

Application of the simulation of a tank capacity proposal for loading and unloading process of bulk material

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In this paper, the algorithm is given - how to design a tank for bulk materials. An important part of the proposal is to set the loading and unloading of a tank, which is also closely related to the proposal of its capacity and volume. Loading and unloading process is dependent on several factors but the main are: method and speed of loading which represents the parameter - hour power of loading device (e.g. continuous by a conveyor belt), method and speed of unloading (continuous or at intervals) and a type and capacity of means of transport, in which the material loading (truck, rail car, conveyor belt system). The paper presents two methods for determination of the loading and unloading process - the graphic method and determination during the simulation - creating a simulation model.

Key words: simulation of a tank capacity, design a tank for bulk materials

Introduction

A tank, in terms of function, is a device for temporary storage of materials and raw materials during their transport or technology needs. The role of a tanks is to create the necessary supply of material to remove the influences of irregular incomes or outcomes of transported material, time separation of the technological processes from other characters, to take into account the physicochemical properties of processed materials. Storage of bulk materials in tanks has its advantages and disadvantages. The main advantages include the protection of stored material from bad weather conditions and automation of filling and emptying of a tank. Tanks are divided according to the several factors and function e.g.: [4,5,7]

- according to terms of ground and elevation dimensions,
- according to the type of bulk material,
- according to a make,
- according to the operational use.

Filling of containers is executed only by pouring from the top, emptying of material is done by gravity at the bottom of a tank in the form of one or more discharge outlets with caps and feeders.

Proposal of the tank capacity

Determination of a volume and the capacity of existing tank is easily determined by calculation based on its dimensions. The volume of stored material is calculated as the geometric volume of the body which is represented by a tank. Capacity - the weight of stored material is calculated by multiplying the geometric volume of the container and bulk density of materials.

Different situation is in case to design capacity and new storage volume for specific operating conditions. Volume and capacity must be designed so efficiently that it is not oversized (large useless volume) or undersized and it could represents a bottleneck in the production or transportation process. In this case, the correct determination of the volume and storage capacity is more complex process. The container design must take into account several factors and operational parameters. These include, for example:

- the way of filling a tank (in cycles, continuously),
- time periods of filling of a tank (discrete, continuous performance, time of performance),
- power of filling equipment, in hours,
- shape and size of the outlet hole,
- the way of emptying of a tank (in cycles, continuously, by a feeder, through the cap etc.)
- power of emptying of a tank in concrete conditions, in hours,
- working time of a plant.

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Proposal of a capacity and storage volume can be divided into two parts. The first part - the calculation is the basis for the development of the second part, which is based on a graphical representation of filling and emptying and subsequent determination of its volume and dimensions.

The basis of the first part consists of mathematic calculations, according to defined mathematical formulas for the input data (Fig. 1) [7].

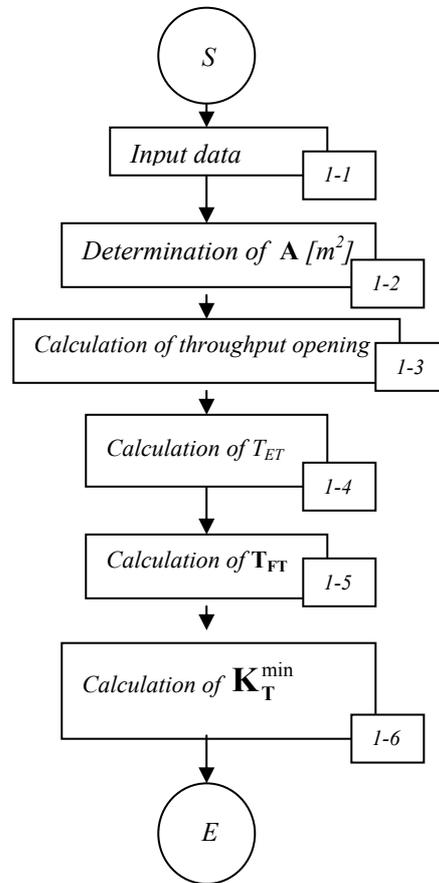


Fig. 1. The algorithm of the first part of a tank design.

