

Dynamic load reduction techniques for the flight of the belt conveyor



Liudmyla Yefimenko

*PhD, Associate professor of Computer Science, Automation and Control Systems department
State Higher Educational Institution "Kryvyi Rih National University", Ukraine*



Mykhailo Tykhanskyi

*PhD, Associate professor of Computer Science, Automation and Control Systems department
State Higher Educational Institution "Kryvyi Rih National University", Ukraine*

Abstract

The analysis of load acting on the understructure of the conveyor depending on traffic (traffic density) and transporting modes was presented, also the impact of individual factors on the metal capacity of the conveyor's flight was evaluated.

Key words: SELF-OPERATED CONTROL, CONVEYOR, TRAFFIC (TRAFFIC DENSITY), UNDERSTRUCTURE, LOAD (DYNAMIC LOAD), GRANULE COMPOSITION, METAL CAPACITY, EFFICIENCY.

The problem and its relation to practical problems

Conveyor flight is the main unit of the belt conveyor, which determines its metal capacity. With the increase of its weight conveyor length increases greatly. According to works [1, 2], with conveyor length up to 100 m, weight of the hard flight is about 20%, and with length up to 500 m –

more than 30% of the weight of entire conveyor. Weight of linear part of the conveyor sections is determined by the width of the belt and by the sort of transported cargo. Belt width determines length of the impact idlers and structural dimensions of the sections. Development of the techniques, which will reduce dynamic load on the flight is the way to reduce metal capacity of the conveyor.

Research and publication analysis

Analysis of calculations, which are performed by number of manufacturers, engineering companies and Ukrainian SRI (scientific research institute) showed that SRI work mainly on the development of new types of constructions, however, existing design methods of impact idlers do not take into account the true situation of its load [3, 4].

Widely known that evaluation of load on the conveyor flight elements when transporting oversized cargo, mainly, done with dynamic factor for bulk cargo and oversized pieces that follow each other with constant velocity. This question was engaged by group of Ukrainian (Soviet) scientists, which are: Dmitriev V.G., Volotkovsky V.S., Nochrin A.G., Karmaev G.D., Galkin V.I., Komarova N.V., Monastursky V.F., Smirnov V.K., Demin G.K.

Primary dimensions of conveyor flights appointed according to design considerations with industry standards took into account. Dimensions that were granted are checked using special calculations. Besides, there is an overloading coefficient in those calculations and it's varying from 1.2 to 1.7 without sufficient justification of its value.

Overview of works, which describe the belt conveyor as regulation entity [3 -8] shows that the structural schemas of primary types of the conveyors were developed in way, when the understructures of conveyor wasn't pointed as the research object.

After overiewing and analyzing theoretical and practical labors a few conclusions were made:

- loadings on the understructure of the belt conveyor depend on constructive and technological factors, work mode, granule composition of the transported cargo, etc.;
- providing a smoothed start (soft start) and control of belts velocity reduces loadings on construction and affects the constructive parameters of the conveyor (width and strength of the belt, distance between neighboring impact idlers, metal capacity of the flight), increases efficiency of using.

Nevertheless, questions, linked with process of reduction loadings on the understructure and metal capacity of the flight using automated gear demands extra research, because:

- dynamic effect of the gear, which increases load on the flight and its metal capacity doesn't considered;

- existing structural schemas of the belt conveyor doesn't include understructures of conveyor pointed as the research object;
- selection of the self-controlled system parameters doesn't contain calculation and insertion of the flexible feedback, that provide limitation to the dynamic load on the constructions.

Problem definition

General lack of the reviewed design methods – when calculating load on the flight only static constitutions are taken into account, with no attention to dynamics of the transition processes and dynamic load by oversized pieces of cargo, solutions that reduce load on the constructions by controlling transportation modes are not used. Usage of regulated gear with non-constant transportation velocity causes extra research from one hand – in the case bulk cargo and from other hand – in the case of transportation separated pieces. Taking those facts into account it is possible to determine load more precisely, reduce the margin of safety for construction elements of the conveyors with constant transportation velocity from one side and for flexible self-controlled production with regulated gear from another.

Representation of material and results

When calculating parameters of the structural pieces of the belt conveyor one of the key components of load on the elements of the flight is a load from a stream of the transported cargo. Oversized cargo transportation is characterized by simultaneous movement of two independent streams: bulk cargo and oversized pieces that follow each other with certain spacing [5]. Herewith each stream can be reviewed separately. Bulk cargo can be reviewed without taking into account regularities and characteristics, which take place without oversized pieces, and oversized cargo stream can be reviewed ignoring the bulk cargo. Mathematical representation of the cargo stream is widely spread in specialized literature, wherein reviewed shapes and dimensions of pieces, expected nature of incoming fractions, characterized by different size and by number of other characteristics, which are needed to determine an impact which cause cargo stream on the understructures. When conveyor is static impact idlers are charged by the sum of load from transported cargo and belt, and flight extra charged by weight of impact idlers. During the cargo transportation load on understructures rises because of dynamic interaction between cargo stream and impact idlers.

