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BOUNDARY CONDITIONS FOR ELEMENTARY FUNCTIONS OF PROBABILITY DENSITIES FOR THE PRODUCTION PROCESS REALISED IN LONGWALLS

WARUNKI BRZEGOWE DLA ELEMENTARNYCH FUNKCJI GĘSTOŚCI PRAWDOPODOBIEŃSTWA PROCESU PRODUKCYJNEGO REALIZOWANEGO W PRZODKU ŚCIANOWYM

Fundamental criterion for assessment of the efficiency of production process realised in a longwall is the lack of breaks in work of mining machine (except breaks which result from the technology applied or operation schedule).

Rated outputs for machines which are used in longwalls are high enough so that only other reasons can cause that it is impossible to make full use of these machines. Among these reasons can be listed e.g. geology-mining conditions which occur in the studied longwall (Sikora, 1991).

The author undertook the study in which numerical model of production process which is carried out in the longwall was used. The model was described in (Snopkowski, 2000).

In this model, it is assumed that time periods for realisation of activities and operations realised in the longwall, which influence the advance of the heading machine, are given in the form of elementary functions of probability densities. The term "elementary" was proposed by the author in order to differentiate these functions from other functions and because these functions describe realisation time in units [minute/meter]. The model is a simulation model (software written in FORTRAN) and it enables to fully reflect of the actual run of the production process with keeping the rules which result from the technology which is used.

In three samples of calculations, different relations between elementary functions of probability densities were assumed. Those assumptions resulted from different geology-mining conditions which occured in longwalls. The influence of those relations on time of the production cycle was determined. The total time of heading machine breaks during "mining" along the whole longwall length was registered.

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On the base of calculations which were performed, the following boundary conditions for elementary functions of probability densities were suggested:

$$\begin{cases} \int_a^{+\infty} f_e(t_u)dt_u - \int_a^{+\infty} f_{e_1}(t_1)dt_1 > 0 \\ \int_a^{+\infty} f_e(t_u)dt_u - \int_a^{+\infty} f_{e_2}(t_2)dt_2 > 0 \\ \vdots \quad \vdots \quad \vdots \quad \vdots \\ \int_a^{+\infty} f_e(t_u)dt_u - \int_a^{+\infty} f_{e_i}(t_i)dt_i > 0 \end{cases}$$

for each value "a" > 0,
where:

$f_e(t_u)$ — elementary function of probability density for variable T_u – mining time by heading machine on 1 meter distance,

$f_{e_1}(t_1), f_{e_2}(t_2) \ldots f_{e_i}(t_i)$, — elementary functions of probability densities for activities or operations carried out simultaneoulsy (paralelly) with mining by heading machine when realisation of these influence the movement of the heading machine.

Key words: coal mining, efficiency of production operation, probability distribution.

Istotnym kryterium efektywności procesu produkcyjnego realizowanego w przodku ścianowym jest brak przerw w pracy maszyny urabiającej (poza przerwami wynikającymi z technologii lub organizacji procesu).

Wydajności nominalne maszyn wykorzystywanych w przodkach ścianowych są na tyle duże, iż jedynie inne przyczyny mogą powodować, że niemożliwe jest ich pełne wykorzystanie. Tymi przyczynami mogą być np. warunki geologiczno-górnicze danego przodka ścianowego (Sikora, 1991).

Autor przeprowadzał w tym zakresie badania, w których wykorzystano numeryczny model procesu produkcyjnego realizowanego w przodku ścianowym, opisany w pracy (Snopkowski, 2000).

W modelu tym zakłada się, że czasy realizacji czynności i operacji realizowanych w ścianie, a mających wpływ na posuw kombajnu, są przedstawiane w postaci elementarnych funkcji gęstości prawdopodobieństwa. Określenie „elementarnych" autor wprowadził w celu odróżnienia od innych funkcji oraz biorąc pod uwagę to, że opisują czas realizacji w jednostkach [minut/metr]. Przedmiotowy model jest modelem symulacyjnym (program w języku FORTRAN) i umożliwia wierne odzwierciedlenie przebiegu rzeczywistego procesu produkcyjnego z zachowaniem reguł wynikających ze stosowanej technologii.

