Application of Cycle-Flow Technology in Coal Mines

Javokhir Toshov[1], Buri Toshov[2], Umid Bainazov[1] and Muxriddin Elemonov[1]
[1]*Tashkent State Technical University named after Islam Karimov, University Str. 2, Tashkent, Uzbekistan*
[2]*Navoi State University of Mining and Technology, Tarobiy Str., Navoi, Uzbekistan*
javokhir.toshov@yandex.ru, elyor.saitov@ yandex.ru, bobomuratovsardor1@gmail.com, sirojiddin6870@gmail.com

Keywords: Open Mining, Rock, Quarry, Cyclical-Flow Technology (SFT), Unloading and Loading Hopper, Ansys Workbench, Conveyor, Belt.

Abstract: This article discusses, describes and analyzes the main problems of open mining in overburden work with the transportation of rock mass at the Angren coal open pit. The analysis of the main problems in the design of cyclical-flow technology with belt conveyors for hard rocks at the unloading and loading section of the bunker has been carried out. Calculations were carried out using the Ansys Workbench program. This article discusses, describes and analyzes the main problems of open mining in overburden work with the transportation of rock mass at the Angren coal open pit. In order to study them, a review was made of the stages of using conveyors for the mining industry both in different countries and at the Angren coal mine. In addition, as a result of the analysis, the author found that the main problem in the design of cyclic-flow technology with belt conveyors for hard rocks is due to the operation of the design of the unloading and loading hopper. In order to solve the problem identified by the author, optimization of the “CPT” with belt conveyors is proposed based on the improvement of the design of the bunker using the “Ansys Workbench» program, the prospects for using this calculation and analytical program are emphasized.

1 INTRODUCTION

In view of the recent political and economic events in the world, the problems of providing countries with energy resources have acquired particular urgency. Of course, these problems are relevant for our state. The fuel and energy complex of Uzbekistan occupies a special place in the economy of the republic, is a life support system for the population, and contributes to the political and economic independence of the state [1, 2]. A special place in solving these problems is occupied by the mining industry of Uzbekistan, which today is characterized by the further development of the open pit mining method. Open-pit mining has already acquired a predominant role in the extraction of ores of ferrous and non-ferrous metals, mining and chemical raw materials and building materials. Open pit mining is also being further developed in the coal industry, in particular, at the Angren coal open pit. To substantiate the origins of the problem considered in this paper, we briefly characterize this coal mine [3, 4]. The experience of recent years, as well as the achievements of modern mining technology, dictate new conditions for the organization of technology and the procedure for mining the Angren coal deposit. The existing railway transport within the section limits the capacity of internal dumps, requires large material costs for the operation of transport, does not provide a modern change in the configuration of the side, which reduces its stability, and the presence of a large length of railway tracks requires significant labor and material resources. So, for example, according to the results of 2000 and 2001, railway transport accounts for 36% of the cost of 1 ton of coal. In addition, the irregular work of railway transport reduced the productivity of excavators by 1.5-2 times. The use of railway transport requires the presence of railway tracks on each ledge, which, with a length of one ledge of 6 km, requires the presence of 126 km of tracks inside the section, not counting the railway stations. With the maximum achieved capacity of 5.6 million tons/year in 1992, the Angrensky open pit had 540 km of railway lines.As of January 1, 2002 y. 350 km remained in stock, while the materials for the maintenance of the tracks are forced to buy outside the Republic of Uzbekistan, which requires constant foreign exchange. One of the options for getting out of this situation was the rebuilding of double and triple ledges, however, this experience turned out to be deplorable. The Angrensky section received a lot of local landslides precisely in places where the height of the ledges increased [5].

