

## Reducing The Risk Of Fires In Conveyor Transport

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**Abstract.** The paper deals with the actual problem of increasing the safety of operation of belt conveyors in mines. Was developed the control algorithm that meets the technical requirements of the mine belt conveyors, reduces the risk of fires of conveyors belt, and enables energy and resource savings taking into account random sort of traffic. The most effective method of decision such tasks is the construction of control systems with the use of variable speed drives for asynchronous motors. Was designed the mathematical model of the system "variable speed multiengine drive – conveyor – control system of conveyors", that takes into account the dynamic processes occurring in the elements of the transport system, provides an assessment of the energy efficiency of application the developed algorithms, which allows to reduce the dynamic overload in the belt to (15-20)%.

### Introduction

In comparison with the fires on the earth surface, fires occurring in mines are more difficult to extinguish and represent a danger and threat to people's health. In addition, the analysis of the causes and circumstances of accidents that have occurred, shows that the vast majority of them occur in the mines during mining operations. Thus, of the 86 accidents reported in the coal industry of Kuzbass in the last 5 years, 82 have occurred in the mines, and 42% were caused by underground fires.

Statistics on accidents show that up to 70% of exogenous fires in underground coal mines occur in the excavations equipped with belt conveyors because of the fire of conveyor belts.

Investigations of accidents fixed a low efficiency of automatic fire suppression systems, currently used for fire protection of belt conveyors in coal mines. This is confirmed by numerous cases when the fire in conveyors belt had spread almost throughout the conveying line, equipped with a functioning automatic fire extinguishing installations[1].

Due to the lack of effectiveness of automatic fire suppression systems on conveyor belts resulting fire front from burning conveyors belt applies to the unworked coal and sometimes in the goaf. As a result, the liquidation of such fires and the consequences of them spent significant material and financial resources.

As the intensification of production and the steady increase in this regard, the load on a mechanized mining face, a sharp increase in intensity of production processes increases the likelihood of fires in mines equipped with belt conveyors.

The conveyor transport of mining companies consumes 1 km length of conveyor is about 1 million kW.hour of electricity per year with actually achievable consumption of about 0.3 million kW.hour. It is obvious that about 70% of the energy consumed on consumption of capital equipment.



Regulation of the conveyor not only provides a reduction in the cost of transportation of ore, but substantially increases the safety of operation. The most severe accident of the conveyors associated with the combustion of the conveyors belt by breaking its coupling with the belt pulley and the broken belt. The reasons in both cases are excessive force applied to the belt.

Disadvantages of existing drive systems of conveyor transport:

- need to create a high pre-tension to prevent slippage;
- if there are multiple drive pulleys occurs uneven distribution of forces on pulleys;
- in the processes of acceleration and deceleration there are higher torques when starting the engines.

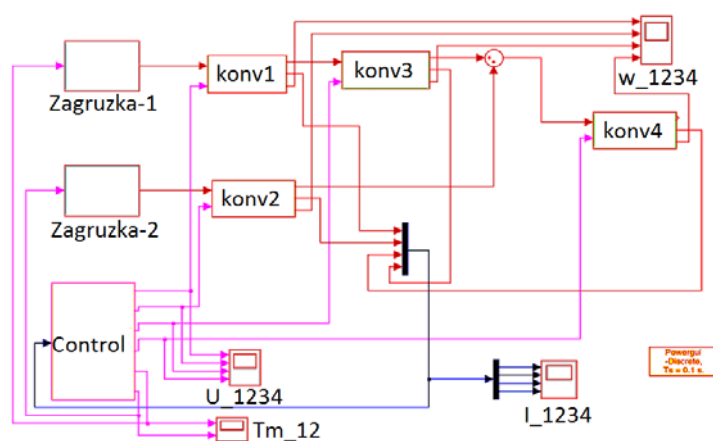
This work is dedicated to the development of a control algorithm that meets the technical requirements of the mine belt conveyors, and enables energy and resource savings taking into account random sort of traffic. The most effective method of decision such tasks is the construction of control systems with the use of variable speed drives for asynchronous motors [2].

### Proposed model of cross conveyors line

On the basis of the chosen scheme of conveyors location in the line with several cross conveyors (Fig.1) in the application Simulink MatLab has been developed the model of conveyor – multiengine electric drive in the form of separate blocks, the inputs of which represent the control and disturbance variables for a given element of the system, and outputs are state variables that are the subject of research or inputs to other blocks [3].

The object model was provided with the following components:

1. Subsystem «drive – conveyor» (konv1-konv4) consisting of a mechanical (belt pulley, belt, etc.) and electrical part of conveyor (multiengine variable speed electric drive).
2. Block which generate the load of conveyor (zagrutzka1, zagrutzka2).
3. Block of control system for cross conveyors line (Control).

