

Simulation of the process of emptying the storage tank into road transport vehicles

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Abstract: Handling bulk material is specific and has different needs than handling piece goods. Bulk material requires a space that is adapted to both filling and emptying of such type of material. It is necessary to dimension the storage tanks in order to ensure an efficient production process. Emptying the storage tank also depends on the transportation of the bulk material to the production process. Road transport trucks must be adapted to transport bulk material, and the vehicle's capacity is the most important for emptying. In addition, it is necessary to monitor the performance of the filling equipment and the emptying technology. In terms of labour input, this process can be effectively monitored with the help of simulation. The simulation model, created in the ExtendSim 10 program, graphically displays various options for setting the emptying process parameters.

1 Introduction

In mining and metallurgy, the occurrence of storage tanks in the main processes is an integral part of the logistics flow. The storage tanks create harmony between the individual activities of the logistics flow, for example, the supply and removal of material and technological processes of other types. The storage tanks protect the bulk material from the weather and ensure its efficient transfer to the means of transport. It is customary and given by the technical conditions to carry out supply through the upper opening of the storage tanks and emptying through the lower openings [1].

Several viewpoints on the division of storage tanks are presented in the literature. However, the fundamental division is into two groups. These are low bunkers or high silos. As a rule, bunkers have a smaller capacity and are mainly used for the seasonal storage of all bulk materials. The horizontal placement of bunkers can be above ground or underground. Large-capacity silos

are used for long-term storage. However, they are limited to small fractions of bulk material, close to fine grains [2].

Designing a storage tank is a process whose output should be the storage tank's capacity. The capacity depends on the process of filling and emptying the storage tank. These activities are affected by the following parameters [3]:

- The hourly performance of the filling equipment determines the method and speed of supply.
- The character of emptying, continuous or interval.
- Truck capacity.

Regarding labour input, the design process can be effectively monitored using simulation. The simulation model, created in the ExtendSim 10 program, provides fast creation of material supply and removal graphs. Graphical outputs allow us to assess the sustainability of the production process's efficiency and reveal insufficient parameters that should be adjusted. The article aims to show the possibilities of using simulation to reveal the unsustainable process of emptying the storage tank

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if trucks are used for subsequent manipulation. If such a process is detected, it is crucial to propose measures that could help eliminate the undesirable state and, at the same time, verify them by simulation.

2 Methodology

2.1 Designing the capacity of the storage tank

During the design of the storage tank, two ways of determining its capacity may occur. If we already have a storage tank ready for storage, we calculate its volume mathematically by substituting the dimensions into the formula. In other situations, however, we do not have to have the storage tank available yet, but we know the rules and regularities of the process for which the storage tank must be designed. In this case, it is necessary to determine the storage tank's volume precisely so we do not inadvertently create a bottleneck in the process. During the design, we have to combine mathematical calculations and create graphs of the change in the amount of raw material during the use of the storage tank. By combining these two activities, the dimensions of the storage tank can be determined and, depending on them, its volume [4].

The authors of this publication discuss the storage tank design methodology in detail and propose the following algorithm as a suitable method [5]:

1. Defining the input data for the calculation,
2. Design of the shape and dimensions of the storage tank outlet,
3. Calculation of the permeability of the opening - the hourly performance of the outlet opening,
4. Calculation of the storage tank emptying time,
5. Calculation of the time of filling the storage tank with the amount of material for one means of transport,
6. Calculation of the minimum amount of material in the storage tank before loading,
7. Construction of a graph of the supply and removal of material from and to the storage tank,
8. Determining the maximum amount of material in the storage tank,
9. Calculation of the volume of the storage tank,
10. Determination of storage tank dimensions.

However, in this article, we will not manually mark the storage tank emptying, as it is assumed in point 7 of the algorithm. We will replace the long and unnecessarily laborious activity with an automatic graph drawing in the simulation software. Inputs and other calculations represent the necessary actions to set the simulation model parameters correctly.

2.2 Creation of graphic results

In logistics and other sciences, we can call simulation a method in which we transform the chosen process into a model corresponding to reality and perform

experiments on it. We can describe the results of experiments as a set of statistical data based on which we can appropriately choose measures to influence the process [6]. A simulation is a suitable tool for evaluating the efficiency of the production process, determining the need for raw materials, planning, rationalising activities, and bottlenecks, or evaluating proposed measures [7].

Currently, many simulation programs are used, such as TECNOMATIX, SIMUL8, WITNESS, STEELA, ExtendSim or ARENA. These simulation programs can also be divided into purely discrete ones, e.g. TECNOMATIX, purely continuous, e.g. STEELA, or complex, e.g. ExtendSim [8].