- 1-1 Definition of input data for calculation: (bulk material density (ρ [t.m⁻³]), the maximum size of the discharged pieces (grains) from a tank (z [m]), power in hours of a filling device (Q_h^{FD} [t/h]), and above mentioned parameters and operating factors. It is important to know the capacity of a facility, which will be filled by the proposed tanks.
- 1-2 **Proposal of the shape and dimensions of a tank outlet:**
- selection of a shape of a tank outlet $\{\circ\square\}$,
 - calculation of the minimum cross-section of a tank outlet A_{min} [m²], which depends on the parameter z [m], the maximum grain size of a material and the coefficient which reflects the lumpiness irregularity of a material,
 - choice of cross-sectional ejection port A [m²],
 - determination of a tank outlet dimensions a, b, d [m].
- 1-3 **Calculation of the permeability of an outlet - hour efficiency of an outlet Q_h^T .**
- 1-4 **Calculation of time emptying of a tank T_{ET} ,** which is a part of time loading vehicle T_L (arrival and departure of a vehicle, its filling). Time T_{ET} depends on the capacity of a vehicle.
- 1-5 **Calculation of time filling of a tank by a material quantity for one vehicle T_{FT} .** This time is larger than emptying time, while filling larger vehicles, $T_{FT} \gg T_{ET}$. The ideal situation would be, if the time interval between the arrival of two consecutive vehicles the same capacity a tank was filled with a material quantity needed only for one vehicle.

1-6

Calculation of minimum amount of material in a tank before loading K_T^{\min} .

The basis of the second part is to construct a line graph showing the loading and unloading of materials to and from a tank. To construct the graph in addition to the calculated values is necessary to know the operating conditions, particularly the work mode – time parameters (length of a shift, the number of shifts, working time of a loader, etc.). The graph is the basis for determining of a tank capacity, volume, and dimensions. This method is laborious and time consuming. There is the algorithm of the graphic design in the Fig. 2.

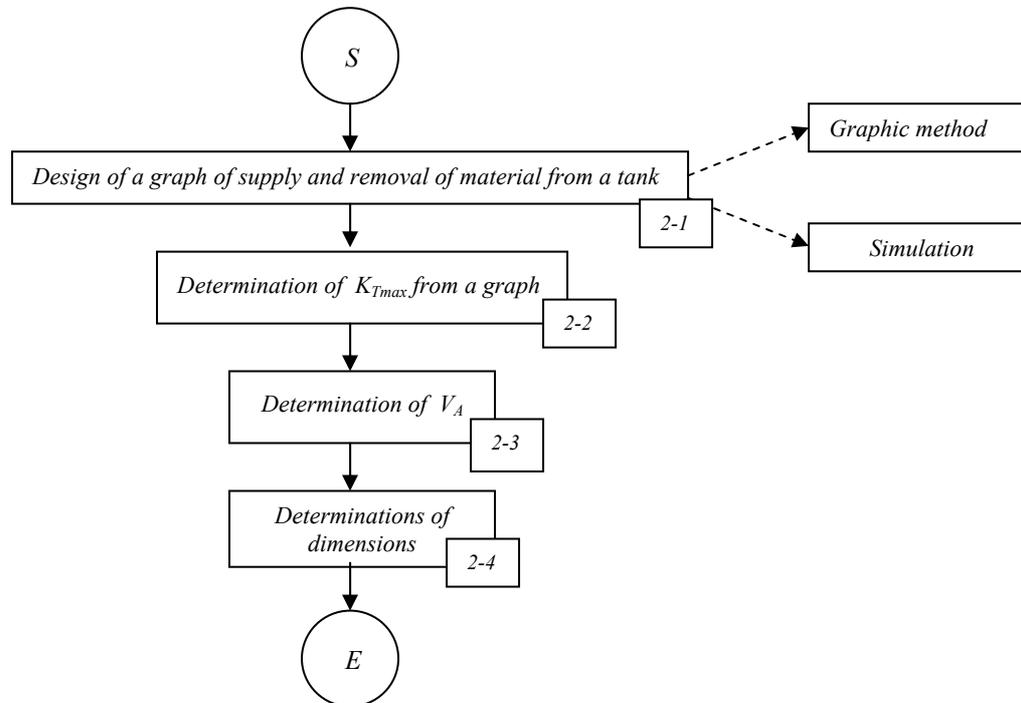


Fig. 2. The algorithm of the second part of a tank design.

