitoring and controlling the conveyor belt of the BTO system, so that in order to automatically perform tasks such as:

- Collection of data and components of the conveyor belt system;
- Interpretation of data and identification of deviations from the "normal" state of the system;
- Discovering the reasons for failure of the conveyor belt and its components;
- Saving data, for the purpose of gaining expert experience and knowledge, as well as improving the performance of the conveyor belt system;
- Download and analysis of experiences and knowledge from databases.

The process of maintenance of conveyor belts takes place through five phases - steps:

1. Visual observation and inspection of critical system components by maintenance personnel, as well as manual maintenance and system control activities;
2. Automatic monitoring (sensors) of critical system components, monitored by maintainers who make decisions, manually maintain and control system activity.
3. Automatic monitoring (sensors) of most system components, monitored by maintainers who make decisions, manually maintain and control system activity.
4. Automatic monitoring (sensors) of most system components, monitored automatically (computer), as well as manually maintained and control of system activity;
5. Automatic monitoring (sensors) of most system components, monitored automatically (computer), as well as automatically maintained and control of system activity (robotic).

The work is primarily focused on the fourth step of automation, which refers to automatic monitoring using sensors and the implementation of various monitoring technologies, which are employed by automatic transmission of data to intelligent systems [2], [3], [9].

Otherwise, the monitoring of the condition of the tape implies:

- Monitoring of the state of the upper and lower surface of the tape;

- Monitoring the condition of the inside of the tire, which also includes steel cables or fabric layers;
- Monitoring of the state of tape joints.

Examples of such types of monitoring are shown in the pictures (Picture no. 2 and no. 3):

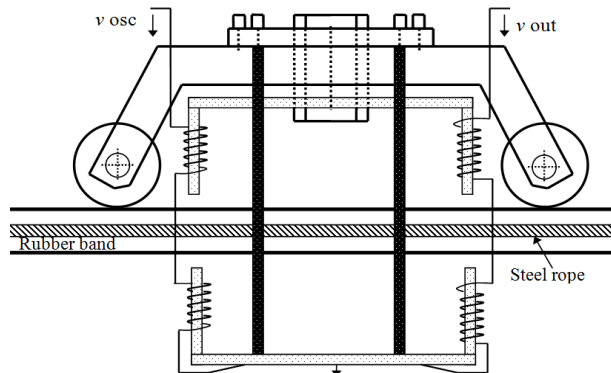


Figure 2 – Monitoring the state of steel wires [8]

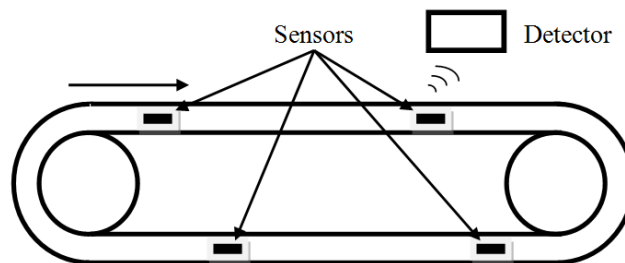


Figure 3 –Monitoring of the state of the upper and lower surface of the tape

On the other hand, it should be noted that the monitoring of the belt is directly dependent, that is, it is directly connected with the monitoring of speed, force, vibrations, temperature and other components of the system, through the implementation and exploitation of adequate sensors. It is obvious that conveyor belt **sensors** are basic components that significantly improve the operational efficiency, as well as safety and economy of transport systems, i.e. they play a key role in optimizing the efficiency of conveyor belts and systems, providing real-time data and enabling the automation of control mechanisms. In fact, such sensors continuously monitor various parameters, such as speed, position, load, force, vibration, temperature, etc., thus ensuring the operation of conveyors and belts in optimal conditions [10]. Table No. 1 shows the most important parameters that are monitored by sensors on the appropriate components of the system, and thus automatically stored in the database.

Table 1 –Parameters for monitoring on components

Parameters	Components
Tape condition	Area
	Steel cables
Velocity	The lane
	Brake disc
	Engine
Torque	Motor shaft
	Brake shaft
	Shaft pulley
Force and strain	The lane

	Frame
Vibrations	Pulley
	Guide roller
	Rotary disc/brake
	Engine
The power	Engine
Position	Lane misalignment
Temperature	Ambience
	Material
	Lane surface
	Brake shaft
	Shaft pulley
	Engine

So, the sensors enable monitoring of data in real time - eg. speed sensors and proximity sensors, as well as automatic control, or the integration of conveyor belt sensors with control systems, facilitate automated adjustments while maintaining optimal performance, which minimizes human intervention, reduces errors and maintains consistent material flow.

Conveyor belt sensors also contribute to significant cost savings, by reducing maintenance and minimizing downtime, as well as by extending the life of the equipment [10].

