Coal homogenization stockyard sizing “Tamnava – Zapad” case study

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COAL HOMOGENIZATION STOCKYARD SIZING, “TAMNAVA – ZAPAD” CASE STUDY

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ABSTRACT

Coal homogenization stockyards are reliable locations for achieving consistent quality according to selected parameter. The purpose of quality homogenization is expressed by the selection of stacking method and stacking the requisite number of layers. The number of layers, stacking method, size and number of piles in the stockyard are selected by applying standard deviation as a statistical decision-making method. This paper presents considerations relating to coal stockyard sizing at the "Tamnava - Zapad" pit. The strata stacking method was selected. Approximately 50 layers need to be stacked for the entire deposit; however, depending on quality the number of layers will be variable, from 16 to over 150. The number of piles was also considered and stockyards with 4 and 6 piles were compared, and the advantages of a larger number of piles demonstrated.

Keywords: coal stockyard, coal homogenization, coal pile, stacker, reclaimer

INTRODUCTION

Every homogenization stockyard consists of several autonomous piles. When the stockyard is connected with a port or commercial stockyard, every pile contains coal of consistent and known quality, and blending coals of various qualities produces the quality the customer demands. However, when the stockyard is connected with a mine (pit), it is used for homogenization of run-of-mine coal or other ore or material. In order to restrict the time necessary for homogenization activities, stockyards are divided into smaller units, piles, used for homogenization of coal delivered in a relatively short period of time. Viewed on stockyard level, each pile contains coal of equal quality, i.e. the quality the customer demands. Sizing a coal homogenization stockyard is practically carried out in two steps. The first step involves sizing the pile, and the second determining the number of piles. i.e. the overall size of the stockyard. In both cases the length, width and height of the stacked coal are sized. In these considerations the problem of self-inflaming of coal, availability of space, availability of funding, etc., are not taken into account. Only the technical and technological parameters affecting the size of the pile and stockyard are considered.

The size of each pile depends on the stacked coal quality. The term "coal quality" is not clearly defined and is treated differently from pit to pit. The common element in all considerations is selection of parameters whose variations have the greatest negative impact on the combustion process, whether because of combustion problems, or impact on the power plant equipment, or environmental impact. Although each parameter has a dominant impact on one of the listed system segments, the fact is that such variations have a negative impact on all of the listed elements.

Coal stacking and reclaiming simulations for evaluating the performances of the modelled stockyard can be conducted in several manners. Zhao et all (2015) modelled a stockpile as a grid of voxels (octants), associated with machine operations.Their 3D quality embedded model can be used to calculate, plan, control and predict the quality of ore being stacked and/or reclaimed with a great degree of accuracy. Robinson (2004) presents mathematical and computer models for the geometry of a stockpile, using both actual grade data and a variogram to describe the input variation. An application of efficient methods of conditional simulation for optimizing coal blending strategies in large continuous open pit mining operations (Benndorf, 2013.) integrates simulated realizations of the deposit with a simulation of transport- and blending models of mining operation. Beretta, et al (2010) used geostatistical simulation for reducing coal quality attributes variability using properly designed blending piles. These models allow assessing the uncertainty associated with the attributes content in the ore.

A software tool for the prediction of the coal blending efficiency in longitudinal stockpiles takes as input the standard deviation and the autocorrelation of the coal property (for blending), then the program initially creates a time series of property values for the coal delivered to the stockyard. Next, the data sequence is rearranged by simulating the operation of the stacking and reclaiming equipment. The output sequence of property values reflects the quality of the coal after blending. Case study from northern Greece mines show that coal-blending efficiency is a function of the capacity of the stockpile, the number of stockpile layers and the combination of the applied stacking and reclaiming methods. (Pavloudakis & Agioutantis, 2001)

For "Tamnava Zapodno-Polje" a simulation was run on a small test site using data from the technological block model, as well as simulated data based on statistical parameters: average value and standard deviation. It should be pointed out that increasing the number of layers decreases variability, but the average value remains the same, so if the average value is outside the desired range, there is no stockyard geometry that will produce the desired output. Considering the increasing variability of coal quality in TZP, determining the geometry should be considered in the context of the other components of the Coal Quality Management System, and not separately.

