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SIMULATION OF MINE VERTICAL TRANSPORT

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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 transport cycle of single-acting 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. Two simulation models are presented in the paper. The first simulation model represents the transport cycle from the underground to the surface during material transport. The second simulation model is extended to transport material from the surface to the underground. The paper also presents the results of the experiments performed on the created simulation models. The simulation model is a suitable auxiliary tool for the decision-making process or analysis of the current state and rationalisation.

Key words:
transport, hoisting equipment, simulation model, experiments

1 INTRODUCTION

Intra-company transport has an important position in the mining industry. 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 comprises a hoist drive, headframe, ropes, conveyances (cage or skips), and control and safety devices (Popescu et al., 2021). Definitions of the basic concepts of vertical transport are given in several publications (Marasova & Šaderova, 2017). According to the method of transport, we differentiate (Šaderová et al., 2022):

A) Single-acting mine hoist - characterised by only one transport container being suspended from the rope. This mine hoist makes 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 hoists 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, with different transport containers suspended on both ropes in drum equipment and on both ends of the rope in friction disc transport.

This paper aims to simulate the transport cycle of a single-acting device in the simulation tool EXTENDSim (Straka, 2017). 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 areas, e.g. for analysing passenger traffic between airport terminals (Fedorko et al.2018), for simulation in order to increase the efficiency and effectiveness of the company's custom production (Rosova et al., 2022), for redesigning the production process (Ondov et al., 2022) for the simulation of homogeneous production processes (Straka et al., 2022) and other.

2 METHODS AND METHODOLOGY

To apply simulation and create a simulation model of a technological process, it is necessary to analyse the activities that make up the process thoroughly. In this case, the traffic cycle of a single-action towing device, which comprises several actions, was analysed. Fig. 1 shows a formalised diagram of the transport cycle of a single-acting hoist device.

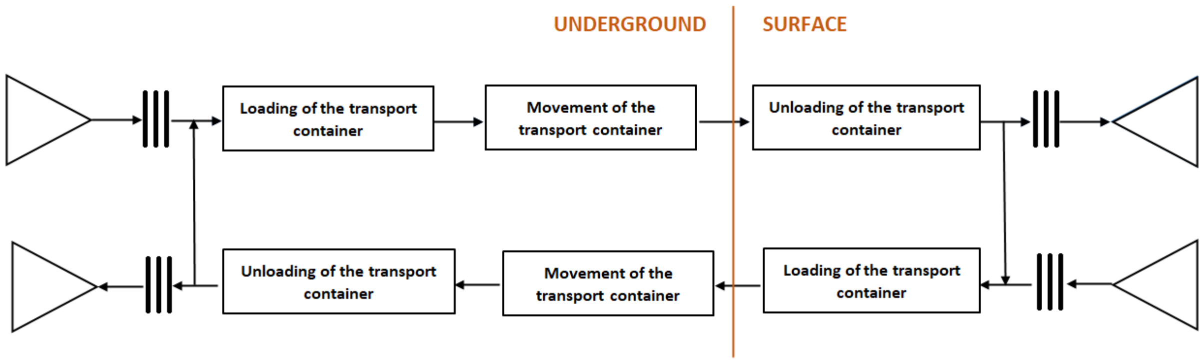

Fig.1 *Formalised diagram of the transport cycle*

The upper part of the formalised diagram represents the loading of the transport container underground (e.g. loading of mine carts with raw materials into the cage), followed by its upward movement (lift), which is divided into individual sections of the journey (acceleration, smooth movement, and braking). The last part of this branch is unloading the transport container (e.g., unloading the mining carts out of the transport cage). The lower part of the formalised diagram represents the return movement from the surface to the underground. Depending on the organisation of the work, either an empty transport container or a full transport container can be started (transportation of crew, transport of material to the mine). In the first case, handling times related to loading and unloading the transport container are eliminated. In the second case, the entire cycle is repeated - loading the transport container, moving it downwards, and unloading it during lifting. For this reason, two simulation model alternatives were created:

Simulation model 1 - Simulation model of material transport from the underground to the surface.

Simulation model 2 - Simulation model for material transport in both directions.

Blocks from 3 libraries will be used to create simulation models. "Item.lix" contains blocks for creating discrete simulation models. "Plotter.lix" - blocks that allow you to display the progress of the simulation. "Value.lix", from which the input and output blocks were used. Figure 2 shows the blocks used. Their functions in simulation models are described below.

