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FUNCTION OF LABOR CONSUMPTION INCREASE IN MINING AND PROCESSING OPERATIONS

Introduction

The efficiency of mining depends basically on the specific features of mining itself and the specific and variable conditions of the process. The character of mining and processing, together with the specific and variable conditions that accompany these processes, is decisive as regards an objective differentiation of the labor efficiency levels and unit costs in particular mines. The variability results in the necessity to adjust the methods, technology and organization of the production processes to the natural geological and mining conditions in particular mines and in the need to monitor and control mining and processing with the aim to achieve the desired increase of efficiency.

In a complex approach, the efficiency- oriented analysis of mining and processing that applies labor efficiency indicators, which was presented in the paper *Work efficiency decrease in mining and processing*[1], needs to be supplemented by investigations on labor consumption of particular elements of the process under analysis, with regard to the changes of employment levels and structure. Such an analysis, together with the opportunity of a practical application of labor consumption indicators and the function of the increasing labor consumption of subsequent production processes in mining, is the subject matter of this paper.

1. Work efficiency versus work consumption

Work efficiency is considered to be the basic and most important measure of the effectiveness and efficiency of company operations and its adaptability to the changing environment. The issue concerns particularly mining as it is characterized by significant fixed

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[1] Utrata A., Jabłońska- Firek B.*: Work efficiency decrease in mining and processing*. Zeszyt Naukowy No 22, WSZiB w Krakowie, Zarządzanie– 2013

costs (approx. 60%-70%) and a substantial share of labor costs in its prime costs (approx. 60%).

The general relationship below presents quantitative and qualitative labor efficiency measures that are useful in the analysis and assessment of the developing and restructuring processes in mining[2]:

$$w = \frac{P}{T} \qquad (1)$$

where:

P – output, obtained by a group of employees under investigation, given in qualitative or quantitative units,

T – labor time consumption , defined by the number of employees or the total number of workdays, hours, etc. depending on the characteristics of the production process.

The analysis of labor absorption of the production processes in mining constitutes a significant supplement to the analysis and assessment that apply quantitative measures of labor and were presented in the paper "Work efficiency decrease in the mining and processing".. Labor absorption is characterized by semantically similar measures – time- and labor-consumption. In practice, time–consumption is used in work standardization in order to determine labor absorption of work tasks or particular production processes, while labor-consumption determines the labor absorption of a production process with reference to a unit of a final product.

Labor consumption *ch* for a particular group of employees engaged in particular mining and processing operations (or its element) is given by formulas:

$$ch = \frac{1}{w} = \frac{T}{P} = \frac{D_1 + D_2 + ... + D_n}{P} = ch_1 + ch_2 + ... + ch_n \qquad (2)$$

Where:

D_i – number of workdays on the ith worksite , i = 1, 2, ...n,

– other denotations as in formula (1).

[2] Krawczyk W., Jabłońska- Firek B.: *Ekonomika przedsiębiorstwa górniczego*. Skrypty uczelniane. No 702. Kraków 1980.

In mining industry, the labor-consumption is usually given by [dn/10 000t] (day/10 000 tons). However, depending on what groups of workers and what elements of the mining and processing operations are subject to analysis, the labor consumption is determined by means of the workdays of manual workers or the workdays of all employees and is given by [rdn/10 000 t] or [pdn/10 000 t], respectively.

Formula (2) that is presented above, shows a unique property of the measure of labor consumption. As opposed to the measure of labor efficiency, labor consumption can be added in a simple way. That means, that the labor consumption of mining and processing operations is a sum of the labor consumption of particular elements (work sites) that are engaged. Moreover, it is possible to determine the labor consumption of specifically defined components of mining and processing operations. Thus, such concepts are used as labor consumption of coal (ore, rock) mining, labor consumption at the face, in a field, underground, on the surface, and a total one. There is also a notion of labor consumption determined for mining sections (production, development) or generated by employee groups (e.g. engineering and technical staff)

As the measure of labor consumption constitutes a straight inverse of the labor efficiency measure (formulas 1, 2), the increase of labor efficiency in mining is determined by the possibility to decrease the labor consumption of mining and processing operations.

2. Analysis of labor consumption of mining and processing operation

The presented of the analysis of labor consumption of mining and processing operation, together with the graphic and tabular illustration of a practical possibility to apply it, is the result of the analysis of areas where labor consumption analysis is possible.

