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Simulation of material flow using vertical transport by a double-action mine hoist

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Abstract: Vertical transport with the help of mining hoisting equipment in the deep mining of mineral raw materials is an essential part of the entire complex of intra-company transport at every mining plant. This paper aims to simulate the material flow ensured by double-action hoisting equipment. ExtendSim was used as a simulation tool, which combines the possibilities of discrete and continuous simulation and is used by researchers in various fields. The paper presents a simulation model of the material flow - coal transport from the underground to the surface. The paper also presents the results of the experiments performed on the created simulation model, too. The simulation model is a suitable auxiliary tool for the decision-making process or analysis of the current state and rationalization.

1 Introduction

As one of the logistics processes, the transport process currently has an irreplaceable place in the logistics systems of companies and the supply chain. The common goal of transport, both internal and external, is to satisfy customers' needs, i.e. move the material at the right time, to the right place and in the required quality with the effective use of means of transport and equipment.

In the mining industry, intra-company transport has an important position. In underground operations, various transport systems are used for horizontal transport (mining rail transport, rake and belt conveyors, suspended transport, trackless mining transport, etc.). Vertical transport with a mine hoist is often used in deep mines to transport material from and to the underground. Mine hoisting machines are complex machinery used to raise ore and waste rock and transport personnel, materials and various mining equipment between the mine surface and its underground. A standard hoisting machine consists of a hoist drive, headframe, ropes, conveyances (cages or skips), and control and safety devices. [1]

Definitions of the basic concepts of vertical transport are given in several publications [2]. Mine hoist can be categorized from several systemic perspectives. For example, the categorization by the maximum rated velocity: the category of large mine hoist machines with a rated velocity above 3 $m.s^{-1}$ and the category of small hoisting machines with a rated velocity below 3 $m.s^{-1}$. According to the method of transport, we differentiate [3]:

A) Single-acting mine hoist. They are characterized by the fact that only one transport container is suspended from the rope. They make it possible to perform mining from any horizon without pushing the transport containers. Compared to double-acting mine hoists, they have half the performance - capacity.
B) Double-acting mine hoist. They are used much more often than single-acting mine hoists. During transport, two transport containers are used, which can be hung on two hoisting ropes of a double drum hoisting machine to both ends of one rope or several hoisting ropes when using a hoisting machine with a friction disc. With this method, drum hoisting machines ensure transport from any horizon, allowing the hoisting rope to be lengthened or shortened. In the case of mining using a friction disc, dual-action transport can only be done from one horizon.

Sometimes combined mine hoists are used, characterized by having different transport containers suspended on both ropes in drum equipment and on both ends of the rope in friction disc transport.

Designing mechanical parts of the mine hoist begins with proposing hoisting machine parameters (identification of an appropriate machine type, calculation of its basic parameters, mining capacity, transport velocity, required output, etc.). For this purpose, manufacturers use special computer software to create several optimization alternatives [4].

This paper aims to present a simulation model of the material flow when using a double-action mine hoist. Simulation as a scientific method is now widely used in research and practice. Currently, they are used for the creation of simulation models in various areas (transportation systems, handling systems, production systems, urban planning systems, logistics systems, ecological problems, etc. [5,6]), several simulation tools such as Witness [7], Tecnomatix Plant Simulation [8], Extend [9] and others.

This paper will use the ExtendSim simulation tool [10]. This simulation system combines discrete and continuous simulation capabilities and is a popular simulation tool for PC_MS Windows and Macintosh computers. This tool was used by several authors in simulations in various fields [9,11,12].

2 Methodology

To apply the simulation and create a simulation model, it is necessary to conduct a thorough analysis of the material flow. In this case, the flow of coal from the underground to the surface was analyzed, which is ensured by a skip double-acting mine hoist with a friction disc used in Slovak mining operations. The material flow is shown in the formalized diagram in Figure 1. As can be seen from Figure 1, the coal is stored in the underground bunker. Coal is poured into the storage bunker via a discharge ramp from a mine railway wagon. Coal is filled from the bunker using a belt scale into a skip transport container. After loading the coal into the skip container, the skip container with coal is hoisted to the surface, where the coal is unloaded through the lower opening in the skip container into the storage bunker, from where it is then moved using belt conveyors for further processing. Since the flow of coal is provided by a double-acting mine hoist (two skip container), it is essential to point out that in that moment of loading coal into the skip (1) underground, coal is being unloaded from the skip (2) on the surface.