COAL QUALITY

Regarding coal quality, an important parameter relates to the quality range of the parameter of interest. Most often the parameters of interest are the lower heating value and sulphur content, but other parameters are also an option (iron or mercury content, ash content...) [Ignjatović et al. 2007]. When the anticipated quality range of the observed parameter is small, the stockpiling conditions (number of layers, size or length of the pile) can be considered to be fixed. When this anticipated range is large all stockyard parameters are variable, practically on a daily basis, especially the number of layers and length of the pile.

The quality of lignite extracted in Serbia is characterized by large variations in moisture and ash content, resulting in variations in lower heating value. The sulphur content is low, as is iron content, while mercury is monitored only sporadically. [Stevanović et al., 2015]. Thus the homogenization process is logically directed towards homogenization of heating value, as the primary parameter.

At the pits operated by Mibrag (Germany) the leading parameters for coal stockyard homogenization are heating value, at the Profen pit, and iron content at the Schleenhain pit [Ignjatović et al., 2007]. Thus different coals, even from pits located close to one another, have different qualities and are homogenized according to different primary parameters.

The number of layers in each pile is selected depending on variability and the value range of the parameter defining the coal quality, while the stacking method depends on the number of layers.

STACKING METHODS AND NUMBER OF LAYERS PER PILE

Generally speaking, there are two basic stacking methods, chevron and windrow, from which ten or so sub-methods have been derived by modifications thereof. When the required number of layers is small, the chevron method or a modification thereof is selected, whereas the method of choice when a large number of layers is required is windrow or a combination of the chevron and window methods. Given than the windrow method is technologically more complex and requires the use of more complicated and more expensive machines, the chevron method is generally more desirable. There is no general rule defining which number of layer is considered small and which large, but in general practice up to 100 layers is considered a small number, and above that a large number of layers.

The number of layers that ensures consistent quality of the stacked coal is linked to the value range of the observed parameter, and is determined by statistical methods - through standard deviation. When quality is assessed based on lower heating value, the acceptable range for a power plant, as the end user, is considered to be ±500 kJ/kg [Ignjatović et al, 2007, Stevanović et al, 2015]. By observing the standard deviation, a diagram can be plotted where the number of layers is given as a function of the value range of the observed parameter. Figure 1 shows a standard deviation diagram for lignite from the "Tamnava – Zapad" pit [Knežević et al, 2014], where the x-axis shows the number of layers in a pile (package), while the y-axis shows the standard deviation for LHV, and the narrow gray lines show the different simulations. The bottom and top dotted lines show the minimum and maximum simulated values, while the middle dotted line is the arithmetic mean of the simulations.