- 2-1 Design of a graph of supply and removal of a material in a tank by graphical method or by simulation model..
- 2-2 It can be determined the maximum amount of material in a tank from a graph plot K_{Tmax} , which represents the maximum storage capacity for the certain conditions.
- 2-3 The quantity of material in tonnes K_{Tmax} is converted by the bulk density of materials (ρ [$t \cdot m^{-3}$]) to V_{Tmax} [m^3]. The calculated volume is increased in practice for sizing because of the physical tank conditions and storage coefficient of irregular supply of a material into a tank, according to the formula: $V_A = V_{Tmax} (1.3 \text{ to } 1.5) [m^3]$ [7].
- 2-4 The dimension of a tank are set according to calculated volume and the chosen type of a tank. It is necessary to take into account also the angle β of tank wall, which depends on the angle of friction between the material and a tank ($\beta \cong 50-60^\circ$).

Simulation model for the process of filling and emptying of the tank of bulk material

This section describes simulation model for the process of filling and emptying a tank. The tank is used for temporary storage of mineral resources and the subsequent loading of vehicles. The tank is filled by a continuous working device and regularly cyclically emptied.

First, it was necessary to perform calculations according to the first part of algorithm design to create the simulation model. Input and calculated data are listed in Table 1

Tab. 1. Input and calculated data for the creation of the simulation model.

	Parameter	Value
Input data	power, in hours, of continual filling equipment Q_h^{FD} , t.h ⁻¹	160
	volumetric bulk density of coal ρ , t.m ⁻³	1
	maximum size of the discharged pieces in the tank z , m	0,03
	capacity of a vehicle K_V , t	51
	coefficient of filling the cross-section discharge outlet φ	0,5
Calculated values	throughput - the performance of an outlet hole of the tank, Q_h^T , t.h ⁻¹	270
	the tank emptying time T_{ET} , min	11
	time of a vehicle manipulation T_{VM} , min	10
	Time of the tank filling by a material for one vehicle (51 t) T_{FT} , min	19,14
	minimum amount of material in the tank before loading K_T^{min} , t	21 t

The simulation model for the process of filling and emptying of the tank was created by using program Extend (Fig. 3). Simulation models, in this simulation environment, are formed by blocks, which together create a so-called block scheme of the model. Each block represents a certain part of real simulation system. The blocks are inserted into the model as needed from a variety of open libraries and blocks are placed into an empty dialog box. The blocks carry data that enter the simulation. Separated blocks are interconnected with each other using connectors. These connectors are links through which flows the flow of information.

It can be proceed to the actual experiment after the successfully construction and tests of the model. There can be seen the results in the form of graphs after the end of simulation. The results are displayed in the coordinate system and also can be imported into other applications.

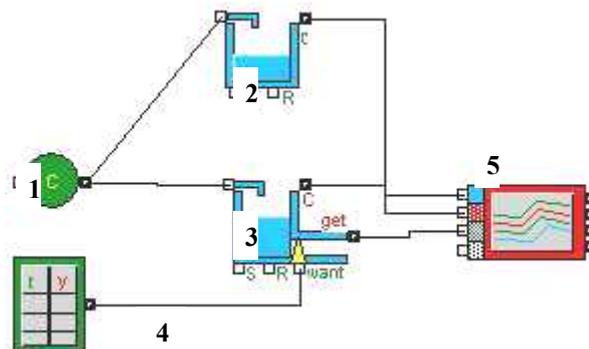


Fig. 3. Block diagram of the process of filling and emptying of the tank.

The compiled simulation model is the continuous simulation model, created from the block library "Generic" and "Plotter". Continuous simulation in language EXTEND is modelled in the course of discrete fixed time step. When an user sets a sufficiently small step for recording continuous simulation, then running the simulation values are close to the simulation of continuous mappings [1,2,3,6].

1st block "Constant" generates the same values in each step of the simulation, it represents a continuous filling machine – conveyor, which continuously fills the tank by a material in required quantity.

2nd block "Accumulate" adds the value accumulated in the tank, it represents a quantity of a material, which was supplied to the tank.

3rd block "Input data" is used to generate input values according to the simulation time, defined in the block table, it represents means of transport, their arrivals, departs and filling.