2.1. Areas of analysis

The analysis of the labor consumption of mining and processing operation can be conducted with different approaches . Among the most commonly applied are [3] [4]:

[3] Baluch K.: *Wykorzystanie wskaźnika pracochłonności w analizie efektywności pracy ludzkiej*. Wiadomości Górnicze 1999. No 1.
[4] Utrata A.: *Wykorzystanie funkcji narastania pracochłonności do analizy chłonności pracy procesu wydobywczo-przeróbczego*. Przegląd Górniczy; 2011 Vol.. 67 No 9 pp. 168–172.

- the analysis of the structure of labor consumption, aiming at the determination of the most absorptive type of operations in a mine, a group of mines, etc.,
- the analysis of the dynamics of change in labor consumption in a defined time period, with regard to the whole mine and particular types of operations, which may constitute the basis for the assessment of the quality of restructuring operations,
- a comparative analysis of the absorption of worksites in various mines that use different technologies, engineering and organizational structures and with different organizational models, which is the basis for the assessment of the usefulness of the solutions applied in given conditions.

In every area in question the investigation of labor consumption can be conducted with an unqualified or qualified approach. In the unqualified approach, the changes in labor consumption are analyzed with regard to one mine or a group of mines:

- for the same group of worksites in time, determining the changing trend as positive or negative,
- for different groups of operation in the same time, searching for the components of the production process with the highest labor absorption.

In the qualified approach, the percentage changes in labor consumption are analyzed with regard to one mine or a selected group of mines.

2.2. Function of labor consumption increase

The function of labor consumption increase is a function where dependent variable is the sum of the labor consumption for subsequent worksites, and its argument is the variable that defines the ratio of workdays within one group of worksites to the total labor absorption of the mining and processing operation. Thus, the independent variable is variable λ_i determined from the relationship:

$$\lambda_i = \frac{D_i}{D_{kop}} * 100\% \tag{3}$$

where:

D_i – number of workdays in the ith group of work sites,

D_{kop} – total number of workdays in the mine,

$i=1, 2, ...,$ – subsequent worksites in the mine.

The relationship between workdays and labor consumption can be given as:

$$D_i = ch_i * P$$
$$D_{kop} = ch_{kop} * P \tag{4}$$

Thus, using formulas (3) and (4), the labor consumption for the ith group of the worksites is as follows

$$\lambda_i = \frac{ch_i * P}{ch_{kop} * P} * 100\% = \frac{ch_i}{ch_{kop}} * 100\% \quad \Rightarrow \quad ch_i = \frac{ch_{kop} * \lambda_i}{100\%} \tag{5}$$

where:

ch_i – labor consumption generated in the ith group of worksites ,

ch_{kop} – total labor consumption generated in the mine.

If ch_1, ch_2 denote labor consumption generated by worksite groups $i= 1$ and $i= 2$, respectively, and λ_1 and λ_2 denote workdays in worksite groups $i= 1$ and $i= 2$, respectively, the total labor consumption for the two groups of worksites can be given by:

$$\Sigma ch_2 = ch_1 + ch_2 = \frac{ch_o * \lambda_1}{100\%} + \frac{ch_o * \lambda_2}{100\%} = \frac{ch_{kop}}{100\%}(\lambda_1 + \lambda_2) \tag{6}$$

Generally, for n groups of worksites, the total labor consumption can be determined as:

$$\Sigma ch_n = ch_1 + ch_2 + ... + ch_n = \frac{ch_o}{100\%}(\lambda_1 + \lambda_2 + ... + \lambda_n) \tag{7}$$

The function of the labor consumption increase in a given mine can be presented in a table or by a graph.

In the case of the tabular option, the arguments of the function and its dependent variables are presented in the columns of the table, which makes it possible to analyze the mining and processing operations both from the point of view of the structure and the trends in labor consumption.

In the case of the graphical option, similar analysis can be conducted. However, a better experience is required on the part of the analyst as the indirect data are more difficult to read.

The tabular version of the examples of functions of labor consumption increase for a selected mine are given in table 1, while the graphical presentation is given in figure 1.