2 METHODS AND MATERIALS

Structurally, the area of the Angren section is confined to the northeastern flank of the main Angren syncline, which plunges in a southwestern direction and is composed of additional small folds, accompanied in some areas by disjunctive disturbances. The displacement amplitude of the coal deposit is 10-40 m. The angles of dip of the layers vary from 5o to 18o. "Upper" and "Powerful". The "upper" complex is represented by frequent interbedding of coal packs with a thickness of 0.2 to 2.5 m, separated by rock interlayers. The total thickness of the complex ranges from 15.0 to 30.0 m. The average thickness of the complex is 21.65 m, the coal mass accounts for 12.45 m. The "powerful" complex occupies part of the coal deposit [6, 7]. In the "Powerful" complex, the coal mass occupies 89-95% and only 5-15% is occupied by rock. Rock layers are usually thin 0.10-0.15 m. In the central part there is a zone of impoverishment of the "Powerful" complex. In this zone the content of coal packs is reduced to 25-30%.

Working with the world's leading companies producing mining equipment and studying their positive and negative experience of introducing new equipment at various coal mines in Germany, Kazakhstan, Russia, India, France, etc., the company's specialists came to the conclusion that the most appropriate technology for production mining operations at the Angren open pit, is a cycle-flow and in-line technology. The chain of cyclic-flow technology involves: an EKG-type excavator + a mobile crushing plant + a self-propelled loader + a conveyor complex + a spreader. One local conveyor takes rock from 3 ledges along three independent chains, consisting of an excavator + mobile crushing plant + loader.

To ensure a stable and uninterrupted supply of objects of economic sectors and the population of the republic with solid fuel, Uzbekugol JSC carried out active preparatory work to attract investment in the coal industry. The set of planned measures made it possible to increase the share of coal in the country's fuel and energy balance to 15%. At present, the explored coal reserves in the republic amount to 1.9 billion tons, and the predicted resources exceed 5.7 billion tons [8, 9].

Modernization of the process of open pit coal mining has shown that the belt conveyor plays a particularly indispensable role in modern production. In this regard, 23 conveyor belts were designed and manufactured by the China North Heavy Industry Corporation at the Angren mine. However, the experience of using the cyclic-flow technology (SFT) at the Angren coal open pit made it possible to identify problem areas in the process of transporting overburden rocks using a belt conveyor. We came to these conclusions as a result of studying the mechanism of overburden transportation [10, 11].

One of the most important problems is the process of reloading the rock from the bunker to the main belt conveyor, which causes frequent breaks in the main conveyor belt due to pieces of overburden falling from a considerable height. The problem is aggravated by the fact that the conveyor lines move at a significant speed: the speed of the face conveyor belt is 5.0 m/s, the main one is 5.6 m/s.Since the use of CCT reduces the distance of transportation of rock mass by 50-60%, reduces the use of electricity by 5-6 times and reduces the number of employees by almost 6 times.

The study of the operation of the belt conveyor gives us reason to assume that one of the main problems is the bins that receive the load and transfer it to another conveyor line. This problem is already chronic, and interruptions in the operation of conveyors due to a stop for repairs directly affect productivity, which is unfavorably reflected in the operation of the transportation complex as a whole. I studied in detail the scientific research and experience of the specialists of the Angren Division on the problem under consideration, so that international experience in solving this pressing issue, we identified possible factors:

1) In all countries of Europe and the CIS, the use of conveyor transport, in comparison with other modes of transport in open-pit coal mining, allows a number of positive factors (economy, high productivity, ensuring the continuity of cargo transportation, the possibility of complex automation of production, labor safety);
2) Problems with groundwater, which increase the moisture content of rocks as a result of soil sticking, which significantly makes the extracted rock heavier, that is, hydrogeological conditions lead to difficulties in the operation of conveyor transport in coal mines;
3) At present, there are conveyors in foreign practice, the productivity of which reaches 25,000 m3 / hour. The belt speed reaches 10 m/s, the installed motor power is up to 10,000 kW.