4th block "Holding Tank" has the same properties as the 1st block, but in addition through the connector block "want" values are taken out which are located in the block – it represents the outlet hole. The connector C shows the current status of the value in the block, it represents a level transmitter. The connector get shows the value of how much was reduced the total value of the block, it represents a flow meter. The connector S allows to change the initial value at the beginning of the simulation, in our case it represents the minimum amount before loading K_Z^{min} .

5th block "Plotter, I / O" processes data to the simple graphs and tables.

Simulation (SIM1): at time zero, there was the amount a material K_T^{\min} in the tank, and it was beginning of filling the tank and arriving of a vehicle. In Fig. 4 black curve shows the flow of material into the tank and the red curve shows the removal of material from the tank during the 120 minutes of simulation.

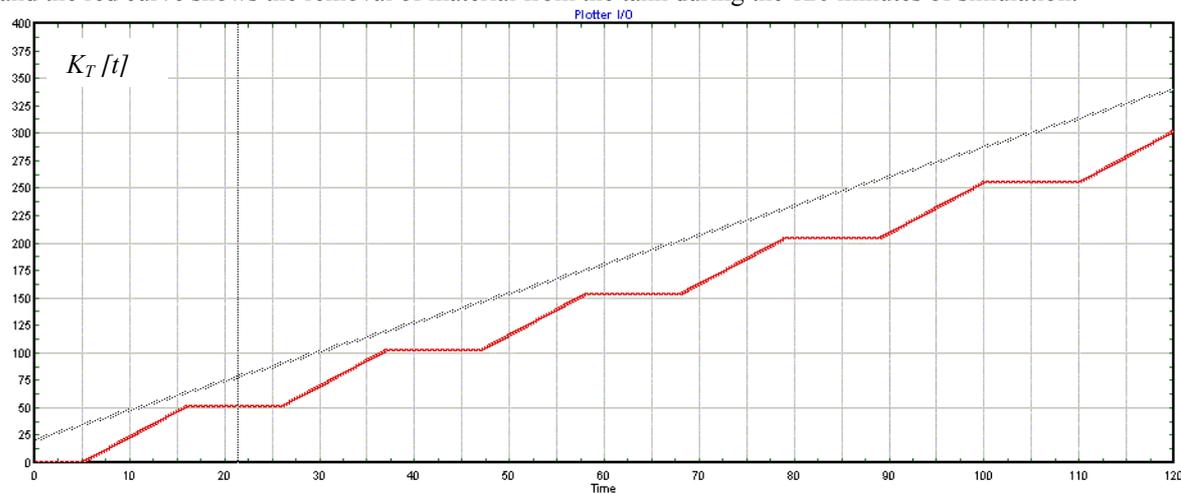


Fig. 4. Simulation SIM1 – the curves of incomes and outcomes of a material in the tank.

In the Fig. 5, the blue curve SIM1 shows the actual amount of a material in the container in tonnes. The green curve represents the emptying of the container (filling of vehicles - 21). Simulation was performed for 450 minutes (one working shift). It is evident, from the shape of the blue curve, that the amount of a material in the tank is increased by a time and at the end of a shift it could reach the quantity from 21 to 136 tons. The ideal situation would be if the amount of a material in the tank, at the end of the shift, was K_T^{\min} .

It can be reach this ideal situation by changes of the following:

1. power, in hours, of continual filling equipment – decrease of Q_h^{FD} (SIM2);
2. handling time (supply and removal) - decrease (SIM3);
3. capacity of vehicles - increase (SIM4);
4. the performance of the tank filling (it is not always possible, depending on the method of manufacturing technology and transportation process) (SIM5).

