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THRESHOLD LEVELS OF SHIFTING AND SPEEDS IN DISCRETE REGULATION OF MINE BELT CONVEYORS

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ABSTRACT
The probability characteristics of load flow of the main belt conveyor of Assarel Mine are determined and the optimal levels of shifting and motion speed in discrete regulation of the speed are found. Regulation of the belt speed will be driven to considerably increase of mine belt conveyors lifetime.

1.INTRODUCTION

One of the possible ways to make economies when mine loads are haulaged with belt conveyors is to put controlled conveyor drive. The following advantages are achieved:
1. Drawing in the energy consumption for transportation;
2. Decreasing wearing of rotating parts and increasing their lifetime;
3. Increasing the lifetime of conveyor bearing structure as a result of decreasing of dynamic shocks.

Controlled driving could be continuous or discrete depending on technical means used for its realization.

Continuous regulation changes uninterruptedly the speed of conveyor belt depending on the intensity of load flow. In discrete the speed shifting is made only when the flow intensity reaches determined edge values.

The modern technique offers comparatively cheap and enough effective equipment for continuous and discrete speed regulation.

We will consider the discrete regulation method in this report because the equipment is cheaper and more available. Discrete regulation could be realized by mechanical devices (switchable gearing) or by using of planet reducers, as well as by electrical means: switching the way of connection of electrical motors or the number of their poles, direct frequency regulation etc.

2. PROBABILITY CHARACTERISTICS OF MINE LOAD FLOWS

Numerous investigations show that intensity of mine load flows is a probability quantity [Schahmaister etc., 1983]. That is due to inhomogenity of mined mineral resources, breaking off the mining in order to displace machines, fulfillment of different technological requirements etc.

The load flow intensity could be divided in some sub-flows:
- Flow of entry load with different intensity;
- Flow of discontinuity (pauses) in feed of the load;
- Flow of load ffeel duration;
- Flow of pause durations, etc.

Only the first sub-flow is considered in this report because it has relation with the change of belt speed. Investigations show, that it is well approximated with normal probability distribution.

The main characteristics of normal distribution of the material flow, haulaged by belt conveyor are:

- density of probabilities

$$f(Q)= \frac{1}{\sigma\ 2\pi} \ell - \frac{(Q - a)^2}{2\sigma^2} \quad (1)$$

- distribution function

$$F(Q_i)= \frac{1}{\sigma\ \sqrt{2\pi}} \int_0^{Q_i} \ell - \frac{(Q_i - a)^2}{2\sigma^2} dQ \quad (2)$$

- mathematical expectation

$$a = \frac{\sum m_i Q_i}{n} \quad (3)$$

- dispersion

$$D(Q) = \frac{\sum (Q_i - Q)^2 m_i}{n} \quad (4)$$

- quadratic mean deviation

$$\sigma = \sqrt{D(Q)} \quad (5)$$

where Q_i is conveyor productivity in the moment *i*;

m_i - frequency of the Q_i intervals.

3. THRESHOLD LEVELS OF SPEED SHIFTINGS

In discrete regulation of belt speeds a control system keep abreast a load flow intensity and unevenly change of the belt speed when the load flow crosses the any of the preliminary defined levels. Regulation will be normal, i.e. with minimum energy losses, if the levels are determined so as to obtain a minimal belt run in load haulage. Determination of optimal levels is made as follows:

We assume that control system is of three-step type. Material flow loaded on the conveyor is changed during the time casualy as it is shown on fig. 1 a.

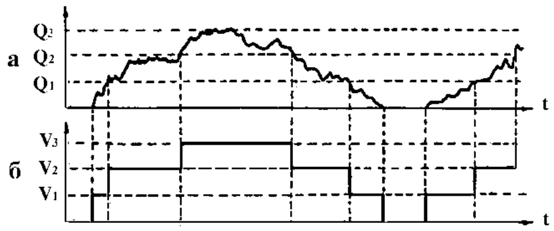

Figure 1.

When the material is loaded on the belt the speed v_1 is turned on, if the flow rate increases to level Q_1 the speed v_2 is turned on and if it reaches and gets beyond Q_2 the speed v_3 is turned on (Fig.1, b).

Probabilities the belt to moves with speeds v_1, v_2 и v_3 are:

$$P_1 = P[0 < Q(t) \le Q_1] = F(Q_1); \tag{6}$$

$$P_2 = P[Q_1 < Q(t) \le Q_2] = F(Q_2) - F(Q_1);$$
$$P_3 = P[Q_2 < Q(t) \le Q_3] = F(Q_3) - F(Q_2),$$

where $Q(t)$ is the load flow intensity in the moment t.

The average speed of the belt is:

$$v_{cp} = v_1 P_1 + v_2 P_2 + v_3 P_3, m/s. \tag{7}$$

becausef

$$v_1 = \frac{Q_1}{q}; \; v_2 = \frac{Q_2}{q}; v_3 = \frac{Q_3}{q}, \tag{8}$$

- where $q = S\rho$ is linear mass of loaded on the belt material, kg/m;

S - maximal section of the material on the belt, m^2;

ρ - density of the transported material, kg/m^3,

$$v_{cp} = \frac{Q_1}{q}\int_0^{Q_1} f(Q)dQ + \frac{Q_2}{q}\int_{Q_1}^{Q_2} f(Q)dQ + \frac{Q_3}{q}\int_{Q_2}^{Q_3} f(Q)dQ. \tag{9}$$

