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Ryszard SNOPKOWSKI, Aneta NAPIERAJ, Marta SUKIENNIK
AGH University of Science and Technology
The Faculty of Mining and Geoengineering
The Department of Economics and Management in Industry
snopkows@agh.edu.pl, aneta.napieraj@agh.edu.pl, marta.sukiennik@agh.edu.pl

EXAMPLES OF USING THE INTENSITY INDICATOR OF WINNING STREAM FOR VARIOUS LONGWALL SHEARER-BASED MINING TECHNOLOGIES

Abstract. In presented article the examples of using the intensity indicator of winning stream for various longwall shearer-based mining technologies have been shown. The following variables have been adopted: the longwall height, the longwall length, the shearer web and an effective working time. The obtained results can be used to assess the progress and effectiveness of work in longwall faces as well as can be used in modeling and planning the output process in Polish hard coal mines. Performed calculations are exemplary, and their purpose is to show many possibilities for analysis with using the intensity indicator of winning stream.

Keywords: longwall faces, effectiveness of production process, output

PRZYKŁADY WYKORZYSTANIA WSKAŹNIKA NATĘŻENIA STRUGI UROBKU DLA RÓŻNYCH TECHNOLOGII URABIANIA KOMBAJNEM

Streszczenie. W artykule podano przykłady wykorzystania wskaźnika natężenia strugi urobku dla różnych technologii urabiania kombajnem. Za zmienne przyjęto: wysokość ściany, długość ściany, głębokość zabioru oraz efektywny czas pracy w ścianie. Uzyskane wyniki mogą posłużyć do oceny postępu i efektywności pracy w przodkach ścianowych, jak również mogą być wykorzystane w modelowaniu i planowaniu procesu wydobywczego w polskich kopalniach węgla kamiennego. Wykonane obliczenia mają charakter przykładowy, a ich celem jest wykazanie wielu możliwości analiz z zastosowaniem wskaźnika natężenia strugi urobku.

Słowa kluczowe: przodki ścianowe, efektywność procesu produkcyjnego, wydobycie

1. Introduction

The production cycle that takes place in longwall faces of coal mines is a subject of many analyzes and studies[1, 2, 3, 4, 5, 6, 7, 8, 9, 10] because of its fundamental importance to the mine's functioning. Stopping the cycle (not provided for by technological requirements) affects directly the size of extracted output, and therefore the loss. The continuity of the obtained output and the continuity of the spoil stream have a great importance.

This paper analyzes the obtained volume of the winning stream for one and two-directional shearer-based mining, which is the technology most frequently used in the Polish mining industry. In the calculations, the intensity indicator of winning stream for the mentioned mining technology was used. The φ_k index has been derived by the authors, and is defined as the quotient of the production cycle and the duration of the cycle. The purpose of the calculations was to show the possibilities of using this indicator to assess the level of the shift output for the conditions of given longwall.

2. The intensity indicator of winning stream-defining method

Scheme of the production cycle executed in technology of two-directional shearer-based mining is shown in Fig. 3. The Longwall length is marked on vertical axis and horizontal axis is scaled in time units. Shearer-based mining is realized with full longwall height in both directions. Shearer slotting takes place at the longwall end in manner shown in the diagram. The scheme in question comprises all activities and workings needed for the coal mining on

[1] Snopkowski R.: Boundary conditions for elementary functions of probability densities for the production process realized in longwalls. “Archives of Mining Sciences”, Vol. 45, No. 4, 2000, p. 501.

[2] Snopkowski R.: Die Kritikalitätsrichtwerte in der Bewertung der Einflusswahrscheinlichkeit der Tätigkeiten Und des am Strebstoss ausgeführten Arbeitsganges auf die Gewinnung. “Archives of Mining Sciences”, Vol. 39, No. 1, 1994.

[3] Snopkowski R.: Longwall output plan considered in probability aspect. “Archives of Mining Sciences”, Vol. 47, No. 3, 2002, p. 413.

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[5] Snopkowski R.: Stochastic model of the longwall face excavation using two-way shearer mining technology. “Archives of Mining Sciences”, Vol. 54, No. 3, 2009, p. 573.

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[7] Snopkowski R., Napieraj A., Sukiennik M.: Method of the assessment of the influence of longwall effective working time onto obtained mining output. “Archives of Mining Sciences”, Vol. 61, No. 4, 2016, p. 967.

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[9] Snopkowski R., Sukiennik M.: Selection of the longwall face crew with respect to stochastic character of the production process. “Archives of Mining Sciences”, Vol. 57, No. 4, 2012, p. 1071.

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whole longwall length with single web cutting depth, including longwall conveyor drive units, which are operated in perpendicular system (no niches are made).

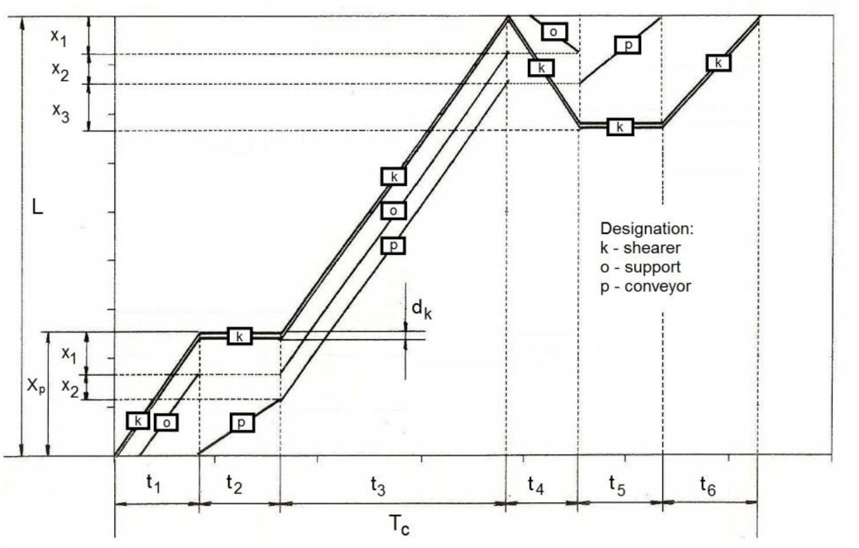

Fig. 1. Scheme of the production cycle executed in technology of two-directional shearer-based mining

Source: Snopkowski R., Napieraj A.: Method of the production cycle duration time modeling within hard coal longwall faces. "Archives of Mining Sciences", Vol. 57, No. 1, 2012, p. 121.

