УДК 622.647.2

L.I. Tsvirkun, A.V. Krisanova, Y.V. Panferova

# MATHEMATICAL MODEL LOADING CONVEYOR BELT AS THE OBJECT OF CONTROL

The process of filling the bulk load of conveyer ribbon of coal mine is examined. Offer mathematical model of loading of conveyer and her investigational parameters with the purpose of further automation with the use of the systems of videoinspection. It is shown that the analysis of the got images of ribbon allows to define the width of the poured coal, and, consequently, and loading of conveyer.

MODEL, LOADING, BELT CONVEYOR, CONTROL

## Introduction

Conveyor transport is the most productive type of continuous transport of coal mines. It is characterized by simple maintenance and low operating costs. At present, in many mines, belt conveyors are used to transport coal from the faces [1]. During the operation of the conveyor line, the most favorable (in terms of energy saving) ratio of parameters - "the degree of belt loading - the value of the belt speed" should be provided, without limiting the bottomhole productivity. If the line load decreases or there is no coal on the belt, the speed of the conveyor should be reduced. This allows you to reduce power consumption by reducing the running time of the conveyors idle, and also increase their service life. To control the loading of the tape, you can use various methods, such as direct weighing of coal on a tape, or indirect. Indirect methods of control include video monitoring systems of technological processes, which are increasingly used in many sectors of the national economy, including the coal industry [2].

## Problem statement

The purpose of the study is to analyze the process of filling the conveyor belt, to develop a mathematical model for loading the conveyor with bulk cargo and to study its parameters for the purpose of further automation using video monitoring.

## The analysis of the process of filling the conveyor belt

Belt conveyors are an integral part of the modern technological process of coal transportation at the mine.

Transportation of coal is characterized by the following properties: size (particle size), strength, density, abrasiveness, moisture, mobility of particles and the like.

The degree of filling the conveyor belt with bulk cargo (coal) is more affected by: size, density and humidity [1].

The size is characterized by the largest linear dimensions of homogeneous particles in a given volume. The density of a cargo is the ratio of its mass to the volume occupied.

The moisture content of the bulk cargo is the ratio of the mass of water contained in the coal and removed by drying the cargo sample at a temperature of 105 □ to the weight of the dried cargo. Humidity is determined in percent.

The angle of the natural slope of the bulk cargo is the angle between the generator of the cone from the freely laden cargo and the horizontal plane. This angle depends on the mutual mobility of the cargo particles. Moreover, when the bulk cargo moves, the angle of the natural slope decreases and is 0,45-0,5 to the angle at rest.

Coal stone lump has the following characteristics: bulk density – 0,65-0,8 t/$m^3$, humidity (can vary in large limits depending on the season, coal mines, etc.) − 65-90%, The angle of the natural slope at rest is 30-45°.

The performance of conveyors is determined by the amount of cargo transported per unit time. The quantity of bulk cargo can be determined in bulk or mass units. Therefore, the productivity can be volumetric or mass, and accordingly the filling of the conveyor depends on the volume or mass of coal that is loaded.

In coal mines, grooved belt conveyors are used, that is, those that have support rollers in the form of a gutter.

Consider the process of filling such a pipeline and how it can be controlled. The cross-section of the grooved conveyor with coal on the belt is of the form [1], which is shown in Figure 1, where:

$B_{стр.}$– width of conveyor belt;

$B_1$– part of the width of the belt filled with cargo;

$d$ – the width of the bulk load on the grooved band, viewed from above;

$a$ – width of the central part of the grooved belt (lower roller)

$b$ – The width of the lateral part of the grooved strip filled with a load;

$\delta$ – angle of inclination of the side rollers of the conveyor belt;

$\varphi$ – angle of repose of bulk cargo on the belt;

$h_{трп}$ – trapezium height of bulk cargo;

$h_{трк}$ – height of the loose cargo triangle.