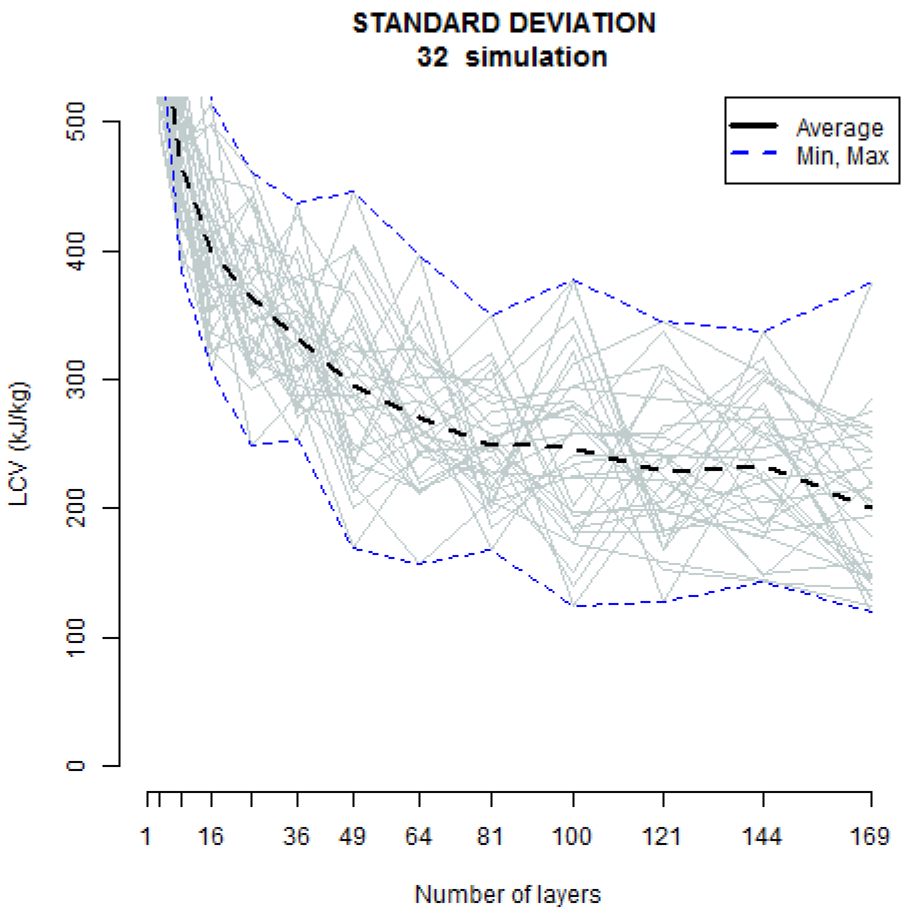

Figure 1. Number of coal stacking layers at the "Tamnava - Zapad" pit as a function of standard deviation expressed through variations in heating value [Knežević et al, 2014]

It can be seen from the diagram in Figure 1 that there is no clear answer as to how many layers coal should be stacked in, but that this depends on the selected range. If the range of 500 kJ/kg that is set by contract is accepted, it is sufficient to stack coal in (only) 16 layers. However, the diagram was plotted based on results obtained by analysis of a certain number of samples from the entire deposit. Not considering the representativeness of the simulated data there is always suspicion that variations in certain parts of the deposit are much greater, meaning that the selected number of layers will not be sufficient for the homogenization process to be carried out. It then follows that for the contractually specified range, in deciding on the level of the pit (mine), for safety reasons that range should be decreased, particularly considering the level of data confidence and exploration of the deposit. This increases the number of stacking layers. In the example shown in Figure 1 it can be seen that for a range of 300 kJ/kg the number of layers should be around 50, while for an extremely small range of 200 kJ/kg more than 170. So, in general, for the entire stockyard the number of layers is around 50, however both a smaller and a larger number of layers should remain an option.

By selecting the number of layers that need to be stacked in order to get coal of uniform quality, the stacking method/sub-method can also be defined. In the case of the "Tamnava - Zapad" pit the selected method was the strata method from the chevron group. The strata method is characterized by the forming of conical piles along the entire stacking length. The first strata pile is formed at the edge, and then each following "layer" is stacked by retreating towards the centre with the necessary increase in height, depending on the required number of layers. In order to apply the strata method, the stacker should be able to stack while travelling on a rail, and the boom should be capable of moving horizontally and vertically. The strata method can be applied by changing the angle between the boom and the stack axis, that is, no boom telescoping is necessary.

Since coal quality determines the number of layers, the stacker speed should be adjusted accordingly. The stacker speed differs for different numbers of layers. However, a problem is encountered when the quality range is large, and the stacker has to work with a large difference in number of layers. Smaller ranges of observed parameters require a smaller number of layers, and vice versa. A small number of layers require a slow stacking speed, but the constructional characteristics of the stacker and its minimum permitted speed need to be taken into account. Because of risk of overheating of the electric motor, every stacker has a minimum travel speed (around 2-4 m/minute), which then restricts the minimum number of layers. This consideration should include an analysis of the stacker's operating capacity. This capacity depends on the operating capacity of the pit, which is quite variable in short intervals (second, minute). In order for the layer sizes to be equal, the stacker has to change travel speed depending on the quantity of coal arriving at the stockyard. The regulation unit applied is mass per minute. Thus the stacking speed for the selected method depends on the number of layers, the stacking capacity and the constructional capabilities of the stacker. What this looks like in practice can be observed on the example of coal stacking at the "Tamnava - Zapad" pit shown on the diagram in Figure 2.