The following symbols are used in the figure:

L – longwall length [m], T_c – duration of production cycle [min], $t_1, t_2, \dots, t_6$ – times of execution of individual phases of the production cycle [min], d_k – shearer length [m], x_1, x_2, x_3 – mutual distances of executed activities and workings in scope of the system shearer – support – conveyor [m], x_p – distance between shearer stoppage place and longwall-roadway crossing [m].

Intensity indicator of the winning stream was defined with a formula (1):

$$\varphi_{2k} = \frac{W_c}{T_c} \tag{1}$$

φ_{2k} – intensity indicator of the winning stream in technology of shearer-based two-directional mining (in the work[11]: mean flow rate of the winning stream) [Mg/min].

Production cycle output that occurs in the formula (W_c [Mg/cycle]), is determined from the formula (2):

$$W_c = H \cdot z \cdot L \cdot \gamma \cdot \rho \tag{2}$$

where: H= longwall height [m], z =shearer web [m], L =longwall length [m], γ =coal bulk density [Mg/m^3], ρ =web factor [-].

[11] Snopkowski R.: The use of the Stochastic Simulation for Identification…, op.cit.

After substitutions, the formula defining the intensity indicator of the winning stream in technology of shearer-based two-directional mining is as follows (3):

$$\varphi_{2k} = \frac{H \cdot z \cdot L \cdot \gamma \cdot \rho}{\frac{1}{V_{cz}}(x_p - d_k) + \frac{1}{V_r} \cdot (L - x_p) + \left(\frac{1}{V_z} + \frac{1}{V_r}\right) \cdot (x_2 + d_k + p + s) + t_2 + t_5} \quad (3)$$

The detailed derivation, description and analysis of the parameters included in the formula (i.a. T_c) are not published because of the volume limitations of the present work, but can be found in the work[12].

Technology of shearer-based unidirectional mining is presented schematically in Fig. 2.

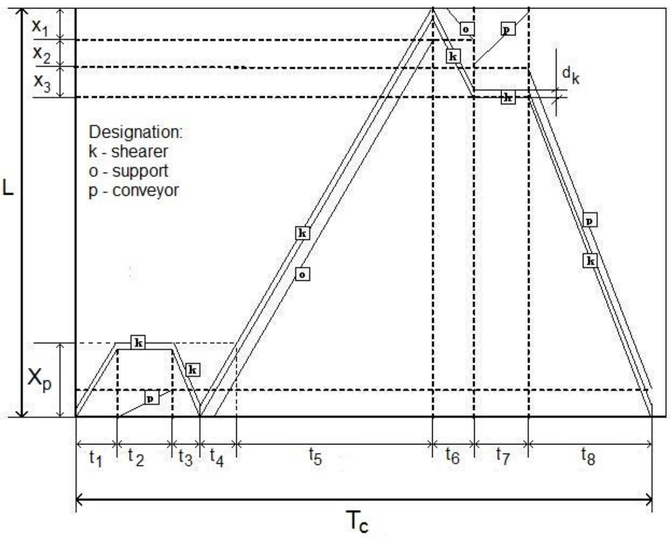

Fig. 2. Scheme of the production cycle executed in technology of shearer-based unidirectional mining
Source: Snopkowski R., Napieraj A.: Method of the production cycle duration time modeling within hard coal longwall faces. “Archives of Mining Sciences”, Vol. 57, No. 1, 2012, p. 121.

The scheme in question comprises all activities and works needed for coal mining execution on the total longwall length at the depth of single web, drive units of the longwall conveyor work in vertical system (no niches are made).

The following markings are present on the diagram:

L – longwall length [m], T_c – duration of production cycle [min], $t_1, t_2, \ldots, t_8$ – times of execution of individual phases of the production cycle [min], d_k – shearer length [m], x_1, x_2, x_3 – mutual distances of executed activities and workings in scope of the system shearer – support – conveyor [m], x_p – distance between shearer stoppage place and longwall-roadway crossing [m].

Intensity indicator of the winning stream in technology of shearer-based one-directional mining φ_{1k} determines the formula (4):

[12] Ibidem.

$$\varphi_{1k} = \frac{W_c}{T_c} \tag{4}$$

φ_{1k} – intensity indicator of the winning stream in technology of shearer-based one-directional mining (in the work[13]: mean flow rate of the winning stream) [Mg/min],
W_c – production cycle output [Mg/cycle] (formula (2)).

After substitutions, the formula defining the intensity indicator of the winning stream in technology of shearer-based one-directional mining is as follows (5):

$$\varphi_{1k} = \frac{H \cdot z \cdot L \cdot \gamma \cdot \rho}{\left(\frac{1}{V_z}+\frac{1}{V_r}+\frac{1}{V_{cz}}\right)(x_p-d_k)+\frac{1}{V_r}(L-x_p-d_k)+\frac{1}{V_{cz}}(L-d_k)+t_2+t_7} \tag{5}$$

The detailed derivation, description and analysis of the sizes included in the formula (i.a. T_c) are not published because of the volume limitations of the present work, but can be found in the work[14].

