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Research of the automatic control system of belt conveyor on the technical basis of the industrial controller schneider electric

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S u m m a r y . The results of the studies of complex system of automatic control of processes of the transportation and the crushing of the ore been presented. The principles of control been based on the measurement of temperature field on the zone of the friction. The efficiency of the approach confirmed by the results of theoretical and experimental research of the control system based on industrial controllers Schneider Electric.
K e y w o r d s . Industrial controllers, belt tension control, mathematical models of distributed parameters.

INTRODUCTION

One of the common problems in using mining equipment is a high level of equipment's accident rate, associated with wear and tear of equipment, as well as using out-dated automated process control systems (APCSs) that have exhausted their lifetime and currently their tasks cannot perform.

The implementation of advanced automatic control systems (ACS TP) on the basis of industrial controllers enables you to programmatically perform a main part of the logical schema control that previously technically implemented at the hardware level, in the form of electric circuits.

A perfect example of using of APCSs conveyor line based on modern industrial microcontrollers is control system for a conveyor line of the Crushing Plant CrP-3 of the mining-concentrating plant "SevGOK" [1].

The development of automatic control systems of the belt conveyors began almost from the time of the first applications of belt conveyors.

Thus, the authors of [2] formulated the requirements for automatic control lines conveyors back in the 60's of the last century.

Assignment of tasks to different levels of the hierarchy in terms of automated control theory is discussed in [3]. The study is important for task of the low level, which lies at the base of the whole pyramid of hierarchy of control problems. It is the task of control the individual aggregates or the processes. The production cost, depending on the nature of the technological process, is the only reasonable criterion functioning of each technological object.

This paper will focus on the implementation of requirements [2] to control for the belt conveyor. The control system, among other things, will help increase lifetime of the conveyor belt, the preservation of its properties [4].

In this paper, to prevent emergency of slip belt on the pulley and its excessive wear is offered use a belt tension control. To implement the developed control method necessary to use a mathematical model with distributed parameters. Based on this model will be generated the model of the optimal control in accordance with the principles, discussed in [5].

The main cause of all these problems is connected with the parameters of the ore, which transported. These parameters define the requirements for the formation of traction factor, and physical processes in the friction pair of conveyor belt-pulley during transportation of the material. The main parameter - is mass per unit length of the transported material. So the work done by VS Volotkovsky, reflected the following results. On belt conveyors with the length from 467 to 1870 m, area of stripped bottom cover varies from 15 to 25%. This is caused by the appearance of slip bands and large values of the stresses in the bottom plate of the tape when it interacts with the driving drum [6, 7]. Increased loading conveyor, weak belt tension results in increase in arc of operative slipping that increases belt wear and may cause emergency slipping. In the case of slipping, in adhesion zone of belt and pulley the temperature rises and reaches 300-350 °C within 15 minutes of operating [8]. In the case of operative slipping there are losses of energy by overcoming friction. It results in temperature change in the zone of the contact pulley-belt.

The problem of temperature change has been studied by the following authors: M.A. Malutin, L.I. Popov, V.G. Piletsky and others [9, 8, 10]. To create a system of automatic control of friction couple drive pulley-belt is proposed to develop a mathematical model of temperature distribution on the arc circumference (as an object of control). In this case, the thermal field of arc of contact can change through the tension of the conveyor belt or speed of pulley rotation.

The problem of conveyor take-up control has been studied by the authors [11, 12, 13, 14, 15, 16, 17], who deduced that the level of belt tension is determined by the material loading level, as well as size of the pieces of ore, conveyer belt durability or its term of exploitation. Control of the station of the pull for conveyor has been determined out as function of measuring tension, as well as depending on load distribution between the drive pulleys and also according to the total conveyor maintenance costs. The study of the dynamic properties of the conveyor with automatic take-up and terms of system operability has been carried out by the authors [18]. Determination of the dynamic properties of belt conveyor as controlled system during conveyor start-up has been carried out in [19].

Study of the dynamic properties of the automatic belt tension control is necessary to obtain information on indicators of the quality of regulation, to get the results of the stability of modes with automatic conveyor belt tension control during transportation of raw materials.

In the process of improving the control also analyzed the possibility of using fuzzy control of conveyor and the research of belt transport system based on PLC [20, 21]. Modeling of control processes of the transport system [22] was carried out in the laboratory automation controller-based firm Schneider Electric (Krivoy Rog Technical University). In forming models were used as classical approaches, and methods of intellectual analysis, as, for example, in [23].