The productivity of the CCT at the Angren coal mine reaches 4,000 m3/hour, the speed of the face conveyor belt is 5.0 m/s, the main conveyor belt is 5.6 m/s.Practice shows that it is necessary to carry out work on further reconstruction of the SFT. Based on the results of studies on the efficiency of conveyor transport at the Angren coal mine, the following shortcomings in the operation of the CLT mechanism were obtained:

- the height of the fall of the product must be minimal. This can be achieved by using a curved chute in which the bulk material moves slowly downward, causing some of the dynamic load of the falling product stream to be absorbed before it reaches the belt;
- a belt with deep grooves has less lateral spillage of the product and holding the load in the center. When transporting fine-grained material, aprons are installed around the loading tray, which prevent it from falling onto the idle branch of the belt;
- bulk material should be loaded at the lowest possible conveyor inclination of no more than 10°, it is preferable to provide a horizontal section for loading;
- the conveyor belt must have additional supports under the loading area, which absorb the inertial force of the falling cargo flow. To do this, roller bearings with a rubber coating or damping devices that absorb shock are used [12].

3 RESULTS AND DISCUSSION

A detailed study of the identified factors at the Angren coal mine, an analysis of the operation of the SFT, made it possible to reveal the following: one of the main reasons for stopping the main conveyor as a result of its rush lies in the features of the mechanism of operation of the unloading and loading hopper of the SFT [13].

For a visual representation of the design of the unloading and loading hopper of the SFT and during its operation in production, this study proposes the use of the Ansys program. In our opinion, this software package allows to carry out calculations of metal structures using the finite element method. The Ansys program also carries out design optimization, which is a computer technology, consisting in the selection of the optimal project from several using finite element analysis [14]. The designer selects the criteria and constraints of the project and creates the same parametric model as in parametric design. As a result of the analysis of the process of operation of the SFT, it was revealed that one of the main reasons for stopping the main conveyor as a result of its rush lies in the features of the mechanism of operation of the unloading and loading hopper of the SFT.

The optimization procedure controls the execution of the analysis based on the decision on the values of the parameters used in the trial calculations. The results of our analyzes based on the Ansys program will be presented in our next papers [15].

Based on this, we have studied in detail the process of operation of the unloading and loading hopper of the SFT using the Ansys program, which is shown in Figure 1.

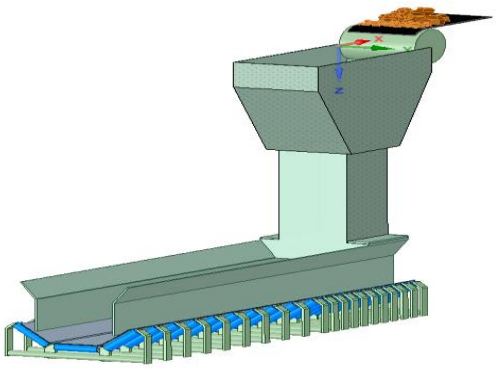

Figure 1: General view of the model for calculation.

The ANSYS software package allows you to calculate metal structures using the finite element method. The ANSYS program also performs design optimization, which is a computer technology that consists in choosing the optimal design from several using finite element analysis. The designer selects the criteria and constraints of the project and creates the same parametric model as in parametric design. The optimization procedure controls the execution of the analysis based on the decision on the values of the parameters used in the trial calculations.

The Ansys program was used as the main method of analysis due to the fact that this program made it possible to carry out the most accurate mathematical calculations of the geometric parameters of this design. The Ansys program, along with other Solidworks programs, Nx and Compas, is successfully used in solving engineering problems. With the help of the AnsysWorkbench program, based on precise geometric parameters, we designed 3D models of the unloading and loading hopper of the SFT located between the conveyor lines. Analysis of the constructed 3D models of the unloading and loading hopper made it possible to determine the reasons for the breakage of the main SFT belt. So, in particular, with the help of graphical and mathematical calculations, it was established that such indicators as: the height of the location of the unloading and loading hopper of the SFT and directly the geometric indicators of the structure itself play an important role.

To identify the most optimal height of the structure under study, its actual indicators of a height of 3.5 m were considered, taking into account the necessary data of materials and the dimensions of the bunker and the main belt. We have obtained graphical and mathematical calculations of the indicated parameters, which are given below (Figure 2).

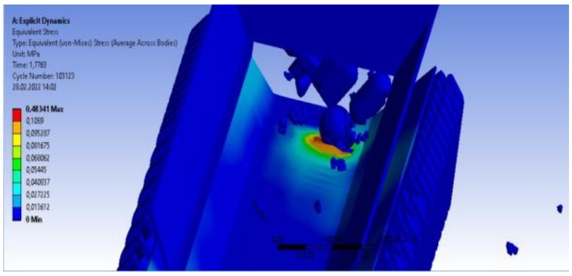

Figure 2: Graph of voltage of the bunker 3.5 m.