3. Examples of using the intensity indicator of winning stream

Performed calculations are exemplary, and their purpose is to show a variety of analysis possibilities with using the intensity indicator of winning stream calculated according to formulas (3) or (5). The data was divided into two groups. The first was data that did not change their values in all the computational examples. Adoption of these data at a consistent level allowed comparisons and conclusions to be made within the same technologies. These data included: γ = 1,3 ρ = 1, x_p = 25, d_k = 12, x_2 = 10, p = 10, s = 9, t_2 = 20, t_5 = 20, t_7 = 20. The second group of data was changed according to the content of each computational example.

Output [Mg/shift] was calculated as the product of the intensity indicator of winning stream [Mg/min] and the effective time in the wall [min/shift].

Speed of shearer feed

The maximum feed speeds of shearers that are currently being produced reach to 35 meters per minute[15]. For comparisons, two differing speeds of shearer feed were selected at 10 and 30 level [m/min]. Calculations were made at longwall length in the range from 150

[13] Snopkowski R.: The use of the Stochastic Simulation for Identification…, op.cit.
[14] Snopkowski R.: The use of the Stochastic Simulation for Identification…, op.cit.
[15] Snopkowski R., Napieraj A., Sukiennik M.: Wybrane aspekty ryzyka w procesie…, op.cit.

to 300 [m], while effective work time was set from 4 to 6.5 [hr]. For these value ranges, the shift output is calculated for various longwall shearer-based mining technologies. The calculations were made by using the intensity indicator of winning stream (Formula (3) and (5)), the results are shown in the following figures. First calculations were made for speed of shearer feed at 10 [m/min] and for longwalls at 1.5 [m] high. Figure 3 shows the calculation results for one and two-directional shearer-based mining technologies.

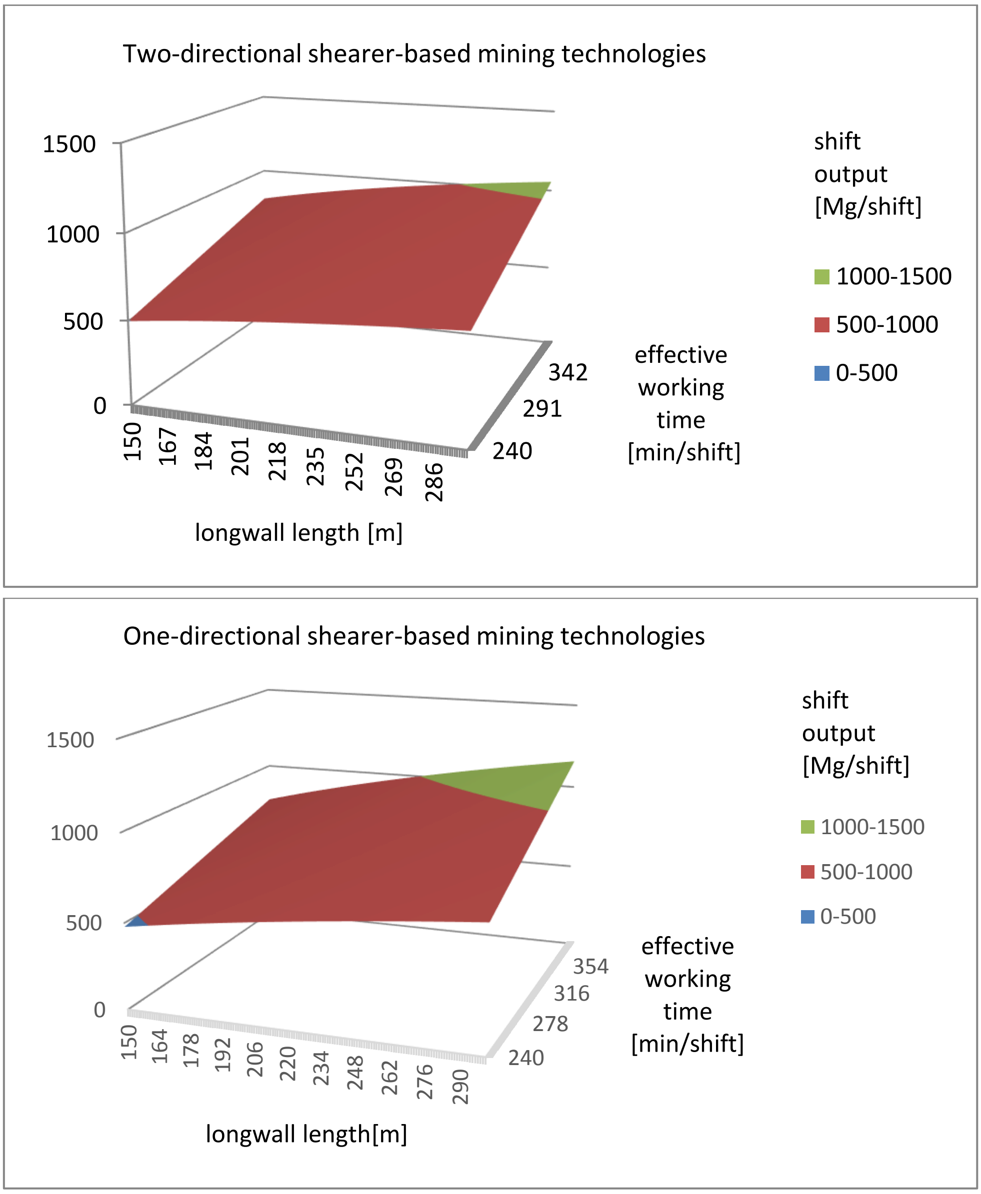

Fig. 3. Shift output: longwall height H = 1,5 [m], speed of shearer feed V_{cz} = 10 [m/min]
Source: Self-reported data.

