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Analyzing the Main Belt Conveyor Dual-motor Asynchronous Electric Drive Operating Modes

[1]***KULIKOV Anatoliy,** *doctoral student, tolyan_kylikov@mail.ru,*
[1]**KAVERIN Vladimir,** *Cand. of Tech. Sci., Associate Professor, kaverinkz@inbox.ru,*
[2]**ZYUZEV Anatoliy,** *Dr. of Tech. Sci., Professor, a.m.zyuzev@urfu.ru,*
[1]*NPJSC «Abylkas Saginov Karaganda Technical University», Kazakhstan, Karaganda, N. Nazarbayev Avenue, 56,*
[2]*Ural Federal University n.a. the First President of Russia B.N. Yeltsin, Russia, Yekaterinburg, Mira Street, 19,*
**corresponding author.*

Abstract. *The article deals with the main aspects of the starting, technological and emergency modes of belt conveyors operation. The subject of the study is a dual-motor electric drive of the main belt conveyor with frequency regulation. The analysis of the belt conveyor electric drive operation in various modes has been carried out. The main causes of damage to the equipment of conveyor lines have been determined. An energy-efficient way to control a dual-motor electric drive has been determined. The actual problem of belt conveyors is increased wear of their components. The most expensive part of the conveyor is the conveyor belt. It is important to ensure smooth increasing the conveyor belt speed in order to prevent mechanical vibrations of the belt and its slippage on the drive drum. The belt slippage on the drive drum leads to premature belt wear. The purpose of this work is to find solutions to increase the conveyor belt resource including that through the optimal control of the dual-motor electric drive of the main belt conveyor. It is proposed to use an individual frequency converter for each drive motor and to organize synchronous operation of the motors by balancing the load as a solution to this problem. It is also proposed to use the vector mode of frequency control to achieve the greatest torque in a wide range of changes in the electric motor speed of rotation, as well as to ensure high-accuracy control of the electric motor rotor speed of rotation. It is expedient to use an adaptive automatic controller that takes into account the variable freight flow in the process of transporting the material.*

Keywords: *conveyor, electric drive, multi-motor drive, frequency converter, asynchronous electric motor, energy saving, resource.*

Introduction

According to the second paragraph of the Comprehensive Strategic Development Plan of the Republic of Kazakhstan till 2025, within the frames of implementing the Kazakhstan-2050 strategy, «It is important to increase the requirements for energy efficiency and energy saving of enterprises, as well as the environmental friendliness and efficiency of the energy producers themselves» [1]. One of the priority tasks of developing the state is energy saving and energy efficiency of technological complexes of industrial enterprises. At manufacturing plants, main belt conveyors are widely used as a continuous means of transportation. This article deals with the energy efficiency of a dual-motor asynchronous electric drive of the main belt conveyor.

There are the following types of construction of main belt conveyor drives: with one multi-motor drive and with two or more drives [2, 3]. In the foreign mining industry, there are examples of the use of dual-engine drives for belt conveyors. One of these conveyors is a belt conveyor for transporting slag and coal at the Kolubara quarry, Serbia [4]. The number of electric motors and drives is selected depending on the length of the conveyor line. At present, there is a tendency to equip main belt conveyors with adjustable drives with asynchronous electric drives.

Figure 1 shows the kinematic diagram of the main belt conveyor with one single-motor drive.

Figure 2 shows the kinematic diagram of the main belt conveyor with one dual-motor drive.

Figure 3 shows the kinematic diagram of the main belt conveyor with two dual-motor drives.

The article deals with the main conveyor with a dual-motor adjustable asynchronous electric drive (Figure 1). This type of drive is widely used on the main conveyors of mining and ore-dressing enterprises of the Republic of Kazakhstan, such as the Kazakhmys Corporation and the KazZinc, which emphasizes the relevance of this topic.

The purpose of this work is to determine an energy-efficient way to control a dual-motor electric drive of the belt conveyor and to increase the conveyor belt resource.