W trzech przykładach obliczeniowych założono różne relacje między wybranymi elementarnymi funkcjami gęstości prawdopodobieństwa, przyjmując, że przyczyną tych relacji mogą być warunki geologiczno-górnicze danego przodka ścianowego. Badano wpływ tych relacji na czas trwania cyklu produkcyjnego. Rejestrowano także sumaryczny czas postoju kombajnu w trakcie „urabiania" na całej długości ściany.

Na podstawie przeprowadzonych obliczeń sformułowano dla elementarnych funkcji gęstości prawdopodobieństwa następujące warunki brzegowe:

$$
\begin{cases}
\int_a^{+\infty} f_e(t_u)dt_u - \int_a^{+\infty} f_{e_1}(t_1)dt_1 > 0 \\
\int_a^{+\infty} f_e(t_u)dt_u - \int_a^{+\infty} f_{e_2}(t_2)dt_2 > 0 \\
\vdots \quad \vdots \quad \vdots \quad \vdots \\
\int_a^{+\infty} f_e(t_u)dt_u - \int_a^{+\infty} f_{e_i}(t_i)dt_i > 0
\end{cases}
$$

dla każdej wartości „a" większej od zera,
gdzie:

$f_e(t_u)$ — elementarna funkcja gęstości prawdopodobieństwa zmiennej T_u — czas urabiania kombajnem na odcinku 1 metra,

$f_{e_1}(t_1), f_{e_2}(t_2) \ldots f_{e_i}(t_i)$, — elementarne funkcje gęstości prawdopodobieństwa dla czynności lub operacji wykonywanych równocześnie (równolegle) z urabiającym kombajnem, których realizacja wpływa na posuw kombajnu.

Słowa kluczowe: górnictwo węgla kamiennego, efektywność procesu produkcyjnego, rozkład prawdopodobieństwa.

Fundamental criterion for assessment of the efficiency of production process realised in a longwall is the lack of breaks in work of mining machine (except breaks which result from the technology applied or operation schedule). Data presented in (Fawcett, Duncan, 1990) showed that for 58% of longwalls mining was slowed down by the velocity of dislocation of mechanical support systems.

Rated outputs for machines which are used in longwalls are high enough so that only other reasons can cause that it is impossible to make full use of these machines. Among these reasons can be listed e.g. geology-mining conditions which occur in the evaluated longwall (Sikora, 1991).

In mining practice, it is very difficult to determine whether heading machine can be stopped or not without using large resources (people, sensors, etc.) for thorough monitoring of the process. If someone wanted to carry out such study in the case of a real longwall, it would be necessary to do it during sufficiently long time period in order to achieve reliable enough statistical results.

According to author's opinion, assuming costs and opportunity that obtained results can be assigned only to the longwall studied, monitoring of the process under real conditions is not justifiable.

Author suggests that the model developed within the scope of "Methods of probability distribution identification for output obtained in longwall of coal mines" should be used. Assumptions, structure and algorithms used in this model were presented in (Snopkowski, 2000). Because of extensiveness of this description, it is not possible to cover it in this publication.

The model is a simulation model (software written in FORTRAN) and it enables to fully reflect of the actual run of the production process with keeping the rules which result from the technology which is used. By using respective algorithms developed by the author, it is possible to model the real process with keeping sequence principle and distance principle. It results in keeping the right order of works in longwall sectors as well as taking into account reciprocal distances e.g. between heading machine and moveable support which depend on permissible surface of uncovered roof.