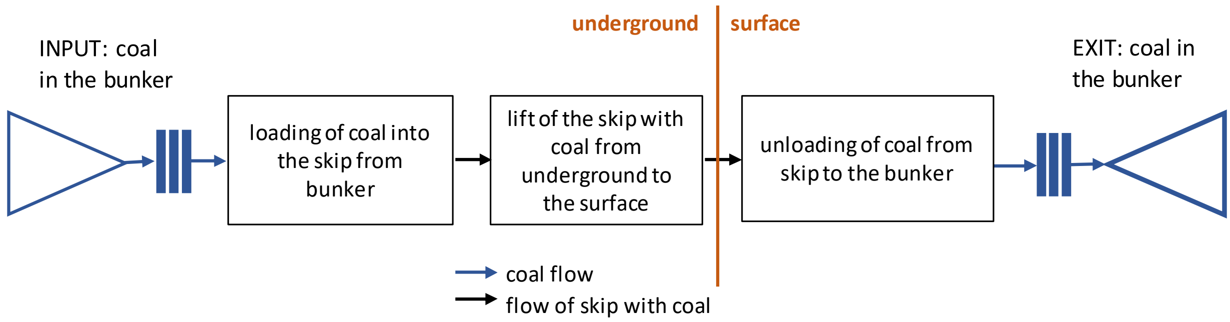

Figure 1 Flow of coal from the underground to the surface

Blocks from libraries were used to create simulation models. "Item.lix", which contains blocks for creating discrete simulation models, and "Plotter.lix" – blocks that allow displaying the progress of the simulation.

The blocks used to build the model are explained in Table 1. In shows the Print Screen of the created coal flow simulation model shows Figure 2

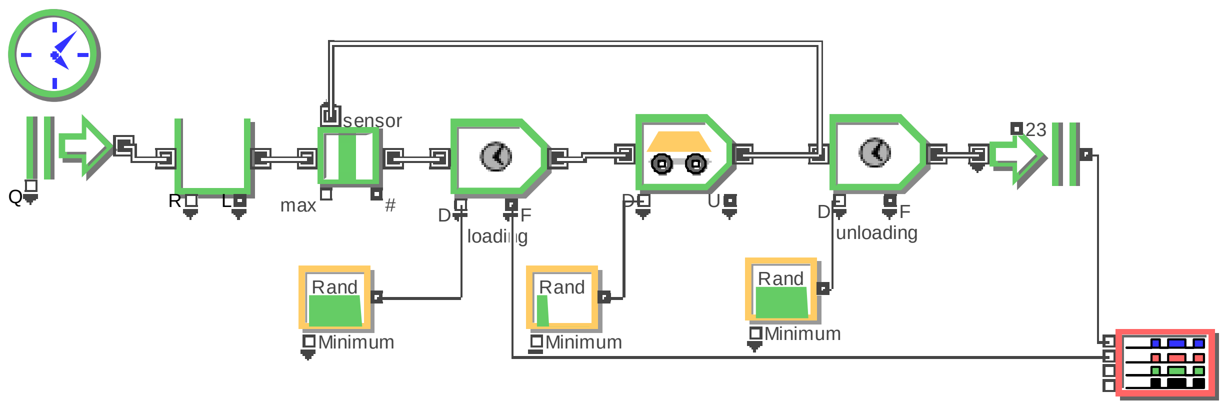

Figure 2 Print Screen of the simulation model

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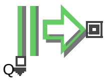
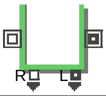
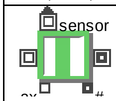
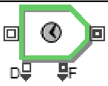
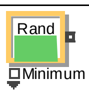
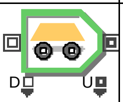
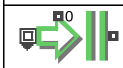
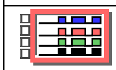
Table 1 Used blocks