The level Q_3 is equal to the maximal productivity of the belt conveyor. Levels Q_1 and Q_2 are variable and in order to find their optimal quantities we determine the partial derivatives of equation (9) toward Q_1 and Q_2 nullify them.

$$\begin{aligned} \frac{\partial v_{cp}}{Q_1} &= F(Q_1) + (Q_1 - Q_2) f(Q_1) = 0 \\ \frac{\partial v_{cp}}{\partial Q_2} &= F(Q_2) + (Q_2 - Q_3) f(Q_2) = 0 \end{aligned} \tag{10}$$

So we are able to subtract the equation of optimal level of regulation if the control system is with *n* degrees

$$F(Q_{n-1}) + (Q_{n-1} - Q_n) f(Q_{n-1}) = 0. \tag{11}$$

4.CALCULATION RESULTS

A determination of threshold levels of the speed is made on the base of data of loading of the main belt conveyor in Assarel mine for the period from 11 to 17 February, 2002 in order to obtain practical results of utilization of the mentioned above formulas. Computer, who controls the belt line, records the data. The curve of loading is average for every half of hour in order to obtain numerical data.

The calculations were made using computer program “Mathematica” for Windows, created by Stephen Wolfram.

The probability characteristics of the haulaged by the belt conveyor load are calculated by using the sub-program Descriptive Statistics, which use the formulas (3)-(5). The calculation results are the following:
Mathematical expectation a=2177 t/h
Dispersion D=5626 t/h
Quadratic mean deviation σ =474 t/h

Using the obtained data and solving the equations (10) and (11) for degree numbers from 1 to 5, i.e. with different number of equations, we find the levels of speed shifting. The upper productivity limit is set to be the maximal productivity of the conveyor Q_{max}=4000 t/h.

Using the obtained levels of shifting and dependences (8) we calculate the necessary speeds. The average speed of belt motion is determined according to the formula (9). Calculation results are given in Table 1.

Shifting Levels

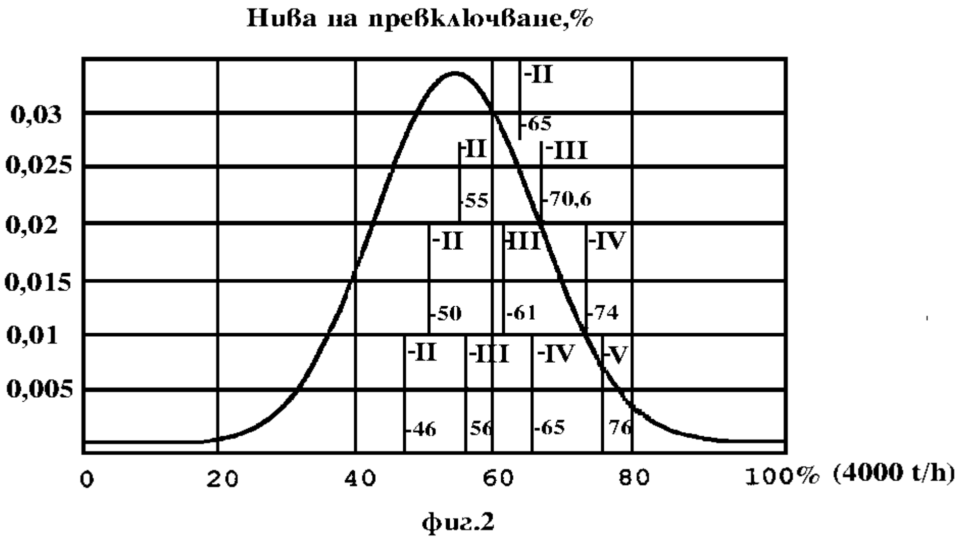

Figure 2.

Table 1 Shifting levels and motion speeds in different number of speed degrees

Number of degrees	Shifting levels, t/h / Motion speeds, m/s					Average speed v_{cp},m/s
	$\frac{Q_1}{v_1}$	$\frac{Q_2}{v_2}$	$\frac{Q_3}{v_3}$	$\frac{Q_4}{v_4}$	$\frac{Q_5}{v_5}$	
2	$\frac{2592}{2,6}$	$\frac{4000}{4}$				2,84
3	$\frac{2202}{2,2}$	$\frac{2823}{2,8}$	$\frac{4000}{4}$			2,58
4	$\frac{1995}{2}$	$\frac{2444}{2,44}$	$\frac{2949}{2,95}$	$\frac{4000}{4}$		2,48
5	$\frac{1859}{1,86}$	$\frac{2233}{2,23}$	$\frac{2587}{2,59}$	$\frac{3035}{3,03}$	$\frac{4000}{4}$	2,4

CONCLUSIONS

The following results could be made on the base of data, obtained in Table 1:

1The results are an product of probability calculations and are concerned to the load flow with determined characteristics. For each particular case it is necessary to make calculations using corresponding statistical data.

2.The threshold levels for different speed degrees are not identical and depend on their place on the curve of probability distribution. (Figr.2).

3.The average speed of belt motion depends on the number of speed degrees. As many are the degrees so lover is the average speed. It is not arithmetical mean of speeds in particular degrees because duration of motion on different levels is different and depends on the interval size $F(Q_i)$.

4.If the conveyor speed without regulation is 100%, in two-degree regulation it will be it will drop to 71% and in five-degree – to 60% With such value will drop the run of the belt and turnover of the rotating parts It should be lead to prolongation of conveyor lifetime. .

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