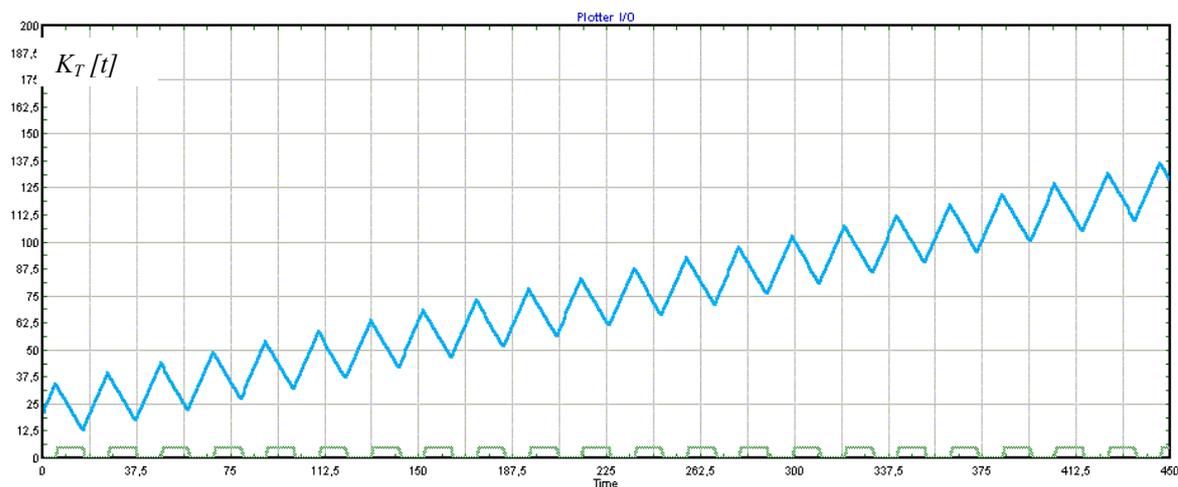


Fig. 5. Simulation SIM1.

Figure 6 shows the simulation (SIM2) in changing the power of continual filling equipment Q_h^{FD} from $160 \text{ t}\cdot\text{h}^{-1}$ to $150 \text{ t}\cdot\text{h}^{-1}$. There was also recalculated value $K_T^{\min} = 23 \text{ t}$ for given values for the simulation needs. The blue curve from the diagram shows, that the quantity of a material in the tank is not increasing so enormously as in SIM1 and after filling the 21st vehicle and before arriving of 22nd vehicle there is 32 tons

of a material in the tank. Finally the simulation reach the value K_T^{\min} by reducing the power of filling equipment at the given mode of loading and handling of vehicles.

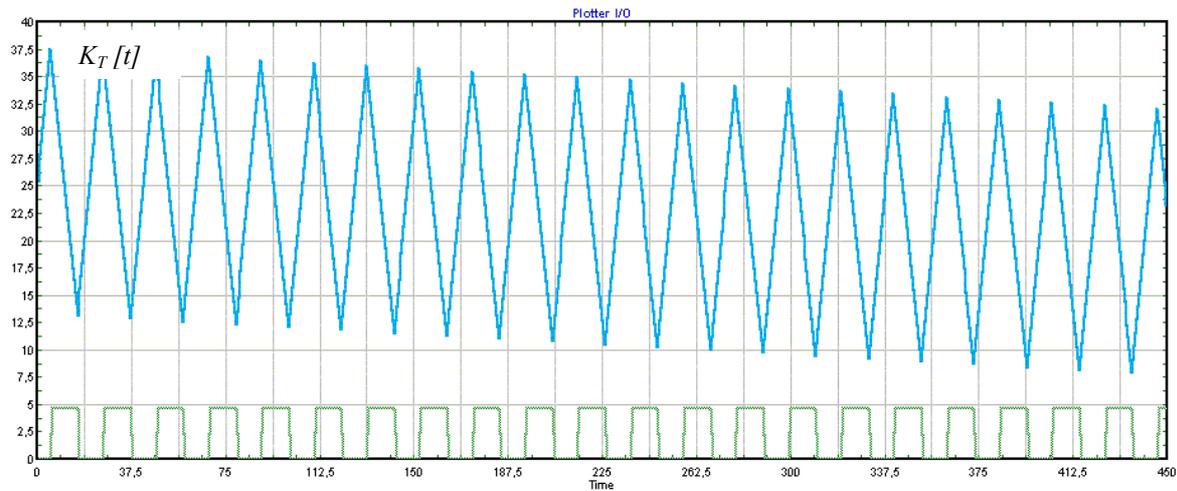


Fig. 6. Simulation SIM2.

Figure 7 shows the simulation (SIM3) at changing - reducing the handling time from 10 min to 8 minutes (however, to reduce the handling time may not be realistic in practice, it may not be possible from a technological point of view) for the specified values. The amount of material in the tank reaches near 0 value after filling with 23 vehicles, but during the exchange of vehicles the tank is filled to almost 22 tons.