Two-directional shearer-based mining technology is obviously more effective than one-directional mining technology. In Figure 3, greater inclination of the results plane in the lower graph provides greater increase in output, with increasing longwall length and increasing effective longwall time.

Analogous calculations were made for a speed of shearer feed at 30 [m/min], so three times higher. The results are shown in Figure 4. It can be seen that the shift output increases significantly, although the longwall height for which the calculations are made is only 1.5 [m]. For a longwall length, up to 300 [m] and with an effective time production of approximately 6.5 [hr.], the shift output exceeds 2000 [Mg/shift].

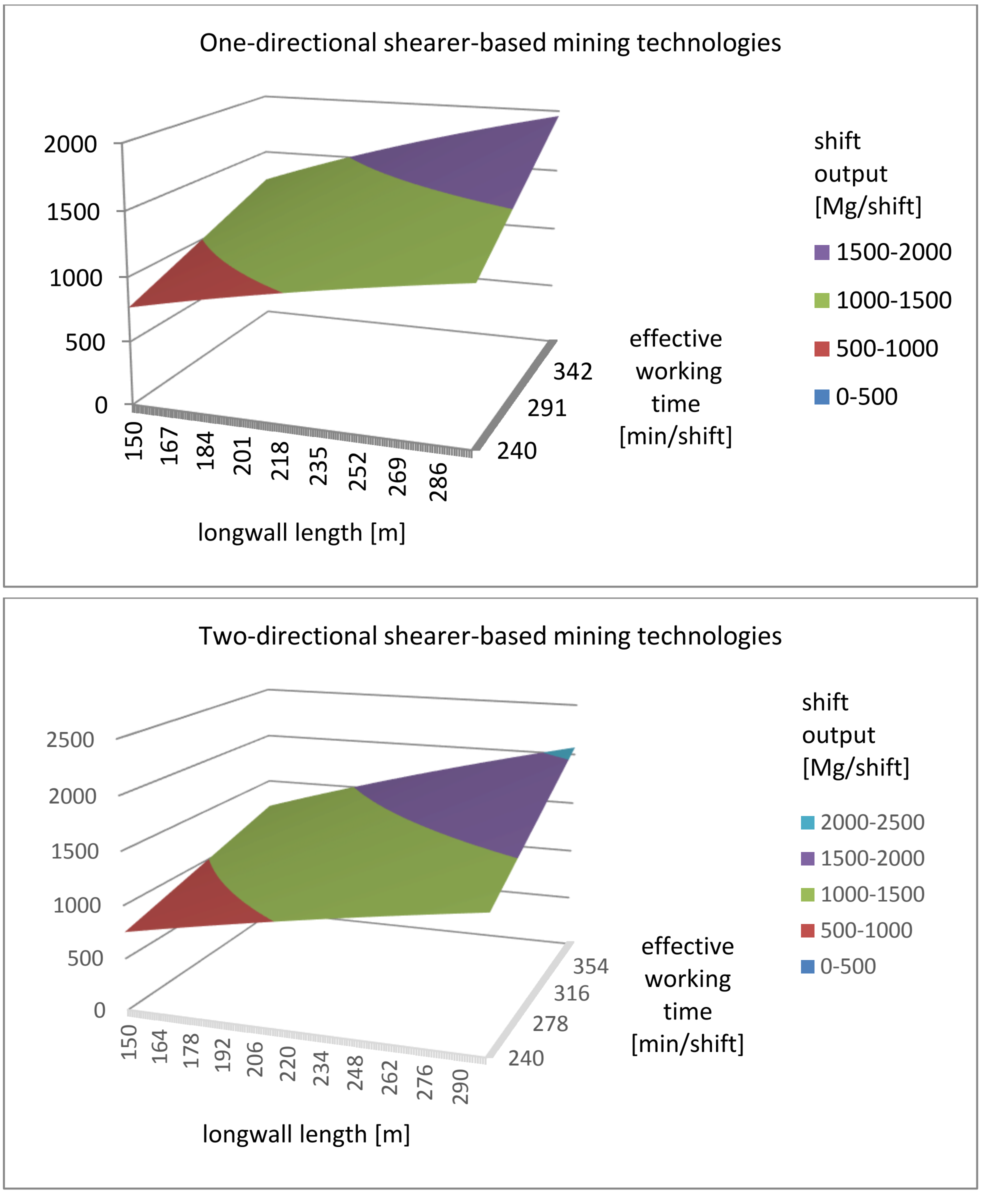

Fig. 4. Shift output: longwall height H = 1,5 [m], speed of shearer feed V_{cz} = 30 [m/min]
Source: Self-reported data.

For comparison, the shift output calculations were performed with the shearer feed on 30 [m/min] level and the longwall height that reaches 3 meters. The results are shown in Figure 5. Maximum shift output (for the longwall shearer-based mining in two-directional technology), which has been recorded, is above 4000 [Mg/shift].

