

# Analysis of Availability of Longwall-Shearer Based On Its Working Cycle

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**Abstract.** Effective use of any type of devices, particularly machines has very significant meaning for mining enterprises. High costs of their purchase and tenancy cause that these enterprises tend to the best use of own technical potential. However, characteristics of mining production causes that this process not always proceeds without interferences. Practical experiences show that determination of objective measure of utilization of machine in mining company is not simple. In the paper methodology allowing to solve this problem is presented. Longwall-shearer, as the most important machine between longwall mechanical complex. Also it was assumed that the most significant meaning for determination of effectiveness of longwall-shearer has its availability, i.e. its effective time of work related to standard time. Such an approach is conforming to OEE model. However, specification of mining branch causes that determined availability do not give actual state of longwall-shearer's operation. Therefore, this availability was related to the operation cycle of longwall-shearer. In presented example a longwall-shearer works in unidirectional cycle of mining. It causes that in one direction longwall-shearer mines, moving with operating velocity, and in other direction it does not mine and moves with manoeuvre velocity. Such defined working cycle became a base for determinate availability of longwall-shearer. Using indications of industrial automatic system for each of working shift there were determined number of cycles of longwall-shearer and availability of each one. Accepted of such way of determination of availability of longwall-shearer enabled to perform accurate analysis of losses of its availability. These losses result from non-planned shutdowns of longwall-shearer. Thanks to performed analysis based on the operating cycle of longwall-shearer time of its standstill for particular phase of cycle were determined. Presented methodology of determination of longwall-shearer's availability enables to obtain information which may be used for optimization of mining process. Knowledge of particular phases of longwall-shearer's operation, in which reduced availability occurs, allows to direct the repairing actions exactly to these regions. Developed methodology and obtained results create great opportunities for practical application and improvement of effectiveness of underground exploitation.

## 1. Introduction

Fast development of technology proceeding in last years in more extent is also used in mining industry. Especially it is regarded to mining machines applied in a process of minerals exploitation and their transport. These machines, thanks to application of novel solutions and optimization of their constructions and operational parameters become more reliable and durable. Also their technical parameters, having significant influence on their efficiency are increased. Application of better, more



effective, reliable and safe machines in mining industry is being observed around the world. It regards also to Polish hard coal mining engineering.

In the last years more technically advanced machines are applied in mines. However, not always high quality of machines being used, translates to the effectiveness of the entire mining process. In recent years in Polish hard coal mines despite the application of new types of very effective machines, a significant increase of mining process effectiveness was not observed. The effectiveness of this process includes operational effectiveness of particular machines taking part in this process.

Effective use of any type of devices, particularly machines has very significant meaning for mining enterprises. High costs of their purchase and tenancy cause that these enterprises tend to the best use of own technical potential. However, characteristics of mining production causes that this process not always proceeds without interferences. Practical experiences show that determination of objective measure of utilization of machine in mining company is not simple. In the article there are presented the methodology allowing to solve this problem.

Authors of the paper decided to apply in the effectiveness analysis of mining machines an OEE model (Overall Equipment Effectiveness), being a quantitative tool of TPM strategy (Total Productive Maintenance) [1, 2, 3]. In their opinion, this model allows analysis of machines' operation in the three most significant enterprise exploitations fields.

It concerns availability of machine, its effectiveness and quality of an output. Analysing the whole technological process of underground hard coal mining one assumed, that the most significant meaning in this process has a direct rock mass mining stage (including the coal).

Because machines applied in this stage decides on amount and quality of the product which in this case is the hard coal. These machines are longwall-shearer, armoured face conveyor, beam stage loader, crusher and powered roof support [4, 5, 6].