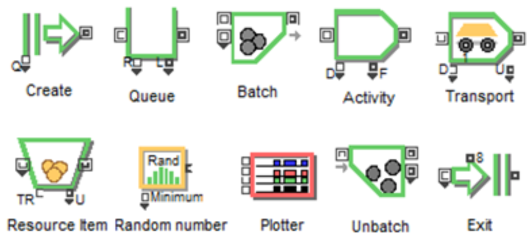

Fig.2 *Blocks used for creating models*

2.1 Simulation model 1

Figure 3 shows the PrtScr of the Simulation model of material transport from the underground to the surface. The first step was to insert an "Executive" block for time management. The simulation model starts with the Create block - transport load in which the material is generated to the "Queue" block - a buffer in which the material is placed until it goes for processing. The following input to the model is the "Resource Item" block, representing a transport container. Next comes the "Batch" block, which connects the material to the transport container. The "Activity" block follows - loading. This block is followed by three "Transport" blocks, representing the three phases of movement of the container with material (acceleration, smooth movement, and braking).

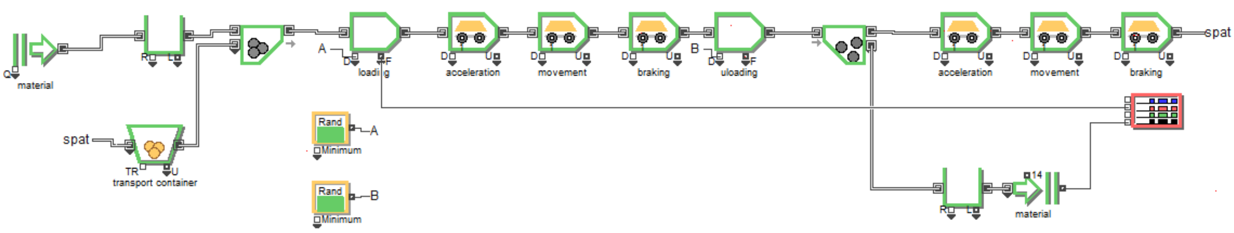

Fig. 3 *Simulation model of material transport from the underground to the surface*

After the Transport blocks, the "Activity" block is included again, representing the unloading of material from the transport container. "Random number" blocks generate loading and unloading times at a specified interval. Subsequently, the "Unbatch" block is included, separating the material from the transport container. Material enters the "Queue" block and goes to the "Exit" block - output, number of material batches. The transport container goes back (from the surface to the underground), again represented by 3 "Transport" blocks. Selected simulation results are displayed via the "Plotter, Discrete Event" block.

2.2 Simulation model 2

Figure 4 shows the PrtScrn of the Simulation model for material transport in both directions. It is an extension of the original model to which additional blocks have been added. The "Create" block was added to the original model - a transport load to the mine, in which the material is generated, to the "Queue" block - a buffer in which the material is placed until it goes for processing. From the "Unbatch" block, the transport container goes to the next "Buch" block, where the container is again connected to the material.