Modelling of course for separate activities in the longwall is done by using elementary functions of probability densities which are introduced in form of data into the model. The term "elementary" was proposed by the author in order to differentiate these functions from other functions and because these functions describe realisation time in units [minute/meter]. Description of time needed for performing the activity (operation) by the function enables to assess that time including the influence of factors which practically can not be separately determined. There can be listed such factors like e.g. efficiency of mechanical devices, influence of organisation on the course of works in longwall, etc.

The above mentioned opinion was presented in studies made by Centralny Ośrodek Informatyki Górnictwa in Katowice which were carried out in the Ośrodek in the 80-ies. Study (Praca zbiorowa, 1981) can be given as an example. The aim of that study was to determine of time distributions for operation of "dislocation of mechanical support" for different types of the support. In the opinion of the authors of that study, determination of those distributions makes it possible to take into account the influence of non-measurable factors on realisation time of that operation. In my opinion, results which were then obtained were not used in practice because of calculational problems associated with estimation of distribution parameters that, in turn, was associated with not sufficient developed computer technology. Computational problems were also mentioned in conclusion given by the authors of those studies. By using respective algorithms and generating random numbers — according to set functions — the course of works in longwall is modelled. It is worth remembering that every generation of a random number (realisation time) means movement of works, associated with this activity, by 1 meter.

For example, if the random number is generated according to elementary function of probability density which describes work movement of heading machine, it means that within generated time the heading machine moves by 1 meter. After each dislocation, reciprocal distances in the longwall are analysed. When the reciprocal distances are not kept, works which caused that the set distance was exeeded are stopped. For instance, when the maximum distance between heading machine during mining and moveable mechanical support is exeeded then the movement of the heading machine is stopped until the roof has been supported. The idle time of the heading machine is then registerd in the model.

Application in the model of the above mentioned procedures enables to determine the influence of works' courses on the movement of heading machine as well as on time of the whole production cycle.

Further part of this publication presents the study results which were obtained by the author within this area of interest.

There were performed calculations which were aimed to determine of the influence of elementary functions of probability densities for chosen activities and operations on time of production cycle. Also, total idle time for heading machine during mining of the wall was registered. Breaks were caused by too slow course of other works.

In the study made by COIG (Praca zbiorowa, 1981), beta distribution was used for describing of the time needed for realisation of the activity. On that base, however, it is not possible to claim that any elementary function of probability density will have the form of beta distribution.

As a result, on the base of analysis of influence of elementary functions of probability densities on the time of production cycle and on total idle time of heading machine, three groups of conditions were developed for which calculations were performed. Those groups of conditions did not take into account distribution types but only their reciprocal relations.

Sample of calculations No. 1

It was assumed in this sample that for each value "a" from the set of positive real numbers, elementary functions met the following group of conditions:

$$\begin{cases} \int_a^{+\infty} f_e(t_u)dt_u - \int_a^{+\infty} f_e(t_p)dt_p = 0 \\ \int_a^{+\infty} f_e(t_p)dt_p - \int_a^{+\infty} f_e(t_0)dt_0 = 0, \end{cases} \tag{1}$$

where:

$f_e(t_u)$ — elementary function of probability density for variable T_u — time of mining by heading machine at 1 meter distance,

$f_e(t_p)$ — elementary function of probability density for variable T_p — dislocation time of wall conveyer at 1 meter distance,

$f_e(t_0)$ — elementary function of probability density for variable T_0 — movement time of mechanical support at 1 meter distance.

Identity of elementary functions results from the above given conditions. It is rather theoretical situation. It would be very rare in practice. This situation was introduced into calculations in order to compare it to results obtained from other calculations.

Sample of calculations No. 2 (a, b)

This sample calculation refers to the situation in which for each value "a" from the set of possitive real numbers, elementary functions meet the following conditions:

$$\begin{cases} \int_{a}^{+\infty} f_e(t_u)dt_u - \int_{a}^{+\infty} f_e(t_p)dt_p > 0 \\ \int_{a}^{+\infty} f_e(t_p)dt_p - \int_{a}^{+\infty} f_e(t_0)dt_0 = 0 \end{cases} \tag{2}$$

Within the scope of the above mentioned conditions, two particular cases were chosen and marked as 2a an 2b. They are presented in Fig. 1.