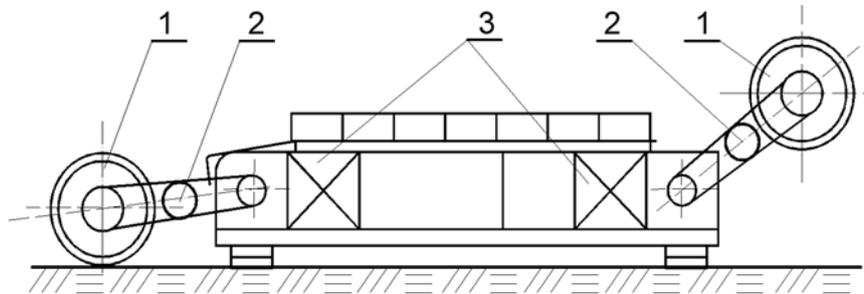
Longwall-shearer, as the most important machine between longwall mechanical complex. Also it was assumed that the most significant meaning for determination of effectiveness of longwall-shearer has its availability, i.e. its effective time of work related to standard time. Such an approach is conforming to OEE model. However, specification of mining branch causes that determined availability do not give actual state of longwall-shearer's operation. Therefore, this availability was related to the operation cycle of longwall-shearer. In presented example a longwall-shearer works in unidirectional cycle of mining. It causes that in one direction longwall-shearer mines, moving with operating velocity, and in other direction it does not mine and moves with manoeuvre velocity. Such defined working cycle became a base for determinate availability of longwall-shearer.

Using indications of industrial automatic system for each of working shift there were determined number of cycles of longwall-shearer and availability of each one. Accepted of such way of determination of availability of longwall-shearer enabled to perform accurate analysis of losses of its availability. These losses result from non-planned shutdowns of longwall-shearer. Thanks to performed analysis based on the operating cycle of longwall-shearer time of its standstill for particular phase of cycle were determined. Presented methodology of determination of longwall-shearer's availability enables to obtain information which may be used for optimization of mining process. Knowledge of particular phases of longwall-shearer's operation, in which reduced availability occurs, allows to direct the repairing actions exactly to these regions. Developed methodology and obtained results create great opportunities for practical application and improvement of effectiveness of underground exploitation.

Presented concept of determination of availability of longwall-shearer consist the new approach to the analysis of its work. Authors assumed that the work cycle of the longwall-shearer can be very interesting time perspective for analysis of its operation. In these analyses unpredictability of external conditions, in which the longwall-shearer works, should be included. Nevertheless, proposed methodology in more precise way should allow for analysis of operation of investigated longwall-shearer.

## 2. Characteristics of the tested longwall shearer

Longwall-shearer, which scheme is presented in Figure 1, and technical parameters in Table 1, was subjected to tests.



**Figure 1.** Scheme of the longwall shearer: 1 – cutting head, 2 – motor of cutting head, 3 – haulage motor

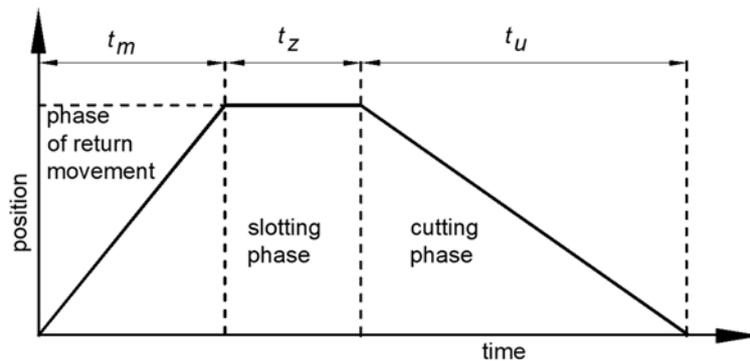
**Table 1.** Technical specification of the longwall shearer.

Specification	Value of the parameter	Value of the parameter in the longwall conditions
Cutting range	for 2.0 m to 3.4 m	to 3.0 m
Maximum power installed:		
– on cutting drums,	2x375 kW	2x375 kW
– on haulage drive,	2x60 kW	2x60 kW
– on hydraulic system.	2x13 kW	2x13 kW
Total installed power	896 kW	896 kW
Supply voltage	3,3 kV	3.3 kV
Cutting drum diameter	2000 mm	2000 mm
Cutting drum web	800 mm	800 mm
Operational Haulage speed	0 – 12 m/min	0 – 12 m/min
Weight	47.85 ton	47.85 ton

This longwall-shearer worked in mining longwall in technology with unidirectional mining. It consists in that the longwall-shearer in one direction mines the rock mass with operating velocity, and in other direction it moves with maneuver velocity without mining the rock mass. In a case of unidirectional mining, longwall-shearer cuts the coal only in one direction (operating movement), whereas in the movement in opposite direction (maneuver movement) only loading of coal takes place.