OBJECTS AND PROBLEMS

In this paper on the basis of existing ore dressing control system of the crushing plant CrP of the “CGOK” PJSC the author puts forward the implementation of an integrated conveyor line APCS using the developed software and technology based on PLC TSX 37-22 Schneider Electric industrial controllers.

Based on the results of the analysis of existing industrial controllers can use to implement hardware and software solutions designed automatic control system based on PLC TSX 37-22 Schneider Electric industrial controller.

After tests the software and algorithmic support of the automatic process control transportation of ore in the lab need to move to testing under industrial conditions at the crushing plant of the “CGOK” PJSC.

And these tests have been carried out under industrial conditions by two directions:

tests of software, validation algorithm of the control with inspection sensors for technological process control;

carrying out control actions (change of belt tension and of cargo weight).

During production tests at the crushing plant of the “CGOK” PJSC the following results have been obtained: software, which was developed and which based on graphic language of step logic Ladder (LD), operates if sensors used in APCS are hooked up. In-process of the study of the control algorithm, the control system (OBCS) ore beneficiation makes signal collection and processing provided by sensors (belt speed, cargo weight on belt). Weight control has been carried out by conveyor scales VTK4-2, mounted on K-2 conveyer of (1-2) primary and secondary crushing. For belt speed control a frequency type sensor was used, which is frictionally bound with bottom-run. During the testing the temperature control with the Mikron M90-V infrared thermometer of the area frictional interaction of the belt and drive pulley has been carried out. To hook up the sensors to the main controller gear, integrated analog inputs for Mikron M90-V, for sensor of belt load and for frequency speed sensor have been used.

The principle of operation of scales is based on the transformation of the value of the mass of material present at the weighing station conveyor to an electrical DC signal proportional to the consumption of material. The transformation is based on strain gauge signals and signals of speed tape sensor. Total value of handling material is defined by current consumption integration by BOI-3V microcontrollers.

Thus, having integrated APCS system under development into the operational ore beneficiation control system (OBCS), receive an integrated automatic ore reduction and beneficiation process control system at the crushing plant. Modern equipment of the test of belt stretching (tension) is based on strain-gauge transducer, which operates with electronic modules meant for integration into industrial network communications. As a belt tension transducer Meradat K-20 tension and compression gauge transducer is recommended for use. The gauge is located between idler pulley with tripper and conveyor take-up pulley system.

Upon the tests at the first stage positive results have been obtained.

For the second stage tests it was necessary to perform the preliminary calculations for finding the range of controlled variable regulation. When the conveyor testing was being carried out during the preventive maintenance, it was possible to change only the tension and belt mass per unit length while ore reduction process reaches the desired capacity.

Table 1. Conveyor pulling calculation results

Cargo weight per unit length with rated capacity, kg/m	425
Belt mass per unit length, kg/m	56
Minimum carrying run pull, N	37600
Minimum bottom run pull, N	12860
Total pulling factor	10,4
Maximum carrying run pull, N	404400
Total drive power, kW	974
Take-up cargo weight, kg	5000
Cargo weight per unit length with rated capacity, kg/m	425
Belt mass per unit length, kg/m	56
Minimum carrying run pull, N	37600
Minimum bottom run pull, N	12860
Total pulling factor	10,4
Maximum carrying run pull, N	404400
Total drive power, kW	974
Take-up cargo weight, kg	5000

For basic data the rated technical specifications of the K-2 conveyer of (1-2) primary and secondary crushing are used.

Upon the calculations of conveyor pulling units according to a simplified circuit (track configuration) the following results presented in Table 1 have been obtained.

Dynamic belt tension change when the conveyer is started up empty (no-loaded) and under load is presented in fig.1.

Thus, according to obtained results it is worth noting that under the conveyor maintenance the belt tension specified by truck type take-up is overestimated and composes $1{,}078\cdot10^5$ N and can be provided to reduce to 49 kN.

When the conveyer is started the conveyor take-up by reeving system (pulley system rate is 4) creates tension equals 431200N. Maximum climbing point of belt against driving pulley equals 404,4 kN, and subject to dynamic component (see fig. 1) equals 448500N. Thus, when the conveyer is started up empty, upon which the dynamic force is 44,065 kN (see fig. 1b), take-up tripper does not move out of location.