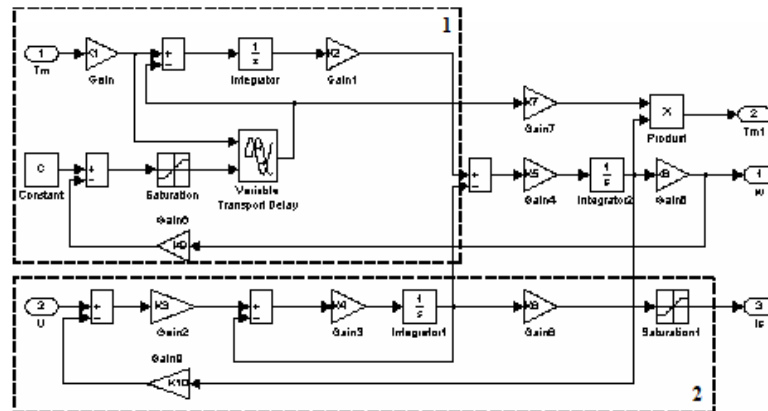


**Figure 1** - Continuous transport system, consisting of four cross conveyors

Mathematical model of this continuous transport system is a model of four cross conveyors, three of conveyors are connected in series (konv 1, 3 and 4) and one parallel (konv 2). In addition to the subsystems, containing models of conveyors (konv 1, 2, 3, 4, Fig.2), also shown in the figure: blocks Zagrutzka-1,2 (Fig.6), simulating the load and taking into account random type of traffic; control block of the transport system (CONTROL), the input of which receives signals (Is) from the conveyors, simulating their load, the output – control actions (U1-U4) to the conveyors, and the signals Tm1 and Tm2 coming on blocks Zagrutzka1,2 and allows to take into account the current load on the continuous transport system.

Digital implementation of continuous transport system was created with the use of C language in

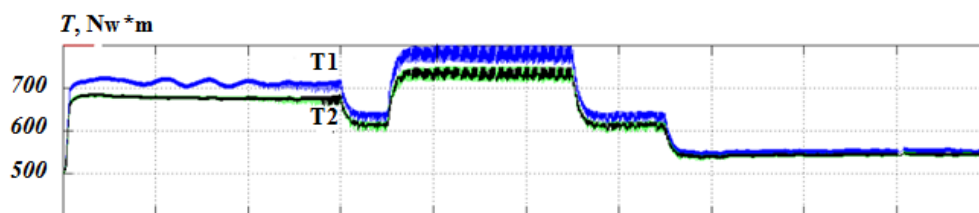
the program Matlab. Using the model of continuous transport system it is possible to analyze operating modes of conveyors start-up in a predetermined order with rated torque up to rated speed, deceleration, conveyors adjustment of the predetermined load and to obtain functions (monitors w-1234, I\_1234, Tm\_12) determining the workload of individual conveyors in the system and showing the speed change of the conveyor depending on the load.



**Figure 2 - Model of conveyor Simulink Matlab**

Unit 1 simulates the variation of the load on the conveyor. The input signals "Tm" from the block "Zagruzka" (Fig.1), taking into account random type of traffic, and a constant value of load Constant. Unit 2 determines the response of the conveyor on the input signal U (control action from the control system of continuous transport system depending on the conveyors load). The output of the model Tm1 – load supplied to the next belt conveyor (Fig.1 blocks konv1-konv4), w is the speed of movement of the belt of conveyor, which is displayed on the monitor (Fig.1, monitor w1234), Is - stator current that determines the load level of the conveyor (Fig.1, monitor I-1234).

With the presented mathematical model the system of direct torque control (DTC) for multiengine asynchronous electric drive of the conveyor was adjusted.



**Figure 3 - Characteristics of torque at start-up, load-off and load-on (blue - existing system of drive control of conveyors; black - direct torque control (DTC)).**

Figure 3 presents curves of moment change at start-up under rated load, the load-off and load-on, illustrating the decrease in dynamic moment (15-20)% compared to existing control systems for conveyor drives.

### Designed control algorithm

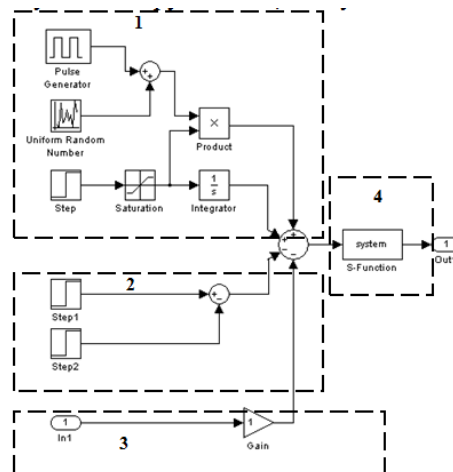
The reference signals generation algorithm in the control system of the multiengine asynchronous electric drive allows to take into account probabilistic type of traffic, improves the uniformity of load transfer between the drive motors to 90% and eliminates slippage of the belt with the change of conveyor operating conditions [4].

As a local control algorithms for multiengine electric drive was used the algorithm of direct torque control (DTC) which provides maximum performance in the current (torque) loop and maximum

value of the current (up to rated torque).

One of the main features of conveyor transport as a technological system is the random incoming of traffic from interconnected process equipment[5].

