ANNOTATION

of thesis submitted for the degree of Philosophy Doctor (PhD)
in specialty 6D071200 – Machine building
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«THE CONSTRUCTIVE AND TECHNOLOGICAL ENSURING THE QUALITY OF ROLLER SUPPORTS OF CONVEYOR BELT OPERATING UNDER SEVERE CONDITIONS»

Relevance of the research. Topic of the thesis «The constructive and technological ensuring the quality of roller supports of conveyor belt operating under severe conditions» according to **State Program of Industrial and Innovative Development of the Republic of Kazakhstan for 2015-2019 years (Decree of the President of the Republic of Kazakhstan dated August 1, 2014 № 874)** correspond to one of the priority sectors of machine building - **Production of machinery and equipment for the mining industry.** According to the statistic data of the SPIID in this sector for 2008-2013, the level of depreciation of fixed assets is observed up to 38% in 2013, and one of the problems is low competitiveness of the products: in price - in comparison with China and Russia, in quality and productivity - with far abroad countries. So the production of high-quality and competitive equipment is very urgent task.

From the experience of operation of belt conveyors in mining enterprises (extraction of coal, limestone, gravel, various ore types), it can be said that most of them work in conditions of high humidity, dusty environment, while in the course of operation these factors have their negative impact on the conveyor assemblies. Rollers account for up to 40% of all costs for repairs and maintenance and up to 30% of the cost of the entire conveyor. How long the conveyor belt will last, and how much the entire conveyor system will consume energy depend on reliable work of rollers. High demands are made on rollers. They must be inexpensive, reliable; they should have a minimum resistance to rotation, they should ensure the centering of the tape; to set the tape the necessary groove and favorable working conditions. Thus, rollers are one of the most important components that determine the operability and reliability, energy efficiency and fire safety of the belt conveyor, also their quality affects the durability of the belt, which is one of the costly elements of the conveyor belt (about 60% of all operating costs account for the tape). Therefore, increasing the reliability and durability of the support rollers of conveyor systems is a relevant task.

The aim of the work. Constructive and technological ensuring the quality of support rollers of belt conveyors operating under severe conditions.

Main research objectives:

- to systemize and conduct analysis of the patent and scientific and technical information about the design of rollers, the technology of their manufacture and assembly, to determine the prospects of the proposed designs;
- to develop new designs of support rollers of belt conveyors, to determine the total loads acting on rollers of a new design;
- to perform an analysis of the stress-deformed state of the roller under various loading by methods of computer simulation, to check the possibility of a joint skewing of the inner ring of the bearing relative to the outer one for a roller of a new design;
- to perform an analysis of the technology of manufacturing the parts of support rollers, including methods of dimensional analysis of the technological process, to develop a progressive technology for the manufacture of roller parts;
- to develop an imitational stochastic model for forecasting the surface roughness after turning, taking into account various systematic and random parameters of tool geometry, cutting dynamics, to obtain theoretical roughness distribution data and to compare them with experimental data.

Object of the research. Support roller of conveyor belt for the mining industry, operated under severe conditions. Wherein under severe conditions, we mean increased humidity, dustiness, corrosive environment, temperature differences, i.e. conditions characteristic for the mining industry.

Subject of the research. Factors, both constructive and technological, those affect the reliability and lifetime of the support roller of the conveyor belt.

The idea of the work. Consists in increasing the resource (lifetime) of the support rollers of belt conveyors, and correspondingly in increasing the reliability of belt conveyors through the improvement of design parameters of rollers and development of recommendations for the technological ensuring the quality of roller parts.

Research methods. Methods of the research are based on the basic principles of such sciences as hoisting vehicles, the fundamentals of design and machine parts, the theory of dimensional chains, the dimensional analysis of technological processes, the calculation of dimensional tolerances, the scientific foundations of technology of machine building, the engineering of the surfaces of parts.

Investigations on the topic of the thesis were conducted on the basis of the laboratories of the Institute of Industrial Engineering named after A.Burkitbaev of the KazNRTU named after K.Satpayev

Investigation of loading on the support rollers of the conveyor was conducted using the Femap with NX Nastran software package on the basis of the computer simulation laboratory of the Technical and Humanitarian Academy of Bielsko-Biala (Poland) during the foreign internship.