 ISSN 1562-9945

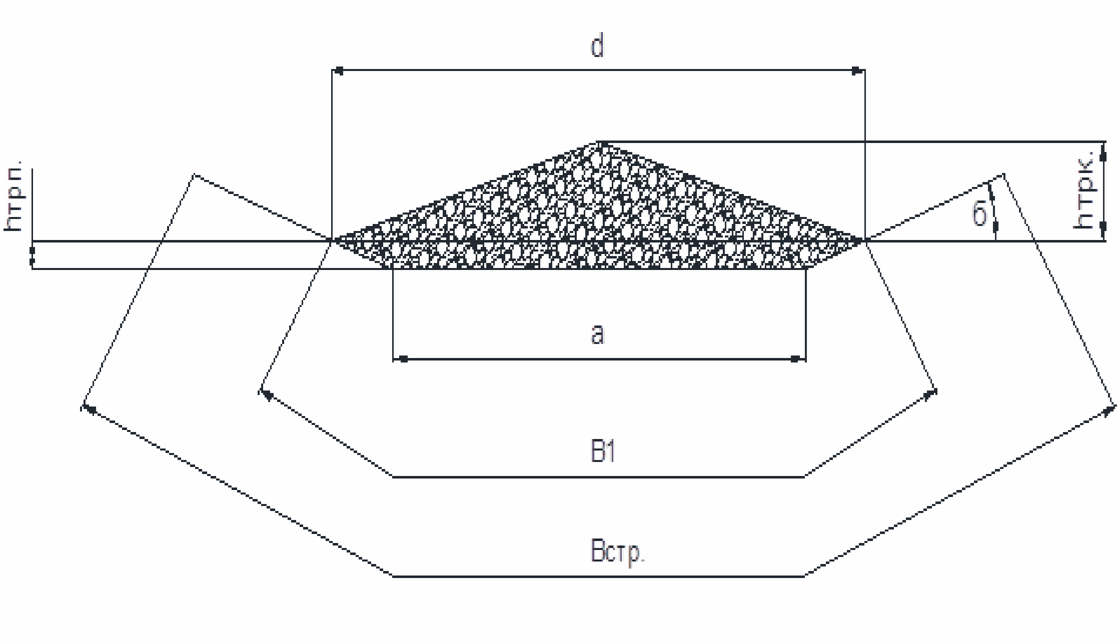


Figure 1 – Cross-section of the grooved conveyor with coal on the belt

**Mathematical model of loading conveyor**

The volume of coal, which is on the conveyor, is characterized by the area of the bulk cargo section. As can be seen from Figure 1, the area of the bulk cargo section consists of the area of the triangle $S_{трк}$ and the area of the trapezium $S_{трп}$.

These areas can be calculated as follows:

$$S_{трк.} = \frac{1}{2} d h_{трк.}, \text{ m}^2 \qquad (1)$$

$$S_{трп.} = \frac{a+d}{2} \cdot h_{трп.}, \text{ m}^2 \qquad (2)$$

The total cross-sectional area equal to the sum $S_{заг.} = S_{трк.} + S_{трп.}$, but filling grooved belt consists of two stages. That is,

$$S_{заг.} = \begin{cases} if \quad d \le a, \ then \ S_{заг.} = S_{заг.1} = S_{трк.} + S_{трп.} = S_{трк.} + 0 = S_{трк.} = S_{трк.} = \frac{1}{2} d h_{трк.} \\ if \quad d > a, \ then \ S_{заг.} = S_{заг.2} = S_{трк.} + S_{трп.} = \frac{d}{2} . h_{трк.} + \frac{a+d}{2} \cdot h_{трп.} \end{cases} \qquad (3)$$

The variables $h_{трк.}$ and $h_{трк.}$ difficult to measure, so try to determine the total cross-sectional area through wide bulk cargo *d*.

For this we define $h_{\text{трк.}}$ and $h_{\text{трк.}}$ through d. Since

$$tg\varphi = \frac{h_{\text{трк.}}}{\frac{1}{2}d},\ \text{а}\ tg\delta = \frac{h_{\text{трп.}}}{\frac{d-a}{2}},\ \text{то}\ h_{\text{трк.}} = \frac{1}{2}dtg\varphi,\ h_{\text{трп.}} = \frac{d-a}{2}tg\delta .$$

Тоді $S_{\text{трк.}} = \frac{1}{2}d\frac{1}{2}dtg\varphi = \frac{1}{4}d^2tg\varphi$, $S_{\text{трп.}} = \frac{a+d}{2}\cdot\frac{d-a}{2}tg\delta = \frac{1}{4}(a+d)(d-a)tg\delta$, а

$$S_{\text{заг.}1} = S_{\text{трк.}} = \frac{1}{4}d^2tg\varphi \quad (4)$$

$$S_{\text{заг.}2} = S_{\text{трк.}} + S_{\text{трп.}} = \frac{1}{4}d^2tg\varphi + \frac{1}{4}(a+d)(d-a)tg\delta = \frac{1}{4}(d^2tg\varphi + (a+d)(d-a)tg\delta) \quad (5)$$

## The results of research

Analysis of the conveyor lines of coal mines shows [3] that in them a large part of the conveyor belts has a width $B_{стр.}$=1 m.