We have obtained equation (1) criteria for the rock to touch the tape, which must have *y_A=0* for the rock to hit the tape

$$\begin{cases} x = \left(x_0 + \frac{\vartheta_0 m}{k}\right) - \frac{\vartheta_0 m}{k} e^{\frac{k}{m}t} \\ y = h - \frac{g x_0^2}{2\vartheta_0^2} + \frac{m}{k}\left(\frac{mg}{k} - \frac{g x_0}{\vartheta_0}\right) + \frac{m}{k}\left(\frac{g x_0}{\vartheta_0} - \frac{mg}{k}\right) e^{-\frac{k}{m}t} \end{cases} \quad (1)$$

On the graph, the maximum voltage value is indicated in green, the average voltage value is blue, and the minimum value is red. According to this graph, the maximum voltage is reached at 2 seconds (Table 1, Figure 3).

Table 1: Numerical value of rock stress.

Time (s)	Min. (Mpa)	Max. (Mpa)	Average(Mpa)
1,1755e-038			
0,12502	8,2027e-005	2,3605e-004	1,4049e-004
0,25002	8,3377e-005	2,2662e-004	1,8545e-004
0,37503	0	1,6845e-004	1,1457e-004
0,5		1,0315e-004	1,0571e-004
0,62501	8,7678e-005	2,2694e-004	1,7351e-004
0,75001	8,6954e-005	2,2516e-004	1,5231e-004
0,87502	0	1,6332e-004	8,9977e-005
1	2,2611e-005	1,6885e-003	1,3835e-004
1,125	2,9019e-005	1,5561e-003	2,4364e-004
1,25	6,0799e-006	1,7772e-003	1,7693e-004
1,375	1,7992e-006	5,9421e-003	2,4124e-004
1,5	6,0799e-006	3,3168e-003	2,7127e-004
1,625	3,0844e-005	0,45364	1,0513e-002
1,75	2,1866e-004	0,39978	1,1952e-002
1,875	4,3258e-004	0,42374	1,385e-002
2	1,3518e-004	0,48341	1,0494e-002
2,125	1,0315e-004	0,37993	1,0449e-002
2,25	8,2195e-005	0,44386	8,3001e-003

The graph shows the distance traveled by rocks from the bunker to the belt per unit time. It was shown that from the 3.5 m bunker to the belt, the maximum impact rock covered a distance of 5269,5 mm (Table 2, Figure 4).

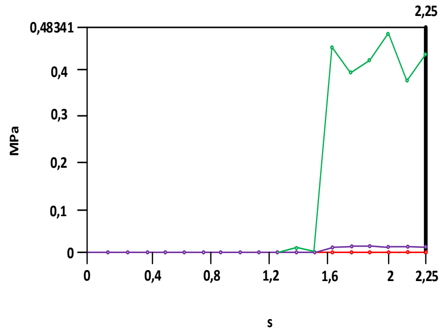

Figure 3: Graph of stress and displacement of rock on the belt from a bunker 3.5 m high.

Table 2: Numerical value of rock movement in the bunker.

Time (s)	Min.(Mpa)	Max. (Mpa)	Average(Mpa)
1,1755e-038			
0,12502	548,32	617,9	583,75
0,25002	1082,3	1235,4	1158,8
0,37503	1611,6	1254,9	1735,7
0,5	2158,7	2492,1	2330,9
0,62501	2753,2	3174,3	2971,9
0,75001	3422,7	3927,8	3684,4
0,87502	3392,6	4393,7	3788,4
1	2790,4	4699,6	3518,1
1,125	2746,1	4719,5	3551,1
1,25	3181,3	4902,2	3847,6
1,375	3573,3	5097,8	4260,8
1,5	4431,8	5170,4	4775,9
1,625	4456,1	5259,8	4840,9
1,75	4447,3	5269,5	4844
1,875	4440,3	5260,6	4832,3
2	4425,5	5253,5	4821,1
2,125	4388	5236	4797,7
2,25	4392,8	5238,1	4798,1