For this mining technology only one slotting out of longwall-shearer takes places, *i.e.* at the beginning of the operating movement. In a case of bidirectional mining, longwall-shearer slot out twice, at each end of longwall, and mines in both directions. Unidirectional mining is characterized by lower effectiveness, than the bidirectional one. Advantage of this way of exploitation is more precise mining of seam, assurance of better work of armored face conveyor and achievement of better size grade of coal. It translates directly into the better economic effects of this process.

Simplified scheme of work cycle of longwall-shearer during unidirectional mining is presented in Figure 2. Also particular stages of the cycle are marked in this figure.



**Figure 2.** Simplified scheme of work cycle of longwall-shearer during unidirectional mining

The concept of the production cycle generally should be understood as the time which is required to complete a particular production task. It means that it is the time between the beginning and the end of the production process of the finished product [5, 7]. Most often, the measure of the cycle is time. The adoption of such a definition of the production cycle in case of underground mining does not fully reflect the essence and specificity of this process. Therefore, in the paper it was assumed that the production cycle in the zones of the longwall faces in the coal mines is a set of operations that are repeated in the specific order and time which is necessary to move the longwall's face at the distance of one take (drum web) [7]. The time needed for these operations was taken as a measure of the production cycle. For this reason, Figure 2 shows the total cycle time ( $T_c$ ), the cutting time ( $t_u$ ), the slotting time ( $t_z$ ), as well as time for returning ( $t_m$ ). The sum of the time of cutting, slotting and returning (manoeuvring) determines the total production cycle time:

$$T_c = t_u + t_z + t_m \quad (1)$$

In case of underground mining, it is worth mentioning about the technological cycle which includes the activities and operations that are necessary to carry out longwall exploitation but are not carried out during the production cycle. These activities include, for instance, rebuilding of crossings in a maingate and tailgate, moving of an armoured face conveyor and shortening of a belt conveyor [5, 6, 7].

### 3. Results and discussions

As it has already been mentioned, the longwall shearer is the basic part of the mechanized longwall system, and its primary task is to cut out the coal. The basis of an availability analysis of the studied shearer was the data obtained from the industrial automation system. Table 2 presents the parameters of the longwall shearer's work that have been recorded by the system and used for the analysis.

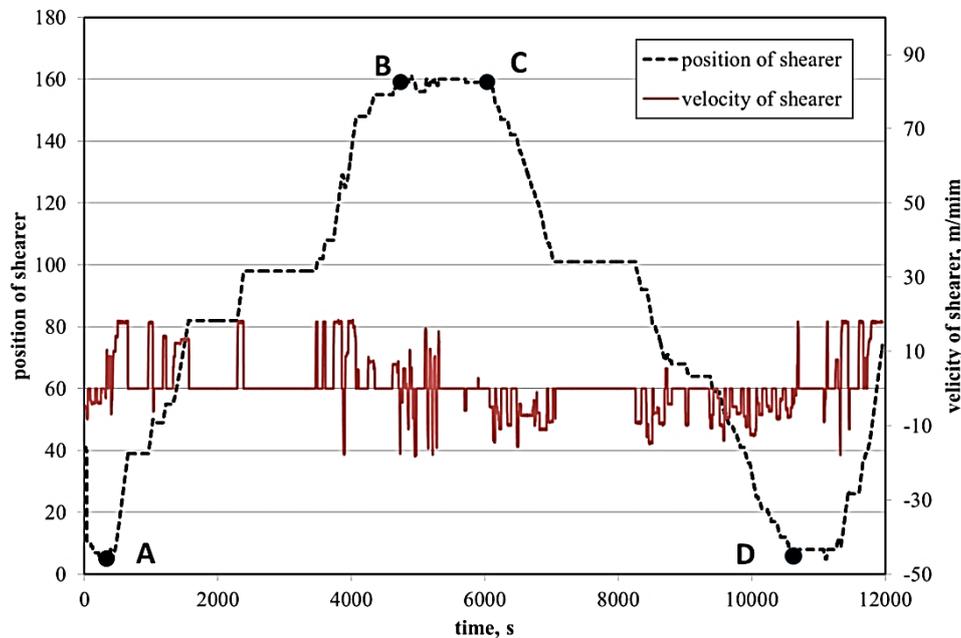
**Table 2.** Summary of recorded parameters of the longwall shearer's work.