Taking into account formulas 4 and 5, let us consider the process of filling such a grooved conveyor. In these formulas, the variables $a$ and $\delta$ depend on the construction of the pipeline and for the calculations will be constants, $\varphi$-depends on the quality of the coal and can be a constant for a while, and $d$ is a variable characterizing the degree of loading of the conveyor.

Define the maximum value of $d$. According to the standards [1]

$$B_{1max} = 0{,}9B_{стр.} - 0{,}05 = 0{,}9\times 1 - 0{,}05 = 0{,}85,\ \text{m}.$$

In practice, the optimal value of a is not used, and for simplifying the design of the rollers, $a$=0,5$B_1$, $\delta$=20°.

So: $a = 0{,}5B_{1max} = 0{,}5\times 0{,}85 = 0{,}425$, m.

The maximum width of the lateral part of the grooved strip filled with the load is calculated as

$$b_{max} = \frac{B_{1\max} - a}{2},\ \text{m}.$$

Then the maximum value of the variable $d$ (the width of the bulk load on the grooved band, viewed from above) will be:

$$d_{max} = a + 2b_{\max}\cos\delta = a + 2\frac{B_{1\max} - a}{2}\cos\delta = 0{,}425 + (0{,}85 - 0{,}425)\cos 20^\circ = 0{,}829\ \text{m}.$$

 ISSN 1562-9945

Taking into account that the angle of the natural slope of the stone lumpy coal in rest is 30-45°, and the angle on the moving belt is 0.45-0.5 to the angle at rest, we calculate the minimum, maximum and average slope angles:

$\varphi_{рух.\min} = 0,45 \times 30^\circ = 13,5^\circ$, $\varphi_{рух.сер.} = 13,5^\circ + 22,5^\circ = 18,0^\circ$, $\varphi_{рух.\max} = 0,5 \times 45^\circ = 22,5^\circ$.

Thus, the change in the theoretical total cross-sectional area of the grooved conveyor with the width of the belt $B_{стр.}$=1 m. Calculated as follows:

$\varphi_{рух.\min} = 13,5^\circ$ $\varphi_{рух.сер.} = 18,0^\circ$ $\varphi_{рух.\max} = 22,5^\circ$

$$S_{заг.} = \begin{cases} if \quad d \le a, \quad then \quad S_{заг.} = S_{заг.1} = \dfrac{1}{4} d^2 tg\varphi = \dfrac{1}{4} d^2 tg\varphi \\ \\ if \quad d > a, \quad then \quad S_{заг.} = S_{заг.2} = \dfrac{1}{4} (d^2 tg\varphi + (0,425 + d)(d - 0,425) tg 20^\circ) \end{cases} \qquad (6)$$

The total cross-sectional area of a strip with poured coal characterizes the filling of the grooved conveyor, and also directly affects the productivity of the conveyor.

The obtained dependences are applicable for calculating the loading of the belt depending on the width (if viewed from above) of the bulk cargo (bulk density 725 kg/m$^3$) and the angle of natural slope and will be presented in the form of graphs in Figure 2.