Measurements of the roughness were made on the basis of the enterprise LLP JV «KAZELECTROPRIVOD» (Almaty city), the roughness determination device is the Surftest SJ-210 profilometer, manufactured by Mitutoyo (Japan).

Scientific novelty of the thesis.

In this work:

- new original design of support rollers, which improve their basic characteristics, such as reliability, service life, were developed;
- by the means of engineering forecasting the prospects of construction of support rollers of a new design was determined;
- analysis of the stressed-deformed state of the support roller under various loads by means of the Femap NX Nastran software package was conducted, possibility of joint skewing of the outer ring of the bearing relative to the internal one was shown for the proposed roller by computer simulation;
- mathematical model, which showed the relationship between load and deformations was developed by the method of regression analysis and the forecast for the further change of deformation depending on loading is given;
- an imitational stochastic model for the formation of surface roughness for turning (boring of the inner surface) was developed taking into account systematic and random parameters, an algorithm for calculating the roughness and a computer program «Calculation of distribution laws for roughness parameters during turning» were developed.

Main statements to be defended:

- construction of support rollers of a new design for belt conveyors of the mining industry, which differs from the existing designs by a combined seal (labyrinth and centrifugal rotor seal) and eliminates the pinching effect in the roller bearing by providing a joint skew of the outer ring of the ball bearing relative to the inner;
- investigation of the stress-strain state of rollers under variable loading in a Femap with NX Nastran environment;
- an imitational stochastic model for the formation of surface roughness for turning of the inner surface taking into account systematic and random parameters;
- theoretical data on the distribution of roughness during turning, obtained with the help of the computer program « Calculation of distribution laws for roughness parameters during turning » and the results of experiments reflecting the influence of the geometry of the cutting tool and the parameters of cutting conditions on the quality of the surface of the workpiece during turning and proving the adequacy of the created program.

In the **first chapter** of the work an analysis of domestic and foreign scientific and technical literature on the topic was conducted, a large array of patent information was investigated. Various designs of roller supports, factors affecting

the quality of their manufacture and assembly are considered. The reasons for the failure of roller supports of belt conveyors, the effect of loads on the assemblies of conveyor belts are analyzed. The aim and objectives of the investigation were set. The **second chapter** considers the issues of engineering forecasting of the designs of conveyor rollers, the prospects for their development. To identify or to verify the prospects of the design of support rollers of conveyors, we use a complex methodology based on patent information. A patent search and analysis of patent information with a depth of 43 years was conducted, from 1970 to 2013 about 125 patents were considered. The information obtained from non-parametric sources (patents, author's certificates, innovative patents, etc.) was classified and transformed into numerical criteria (completeness coefficients - r, reduced number of patents - M, generalized completeness coefficient - $r_{об}$), which characterize these ideas. This made it possible to forecast the prospects of the proposed designs and showed the prospects for further development and improvement of roller designs with self-aligning bearing assemblies. In the **third chapter** a dimensional analysis of the roller assembly of the new design was conducted, and it was shown that the necessary accuracy of the relative location of the roller assemblies and parts is achieved, a dimensional connection between the parts of the assembly is available.

The overall risk percentage of the appearance of defective product for this roller is $P_{\sum} = 0{,}42\%$, which does not exceed the allowable value and the risk is minimal. The calculation of nominal values, deviations and tolerances of the dimensions of the roller parts were made, methods for achieving the required accuracy in the overall assembly of the machine were determined. Recommendations on the direction of automation of the process of assembly of roller parts are given. The **fourth chapter** is devoted to the investigation of the stress-strain state of rollers under variable loading in a Femap with NX Nastran environment; analysis of the effect of loads on the rollers of the conveyor belt was conducted, the maximum load on the rollers was calculated, a program for calculating the load for all types of cargo was created using computer. By simulation of loads in the Femap with NX Nastran environment values of stresses and deformations under different loading were obtained which allow us to assume that when the roller is loaded, joint skew of the bearing rings relative to each other is provided, thus avoiding pinching of the bearing ball, thereby increasing its service life. Using regression data analysis tools, mathematical dependencies between such variables as load and deformation were obtained, a forecast estimate of deformation change with increasing load is given. In the **fifth chapter**, the issues of technological ensuring the quality of roller were considered. The analysis of manufacturability of parts included in the product was conducted and a number of recommendations on technological processing and choice of blanks were given.