	"Executive" – block for controlling the simulation time.
	"Create" - the block generates inputs to the simulation model. In this case, it generates coal batches.
	"Queue" - a bunker, represents a series of generated inputs (coal batches) waiting for loading.
	"Gate" - the task of the block is to ensure that the request enters the process at the moment the previous request completes the "Transport" block, i.e. that, in this case, ensures that both loading and unloading occur within the one-time interval.
	"Activity 1" – the block delays the element for a specific time, representing the activity of loading coal into the skip. "Activity 2" - the block will delay the element for a specific time, representing the activity of unloading coal from the skip.
	"Random Number" - blocks generate inputs (times) of activities (loading, lifting, unloading)
	"Transport" - transports elements from one place to another, representing the relocation (lifting) of a batch of coal from the place of loading to the place of unloading.
	"Exit" - request output, number of unloaded coal batches
	"Plotter, Discrete Event" - the block from the input values draw graphs of the simulation and writes the values of the monitored inputs into a table.

3 Results and discussion

Several experiments were performed on the simulation model. The input data was obtained directly from the operation. The time of loading and unloading coal to and from the skip container is 90-120 s for a weight of 10 tons of coal. This interval was entered into the "Random Number" blocks as input for the "Activity" blocks. The hoist time of the skip container was measured in the range of 45-50 s. The interval was entered in the "Random Number" block for the "Transport" block.

Several experiments were performed on the simulation model. Experiment A for a simulated time of 1 hour. Experiment B for a simulation of 5 hours and 30 minutes corresponds to the real working time on the mine hoist. The average results from the experiments are summarized in Table 2.

Table 2 Used blocks

Experiment	**A**	**B**
Simulated time [hours]	1	5,5
Number of loaded skip containers	24	130
Number of hoisted skip containers	24	129
Number of unloaded skip containers	23	129
Block using "loading" [%]	68	69
Block using "Transport" [%]	32	31
Block using "unloading" [%]	69	68

Figure 3 shows one of the outputs of Experiment A. The blue curve represents the number of unloaded batches of coal, and the red curves represent the number of loaded batches and their duration. It can be seen in the figure that the first batch of coal was unloaded at the moment when the second batch of coal was loaded underground. Figure 4 shows one of the outputs of Experiment B.

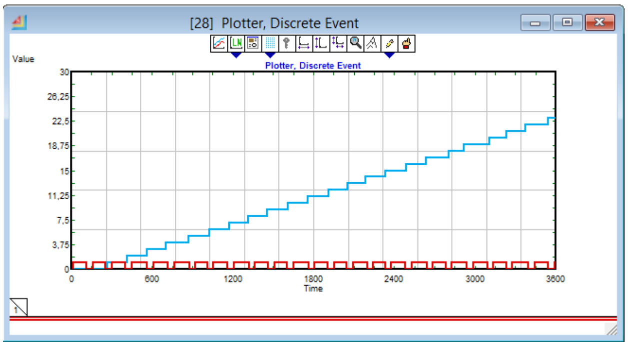


Figure 3 Graphical results of Experiment A

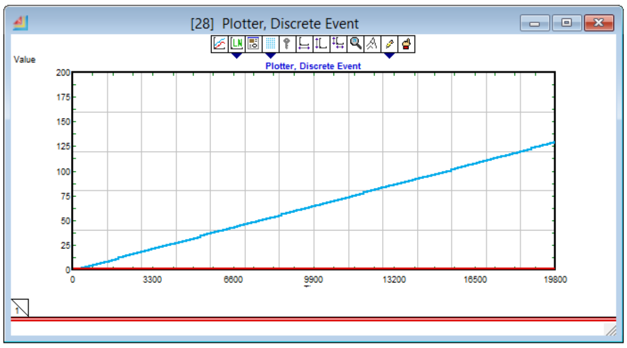


Figure 4 Graphical results of Experiment B

3 Conclusions

The simulation model simulates the material flow ensured by vertical mine transport, which is realized by a double-action mine hoist.