Analyzing the disturbing factors that have a negative impact on the mechanical parts of the belt conveyor

Figure 1 – Kinematic diagram of the main belt conveyor with one drive (M1 – electric drive; G1 – gearbox)

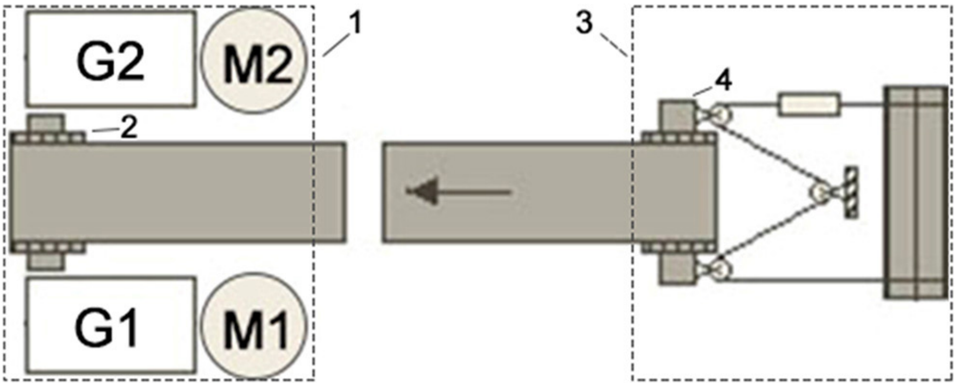

Figure 2 – Kinematic diagram of the main belt conveyor with one dual-motor drive (1 – drive end; 2 – drive drum; 3 – tension station; 4 – tension drum; M1, M2 – electric drives; G1, G2 – gearboxes)

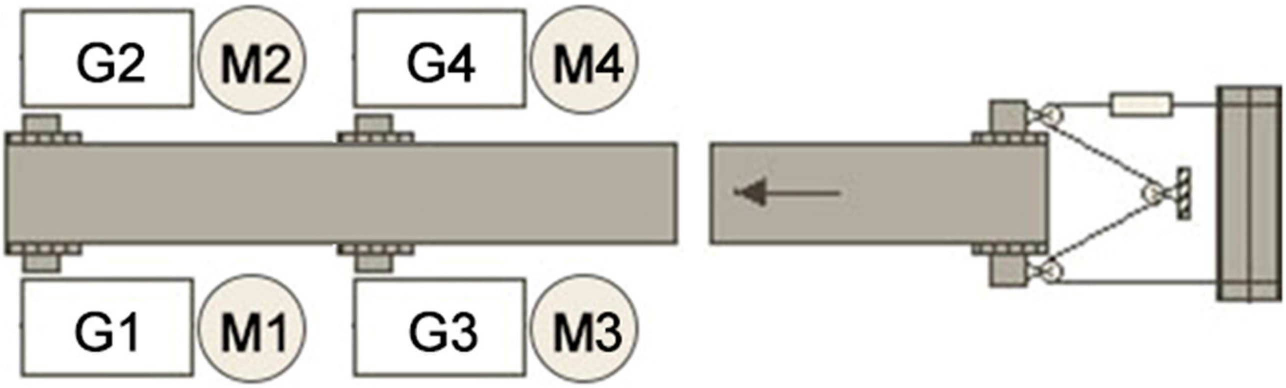

Figure 3 – Kinematic diagram of the main belt conveyor with two dual-motor drives (M1, M2 – first drive electric drives; G1, G2 – first drive gearboxes; M3, M4 – second drive electric drives; G3, G4 – second drive gearboxes)

At mining enterprises, taking into account the peculiarities of operation, the following negative factors can be distinguished that lead to decreasing the conveyor line resource: increased humidity and dustiness, the impact nature of the load, as well as the emission of substances that impact destructively on the machines and mechanisms components.

The purchase price of a conveyor belt is 50-60% of the entire conveyor cost. The belt is the least durable element of the conveyor [5]. Thus, the conveyor belt is the key element for the efficient and reliable operation of the conveyor.