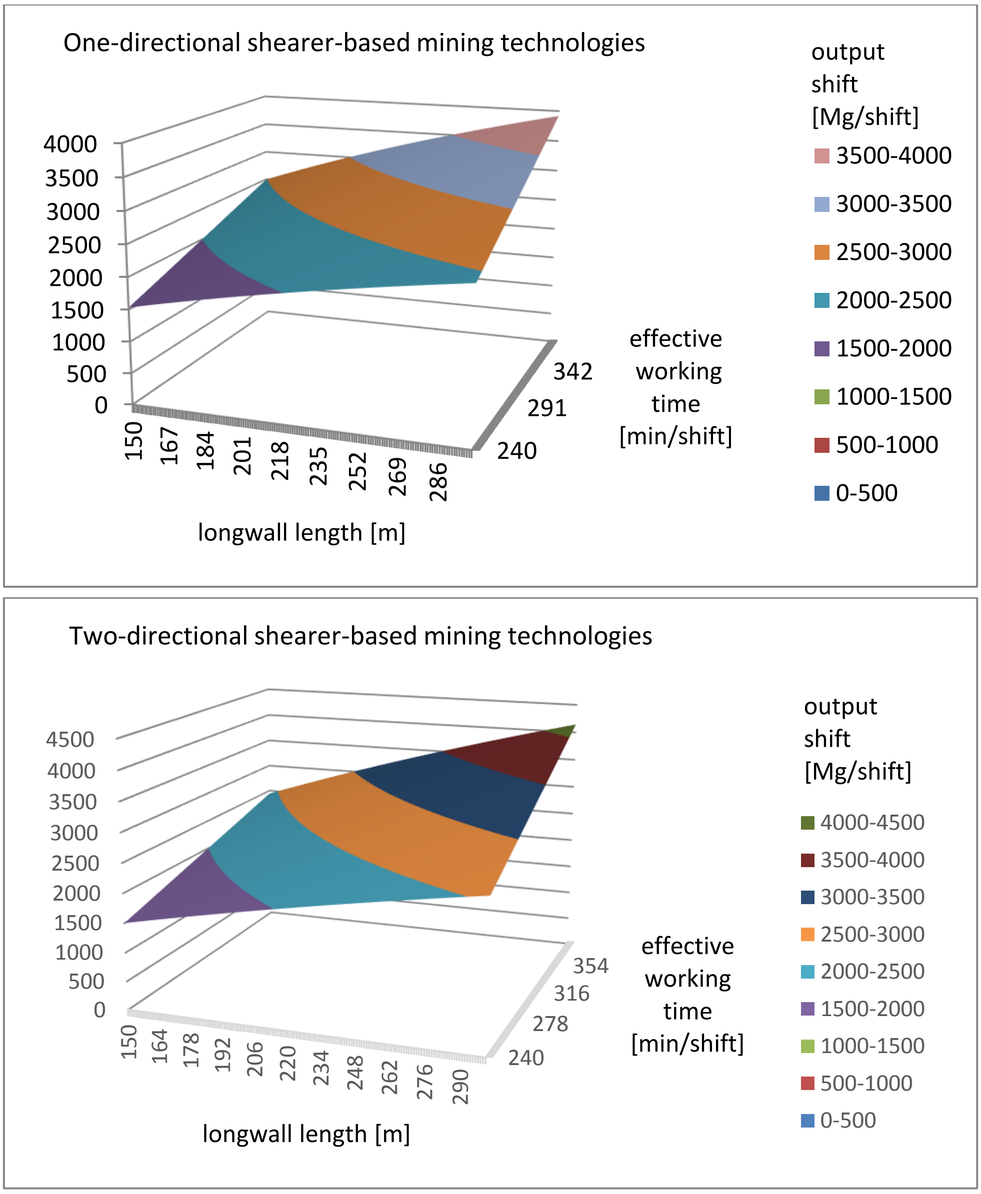

Fig. 5. Shift output: longwall height H = 3,0 [m], speed of shearer feed V_{cz} = 30 [m/min]
Source: Self-reported data.

Figure 6 shows the results of the calculations in the form of a surface chart.

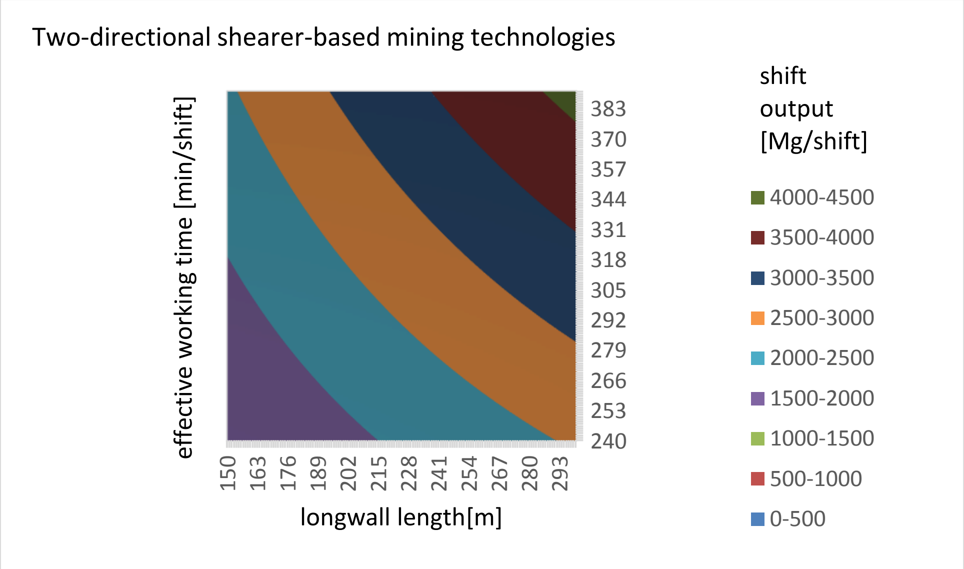

Fig. 6. Surface chart: longwall height H = 3,0 [m], speed of shearer feed V_{cz} = 30 [m/min]
Source: Self-reported data.

Shift output calculation involves a longwall height of 3.0 [m] and speed of shearer feed rate of 30 [m/min]. Particular colors indicate intervals of shift output [Mg/shift]. The boundaries of individual colors (output intervals) are not straight lines, what provides to the conclusion that the increase of shift output coming from the increase of longwall length and effective working time is not linear.