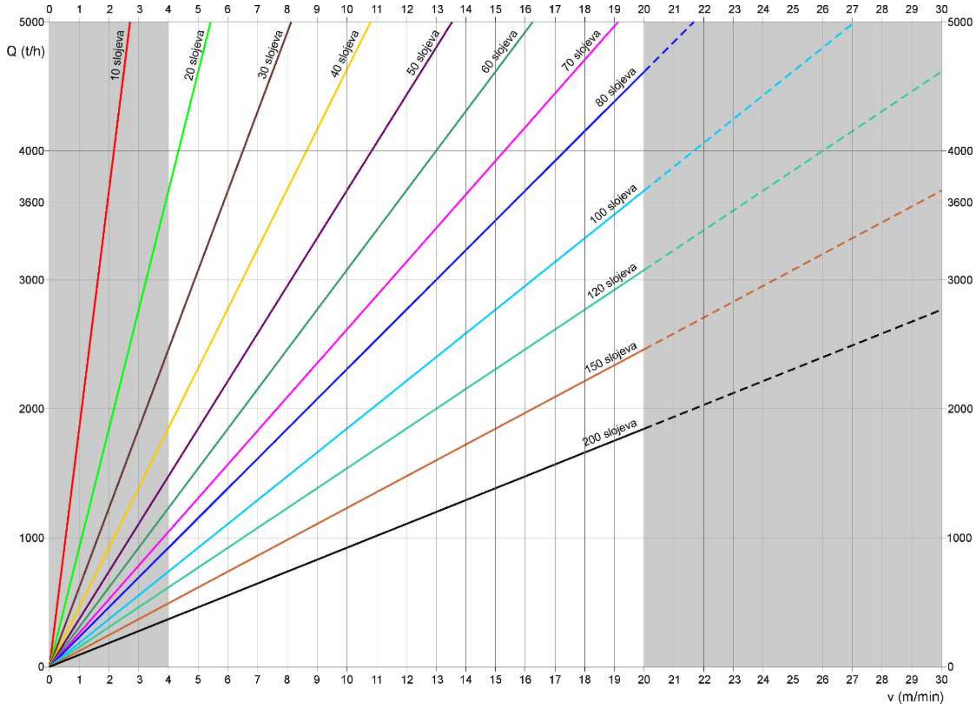

Figure 2. Changes of stacking speed as a function of the number of layers, capacity and capabilities of the stacker stacking coal from the "Tamnava – Zapad" pit

Thus for the maximum hourly pit capacity of 5000 t and the permitted speed range of the stacker (4-20 m/min) coal can be stacked in 16 to 90 layers. For a more realistic hourly capacity, the minimum and maximum number of layers changes. For a pit rate of 3000 t/h, coal can be stacked in 25 to 150 layers.

The example in Figure 2 shows the problem when the pit operates at a lower capacity, and in a zone containing coal with a small quality range. To avoid the stacker operating below minimum travel speed, it will occasionally have to stop and stack, which is not rare in practice, Figure 3. The opposite problem occurs when the quality range is large and when coal needs to be stacked in a large number of layers. The stacker can resolve this by not luffing the boom layer by layer, but by several layers (3-5), while continuing to travel horizontally for each layer. Luffing by several layers will not significantly elevate the stacking point relative to the pile, because of the large number of layers, so there will be no additional scatter of small pieces of coal. Another way to resolve the problem of extremely small and extremely large numbers of layers, relative to the average selected for the entire deposit, is by changing the length of the pile. Thus in this case the pile and its geometric parameters should not be considered fixed; shortening or lengthening the pile can resolve the problem.