In their work, such authors as Piotr Walker, Błażej Doroszuk, Robert Król paid attention to the ore reloading unit between two conveyors of the flow-transport system. The section of the belt to which the ore is fed is most susceptible to abrasive wear. The studies have shown that the use of a feed hopper that redirects the flow of material can lead to a 10-fold wear reduction in the receiving conveyor belt [6].

Such scientists as O.M. Pihnastyi, S.M. Cherniavska studied the dynamic stress that occurs during acceleration and deceleration of the conveyor electric drive impact on the conveyor belt resource. The conveyor belt is an elastic-viscous closed mechanical system. As a result of the studies, it has been established that the magnitude of dynamic stresses is directly related to the magnitude of the belt acceleration [7].

The misalignment of the conveyor shafts and drums contributes to the active wear of the conveyor belt. In his publication [8], Vadim Yurchenko gives the results of the analysis that show that the effective alignment of conveyor belts is performed with the use of self-leveling roller bearings. In turn, the service life of the rollers can be significantly reduced due to the appearance of resonance phenomena caused by the vibration of the conveyor belt during material transportation. In the work by Andrey Smirnov and Vsevolod Beikhul [9], there are presented graphs of the roller service life dependence on the linear load of the conveyor, the composition of the transported fright, and the features of the conveyors.

The belt slippage on the belt conveyor drive drum has a huge impact on the drive drum lining wear and leads to its destruction, reduces the performance of the entire device. The greatest dynamic shocks do not occur during slippage but at the moment of «picking up» the belt on the drive drum lining. Under certain circumstances, the belt «clings» not immediately but slips momentarily a few more times. This causes a significant dynamic shock, both on the conveyor belt and in the supporting structure, drive, clutch, gearbox and drive drum that can be damaged, especially its adhesive coating [10]. The conveyor belt slippage on the drive drum affects negatively the belt service life.

The trouble-free operation of the conveyor line, in addition to the conveyor belt, is affected by the conveyor drive and its components (gearbox, electric motor) reliability. Mine belt conveyors work in severe conditions. The failure of the conveyor gearbox affects the operation of the entire flow-transport system. The gearbox replacement can take up to 24 hours, which leads to equipment downtime and brings losses to the mining company [11].

When operating the main conveyor with a dual-motor drive, an important task is to synchronize the operation of the electric motors that rotate the drive drum. Uneven load distribution leads to the overloading of one of the motors, which leads to decreasing its resource, and as a result, decreasing the overhaul interval of the drive equipment.

To prevent the belt slippage on the drive drum, starting the conveyor with a dual-motor drive must be performed by smooth changing the speed of the drives. With an increased starting torque, there is a risk of slipping, which leads to the belt vibrations. This in turn leads to significant wear of the belt and equipment breakdowns, which requires additional repair costs. Smooth acceleration lasts longer but the movement of the distributed masses of the belt is more consistent, less oscillatory, which indicates smaller dynamic forces in the belt. With smooth acceleration, there are also no additional energy costs that occur with direct starting the motor.

Synchronous operation of the dual-motor drive motors is achieved by optimal adjustment of the automatic controller. With an incorrectly tuned controller, there occur the belt oscillations, which leads to premature wear of the belt and decreasing the efficiency of the system [12].

Belt conveyor starting modes

V.P. Metelkov, Ya.L. Lieberman (Ural Federal University) considered the possibility of reducing the likelihood of belt slippage during the start of the conveyor by increasing the initial tension of the belt by an automatic tension station [13]. But there is the following problem: not all the belt conveyors are equipped with an automatic tension station. In conveyors with the length of more than 2000 m, it is necessary to exert great effort to tension the belt along the entire length of the conveyor towards the tail section. The greatest tension will be on the section of the belt located on the tail (tension) drum. Excessive belt tension in this area will cause its premature wear.

Scientists from UrFU A.M. Zyuzev, V.P. Kozhushko, V.P. Metelkov studied the starting mode of an asynchronous electric drive of a belt conveyor using a soft starter device (SSD). The work revealed that the use of soft starters in open-loop control systems for an asynchronous motor does not allow limiting dynamic loads in the conveyor belt. The results of the studies show that it is expedient to use an electric drive system with a soft starter device with speed feedback. It has also been found that a long starting mode of an asynchronous electric drive leads to its rapid overheating [14].