Table 1. Labor consumption characteristics for a selected mining and processing operation

No	Group of operations (worksites)		Ratio of workdays of the group to the total number of work days	Labor consumption of the group ch_i	Ratio of workdays increasingly	Labor consumption, inceasingly Σch_i
		i	λ_i	[dn/10 000 Mg]	$\Sigma\lambda_i$	[dn/10 000 Mg]
	1	2	3	4	5	6
1.	Work at the face	1	9,41%	206,24	9,41%	206,24
2.	Auxiliary work	2	53,14%	1 164,13	62,55%	1 370,37
3.	Supervision underground	3	9,99%	218,81	72,54%	1 589,17
4.	Workers on the surface	4	19,16%	419,83	91,70%	2 009,01
5.	Supervision on the surface	5	5,89%	129,09	97,59%	2 138,10
6.	Office and engineering and technical staff	6	2,41%	52,71	100,00%	2 190,80
7.	Mine - total	7	100,00%	2 190,80	100,00%	2 190,80

Source: Utrata A.: *Wykorzystanie ....*, op. cit.

The arguments of the function of labor consumption increase and its dependent variables are given in columns 5 and 6 of table 1. The same values are given in the graph in fig.1. The values from columns 3 and 4 are present in the graph indirectly, which is shown by the determination of values λ_1, λ_2 and ch_1, ch_2. When analyzing the graph and the data in table 1, the worksites with the highest labor consumption can be determined. The analysis provides information about the efficiency of both the developing and restructuring operations.

However, a static analysis does not make it possible to investigate the change dynamics as regards labor consumption and the determination of trends in labor absorption changes of a process under investigation. Moreover, it does not allow for comparison of a given mine with other ones (external benchmarking) or the comparison of different sections within one mine (internal benchmarking). The aim of benchmarking is to assess the impact of geological and mining conditions, the type of mine, its technological facilities and the qualifications of the staff on the labor consumption of mining operations.

Fig.1. Function of labor consumption increase for a selected mine
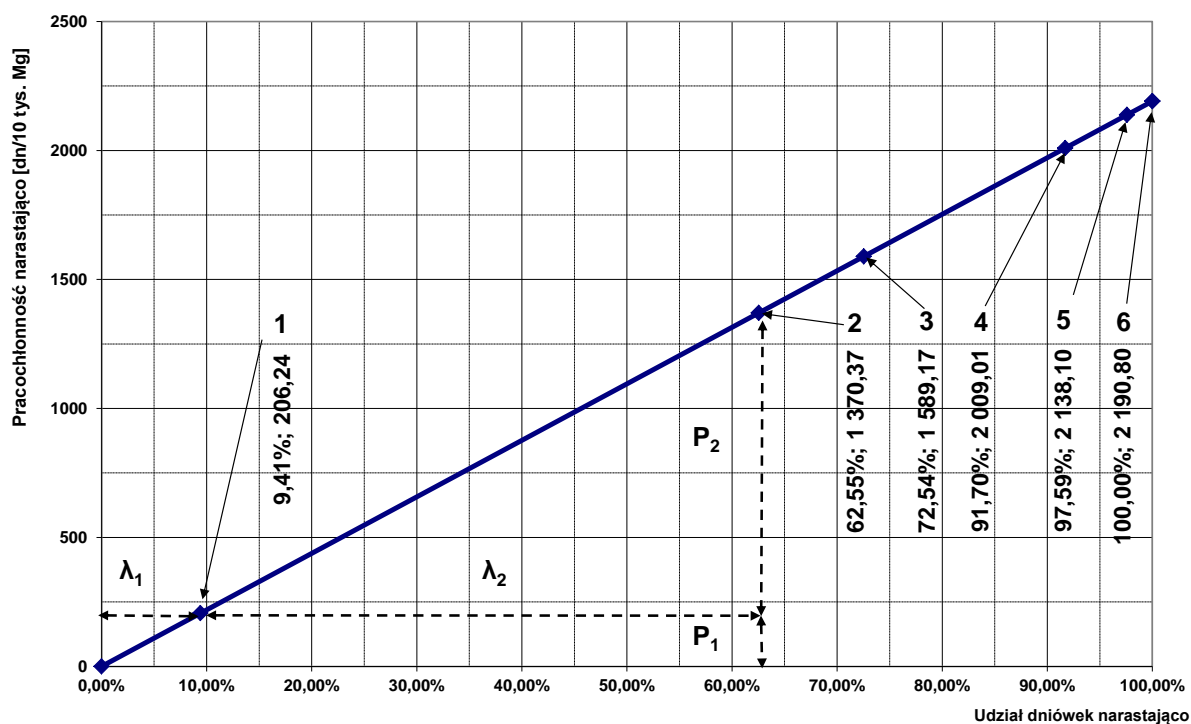

Key: 1 – work at face, 2 – work at face and auxiliary work, 3 – work underground with supervision, 4 – work underground and workers on the surface, 5 – mine without Office and engineering staff, 6 - mine

Source : Author's study based on the data from table 1.