Depth of shearer web

One of the factors directly influencing the shift output from the longwall face is the shearer web. Currently produced shearers are able to obtain the web at level of more than one meter[16].

Exemplary calculations of the effect of the web depth on the output from the longwall were made, assuming a longwall height of 3 [m], speed of shearer feed rate of 20 [m/min]. Of course, the calculations were done as before – for a longwall length from 150 [m] to 300 [m] and with an effective working time in the range of 4 to 6.5 [hr]. The obtained results for the web of 0.6 [m] and 1.0 [m] were compared. The results are shown in Figure 7 (for one-directional shearer-based mining) and Figure 8 (for two-directional shearer-based mining).

Figure 9 shows the results of calculations made for two-directional shearer-based mining (according to formula (3)), assuming a longwall length of 250 [m] and a shearer feed of 20 [m/min]. The calculations show that for effective working time of 240 [min], the difference in the shift output (for 0.6 [m] and 1.0 [m]) is just over 1000 [Mg/shift]. For an effective working time of 390 [min], this difference increases to almost 2000 [Mg/shift].

[16] Snopkowski R., Napieraj A., Sukiennik M.: Wybrane aspekty ryzyka w procesie…, op.cit.

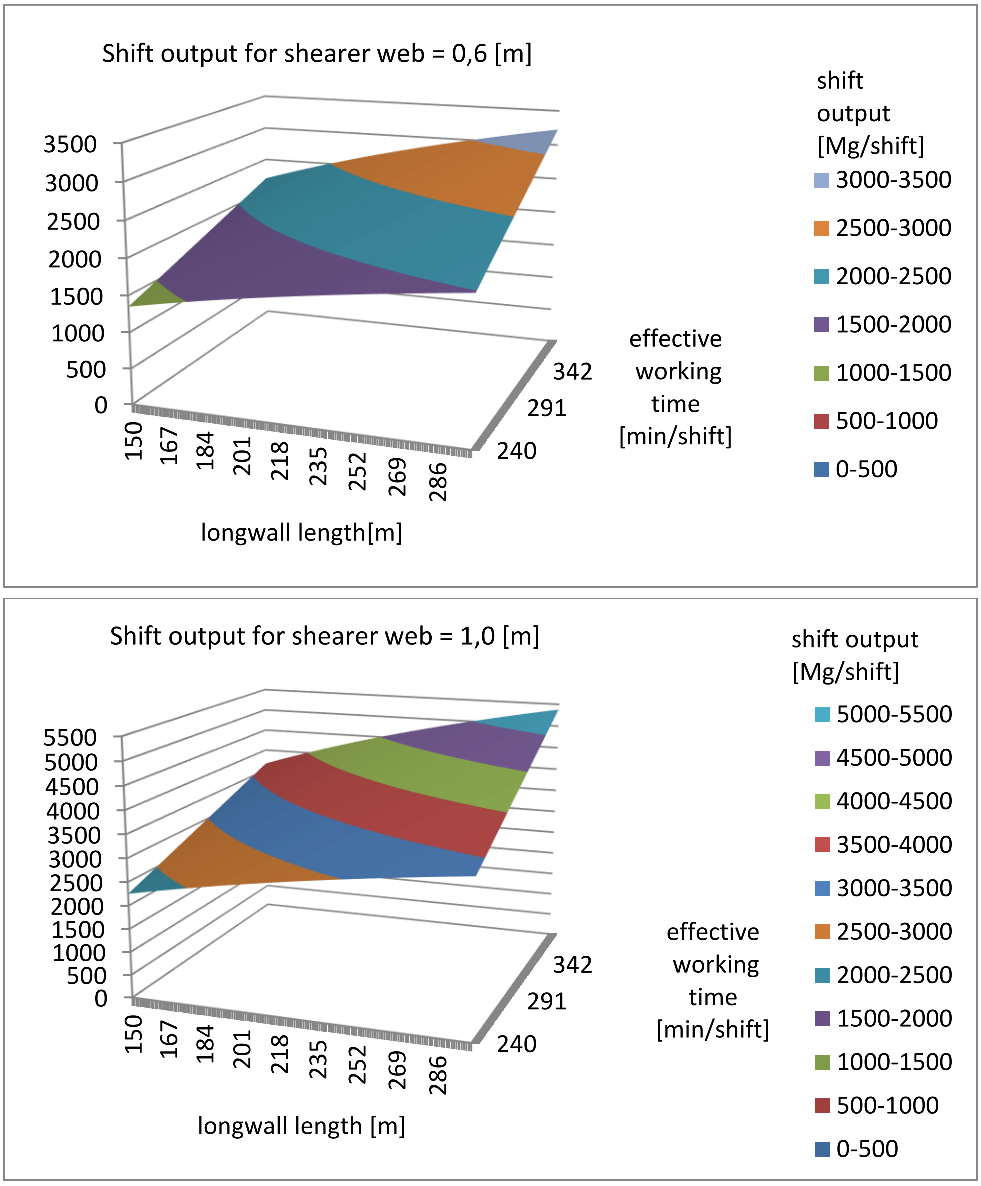

Fig. 7. One-directional shearer-based mining, longwall height *H* = 3,0 [m], speed of shearer feed V_{cz} = 20 [m/min]
Source: Self-reported data.