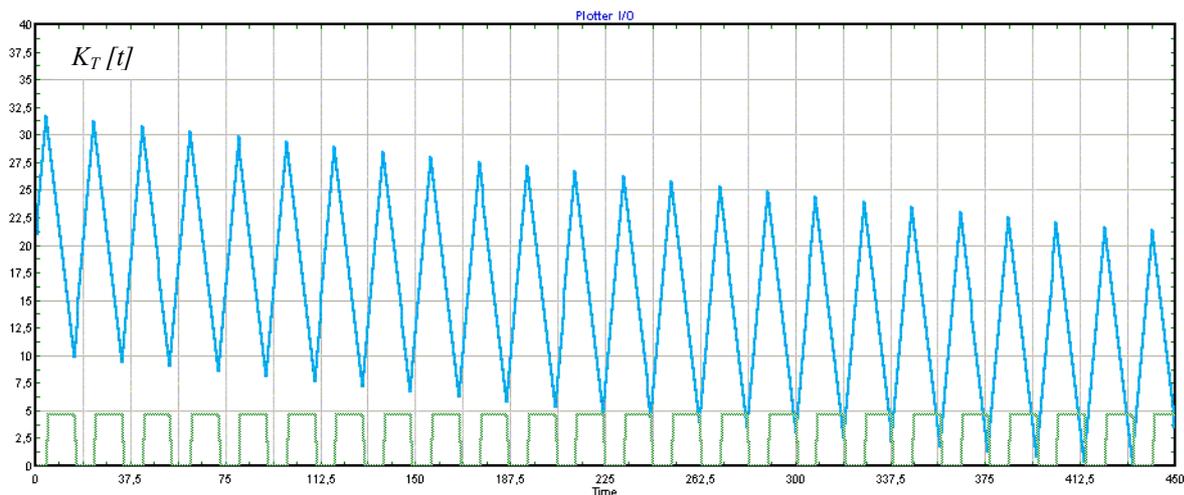


Fig. 7. Simulation SIM3.

The simulation (SIM4), in the fig. 8, shows the situation, when it is changed vehicle capacity $K_V = 63$ t at the original conditions. The time of filling of a vehicle is also changed from 11 to 14 minutes by changing the capacity. As it is evident from the green curves, nearly 19 vehicles are loaded during 450 min and the amount of a material in the tank reaches 26 tons.

If there is a tendency of increasing of the amount of a material in the tank in time as in SIM1 (also in SIM 4, but in lower rate), the value can be reached by change of the filling mode of the tank during a shift e.g. by stopping of filling the tank within regular intervals or when the set level of a material is reached in the tank. This type of change is not always possible, the technology production and transport process does not allow it. SIM5 Figure 9 shows the simulation process, at which it is stopped the filling of the tank when time is 415 minutes while the emptying of the container is kept.

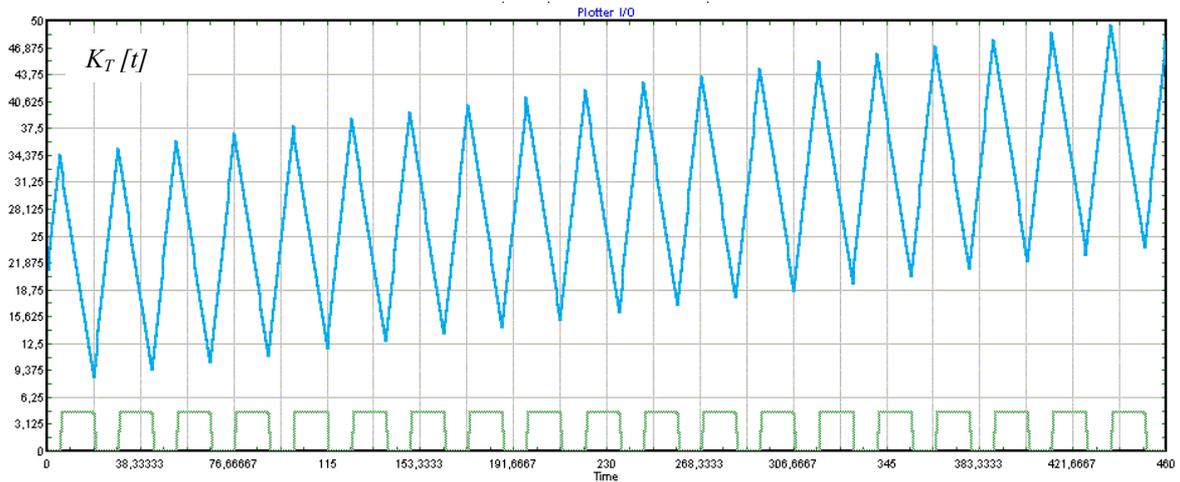


Fig. 8. Simulation SIM4.