The model of load was created in Simulink Matlab (Fig.4), simulating random traffic arriving on the conveyor.



**Figure 4** - The model of load traffic.

Block 1 simulates the traffic as a discrete sequence of pulses with random duration of incoming load and with random intervals of its absence. Within the duration of impulses the traffic is described as a continuous random process [6].

Block 2 simulates the load-off mode of conveyor.

Block 3 simulates the incoming of load from the other cross conveyors.

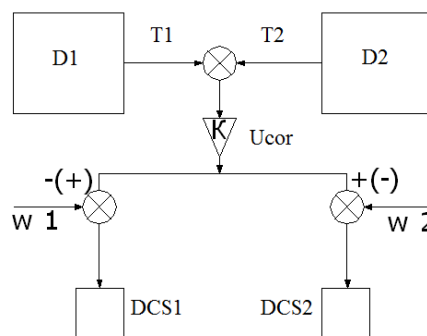
Block 4 is written in the Matlab language s-function that describes the distribution of traffic.

The reference signals generation algorithm in the control system of the multiengine asynchronous electric drive, taking into account the random type of the load is: the value of load mismatch (actual current of semiconductor converters) is used to adjust the speed of the individual drives [7].

The algorithm of reference signals adjustment is shown in Fig.5.

1. If  $T_1 = T_2$ , then  $K \times (T_1 - T_2) = 0$ , a corrective signal equal to 0.
2. If  $T_1 > T_2$ , then  $K \times (T_1 - T_2) > 0$ . The speed controller assignment (PC1) is reduced, and PC2 increases.
3. If  $T_1 < T_2$ , then  $K \times (T_1 - T_2) < 0$ . The speed controller assignment (PC1) is increased and PC2 decreases.

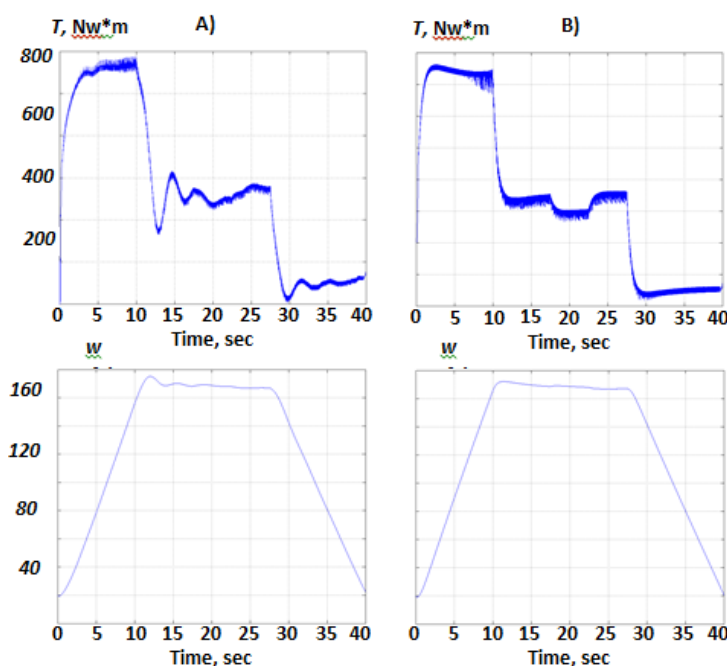
Coefficient K regulates the performance of torque adjustment [8].



**Figure 5** - Algorithm of reference signals adjustment (D1,2 – drives, Ucor – correction signal, w1,2 – speed assignment, DCS1,2 – drive control systems).

Fig.6 demonstrates curves of torque and speed of AC drive with the random load at start-up mode to full speed and subsequent braking to a complete stop and stepped load-on. From these curves it is seen that with the use of developed algorithm reduces the overshoot and torque oscillations, and therefore speed [9].

Researches of the drive operating modes showed that the implementation of speed adjustment algorithm of the individual drives have provided increased uniformity of load distribution between drive motors (mismatch is not more than 10%), limiting the overshoot of the engine torque (up to 15%), and therefore, the restriction of dynamic loads on the conveyor drive with the use of direct torque control algorithm and elimination of belt slippage when changing the conveyor operating conditions [10].



**Figure 6** - Curves of drive torque and speed without adjusting the signals (A) and with the developed algorithm (B).

## Conclusion

Improving safety operation, energy and resource savings of conveyor transport requires the installation of regulated asynchronous electric drive with semiconductor frequency converters and control of operating modes of cross conveyors line in consideration with the technological requirements and random type of traffic.

Mathematical model of electromechanical system of conveyor – multiengine variable speed drive with implementation in Simulink Matlab allows to perform researches of the conveyor operating modes taking into account the specifics of the mechanism operation at different control algorithms of electric drives.

Was demonstrated the necessity of applying the local digital torque control of induction motor with the developed algorithm of reference signals adjustment, providing increased uniformity of load distribution between drive motors, elimination of belt dynamic loads (over-regulation until 15%), and therefore, reduced risk of fires in conveyor transport.

**References**

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