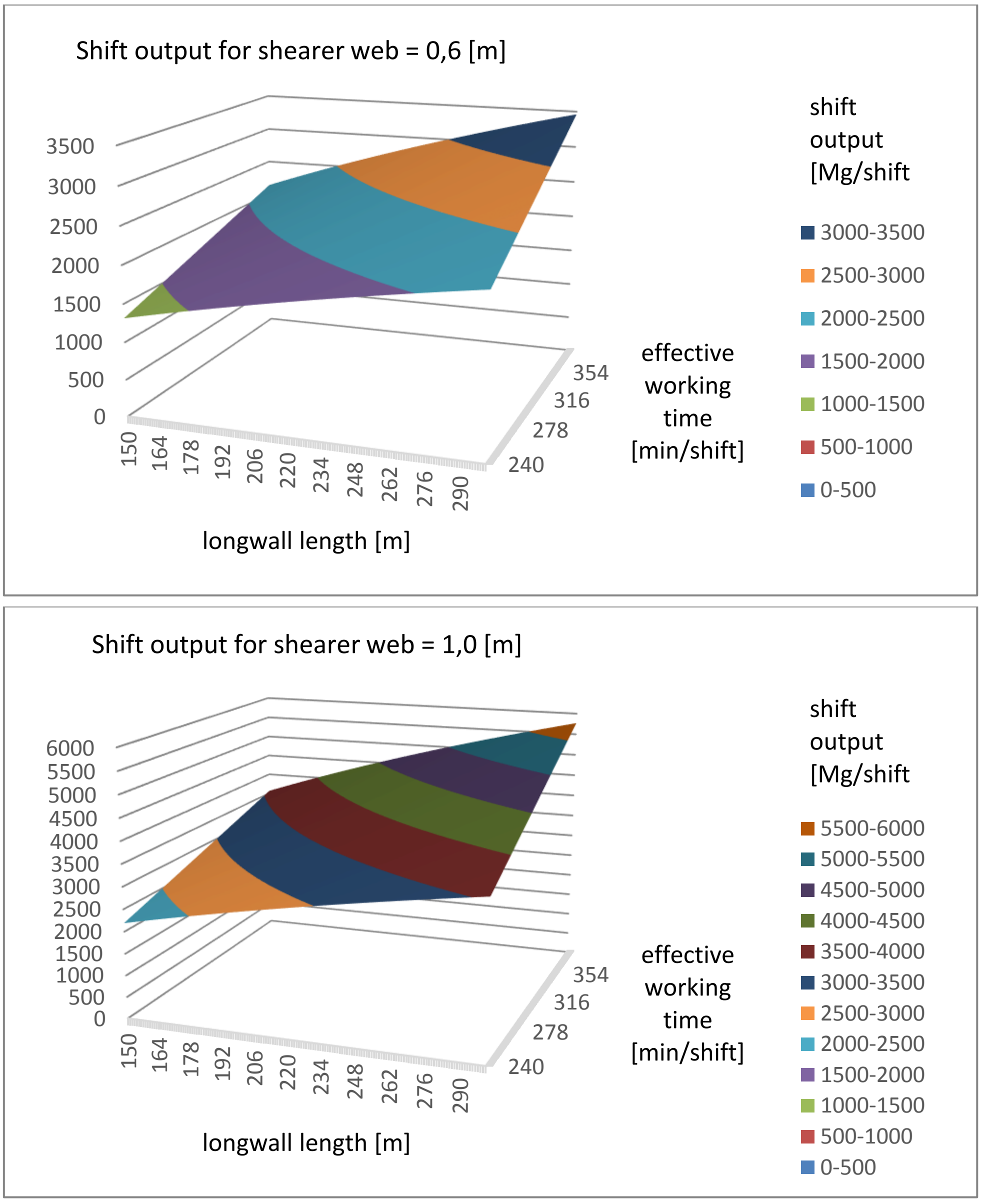

Fig. 8. Two-directional shearer-based mining, longwall height *H* = 3,0 [m], speed of shearer feed V_{cz} = 20 [m/min]
Source: Self-reported data.

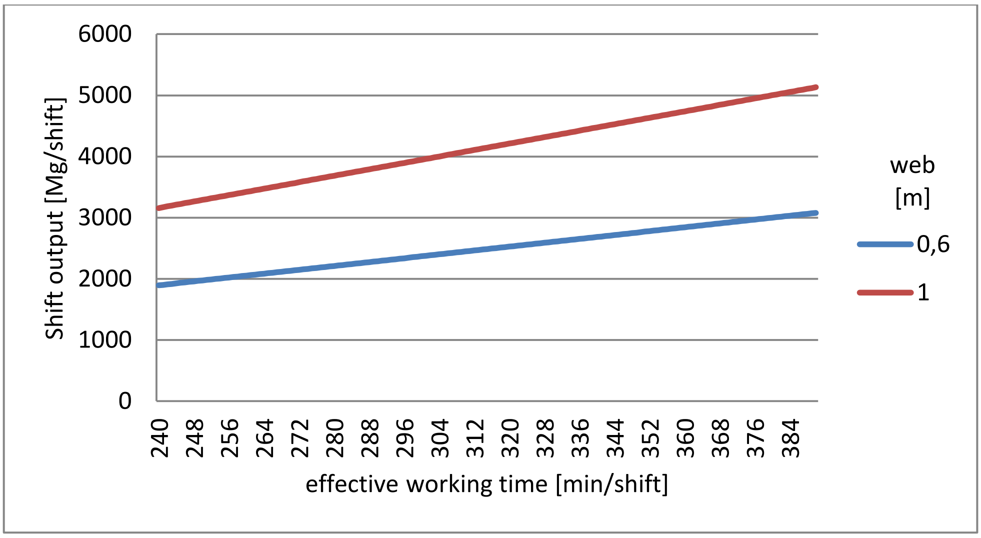

Fig. 9. Two-directional shearer-based mining, longwall length *L* = 250 [m], longwall height *H* = 3,0 [m], speed of shearer feed V_{cz} = 20 [m/min]
Source: Self-reported data.

In this way, calculations can be made for any longwall length and other longwall parameters, resulting in the influence of the depth of the shearer web on the shift output.

