MECHANIZATION AND AUTOMATION OF MINING

FORMATION OF MATHEMATICAL MODELS FOR CALCULATING THE LINEAR LOAD OF CONVEYOR BELTS TRANSPORTING COARSE ROCK

G. V. Prisedskii and V. P. S@lakov

Establishing a mathematical relationship between the amount of coarse rock located in the trough of a conveyor belt \((q_T)\) and in the space above the trough \((q_n)\) with the size of a fraction and its percentage composition of the total material mined was a problem for an experimental and theoretical study carried out at UkrNIiproekt.

The test quantities \(q_T\) and \(q_n\) are affected by morphological characteristics (lump shape) of the rock, mechanical properties (slope of repose angle, internal friction angle, cohesive force), and mutual disposition of large lumps on the belt. They also depend on a number of external conditions such as length of time in a loose state (self-packing), pressure, moisture content, and loading method. On the other hand, \(q_T\) and \(q_n\) depend on the ratio \(Z/B\) of lump size to belt width \(B\), and the shape of the belt trough. In practice, only the size fractions, their percentage composition of the overall mass, and the ratio \(Z/B\) have a significant effect on the values of \(q_T\) and \(q_n\). The effect of lump shape and rock mechanical characteristics were taken into account by selecting mined material for experimental studies with characteristics similar to strong rock in coal mines.

Under real conditions during belt charging, the relationship of different fractions will be a random value governed by the fractional composition of crushed rock loaded on the conveyor belt. Consequently, values of \(q_T\) and \(q_n\) should also be considered random.

In order to obtain a mathematical description by experimental methods there has been extensive use of mathematical planning for experimental studies. However, the mathematical theory of experimental planning for a system of different components has its drawbacks. Our variables (input factors, which are size fractions) are proportions (relative content) of mixture components. In describing a system there is a difficulty connected with the fact that the sum of independent variables is normalized and satisfies the condition \(\sum X_i = 1\) \((X_i \equiv 0)\), which leads to correlation of factors and the impossibility of orthogonal planning. Therefore, we used special planning for the case "composition-property" of the Scheffe plan or simplex-grid planning.

The whole of the crushed, mined material with a volumetric weight of 2.5 ton/m\(^3\) (granite) was used for the study. Screen analysis was used to separate it into fractions. For metrologically based comparison and indication of the limits for using results obtained in order to establish lump shape, a correlation analysis was carried out between their sizes.

Equations for regression lines relating lump size have the form: \(b = 1.53c, b = 0.072a\) \((a, b, c\) are length, breadth, and thickness of lumps, respectively). Lump shape for the experimental material is very similar to the shape of rock lumps stripped from the Kuznetsk Basin coal deposits. The amount of each fraction involved in an experiment was 1.5 tons. Rock used in the study was taken from material obtained by blasting, and therefore the distribution which followed linear lump size was not a random value.

The study was carried out on conveyor units with a belt width of \(B = 400\) or \(1200\) mm.

Basic experiments to accumulate statistical data in order to obtain regression equations for values of \(q_T\) and \(q_n\) were carried out on a conveyor unit with \(B = 400\) mm and an inclination angle for the lateral rollers of 45° (the most suitable value from the point of view of obtaining the minimum dispersion of initial \(q_n\) values).

Selective experiments to reveal the effect of the scale factor were carried out in a unit with \(B = 1200\) mm. Lump size for the fraction 0 to 0.05 kB for belts with \(B = 500\) and 1400 mm with a utilization factor for the belt width \(k = (0.9B - 0.05)/B\) was 0-20 and 0-60 mm,

respectively. The content of fractions 0-20 and 20-60 mm which constitute the 0-60 mm fraction depends on blasting parameters. Therefore, on conveyor belts having \( k_B = 400 \) and 1200 mm and in measured troughs of the same dimensions, experiments were carried out with fractions 0-0.05 \( k_B \), which for a belt with \( k_B = 1200 \) mm fractions 0-20 mm and 20-60 mm were selected in proportions of 1/3 and 2/3, respectively, and for a belt with \( k_B = 400 \) mm they were separated by screen analysis of the whole volume of mined material. It was established by experiment that the looseness factor for the 0-0.05 \( k_B \) fraction on belts with \( k_B = 400 \) and 1200 mm may be adopted as an almost constant value \((K_p = 1.51)\). With a confidence level of 95% the error for the predicted \( K_p \) value for the 0-0.05 \( k_B \) fraction on different width belts does not exceed 4%. The looseness factor is independent of belt trough shape and inclination angle for the lateral rollers which was varied in the range 30-45°. Studies were carried out on UkrNIiproekt traversing units, and also on a rock-face conveyor at a pilot section of the Mezhdurechenskii PO Kemerovugol' cutting.

The moving belt of a conveyor unit was loaded to overfilling from a special suspended bunker until the material flowed over the edges of the belt. Then the conveyor was stopped, material was removed from a 4-m section, weighed, and in order to do this, material removed from the belt was loaded into a trough of special prismatic shape with a hexagonal base whose dimensions corresponded to the trough of conveyor belt units where the study was carried out (with three roller supports having equal length rollers). The troughs were of closed form so that loading was carried out with a filling factor equal to unity (without a "cap"). Joints on each side of the prism made it possible to change the shape of the cross section, simulating the inclination angle for the lateral rollers in the range 30-45°. Since the rock was taken from a 4-m section of the conveyor, the length of the matched measuring trough was 2 m.

Rock remaining after filling the trough corresponded to the amount which was located above the trough.

A rockface conveyor with a belt \( B = 1200 \) mm in the Mezhdurechenskii cutting was loaded through a cranked feeder. Mined material consisting of argillites, siltstones, and sandstone with a volumetric weight \( j = 2.5 \) ton/m\(^3\) charged artificially into a bunker was loaded onto a belt until it flowed over the sides. The belt charged with mined material was transported a distance of 400 m at a speed of 3.66 m/sec, then the conveyor was stopped and the material weighed.

The task of the experiment was to select in the best way an optimum number of threshold points pertaining to a simplex system, to carry out measurements within them, and from the values of the functions (values of \( q_t \) and \( q_{tn} \)) at these points to obtain an equation

\[
q = f(X_1, X_2, \ldots, X_i).
\]

Tests were carried out with mixtures of specific composition representing nodes of the simplex grid \((q, n)\) which were a selection of points in the form

\[
(X_1, X_2, \ldots, X_i); \ X_t = 0, \ \frac{1}{m}, \ \frac{2}{m}, \ldots, 1 \text{ and } \sum_{t=1}^{i} X_t = 1,
\]

where \( m \) is the power of the polynomial.

The required number of experiments was calculated by the equation

\[
n = \frac{m + q + 1}{m(q - 1)}.
\]