To increase the energy efficiency of the belt conveyor, it is necessary to adjust its speed depending on the input freight flow. A soft starter does not have the ability to control the speed of the drives.

Direct start of a dual-motor drive of the main conveyor is unacceptable for a number of reasons, firstly, due to high starting currents, which contribute to increasing the motor heating. Secondly, the motor may not be able to cope with the load and stop when the current protection (cut-off) is triggered. In this case, the absence of current protection will lead to overheating the motor winding. Thirdly, direct start causes sharp increasing the speed of the drive drum, which contributes to the conveyor belt slippage and its premature wear. All of the above reasons are exacerbated with a heavy start-up of the conveyor with the loaded belt.

The starting mode becomes much more complicated in long conveyors with a dual-motor asynchronous drive. In such conveyors, there is required not only smooth speed increasing but also synchronous operation of the motors that rotate the drive drum. The process of starting a belt conveyor with a dual-motor drive is highly dynamic. Therefore, to synchronize the drive motors, an automatic controller with a sufficiently high response rate to the setting and disturbing impacts is required.

Taking into account the peculiarities of the considered types of conveyor start, it is advisable to use individual for each motor frequency converters to start the belt conveyor with a dual-motor asynchronous electric drive. Synchronization of two frequency-controlled asynchronous electric drives must be performed by the electromagnetic torque. The similar electric motors manufactured at the same factory can have different mechanical and electromechanical characteristics. According to work [15], the permissible deviation of the minimum torque is minus 15%. Therefore, it is expedient to synchronize the motors by equalizing their moments and loads. To reduce the possibility of belt slippage and the belt wear, there is required a smooth frequency change when starting the conveyor. Smooth running and maximum torque over a wide range of speed changes can be achieved by vector control of the asynchronous electric drive.

Technological modes of the belt conveyor

In the mining industry, the belt conveyor is unevenly loaded during operation.

Kaung Py Aung dealt with the issue of increasing the efficiency of the powerful conveyor plants operation. The studies were carried out to stabilize the traction factor of the belt conveyor. The inefficient operation of high-capacity conveyors is caused by the fact that the input freight flow is significantly uneven in time and by a large number of intervals of the freight absence. Significant uneven loading of the web is the main cause of wear of the mine conveyor belt. The Kaung's studies focused on the dual-motor drive belt conveyor. The results of the studies are a mathematical model of the movement of the dual-drive conveyor belt with an automatic tension station and an algorithm for automatic stabilization of the traction factor. But in this work, attention is not paid to the synchronization of drive stations. If the conveyor drives synchronization is not satisfactory, even with the optimal traction factor, there will be oscillations in the belt and its slippage on the drive drums. Non-synchronous operation of the drives leads to fluctuations in the frequency of the electric motors, as well as in the moments acting on the drive drums and as a result leads to increasing the belt wear.

An automatic controller that synchronizes the operation of electric motors must take into account a variable freight flow. With non-synchronous operation of electric motors rotating one drum, there occur dynamic overloads of the mechanical parts of the drive: motors, gearboxes, drive drums, clutches. Alongside with dynamic overloads, vibrations of the belt occur, which contributes to its increased wear [13]. The automatic controller that is optimally tuned at idling of the conveyor, can carry out synchronous operation of electric motors. At the same time, when operating under load with the same parameters of the automatic controller, synchronization of electric motors can turn out to be unsatisfactory. Therefore, during the operation of the belt conveyor, it is expedient to change the parameters of the automatic synchronization controller for the electric motors of the drive drum depending on the input freight flow.