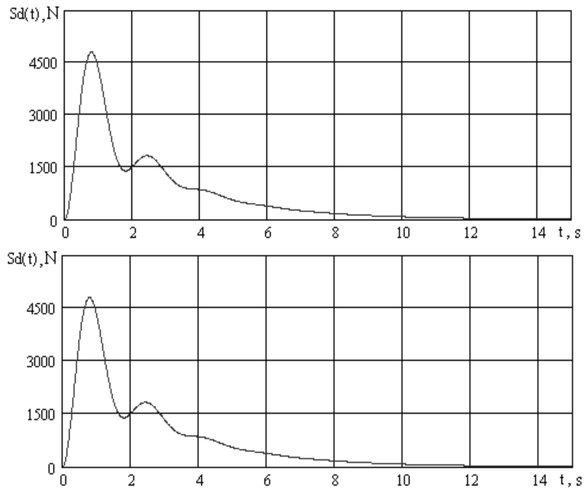

Fig. 1. Dynamic belt tension change when the conveyer is started empty – a; under load – b

Conveyor-drive power is also overestimated, installed power is 1200 kW, and design power is 974 kW. Such reserve power is useful only for engines in order to limit overloading as pulling factor of drive pulleys, following the calculations, doesn't ensure specific margin.

Design value of total pulling factor is 10,4 but recommended value is 5,22 on one drive pulley with the diameter of 2000 mm, wrap angle of 270 grad and adhesion coefficient of 0,35.

As a result, the range from 3000 kg to 11000 kg for belt tension control is adopted.

During the tests belt ore value-tonnage and its speed have been displayed by ore beneficiation control system (OBCS) v0.04. The system displays the current handling cargo capacity on the conveyor within an hour at 5 minute intervals and during the changeover at 1 hour intervals, in tabular format and diagrammatically. The process received results are depicted in fig. 2.

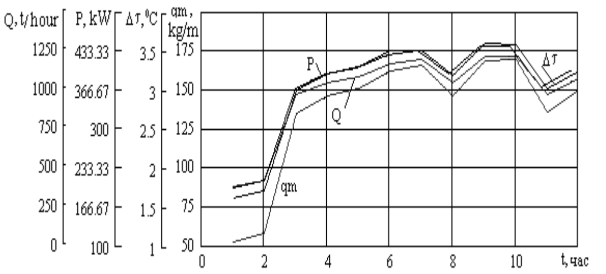

Fig. 2. Consumed conveyor capacity and its behavior, variation of belt mass per unit length and lining temperature increment during the changeover on K-2 conveyer of the crushing plant

According to the results it is worth noting that conveyor capacity falls short of rated capacity and during the changeover changes in a broad range. Based on the results of the current capacity belt ore value-tonnage and its behavior during the changeover have been obtained (see fig. 2). Consumed conveyor capacity and its behavior during the changeover are depicted in Fig. 2.

Conveyor drive power consumption behavior is proportionally with ore handling capacity behavior that is due to belt turning force variation by pulley driving. As a result of load growth the frictional interaction of belt and drive a pulley increase that is evident as heat emission in wrap angle. Turning force value (pulley belt pressure) is corrected by belt tension conveyor control. For heat losses control temperature measurements have been performed by Mikron M90-V infrared thermometer. Thermometer readings were recorded in parallel with the existing system.

Belt tension change has been carried out by change of conveyor take-up cargo value, within the range from 3000 kg to 11000 kg. According to obtained results tension change expressed as percentage.

During the testing the conveyor has been started up for several times with various weight values on conveyor take-up, at the same time temperature measurements of drive pulley lagging have been carried out. Measurement results are depicted in fig. 3 - characteristic curve 1. In that Figure Characteristic curve 2 is depicted, obtained upon calculations.

Thus, according to obtained results it is worth noting marginal differences in measured and rated values but the temperature trend through the reduce of belt tension is identical.