Consider the most appropriate technique of determining dynamic load from cargo stream, in

the case of bulk cargo, using method introduced in [6], where overall cargo stream submitted as sum of single fractions cargo streams, which affect the understructures with their coefficients of dynamics:

$$P_n = \ell_p \sum_1^c K_{Di} q_i,$$

where P_n – dynamic load, caused by stream of the transported cargo which affect the flight, N;

ℓ_p – step between neighboring impact idlers, m;

K_{Di} – coefficient of dynamics for i-th component fraction of the cargo stream;

q_i – linear weight of i-th component fraction of the cargo stream including belt, kg/m;

c – number of fractions, which are taken into account in calculation process.

Generally, when oversized cargo transported along with bulk cargo there is a percentage of fractions in cargo stream [5, 7] and in labor [6] recommended coefficient of dynamics that correspond to given fractions.

When calculating understructures of belt conveyor, power of bulk stream impact is determined by maximum load. So when determining the particle size of structure of the n-th impact idler section the right way is to proceed from the assumption that in the section of each impact idler located oversized pieces with smaller fractions. When classifying cargo using degree of fineness according to [5], oversized considered cargo with $K_{kp} > 0.2$, so to find out relative content (δ_i) of oversized pieces in section using known formulas or table, it's necessary to sum values relatively to content in rock mass for fractions higher than fourth.

With known relative content δ_i of each fraction in rock mass on the belt let's find the linear weight of each fraction in cross-section of the belt:

$$q_i = \delta_i Q (n \ell_p)^{-1} = \delta_i Q L^{-1} = \delta_i q,$$

where Q – weight of material on the conveyors belt, kg;

n – number of impact idlers on the flight;

ℓ_p – distance between impact idlers of the functional branch, m;

q – linear load, kg/m.

Changing velocity of transportation when coarse grinding cargo (maximum size of separate piece is about 400 mm) and oversized cargo (up to 600mm) transported causes changes in dynamic impact of the cargo on the conveyor flight elements. Value of dynamic load from stream

depends on particle size of the cargo, transporting velocity, maximum size of the separate piece, which causes dynamics coefficient of different fractions.

Let's find out the dependence of the load on the impact idlers from cargo stream and conveyors flight from transportation velocity. When transporting cargo, interaction between it and impact idler caused by sag and breakdown of belt sides between neighboring impact idlers. In each moment of time cargo stream presses the belt across all cross-section of impact idler and power of its impact rises with increasing velocity of transportation.

Consider the case of interaction between cargo stream and impact idler with non-rotating rollers. In the moment of meeting with impact idler cargo stream q_n have a velocity V , while impact idler was static. To the end of the first period of interaction during a short term of time t , which is equal to the length of interaction arc divided on velocity of interaction, all elements of impact idler starting to move (bending in the direction of cargo movement) and gain certain velocity V_1 and the velocity of cargo stream itself starting to decline and its value becomes V_1 as follows:

$$V_1 = V(1 + 17 \cdot 35^{-1} g m_{p.o} (q_n \ell_p)^{-1})^{-1},$$

where $m_{p.o}$ – weight of impact idler, kg;

q_n – linear weight of cargo, kg/m.

Using dependencies, known from theoretical mechanics, let us determine the power, with which cargo stream on the move affects the impact idler, in this case, power can be determined in the next way:

$$P = m V t^{-1},$$

kinetic power: $E_K = m V^2 / 2$;

hence: $P = 2 E_K / V t$.

If kinetic energy of the stream equals:

$$E_{Kn} = q_n \ell_p V^2 / 2 g,$$

Then the pressure force of the stream on the impact idler equals:

$$P_n = q_n \ell_p V_1 / g t.$$

Let us express in terms of transportation velocity, with taking into account working point and state of the rollers:

$$P_n = q_n \ell_p g^{-1} V k_p [1 + 0.486 g m_{p.o} (g_n \ell_p)^{-1} t]^{-1},$$

where k_p – coefficient, which depends on working point and state of the rollers. With non-rotating rollers:

$$k_p = \sin \alpha \varpi_{TP}$$

where α – angle between tangent in the entrance point of the belt on the roller with power direction, depends on tension, in practice: $\alpha = 5+8^\circ$;

ϖ_{TP} – friction coefficient between belt and roller.

With rotating rollers:

$$k_p = \sin \alpha \varpi$$

where ϖ – movement resistance coefficient; $\varpi = 0,03+0,09$ (with steady movement and at the launch of the conveyor).

In real conditions conveyor load is non-constant value. For oversized cargo stream its oscillation is more than 30% [5]. Here special interest is to find out load from separate pieces on the belt combining them with overall rock mass in different proportion [8-11].

Conclusions and direction of future research

Analysis of calculation techniques of the understructure separated elements shows, that use of self-controlled gear will provide extra abilities to enhance efficiency in the case of use belt conveyors, because guaranteed reduction of dynamic impact of the gear and huge pieces of the cargo on the understructure allows reducing their metal capacity. Herewith appear a necessity using developed model to get the functionality of metal capacity of the conveyor flight with self-controlled features of the gear taken into account.

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