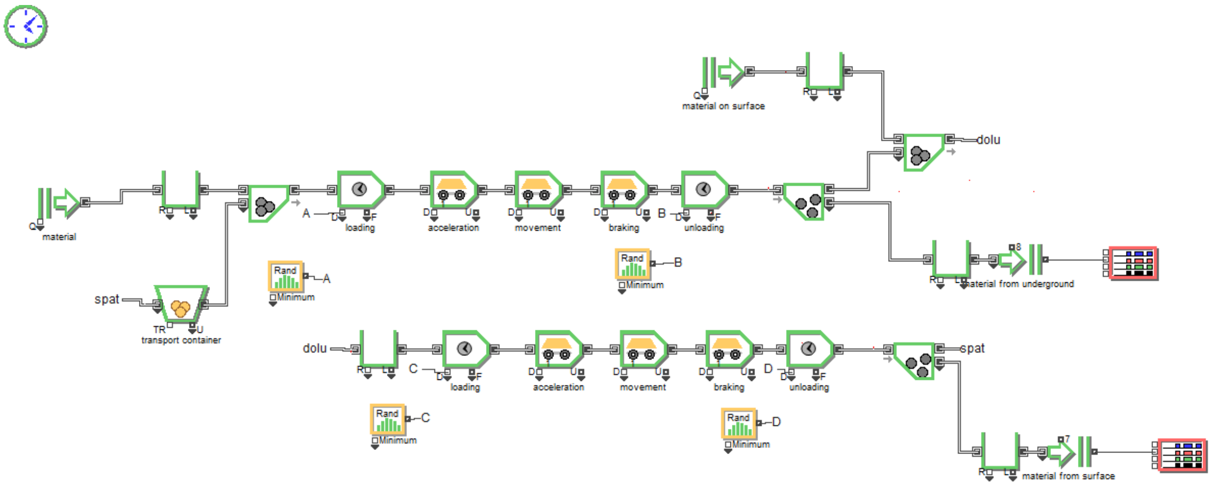

Fig.4 *Simulation model for material transport in both directions*

The branch representing the drive to the mine is extended by 2 "Activity" blocks - surface loading and underground unloading and 3 “Transport” blocks. The material arriving at the mine is accumulated in the Queue block and then goes to the "Exit" block - cargo brought into the mine. "Random numbers" C and D generate loading and unloading times in the opposite direction.

3 RESULTS

Experiments were performed on Simulation model 1 for a simulated time of 1 hour. The input values to the model were as follows: loading and unloading time of the transport container: 70-120 s, acceleration time - uniform movement – braking time: 11s - 23s - 10s.

Fig. 5 shows the result of one of the simulations. The red colour shows the loading of the transport container with material, and the black colour shows the number of transport cycles, the number of journeys from the underground = the number of unloading in a simulated time of 1 hour. During the 1-hour simulation, 15 transport containers were loaded, and the 16th transport container was loaded.

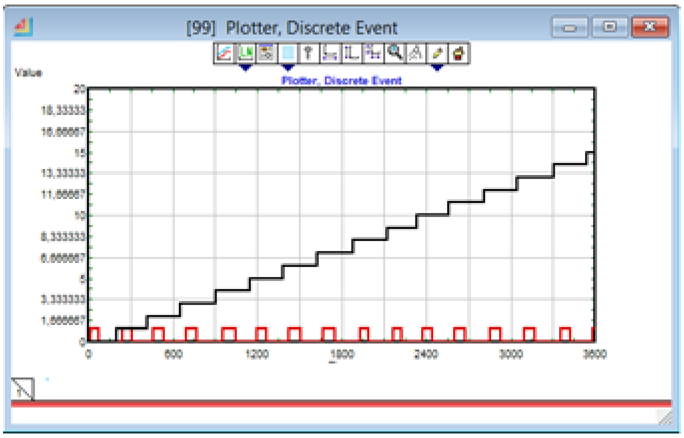

Fig.5 *Simulation result (1st model) – Plotter block*

Fig. 6 shows the result of one of the simulations performed on the Simulation model 2. The red indicates the number of unloaded transport containers on the surface, and the green indicates the number of unloaded transport containers underground for a simulated time of 1 hour.

Several experiments were performed on the simulation models, in which the input data and the simulated time were changed.

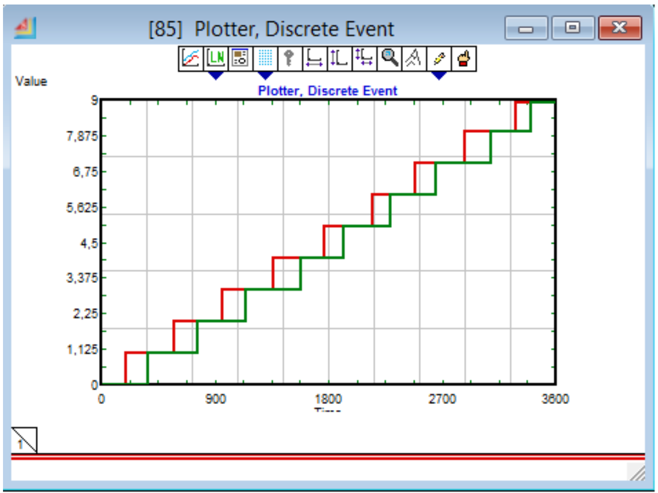

Fig.6 *Simulation result (2nd model) – Plotter block*

4 CONCLUSIONS

Simulation models simulate the transport cycle of vertical transport, which is carried out by hoisting equipment. The first simulation model represents the transport cycle of a single-action mine hoist during the transport of material from the underground to the surface and the return of the empty transport container to the underground. The second simulation model represents the transport cycle, extended by loading the container on the surface and unloading it underground. The simulation result in both model examples is the number of transport cycles per simulated time (1 hour) and the number of loaded and unloaded transport containers. The number of transport cycles 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 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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