The investigation of the dynamics of trends in the labor consumption of mining operations as regards selected groups of operations or the whole mining and processing process requires the knowledge of the function of the labor consumption increase in various time periods. A comparative analysis makes it possible to determine the character of the trends observed and to assess the efficiency of the restructuring operations that were undertaken. The examples of the functions of labor consumption increase for three subsequent time periods are presented in fig.2.

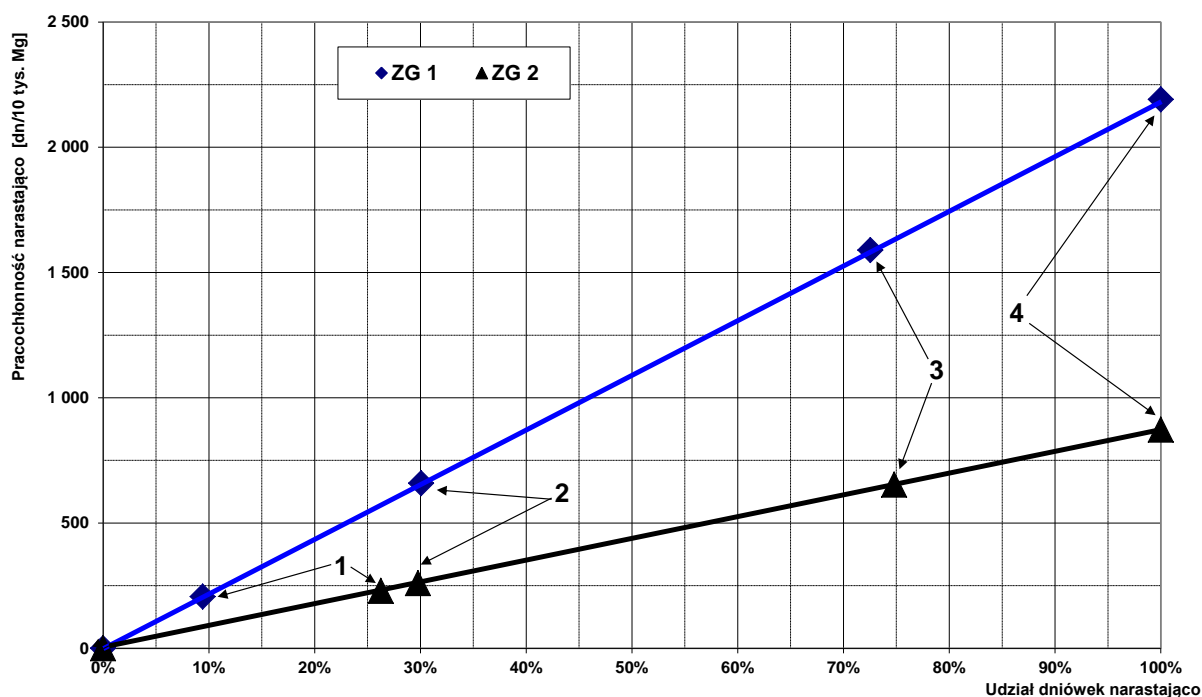**Fig.2. Functions of labor consumption increase for a selected mine, a dynamic approach**
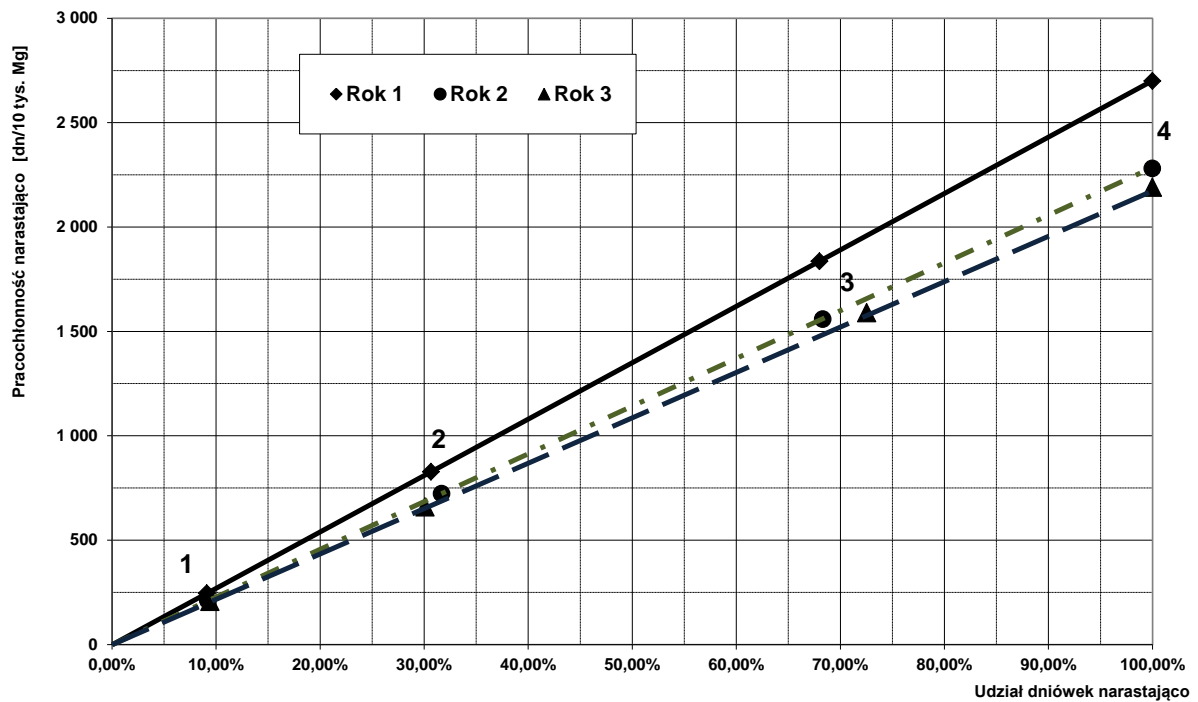
Key: labor consumption : 1 – face, 2 – section, 3 – underground, 4 - mine