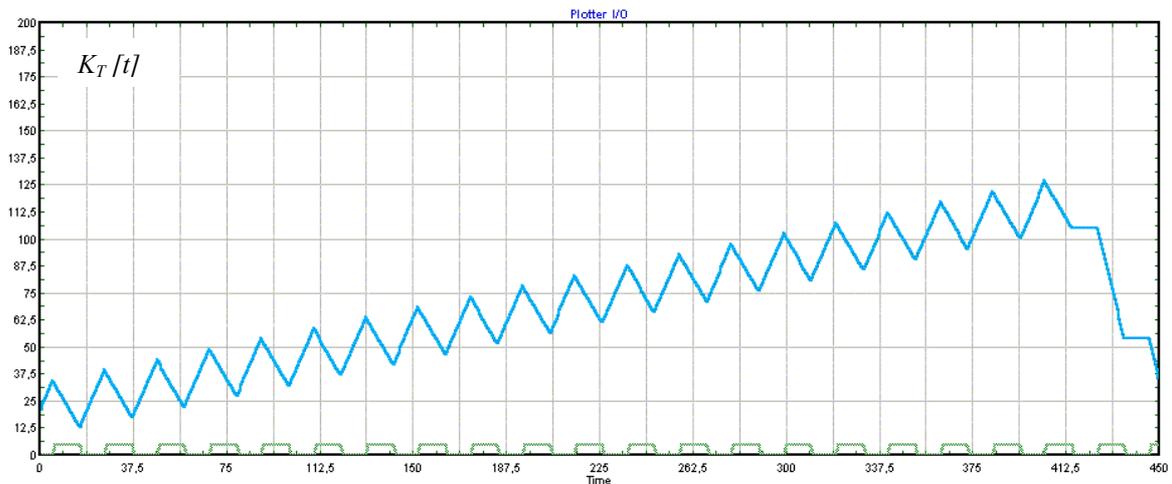


Fig. 9. Simulation SIM5.

The results of simulations SIM1 - SIM5 are summarised in the table 2 and in the figure 4.

Tab. 2. The comparison of simulations.

Parameter	SIM1	SIM2	SIM3	SIM4	SIM5
$Q_h^{FD} \text{ t.h}^{-1}$	160	150	160	160	160
$K_V \text{ t}$	51	51	51	63	51
$T_{VM, \text{min}}$	10	10	8	10	10
Number of loaded vehicles	21	21	21	19	21
$K_{Tmax} \text{ t}$	137	38	32	50	127
$K_F^1 \text{ t}$	1200	1125	1200	1200	1104
$K_F^2 \text{ t}$	1071	1071	1071	1197	1071
$R^3 \text{ t}$	129	55	129	3	33

¹ quantity of a material delivered into the tank during 450 min

² quantity of a material delivered from the tank during 450 min

³ difference of a material delivered to and from the tank in a simulated time

Conclusion

In addition to the above practical examples, emptying of tanks can be performed in vehicles of different types and different capacity. For example, there can be loaded various road trucks of varying capacity, train sets of various number of railway wagons. In this case it is necessary to take into account the exchange of a whole train set (furnishing of a train), not only the movement of railway wagons.

When deducting the maximum amount of material in the tank K_{Tmax} from the blue curve, the given amount is converted to volume $V_{Tmax} \text{ [m}^3\text{]}$ by bulk density of raw materials ($\rho \text{ [t.m}^{-3}\text{]}$). V_{Tmax} value is the basis for determining the tank dimensions and its capacity.

When designing the dimensions size and shape of a tank it have to be taken into account kinetic and dynamic properties, rheological properties of a bulk material, fluency of flow disorders (e.g. the risk of arch, arch formation, etc.), which may occurred due to storage conditions, the influence of environment and natural as well as the unpredictable properties of bulk materials.

The simulation model can be used for the new design and as well as in the case of redesign of some changes to the process of filling and emptying of existing tanks, somewhere in practice.

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