Speed monitoring is one of the most fundamental parameters of the conveyor belt system, not only for the purpose of determining the operation of the system within the designed limits, but also in order to determine the dynamics of starting and stopping the entire transport system. Thus, the operating conditions of the system components, such as pulleys, motor or brake disc, are simultaneously monitored [5, 6, 8]. Conveyor belt speed sensors are designed to accurately monitor belt speed, by detecting the speed of rotation of the rollers using a tachometer, or by using optical and magnetic encoders to directly measure belt speed.

Force parameter monitoring implies the exploitation of strain force sensors, as the most commonly used type of sensor. The description of the measurement of this sensor can range from a few kilograms to several hundred tons (Figure no. 4 Strain force sensors):



Figure 4 –Strain force sensors

Vibration monitoring deals with vibrations that occur in system components that oscillate around their equilibrium points, such as pulleys, shafts or bearings. The operational state of such components is monitored by detecting vibrations through vibration sensors.

Power monitoring can be achieved by measuring, for example, the power on the drive pulley shaft, which can be calculated as the product of torque and belt speed, divided by the value of the pulley radius [8].

Monitoring belt misalignment is extremely important, because as a result of such misalignment, a stoppage may occur, as well as major material damage to the belt or rollers. Switches indicating misalignment are located on the side of the conveyor belt [6].

Temperature monitoring is carried out by means of optical infrared sensors, in a non-contact manner, as the sensors measure the emission of the infrared spectrum of light the object being

measured. The method is particularly applicable when measuring moving components (pulleys, brake disc, etc.), but it is not applicable for measuring a large number of components that are widely distributed (eg roller).

Some sensors also allow measuring the wear of the system components, such as, for example, the wear of the surface of the rubber belts due to abrasion (Figure no. 5 Monitoring the wear of the conveyor belt surface due to abrasion):

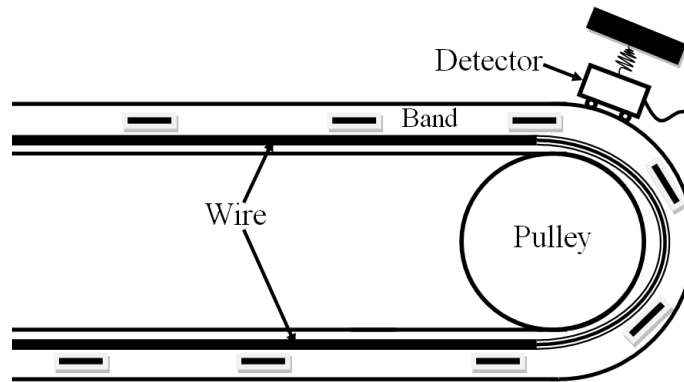


Figure 5 –Monitoring of conveyor belt surface wear due to abrasion

4. PROCESS OF KNOWLEDGE ACQUISITION AND DECISION MAKING

It should be emphasized that for the purposes of more effective and efficient operation of the conveyor belt system, it is necessary to exploit the data collected by monitoring the system in order to convert it into knowledge, which can otherwise be interpreted and exploited by intelligent systems. In fact, it can be said that the process of knowledge acquisition involves converting data into adequately presented knowledge, which in fact means converting it into an algorithm format, which enables interpretation in the further exploitation of knowledge for diagnostic and analytical purposes [11], [12].

An example of a software model of data acquisition and conversion into expert knowledge (Diagram No. 1) shows the development of a simulation model, where system parameters are generated by software that simulates the behavior of the system, noting that when the simulation creates outputs, then they are compared with the real system. The simulation model is generated as a precisely represented real system, so that the desired knowledge can be derived from the simulation output [9].

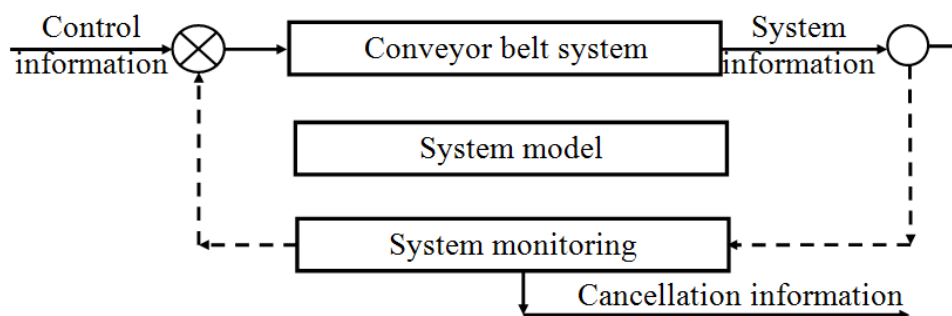


Diagram 1 –Software model of data acquisition for the case of a conveyor belt system

The processes of verification, comparison and validation of the software model, with all its phases - stages of development or constituent elements, are shown in Diagram No. 2:

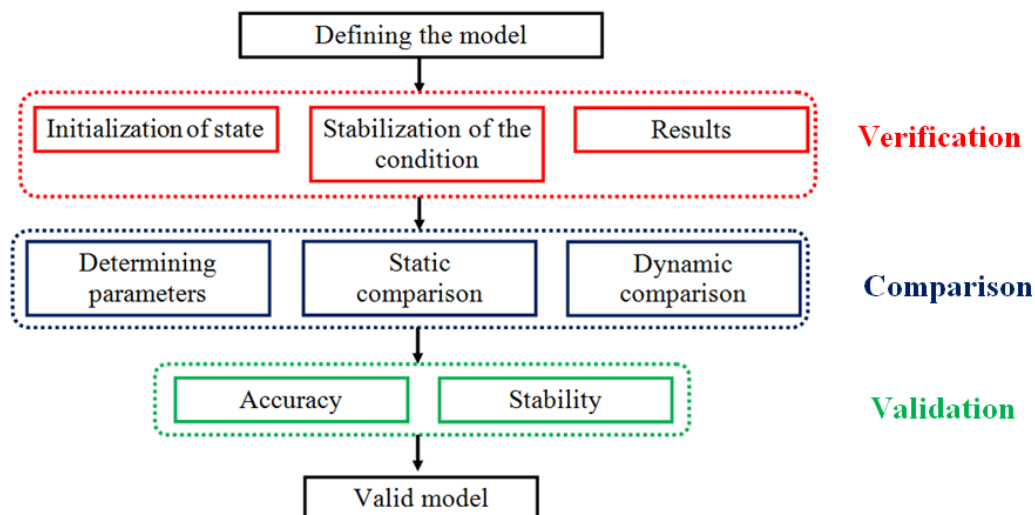


Diagram 2 –The process of verification, comparison and validation of the software model

When the parameter deviations are finally identified, the analysis is performed with the aim of determining:

- Reliability assessments of components of the entire system;
- System and component degradation evaluations;
- Description of abnormalities;
- Fault diagnostics;
- Failure predictions;
- Discovering the causes of malfunctions and potential failures.

It should be emphasized that for the efficient functioning of the conveyor belt system, quick and efficient decision-making regarding the current situation is of great importance, so it can be said that the ultimate purpose of collecting data and converting it into knowledge is obtaining feedback, and thus understanding the situation and making decisions for problems related to the current situation (the entire decision-making procedure is shown in Diagram No. 3 Decision-Making Process).

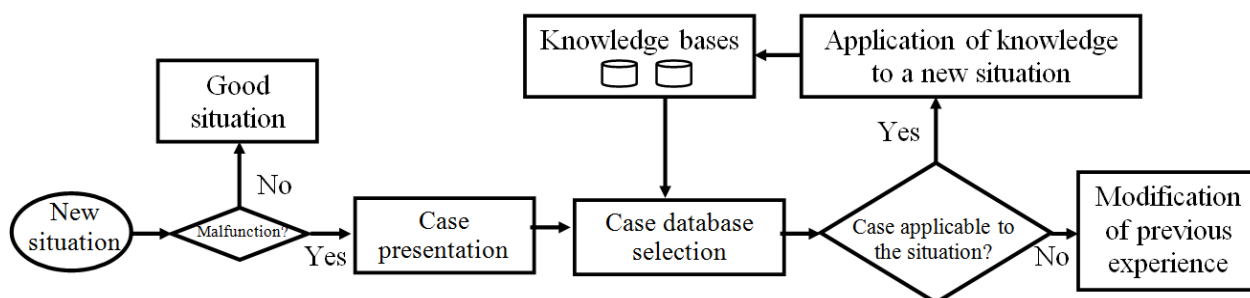


Diagram 3 – Decision-making process

The newly created monitored situation is re-examined in terms of the existence of a malfunction, so if there is one, the previous case is treated as newly created, and previous knowledge is applied to the real situation, while in cases of inapplicability, previous knowledge is supplemented.

5. CONCLUSION

The paper presents and points out the possibility of creating a monitoring and control system for conveyor belts in the processes of data collection and identification of system abnormalities, as well as discovering potential causes, assessing the operational states of the system and converting data into knowledge, for reuse in similar situations or supplementing knowledge with innovative experiences, based on which it is possible to create automatic data analysis and a database for quick use to make effective decisions for the purpose of effective expert knowledge.

It can be concluded that the system of monitoring and control of conveyor belts is also feasible using traditional data collection systems, and that it is not necessary to make excessive investments for the cost-effectiveness of the implementation of such systems. It can also be concluded that the development of these types of intelligent monitoring and control systems, for the case of conveyor belts, is still in the early stages of development, and the realization of such systems, as highly reliable and automated, due to its complexity, places such research in the focus of future research development projects.

By providing real-time data and enabling automated control, safety and proactive maintenance, conveyor belt sensors prove their important role in increasing the operational efficiency, safety and cost-effectiveness of transport systems, which ultimately directly helps companies achieve optimal performance and generate significant savings.

6. REFERENCES

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