Source: Author's study based on: Utrata A.: *Wykorzystanie ....*, op. cit.

Figure 3 presents two functions of labor consumption increase for two different mines and four selected groups of operation. When analyzing the graph, a significant difference in both processes can be observed. However, certain similarity is visible as regards the ratio of the section and underground workdays to their total number.

Fig.3. Functions of labor consumption increase for two selected underground mines with different deposits and methods of winning

Key: labor consumption: 1 – face, 2 – section, 3 – underground, 4 - mine

Source: Author's study based on: Utrata A.: *Wykorzystanie funkcji narastania pracochłonności do analizy chłonności pracy procesu wydobywczo-przeróbczego*. Przegląd Górniczy; 2011 Vol. 67 No 9 pp. 168–172.

3. Conclusion

With reference to the article mentioned before[5], where - with the consideration of the specific features of mining processes and the conditions for their successful realization - the characteristics and opportunities to apply the function of labor efficiency decrease were presented, the present paper provides a scheme of the analysis of the function of labor consumption increase and the examples of its application in the analysis of labor absorption in mining and processing operations. The following clues and conclusions can be presented as the result of the considerations:

- Labor consumption, beside the measure of labor efficiency, constitutes an effective tool used in the analysis of the efficiency of production processes and their components.

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[5] Utrata A., Jabłońska- Firek B.*: Funkcja ...., op. cit.*

- The advantage of the labor consumption measure is the possibility of simple addition.

- The analysis of the function of labor consumption increase allows for a quick analysis of the labor absorption of mining and processing operations; the work sites with the highest number of workdays that can be identified on the basis of the analysis, make it possible to determine the areas of action as regards the employment restructuring.

- The comparison of the functions of labor consumption increase that are determined for different mines should enable the identification of the causes of the differences in labor absorption and the implementation of appropriate directions and schedules of restructuring measures.

- When analyzing labor consumption, two elements influencing it should be taken into consideration. On the one hand, it is the workdays on particular worksites and on the other, the production volume. The increase of the number of workdays is not always a negative trend as the trend in the volume of the output is also a crucial factor.

Bibliography

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Abstract

The article characterizes the function of labor consumption increase against the background of the concepts of labor efficiency and consumption and the specific features of production processes in mining. It also presents the necessity and possibilities to investigate and analyze the function as regards monitoring and control of mining and processing operations. With reference to selected mines, examples are provided to describe the functions of labor consumption increase in the static and dynamic approach.