ExtendSim is a block-oriented simulation program. The simulation models created in the program can be both continuous and discrete. The advantage of the program is the possibility of creating combined models. Program blocks are divided into Value, Item, Chart, Rate, Utilities, Report and Reliability libraries. The individual blocks of the libraries are made up of a single programming language. They require minimal user experience with programming, making it easier for creators to work with their models. Users can edit library blocks. Frequently, their graphic editing is mainly needed, with the aim of better understanding the model. The easiest way is then to create hierarchical ones from basic blocks, such blocks can combine several blocks or just one [9]. An overview of some essential blocks for the model created to solve this task is in Table 1.

2.3 Choice of the type of raw material transport

The storage tank is filled by a continuously working device and emptied periodically. The raw material is loaded into the means of transport from the storage tank. The entire process described so far is highly dependent on the transport and, thus, the type of transport chosen [3]. Transport in such cases can be carried out by a conveyor belt when it is necessary to adapt the simulation to continuous emptying. More discreetly focused simulations are created when using rail or road transport. The use of rail transport requires increased attention when filling wagons and assembling the train set.

This article will focus on road transport, specifically dump trucks. The 6x6 TATRA single-sided tipper, shown in Figure 1, was chosen as a model vehicle. Its payload can be 25,000 kg, reaching a speed of 60 km/h [10].

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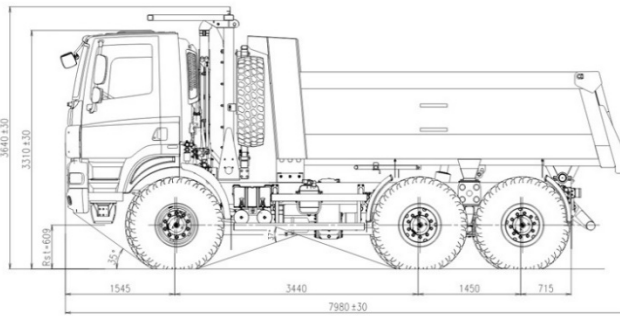

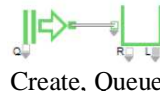











Figure 1 25t one-sided tipper, [10]

Table 1 Blocks of the ExtendSim simulation program, source author, amended [9]

Block	Function	Hierarchical block
 Executive	It must be in the left corner. Controls the simulation time.	—
 Create, Queue	They simulate the arrival of vehicles in the model.	
 Get	Passes information from the vehicle to the stack.	—
 Activity	Holds the vehicle for the necessary time.	—
 Exit	Removes the vehicle from the simulation model.	—
 Holding Tank	Holds and recalculates the value of the raw material.	
 Constant	Generates a constant value.	
 Line chart	Creates graphs during simulation.	—

3 Results and discussion

The first step in creating the simulation model was to perform calculations according to the model from the authors [5]. The following characteristics were entered or calculated based on the formulas:

1. hourly performance of the continuous filling device = 180 t.h-1,
2. vehicle capacity = 25 t,
3. performance of the discharge hole of the storage tank = 560 t.h-1,

4. storage tank emptying time = 2.7 min
5. vehicle handling time = 4 min,
6. time to fill the storage tank with the amount of material for one vehicle = 8.33 min,
7. a minimum amount of material in the storage tank before loading = 16.89 t.

A simulation model created using the previous parameters is shown in Figure 2.

The simulation model in Figure 2 is continuous-discrete. The arrival and departure of trucks are simulated discretely, and the flow of raw material in the form of values is continuous with recording at specific time points. The regular arrival of dump trucks models a hierarchical block with a truck icon. The get block reads its capacity and sends the request to the storage tank.

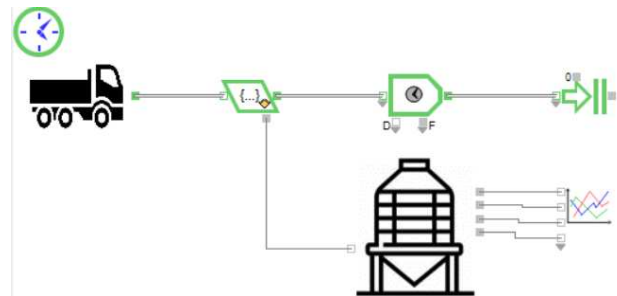


Figure 2 Simulation model of storage tank emptying

The activity block simulates the delay during the storage tank's loading, handling, and emptying. Within the hierarchical block with the silo icon, some blocks fill the storage tank regularly with the value generated in the constant block. Holding tank accumulation blocks accumulate values for plotting curves in the graph. The first experiment in Figure 3 was performed without changing the parameters calculated before the simulation. The duration of the simulation is one work shift, i.e. 450 minutes.