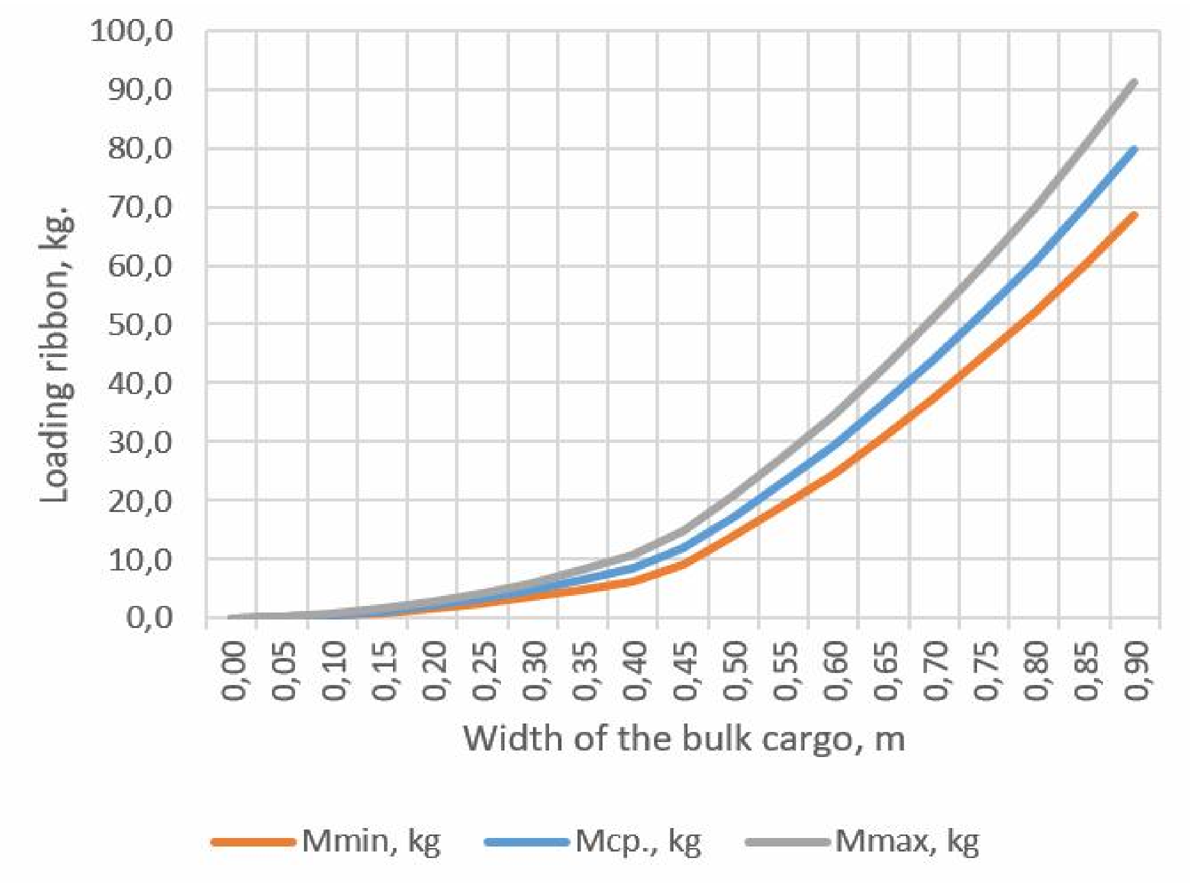


Figure 2 - Dependence of loading width of conveyor belt for bulk cargo $\varphi_{рух.\min} = 13,5^{\circ}$, $\varphi_{рух.сер.} = 18,0^{\circ}$, $\varphi_{рух.\max} = 22,5^{\circ}$

As can be seen from the graphs, when determining the width of the coal from the images obtained, it is possible to clearly determine the loading of the conveyor.

For example: for d=0,01-0,4 the load increases to 12,5%, for d=0,4-0,65 − to 43,8%, for d=0,65-0,8 − to 75 %.

## Conclusions

1. The conducted analysis of control methods made it possible to choose video monitoring as the most effective for controlling the loading of the conveyor belt.

2. A detailed consideration of the parameters and the filling process made it possible to develop a mathematical model for loading the conveyor with coal in order to further automate it using video control.

## Literature

1. Біліченко М.Я. Транспорт на гірничих підприємствах: Підручник для вузів / М.Я. Біліченко, Г.Г. Півняк, О.О. Ренгевич та ін., заг. ред. доп. та змін проф. М.Я. Біліченко. – 3-е вид., авт. доп., змін., кор. – Дніпропетровськ: Національний гірничий університет, 2005. – 636 с. – ISBN 966-350-002-6.

2. Цвиркун Л.И. Разработка модели работы подсистемы отображения информации при видеоконтроле технологических процессов угольной шахты / Л.И. Цвиркун // Оптимизация производств. процессов. Сб. науч. тр. Севастоп. нац. техн. ун-т. − Севастополь: Изд-во СевНТУ, 2007. – Вып.10. – С. 81-85.

3. Цвиркун Л.И. Топологическая оптимизация CAN-сети системы контроля конвейерных линий угольной шахты / Л.И. Цвиркун, Р.В. Липовой // Збірник наукових праць НГУ. – Дніпропетровськ: РВК НГУ, 2009. – № 32. – С. 141-146.