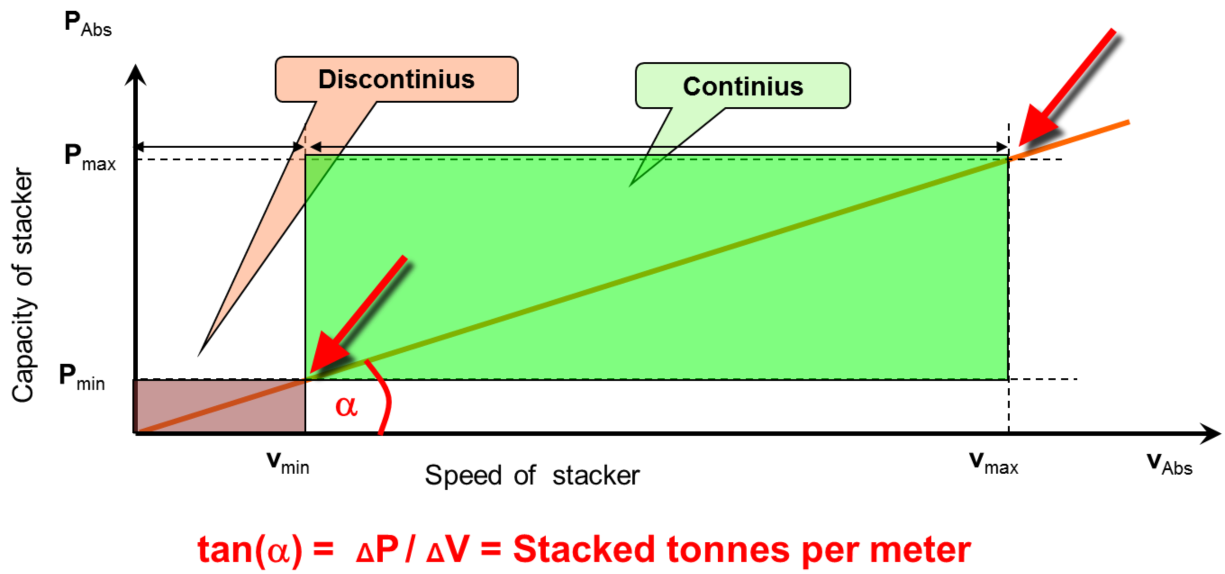

Figure 3. Zones of continuous and discontinuous stacker operation

Software application comprises the components for stacking and reclaiming, for Tamnava West using Strata model, as presented in the figure.