Emergency modes of the belt conveyor

At mining enterprises belt conveyors are equipped with automatic control systems. There are installed limit switches of the belt drift, cable-rope switches along the entire undercarriage of the conveyor, a sensor of the longitudinal rupture of the belt, a sensor for monitoring damage and wear of the belt. An effective way to monitor the presence of belt slippage on the drive drum is to install angular velocity sensors on the drive and bypass drums. In the normal operation without slippage, the angular speeds of the drive and bypass drums rotation have a certain ratio. Changing the ratio of the angular speeds of rotation indicates slippage of the belt on the drive drum (with increasing the angular speed of the drive drum rotation on and as a result decreasing that on the bypass one). In some systems of automatic control of the conveyor line, temperature sensors are also provided for the motor windings, bearing units of the drive, oil in the gearboxes. Exceeding any temperature is an emergency situation that can lead to serious damage to the conveyor. It is necessary to stop the conveyor immediately in the event of any emergency.

T.P. Mishchenko (Donetsk National Technical University) studied the emergency modes of belt conveyors, in which a large amount of heat is released under the action of friction and, at the same time, there increases the likelihood of the conveyor parts ignition that are subject to increased friction. There are three main modes of operation of the belt conveyor, in which a large amount of heat is generated:

- belt slippage on the drive drum. One of the causes of slippage is insufficient belt tension at the point of its run-off from the drive drum;
- jamming of any drum (drum of tension station, tail drum, bypass drum). The belt on the jammed drum moves with full slip;
- failure of rollers. If a roller is jammed and there is sufficient force of pressing the belt against the jammed roller, intense friction occurs. The service life of the conveyor rollers depends on the linear load, the parameters of the conveyor, the composition of the transported freight, the type and parameters of the roller bearing.

The above emergency modes lead to increased wear of the conveyor belt.

Conclusions

There have been considered the main causes of damage to the equipment of conveyor lines. The analysis of the belt conveyor operation in starting, technological and emergency modes of operation has been carried out. The harmful factors influencing the resource of the conveyor belt have been revealed.

To increase the service life of the conveyor line equipment, it is expedient to use a frequency-controlled asynchronous motor with a squirrel-cage rotor as a drive. The use of frequency converters allows smooth starting and stopping the conveyor drive, adjusting the speed of the motors, as well as increasing the energy efficiency of the conveyor electric drive. Updated frequency converters have the function of vector control, both with the use of a feedback sensor and without sensor control of the magnetic flux vector. Vector control of the asynchronous motor contributes to obtaining a high efficiency, high accuracy of the rotor speed control, smooth shaft rotation at low speeds, which is important in controlling the main belt conveyor electric drive.

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Негізгі таспалы конвейердің қос қозғалтқышты асинхронды электр жетегінің жұмыс режимдерін талдау

*[1]***КУЛИКОВ Анатолий Петрович,** докторант, tolyan_kylikov@mail.ru,*
*[1]**КАВЕРИН Владимир Викторович,** т.ғ.к., доцент, kaverinkz@inbox.ru,*
*[2]**ЗЮЗЕВ Анатолий Михайлович,** т.ғ.д, профессор, a.m.zyuzev@urfu.ru,*
[1]«Әбілқас Сағынов атындағы Қарағанды техникалық университеті» КеАҚ, Қазақстан, Қарағанды, Н. Назарбаев даңғылы, 56,

[2]Ресей Федерациясының бірінші президенті Б.Н. Ельцин атындағы Орал федералды университеті, Ресей, Екатеринбург, Мира көшесі, 19,

*автор-корреспондент.