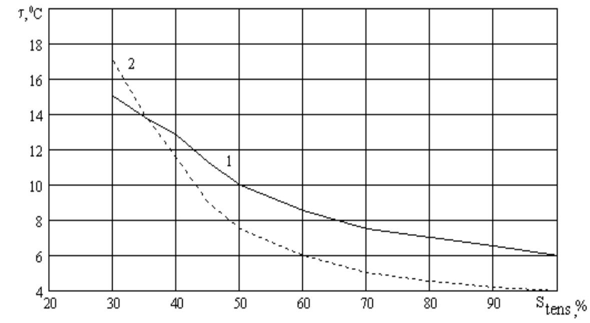

Fig. 3. Variation of pulley lagging temperature when the conveyer is started at various belt tension values:1- experimental characteristic; 2- rated characteristic

When starting up the conveyor the temperature measurements of dynamic pulley lagging have been carried out. The received results are depicted in fig. 4. Characteristic curve 1 reflects testing data. Characteristic curve 2 reflects data, obtained by calculations where the emergency takes place.

According to the testing results, measured during the changeover, i.e. capacity, mass per unit length, consumed capacity, temperature change calculations have been performed, more specifically its increment within an hour of conveyor operating at current capacity. The results are depicted in fig. 3. The received results reflect the capacity losses due to drive conveyor take-up friction, which are evolved as heat and define the arc size of operative slipping at the current conveyor starting up. According to the results it is worth noting that conveyor operates not on the excess (rated) capacity, drive pulley behavior is set and friction losses are minimum, which means that the wearing of pulley lagging and belt nonworking surface has been kept to a minimum

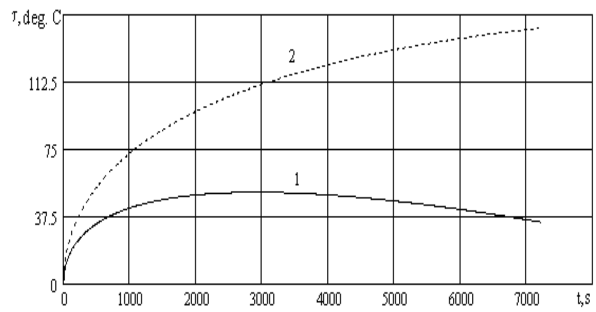

Fig. 4. Variation of pulley lagging temperature when the conveyer is started in steady state operation by regular conveyor start-up -1 and emergency operation -2

Industrial test data carries the following readings. Thus, at starting-up the traction load increase has been stated, with temperature raise to

+15 deg. C at ambient temperature +4 deg. C. In steady-state operation during the ore handling the temperature rise composed 3,6 deg. C. Measurement uncertainty composes 1%. The signal processing time suggested to use by transducer is ≤ 100 ms.

Conveyor start-up control with friction drive heating temperature prevents from emergency drive pulley slipping. At the same time it can eliminate the possibility of damage of the belt nonworking surface, pulley lagging as well as fire emergency, thereby eliminating the possibility of conveyor shut down. The test results have corroborated that during the belt tension control the drive power consumption upon handling by reduction in belt resistance varies.

Drive friction couple efficiency is evaluated by pulley efficiency. Raise of temperature in the friction engagement results from consume power losses. By regular conveyor operation power losses compose 150 – 300 W, the efficiency variation as a result of belt tension change is small - 0,974÷0,977. If as a result of environmental impacts and other factors the friction power losses increase a hundredfold then efficiency will significantly change 0,4÷0,9 under the belt tension change.

CONCLUSIONS

The developed software according to controlled quantities enables to specify technological process state, equipment condition and its operation: startup, steady state, and shutdown. The rational process operation selection is based on algorithm of automatic adaptive control system with modifiable structure.

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ИССЛЕДОВАНИЕ СИСТЕМЫ АВТОМАТИЧЕСКОГО УПРАВЛЕНИЯ ЛЕНТОЧНЫМ КОНВЕЙЕРОМ НА ТЕХНИЧЕСКОЙ БАЗЕ ПРОМЫШЛЕННЫХ КОНТРОЛЛЕРОВ SCHNEIDER ELECTRIC

Ольга Поркуян, Игорь Курганов

Аннотация. Представлены результаты исследований комплексной системы автоматического управления технологическим процессом дробления и транспортирования руды. Разработаны принципы управления на основе измерения температурного поля. Эффективность похода подтверждена результатами теоретических и экспериментальных исследований системы управления на базе промышленных контроллеров Schneider Electric.
Ключевые слова. Промышленные контроллеры, контроль натяжения ленты, математические модели с распределенными параметрами.