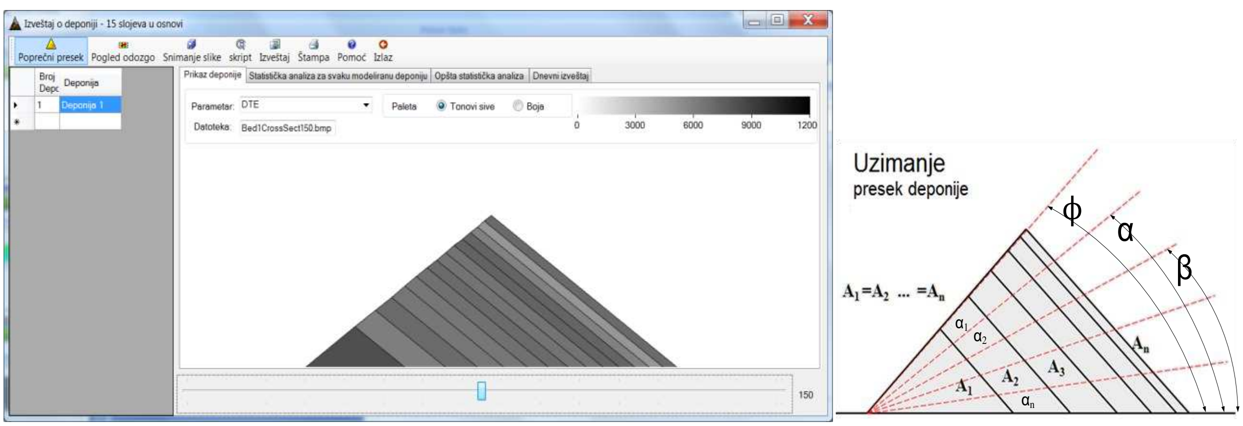

Figure 43. Staking simulation

PILE SIZE

Variability of the geometry of each pile causes problems in organizing operations at the stockyard and arranging coal stacking and reclaiming. Namely, the rule is that piles are alternately filled and emptied, so that when the pile is being filled it is filled completely, and emptied completely when being emptied. In the example of coal from the "Tamnava - Zapad" pit filling takes 18 to 30 hours (net), meaning a gross value of 1 to 2 days, while emptying takes twice as long. The variability of pile size moves this rule, because filling a shorter pile will take a shorter amount of time, and conversely, a longer pile takes longer to fill. Of course, planning pit operations as a function of block quality at the deposit can resolve this practical problem.

Thus from the aspect of stockpiling, the size of the pile depends on the stacking capacity and the value range for the selected parameter defining coal quality. The number of piles, apart from the aforementioned, also depends on the organization of stacking and reclaiming operations and on the necessary reserves which enable autonomy of pit and power plant operations.

STOCKYARD SIZE AS A FUNCTION OF COAL RECLAIMING METHOD

Just as there are several stacking methods, there are also several methods for reclaiming material from stockyards. The reclaiming method does not greatly affect the size of the homogenization stockyard, since most of the activities of importance for achieving consistent quality are completed at the pit, in transports and during the stacking stage. However, to round up the process it is necessary to select the reclaiming method that will most effectively ensure consistent quality of the reclaimed coal. The strata stacking method is characterised by conical stacking in a row parallel to the rails the stacker travels on. Given the possible significant differences in quality of coal stacked in different layers, it is important to select a reclaiming method which slices though several or all of the stacked layers. Thus the reclaiming direction should be at a 90^{o} angle to the stacking direction. Therefore, at the stockyard of the "Tamnava - Zapad" pit the selected reclaimer is a scraper which can best slice crosswise through the entire pile.

NUMBER OF STOCKYARD PILES DEPENDING ON ORGANIZATiON OF STACKING AND RECLAIMING

The smallest number of piles is two, because that enables simultaneous filling of one and emptying of the other pile. Because of the different capacities of stackers and reclaimers (roughly speaking, stacking it twice as fast as reclaiming), this number is not recommended. This therefore raises the minimum number of piles to three, if the piles are all in the same row, or 4 if the piles are in two rows. Arranging the piles in a single row is more practical, because one fewer reclaimer can be used, but does not have to be, while the probability of collisions between stackers and reclaimers is lower than with stockyards arranged in two rows. However, stockyards arranged in two rows enable greater comfort in organizing operations, increasing the number of piles and ensuring larger reserves at the stockyard. The relationship between the number of rows and reserves at the stockyard is shown in Figure 4 and Table 1 on the example of the "Tamnava - Zapad" pit. The example shows stacking in two rows, in four and six piles when the stacking capacity equals the reclaiming capacity, because 2 reclaimers and one stacker are used.