Parameter	Designation	Parameter	Designation
Velocity of haulage	VelHaulage	Position of shearer	Mach_shield pos
Current of the left cutting engine	RCutterCurrent	Current of the right cutting engine	LCutter Current
Current of the left haulage	LHaulage Current	Current of the right haulage	RHaulage Current

Based on the recorded data, the analysis of the longwall shearer's work was conducted. The basis of this analysis was the cycle of its work determined by the shearer's position in relation to sections of

the roof support. This analysis also takes into account currents consumed by the shearer's engines and its velocity.

Figure 3 shows the temporal velocity waveforms and positions of the longwall shearer during one exemplary work cycle.



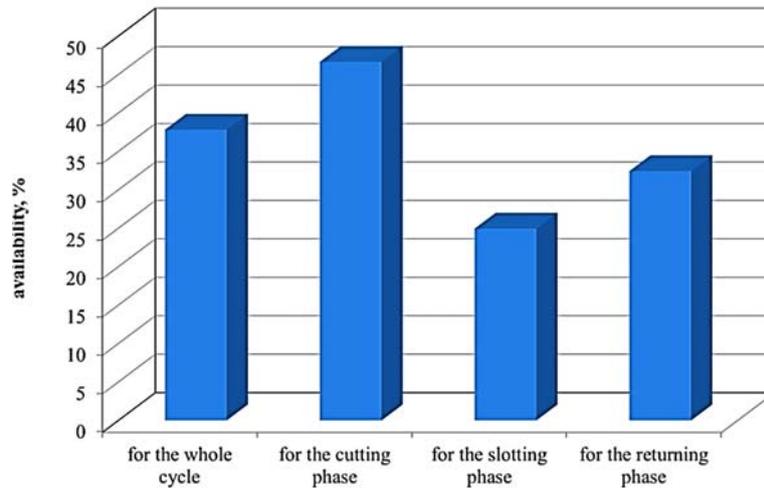
**Figure 3.** Temporal waveforms of the velocity and position of the longwall shearer for one cycle of its operation

By analysing the presented waveforms, it can be claimed that the presented work cycle was 171 minutes and 38 seconds long ( $T_c = 10\,298$  sek.). During this cycle, the cutting time was 76 minutes and 29 seconds ( $t_u = 4\,589$  sek.), the slotting time was 21 minutes and 39 seconds ( $t_z = 1\,299$  sek.) and the returning time was 73 minutes and 30 seconds ( $t_m = 4\,410$  sek.). The further analysis of the cycle enabled the determination of downtimes registered for each phase of the cycle. Table 3 shows the obtained results that characterize the studied cycle of the shearer's work.

**Table 3.** Characterize the studied cycle of the shearer's operation.

Parameter	Time [s]
Time of the whole cycle	10 298
The cutting time	4 589
The slotting time	1 299
The returning time	4 410
Downtimes during the cutting phase	2449
Downtimes during the slotting phase	975
Downtimes during in the returning phase	2980
Total downtimes	6404

Based on the data, presented in Table 3, the total availability indicator of the longwall shearer's work for the presented cycle and the partial availability indicators for each phase of the cycle were determined. Figure 4 presents the availability values for the analyzed cycle of the shearer's work.