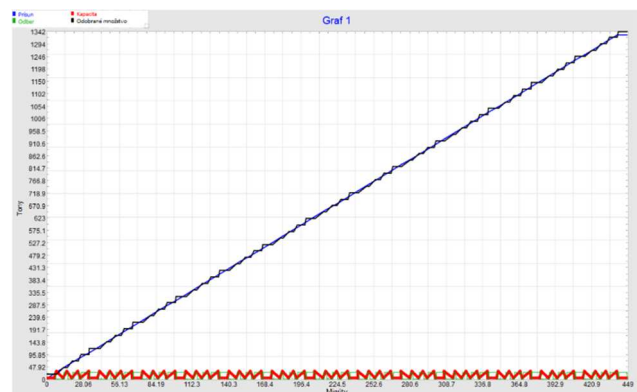


Figure 3 Results of experiment 1

The amount of raw material in the storage tank during the simulation is not enough to cover the needs of the following activities. During the simulation,

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67 vehicles were filled with a consumption of 1,341.89 t, which means that the vehicles were not fully loaded. The filling device added 1,325 t. The process set up in this way is not sustainable in the long term. The ideal situation would be if, at the end of the shift, there was again a minimum amount of material in the storage tank before loading.

We can approach this ideal state either by changing:

1. performance of the filling equipment - by increasing,
2. manipulation time - by increasing,
3. the capacity of means of transport - by reduction.

Figure 4 shows experiment 2, when the performance of the filling equipment is changed from 180 t/h to 230 t/h.

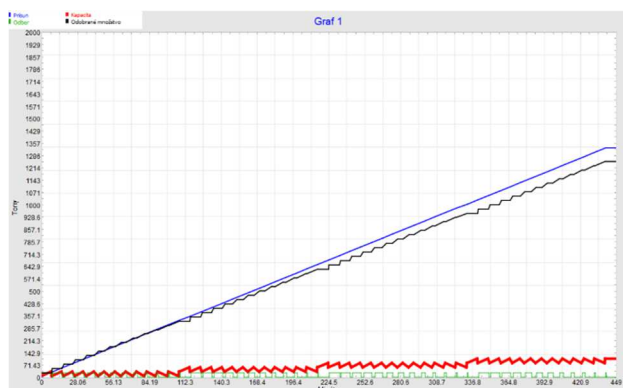


Figure 4 Results of experiment 2

For simulation, the value of the minimum amount of material in the storage tank before loading was recalculated to 22 t for the specified values. However, more than this change is needed, so the arrival of cars was extended from every 6.7 minutes to 9 minutes. The graph shows that the storage tank capacity will slightly increase to 100 t (red curve), and the raw material supply (blue curve) will exceed the withdrawal (black curve).

Figure 5 shows experiment 3 when changing the vehicle to a vehicle with a capacity of 15 t while maintaining the original conditions. For simulation, the value of the time to fill the storage tank with the amount of material for one means of transport was recalculated for 5 minutes. With such a change, the capacity reaches a value of up to 330t at the end of the simulation. It follows that there is no need to reduce the vehicle's capacity by up to 10 t.

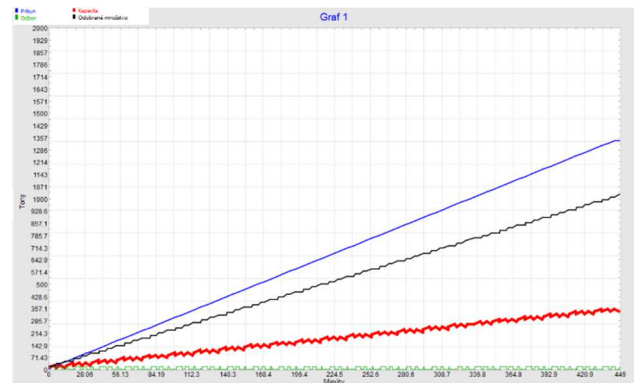


Figure 5 Results of experiment 3

None of the experiments carried out led to the achievement of an ideal state. Experimentation should continue towards balancing storage tank filling and emptying. After experiment 3, it is not necessary to change the means of transport, but rather to change the filling device or the storage tank does not need such a large outlet opening.

4 Conclusions

When we read the maximum amount of material in the storage tank and convert the given amount into a volume using the bulk weight of the raw material, we obtain a value for determining the dimensions of the storage tank and its capacity and thus complete the algorithm from the second section.

The experiments show the development of stocks in the storage tank based on calculated values according to available formulas. None of the experiments managed to approach the so-called ideal state. The most appropriate way to achieve such a state is by combining proposed measures. Other solutions may include changing the filling device or reducing the emptying hole. Such combinations also mean deviation from the values calculated according to the usual formulas.

In addition to the above examples, in practice, storage tanks can be emptied into vehicles of different types and capacities. For example, different train sets with different numbers of railcars can be loaded. In this case, the replacement of the train set must also be considered. In other cases, continuous conveyor belts can also be used.

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