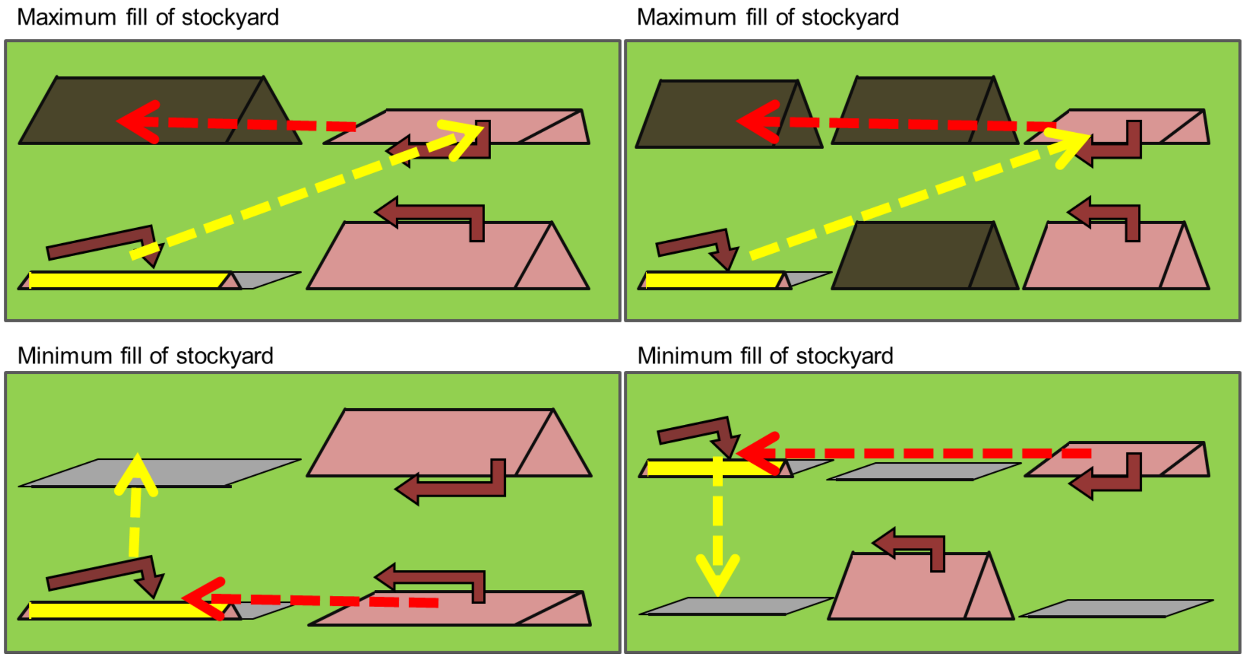

Figure 4. Number of piles for the purpose of securing reserves at the stockyard

Table 1. Comparing coal stockyard capacity utilization with 4 and 6 piles

	Number of packages	
	2 + 2	3 + 3
Total length	570 m	
Coal mass, total	400,000 t	375,000 t
Coal mass per package	100,000 t	**65,000 t**
Reserve	8 days	**7.5 days**
Time per package	6 shifts	**4 shifts**
Max. number of filled packages	**2.5**	4.5
Min. number of filled packages	1.5	1.5
Max. coal mass at coal yard	**250,000 t**	270,000 t
Min coal mass at coal yard	**150.000 t**	90,000 t
Difference (Delta)	**100,000 t**	180,000 t

Thus, statistically speaking, a larger quantity of coal can be stored in the same area if there are fewer piles, because less space is left between piles. The homogenization stacking system always starts so that at least one pile is completely filled, while another is being emptied. The further course of operations is dependent on harmonizing the pit capacity with the capacity of shipping to the power plant, however the stockyard should never remain completely empty. Because of the organization of operations with simultaneous stacking and reclaiming, Figure 4, the maximum quantity of coal that can be stacked is larger if the number of piles is larger, while the minimum quantity is smaller, meaning that the difference between them is greater and more favourable if the number of piles is larger. Of course, for organizational reasons the number of piles cannot be increased indefinitely, but is always around a rational 4 to 8 piles.

CONCLUSION

At open pit "Tamnava - Zapad" coal quality homogenization is planned according to lower heating value, and the process takes place in several steps. The homogenization entails realistic planning of surface mining based on a precise and accurate coal quality database and proper use of available equipment. However, anticipated large oscillations and a large value range for lower heating value can result in inability to achieve the required results at the pit, without stifling the capacities and with a technologically normal development of the pit. Therefore, in all dubious situations use of a new homogenization stockyard with crushed coal is planned.

The considerations relating to stockyard sizing have shown that homogenization stockyards should be sized completely differently than a reserve stockyard for autonomy of pit and power plant operation. Instead of defining the required daily reserves, homogenization stockyard sizing is based on the quality range of the observed parameter. In the case of the "Tamnava - Zapad" pit, the observed parameter is heating value. Because of the variability of this parameter, the pile size was considered in stages, first as pile size, and then as the sum of all piles. Standard deviation was used to measure success of operation and the required number of layers at the stockyard, while the selected travel speed of the stacker depends on coal quality, the operating rate of the mining machines and the capacity of the stacker. The selected reclaimer is a scraper, which slices each pile crosswise, taking coal from each of the stacked layers.

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