Rational technologies for the manufacture of roller parts were developed, dimensional analysis of the technological process of the roller part - a bearing shell was conducted. It showed the existence of accuracy reserve in some dimensions, which makes it possible, if necessary, to expand the tolerances for some complex operations and help to reduce costs. A technological process of stamping was developed - a thin-walled hub part, which shows the possibility of its production by a high-performance method with a specified accuracy. An imitational stochastic model for the formation of roughness during the turning of internal surfaces that takes into account various systematic and random factors, such as tool geometry, cutting modes, vibrations was developed. Algorithm and computer program for calculation the laws of distribution of roughness parameters during boring of internal surface allowing to predict the numerical parameters of the profile of the processed surface, in particular the distribution of Ra, Racp were developed.

The computer program for calculating the roughness allows one to accurately calculate the roughness at various cutting parameters; at the design stage to work out various options for the machining process and select the optimal mode of processing and cutting tools; allows to avoid ineffective solutions in the development of TP of machining process; to minimize spoilage during processing. The obtained theoretical data on the roughness distribution were verified in experimental way by showing that the obtained data fit within the range of theoretical scatter of roughness, which shows the adequacy of the computer program. The calculation of economic efficiency was conducted, resource of the roller of the new design was calculated, which showed an increase in the service life in comparison with analogues (in linear sections up to 35-40 thousand hours instead of the available maximum 25-30 thousand hours), the cost-effectiveness of the roller implementation was calculated, following data was obtained: payback of production is 3,6 years; investment efficiency level is 28%; cost price of the roller is 12063 tng with VAT per unit.

Practical significance of the work.

- a new design of the BC support roller was developed, which differs from the existing designs by a combined seal (labyrinth and centrifugal rotor seal) and by the ability under the load to provide a joint skew of the outer and inner ring of bearings, on the design of the roller an application for granting the patent of RK was made, registration number № 2016/0368.1, which passed a formal examination and at the moment is on substantive examination;

- the computer program «Determining the load on the bearings of the belt conveyor rollers» was developed, this program is universal and can be used for different types of cargo, the program received a certificate of state registration of rights to the copyright object № 1599 dated 2 April 2016;

- a technique for forecasting the roughness for turning at the stage of designing the technological process of mechanical treatment using computer program «Calculation of distribution laws for roughness parameters during turning» was developed, this program received a certificate of state registration of the computer program № 20107610890, Russian Federation;

- progressive technology for manufacturing roller parts, using modern tools and blanks was proposed, technology of stamping for a thin-walled roller hub of a new design was developed.

Approbation of the work. Results of scientific work were reported and discussed at international conferences: international scientific and practical conference «Industrial and innovative development of transport, transport equipment and machine building», (Almaty, 2013); 4th international scientific conference «Actual problems of mechanics and machine building», (Almaty, 2014); international scientific and practical conference «Prospects of development of machine building and transport in 21 century», (Semey, 2014); 5th international scientific conference of students and PhD students «Engineer of 21 century», Technical and Humanitarian academy, Bielsko-Biala city (Poland, 2015); LXI international scientific and practical conference, №8 (56) (Novosibirsk, 2016); scientific seminar of branch of Polish Society of Applied and Theoretical Mechanics, Bielsko-Biala city.

Publications. The main results on the topic of the thesis are presented in 17 printed works, including 6 papers in scientific publications from list of the Committee for Control of Education and Science of MES RK; 2 papers in peer-reviewed journals, indexed in Scopus database; 1 – scientific journal, Russia; 8 papers in international conference proceedings, including 2 - in foreign conference in Russia and Poland.