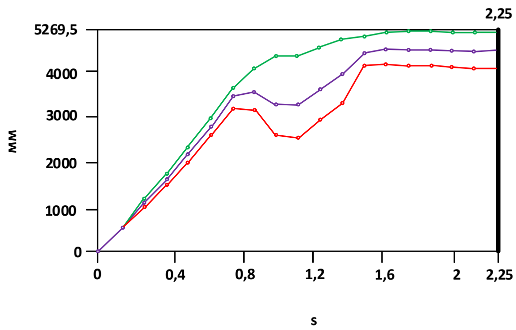

Figure 4: Graph of the movement of rock from the bunker to the conveyor belt.

This graph depicts the thrust and tension of the rock falling from the hopper onto the belt per unit time. The graph shows that the rock that had the maximum impact on the belt from the 3.5-meter bunker covered a distance of 5238 mm. (Table 3, Figure 5).

Table 3: Stresses and displacements of the hopper height.

Time (s)	(B)Equivalent Stress (Max) (MPa)	Total Deformation (Max) (mm)
1,1755E-38	0	0
0,12502	2,3605e-004	617,9
0,25002	2,2662e-004	1235,4
0,37503	1,6845e-004	1854,9
0,5	1,6863e-004	2492,1
0,62501	2,2694e-004	3174,3
0,75001	2,2516e-004	3927,8
0,87502	1,6332e-004	4393,7
1	1,6885e-003	4699,6
1,125	1,5561e-003	4719,5
1,25	1,7772e-003	4902,2
1,375	5,9421e-003	5097,8
1,5	3,3168e-003	5170,4
1,625	0,45364	5259,8
1,75	0,39978	5269,5
1,875	0,42374	5260,6
2	0,48341	5253,5
2,125	0,37993	5236
2,25	0,44386	5238,1

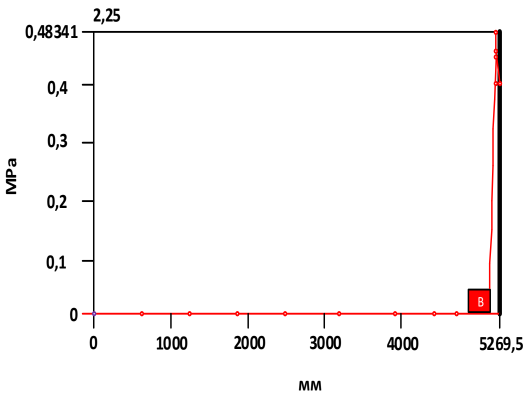

Figure 5: Graph voltage and displacement of the hopper 3.5 m.

4 CONCLUSION

We have studied and analyzed in detail the problems of the CLT operation process during overburden operations at the Angren coal mine. As a result of the analysis, it was revealed that the main problems of overburden transportation are due to various reasons for the rupture of the main line 3.8. In this regard, a scientific study of this problem was carried out, which made it possible to identify one of the main problems of frequent ruptures of the main belt conveyor during operation, due to both the structural and technical features of the main belt itself, and the impact force of the mined rock from the loading and unloading bunker of the SFT. In order to identify the causes of the identified problems, an analysis was made of the operation of the SFT, taking into account its technical parameters (belt speed, degree of hardness and angle of fall of the rock onto the tape, as well as the height of the bunker, from which the rock is unloaded onto a tape 3.5 m high, according to the Ansys program. The analysis showed that one of the main problems is due to the height of the production bunker. Determining the optimal height of the operational hopper allows you to avoid frequent breaks in the main belt conveyor No. 3.8. An important role is played by the peculiarity of the design of the loading and unloading bunker itself.

Our analysis showed that from a bunker height of 3.5 meters, the impact stress of the falling rock on the main line is 0.48341 MPa.