Effective working time in a longwall

The intensity indicator of winning stream can also be used to analyze the influence of the effective working time in the longwall on the shift output.

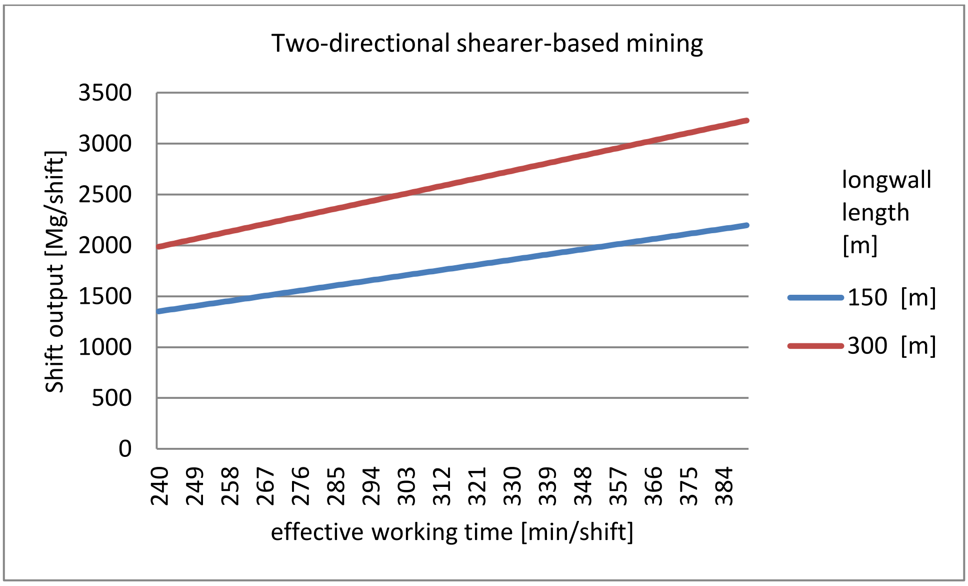

Fig. 10. Shift output: longwall height *H* = 3,0 [m], speed of shearer feed V_{cz} = 20 [m/min], web *z* = 0,6 [m].
Source: Self-reported data.

Figures 10 and 11 show the results of the calculations made for one and two-directional shearer-based mining with the assumed longwall parameters. Difference in the shift output increases with the growth of an effective working time in the longwall, comparing the longwall of 150 [m] with the longwall of 300 [m] (under the same conditions). In figure 10, the difference is 845 [Mg/shift] for an effective working time of 240 [min/shift], and increases to 1242 [Mg/shift] for an effective working time of 390 [min/shift]. The corresponding values in Figure 11: 1369 [Mg/shift] for effective working time of 240 [min/shift] and 2219 [Mg/shift] for an effective working time of 390 [min/shift].

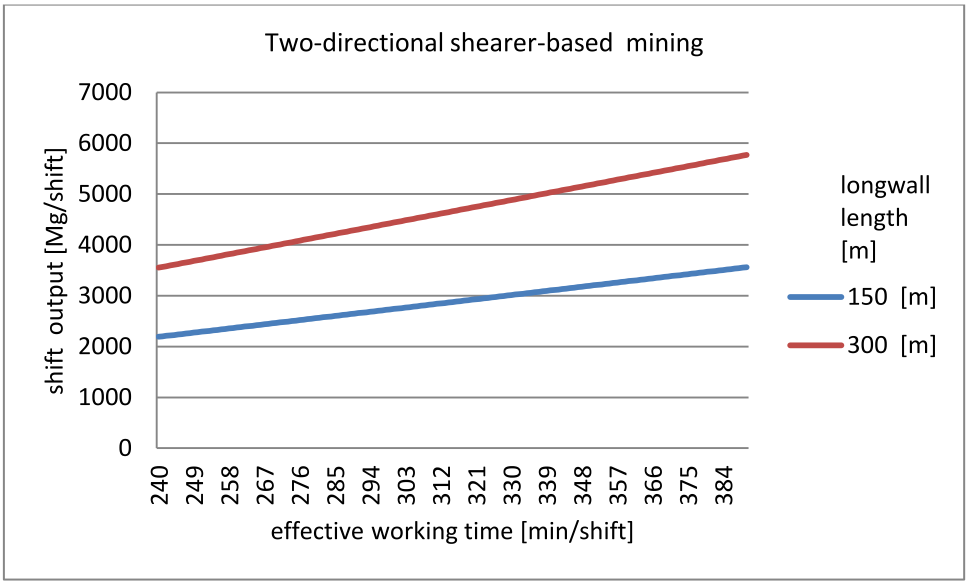

Fig. 11. Shift output: longwall height H = 3,0 [m], speed of shearer feed V_{cz} = 20 [m/min], web z = 1,0 [m]
Source: Self-reported data.

Performed calculations are exemplary, and their purpose is to demonstrate many possibilities for analysis with using the intensity indicator of winning stream.

Conclusion

This publication presents examples of using the intensity indicator of winning stream. The indicator formula has been derived for one-and two-directional shearer-based mining technology. The indicator can also be defined as the mean flow of winning stream for a given mining technology. Its unit is presented in [Mg/min].

The advantage of the formulated intensity indicator of winning stream is its universality, since it takes into account all the parameters characterizing the production cycle in the longwall. These are parameters that determine the productivity of the machine (e.g. speed of shearer feed), operating times, and parameters of the longwall face itself (including the length and the height of the longwall).

By calculating the product of this indicator and an effective working time in the face longwall – in an easy way – the volume of the shift output can be obtained that is possible under the conditions of a given longwall, which may be useful at the design or operation stage.

In this paper, calculations for several examples have been made, what is an illustration of the use of this indicator.

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