Аңдатпа. *Мақалада таспалы конвейерлердің іске қосу, технологиялық және авариялық жұмыс режимдерінің негізгі аспектілері қарастырылады. Зерттеу пәні жиілікті реттейтін негізгі таспалы конвейердің қос қозғалтқышты электр жетегі болып табылады. Таспалы конвейердің электр жетегінің әртүрлі режимдегі жұмысына талдау жүргізіледі. Конвейерлік желілердің жабдықтарының зақымдануының негізгі себептері анықталады. Екі моторлы электр жетегін басқарудың энергияны үнемдейтін тәсілі анықталды. Таспалы конвейерлердің өзекті мәселесі тетіктердің тозуының жоғарылауы болып табылады. Конвейердің ең қымбат бөлігі - конвейер лентасы. Таспаның механикалық тербелісін және оның жетек барабанында сырғып кетуін болдырмау үшін конвейердің жылдамдығын біркелкі арттыруды қамтамасыз ету маңызды. Жетек барабанындағы белдіктің сырғып кетуі белдіктің мерзімінен бұрын тозуына әкеледі. Бұл жұмыстың мақсаты – конвейер ресурсын ұлғайту, оның ішінде негізгі таспа конвейерінің екі моторлы электр жетегін оңтайлы басқару арқылы шешімдерді табу. Бұл мәселені шешу ретінде әрбір жетек қозғалтқышы үшін жеке жиілік түрлендіргішін пайдалану және жүктемені теңестіре отырып, қозғалтқыштардың синхронды жұмысын ұйымдастыру ұсынылады. Электр қозғалтқышының айналу жиілігін өзгертудің кең диапазонында ең үлкен моментке жету үшін, сондай-ақ ротордың айналу жылдамдығын жоғары дәлдікпен басқару үшін жиілікті реттеудің векторлық режимін пайдалану ұсынылады. электр қозғалтқышы. Материалды тасымалдау процесінде ауыспалы жүк ағынын ескеретін адаптивті автоматты контроллерді қолданған жөн.*

Кілт сөздер: *конвейер, электр жетегі, көп қозғалтқышты жетек, жиілікті түрлендіргіш, асинхронды электр қозғалтқышы, энергия үнемдеу, ресурс.*

Анализ режимов работы двухдвигательного асинхронного электропривода магистрального ленточного конвейера

[1]****КУЛИКОВ Анатолий Петрович,*** *докторант, tolyan_kylikov@mail.ru,*
[1]***КАВЕРИН Владимир Викторович,*** *к.т.н., доцент, kaverinkz@inbox.ru,*
[2]***ЗЮЗЕВ Анатолий Михайлович,*** *д.т.н., профессор, a.m.zyuzev@urfu.ru,*
[1]*НАО «Карагандинский технический университет имени Абылкаса Сагинова», Казахстан, Караганда, пр. Н. Назарбаева, 56,*
[2]*Уральский федеральный университет им. первого Президента России Б.Н. Ельцина, Россия, Екатеринбург, ул. Мира, 19,*

**автор-корреспондент.*

Аннотация. *Рассматриваются основные аспекты пусковых, технологических и аварийных режимов работы ленточных конвейеров. Предметом исследования является двухдвигательный электропривод магистрального ленточного конвейера с частотным регулированием. Выполнен анализ работы электропривода ленточного конвейера в различных режимах. Определены основные причины повреждения оборудования конвейерных линий. Определен энергоэффективный способ управления двухдвигательным электроприводом. Актуальной проблемой ленточных конвейеров является повышенный износ составных частей. Наиболее дорогостоящей частью конвейера служит конвейерная лента. Важно обеспечить плавный набор скорости движения конвейерной ленты для предотвращения механических колебаний ленты и ее проскальзывания на приводном барабане. Проскальзывание ленты на приводном барабане приводит к ее преждевременному износу. Целью данной работы является поиск решений для увеличения ресурса конвейерной ленты, в том числе за счет оптимального управления двухдвигательным электроприводом магистрального ленточного конвейера. В качестве решения данной проблемы предложен индивидуальный частотный преобразователь для каждого электродвигателя привода и организовать синхронную работу двигателей, выравнивая нагрузку. Предлагается использовать векторный режим частотного регулирования для достижения наибольшего момента в широком диапазоне изменения частоты вращения электродвигателя, а также для высокоточного регулирования скорости вращения ротора электродвигателя. Целесообразно использование адаптивного автоматического регулятора, учитывающего переменный грузопоток в процессе транспортировки материала.*

Ключевые слова: *конвейер, электропривод, многодвигательный привод, частотный преобразователь, асинхронный электродвигатель, энергосбережение, ресурс.*

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