The result of the simulation experiments is the number of coal batches that were moved from the underground to the surface during the simulated time and the utilization of individual blocks, too. The number obtained in this way can be used to calculate the mine hoist's hourly capacity and the mine hoist's daily capacity. The simulation model is a suitable auxiliary tool for decision-making, either when designing new systems or evaluating existing ones. Expansion of the model is also possible with other activities, or it may represent other activities that should be addressed in future research.

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References

[1] POPESCU, F.D., RADU, S.M., ANDRAȘ, A., BRÎNAȘ, I.: Numerical Modeling of Mine Hoist Disc Brake Temperature for Safer Operation, *Sustainability*, Vol. 13, No. 5, pp. 1-20, 2021. https://doi.org/10.3390/su13052874

[2] MARASOVÁ, D., ŠADEROVÁ, J.: *Technologies of intra-company transport*, TU, Košice, 2017. (Original in Slovak)

[3] MARASOVÁ, D., MIKUŠOVÁ, N., BOROŠKA, J., STRAKOŠ, V., LUKÁČ, S.: *Intra-company transport in the mining industry*, TU, Košice, 2009. (Original in Slovak)

[4] ŠADEROVÁ, J., STRAKA, M., ERDELJAN, D.J.: New approach to increasing the vertical conveyance capacity through transport cycle modification, *Archives of mining sciences*, Vol. 64, No. 4, pp. 709-723, 2019.

[5] STRAKA, M., ŠOFRANKO, M., GLOVA VÉGSÖOVÁ, O., KOVALČÍK, J.: Simulation of homogeneous production processes, *International Journal of Simulation Modelling*, Vol. 21, No. 2, pp. 214-225, 2022. http://dx.doi.org/10.2507/ijsimm21-2-597

[6] JANIC, P., JADLOVSKÁ, S., ZÁPACH, J., KOSKA, L.: Modeling of underground mining processes in the environment of MATLAB / Simulink, *Acta Montanistica Slovaca*. Vol. 24, No. 1, pp 44-52, 2019.

[7] ONOFREJOVA, D., JANEKOVÁ, J., GRINČOVÁ, A., ŠOLTYSOVÁ, Z.: Simulation and evaluation of production factors in manufacturing of fireplaces, *International Journal of Simulation Modelling*, Vol. 19, No. 1, pp. 77-88, 2020.

[8] KLIMENT, M.: Production efficiency evaluation and products' quality improvement using simulation. *International Journal of Simulation Modelling*, Vol. 19, No. 3, pp. 470-481, 2020. https://doi.org/10.2507/IJSIMM19-3-528...

[9] SISOL, M., MARCIN, M., BREZÁNI, I., STRAKA, M., ROSOVÁ, A., MAKYSOVA, H.: Geopolymerization of aluminosilicate wastes used in building chemistry, *Przemysł Chemiczny*, Vol. 98, No. 4, pp. 569-574, 2019.

[10] STRAKA, M.: *Theoretical basis of simulation of the simulation system EXTENDSIM 9.x*. TU, Košice, 2017. (Original in Slovak)

[11] ROSOVA, A., BEHÚN, M., KHOURI, S., CEHLÁR, M., FERENCZ, V., ŠOFRANKO, M.: Case study: the simulation modeling to improve the efficiency and performance of production process, *Wireless networks: the journal of mobile communication, computation and information*, Vol. 28, No. 2, pp. 863-872, 2022. http://dx.doi.org/10.1007/s11276-020-02341-z

[12] ONDOV, M., ROSOVA, A., SOFRANKO, M., FEHER, J., CAMBAL, J., FECKOVA SKRABULAKOVA, E.: Redesigning the Production Process Using Simulation for Sustainable Development of the Enterprise, *Sustainability*, Vol. 14, No. 3, pp. 1-21, 2022. https://doi.org/10.3390/su14031514

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