The results of the analysis show that the determination of the optimal height of the loading and unloading hopper makes it possible to extend its service life and reduce the frequency of repair work of this design

REFERENCES

[1] W. Gang, X. Jun, X. Sheng, and W. Haiyang, "Mining a coal seam below a heating goaf with a force auxiliary ventilation system at Longhua underground coal mine, China," International Journal of Mining Science and Technology, vol. 25, pp. 67-72, Jan. 2015.

[2] A.I. Leleko, "Coal industry of Uzbekistan: stages of development," Mining Bulletin of Uzbekistan, no. 1, pp. 3-7, 1998.

[3] G. Bulatov and T. Annakulov, "Investigation of the width of the entry of an excavator when loading a mobile crushing plant in the conditions of the Angren coal mine of Uzbekistan," IOP Conference Series: Earth and Environmental Science, vol. 937, no. 4, article 042088, 2021.

[4] T.J. Annakulov, S.B. Gaibnazarov, O.A. Kuvandikov, F.O. Otajonov, and B.O.Otajonov, "Development of a Methodology for Determining the Economic Efficiency of Cyclic-Flow Technology Schemes for Rock Mining Using Mobile Crushing and Reloading-Conveyor Complexes," AIP Conference Proceedings, vol. 2432, article 030115, 2022.

[5] M.U. Musirov and N.Yu. Kholmanov, "Investigation of String Vibrations of a Transporting Device," in Proceedings of the 7th International Conference on Industrial Engineering (ICIE 2021), pp. 126-133, Jan. 2022, doi: 10.1007/978-3-030-85233-7_15.

[6] N.S. Usmanov, I.V. Tsoi, U.U. Irkabaev, I.Kh. Nasriddinov, and T.Zh. Annakulov, “Experience in the implementation of cyclic-flow technology at the overburden complex of the Angrensky open-pit mine,” Mining Bulletin of Uzbekistan, no. 1 (60), pp. 82-86, 2015.

[7] B.N. Baratov, F.Y. Umarov, and Z.H. Toshov, “Tricone drill bit performance evaluation,” Gornyi Zhurnal, no. 12, pp. 60-63, 2021, doi: 10.17580/gzh.2021.12.11.

[8] Z. Bubnicki, “Modern Control Theory,” Springer, 2005, [Online]. Available: https://doi.org/10.1007/3-540-28087-1.

[9] J.B. Toshov, B.R. Toshov, B.N. Baratov, and A.L. Haqberdiyev, “Designing new generation drill bits with optimal axial eccentricity,” Mining Informational and Analytical Bulletin, no. 9, pp. 133–142, 2022, doi: 10.25018/0236_1493_2022_9_0_133.

[10] E.E. Sheshko and L.N. Atakulov, “Justification of radius for transition loading section of sandwich belt high-angle conveyor,” Gornyi Zhurnal, no. 12, pp. 61-64, 2019.

[11] G. Akanova, U. Kayumov, L. Sagatova, M. Istamov, and L. Atakulov, “Choosing the flow part geometric shape of the dredge pumps for viscous fluids,” Mining of Mineral Deposits, vol. 15, no. 4, pp. 75-83, 2021.

[12] K. Forrest and L. Loate, “Power and Accumulation Coal Mining, Water and Regulatory Failure,” The Extractive Industries and Society, vol. 5, no. 1, pp. 154-164, Jan. 2018, doi: 10.1016/j.exis.2017.12.007.

[13] V.I. Efimov, N.I. Abramkin, V.V. Vernigor, and B.Kh. Khakimov, “Underground mining equipment kits coal in shallow beds,” Sustainable Development of Mountain Territories, vol. 12, no. 4 (46), pp. 510-516, 2020, doi: 10.21177/1998-4502-2020-12-4-510-515.

[14] E.E. Sheshko and L.N. Atakulov, “Elasticity modulus steel-cable rubber conveyor belts,” Gornyi Zhurnal, no. 4, pp. 73-76, 2019.

[15] V.A. Bruyaka, V.G. Fokin, E.A. Soldusova, N.A. Glazunova, and I.E. Adeyanov, “Bruyaka Engineering Analysis in ANSYS Workbench: Proc. Allowance,” Samara, 2010, 271 p.