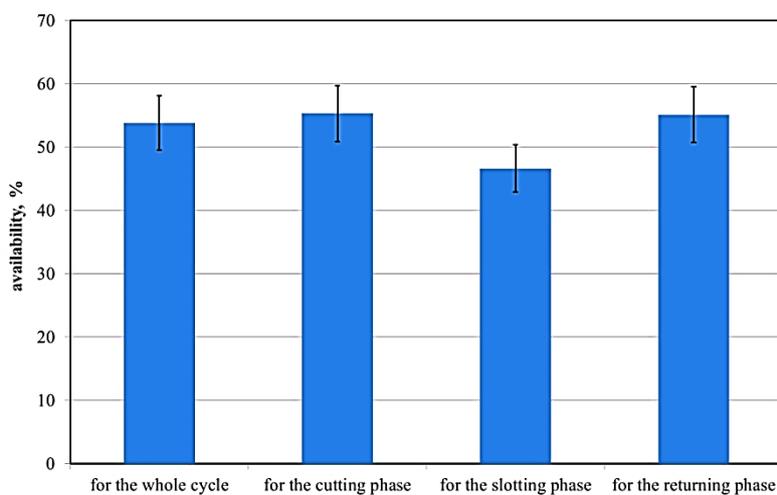


**Figure 4.** Values of availability indicators of the longwall shearer’s work for the presented cycle

Similar analyzes were carried out for the next 20 cycles of the shearer’s work. Table 4 shows the determined average values of the particular times that characterize these cycles. Moreover, Figure 5 presents the average values of the shearer’s availability indicators for the studied 20 cycles, taking into account the individual phases of the cycles.

**Table 4.** Average values of the particular times that characterize 20 cycles of the shearer’s work.

Parameter	Time, [s]
Time of the whole cycle	7661±1132
The cutting time	3865 ±531
The slotting time	898 ±193
The returning time	2898 ±593
Downtimes during the cutting phase	1763 ±531
Downtimes during the slotting phase	498 ±193
Downtimes during in the returning phase	1359 ±576
Average downtimes for the cycle	3622 ±1112



**Figure 5.** Average values of the shearer’s availability indicators for the studied 20 cycles, taking into account the individual phases of the cycles

#### 4. Conclusion

One of the areas, where there are opportunities to effectively reduce the cost in mining companies, is that one which includes a selection and a use of all types of technical equipment, in particular mining machinery. It is necessary to acquire adequate knowledge about the level of a technical resources use in these companies to make taken actions efficient.

The presented analyzes of the longwall shearer's availability shows how important this issue is. Despite the fact that this machine is technically highly advanced, its use is unsatisfactory.

By analysing the obtained values of the availability indicators of the shearer, it can be claimed that they are low. However, the division of the shearer's work into different phases makes it possible to conduct a very thorough analysis. It can also be seen that the greatest losses of availability occur in the cutting phase. The main causes of these losses are unplanned downtimes. Therefore, it is justified to take appropriate actions to identify the real reasons for recorded downtimes and then, to improve the values of availability indicators.

The obtained results may provide the basis for a more comprehensive analysis of the longwall shearer's work and reasoning in the range of the necessary actions that should be taken to improve this state. Particularly, the presented results should form valuable source of information for the maintenance service.

The results of the study clearly indicate that there are a lot of reserves in the availability area of examined mining machines and the indicators values are unsatisfactory. In order to improve this situation, it is justified to continue a study and to more completely diagnose the causes resulting in such low values of these indicators.

Developed methodology and obtained results create great opportunities for practical application and improvement of effectiveness of underground exploitation.

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#### References

- [1] D. E. Avison and G. Fitzgerald, “Information Systems Development: methodologies, technologies, tools”. 2nd Ed. McGraw-Hill, London, 1995.
- [2] S. Eelevli, and B. Eelevli, “Performance Measurement of Mining Equipments by Utilizing OEE”, *Acta Montanistica Slovaca* t. 15, nr 2, 2010.
- [3] S. Nakajima, “Introduction to TPM. Total Productive Maintenance”, Productivity Press, Portland Oregon 1988.
- [4] J. Brodny, K. Stecula and M. Tutak, “Application of the TPM strategy to analyze the effectiveness of using a set of mining machines”. SGEM2016, Conference Proceedings, Book1 Vol. 2, pp. 65-72, DOI: 10.5593/SGEM2016/B12/S03.009.
- [5] M. Kozdrój and M. Kozdrój –Weigel, “ Theory and practice of organizing mining production”, Wydawnictwo Politechniki Śląskiej , Gliwice 1993.
- [6] A. Gumiński, “Analysis of possibilities to increase the efficiency of the means of production in the longwalls of a coal mine”. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, z. 78, 2015, pp. 167-177.
- [7] M. Myszkowski and U. Paschedag, “Longwall Mining in Seams of Medium Thickness”, *Comparison of Plow and Shearer Performance under Comparable Conditions*. Bucyrus, www.bucyrus.com 2010.