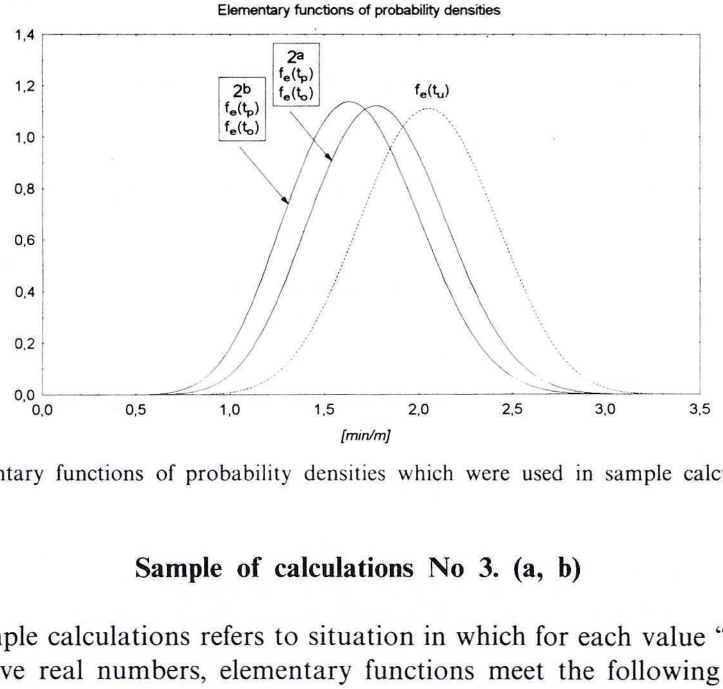

Fig. 1. Elementary functions of probability densities which were used in sample calculation No. 2

Sample of calculations No 3. (a, b)

This sample calculations refers to situation in which for each value "a" from the set of positive real numbers, elementary functions meet the following conditions:

$$\begin{cases} \int_{a}^{+\infty} f_e(t_u)dt_u - \int_{a}^{+\infty} f_e(t_p)dt_p < 0 \\ \int_{a}^{+\infty} f_e(t_p)dt_p - \int_{a}^{+\infty} f_e(t_0)dt_0 = 0. \end{cases} \tag{3}$$

Within the scope of these conditions, two particular cases were also chosen and marked as 3a and 3b. They are presented in Fig. 2.

Other elementary functions of probability densities with stable courses for all sample calculations are presented in Fig. 3.

Calculations were performed for the longwall which two-way mined by heading machine at lenght 100 meters. The maximum distace between heading machine and moveable support did not exeed 25 meters.

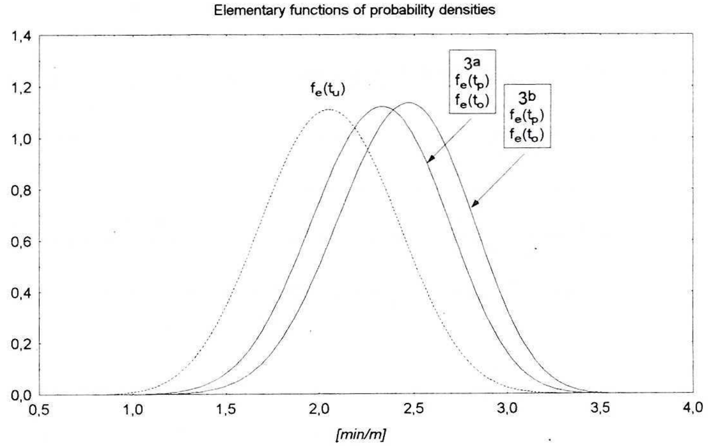

Fig. 2. Elementary functions of probability densities which were used in sample calculation No. 3

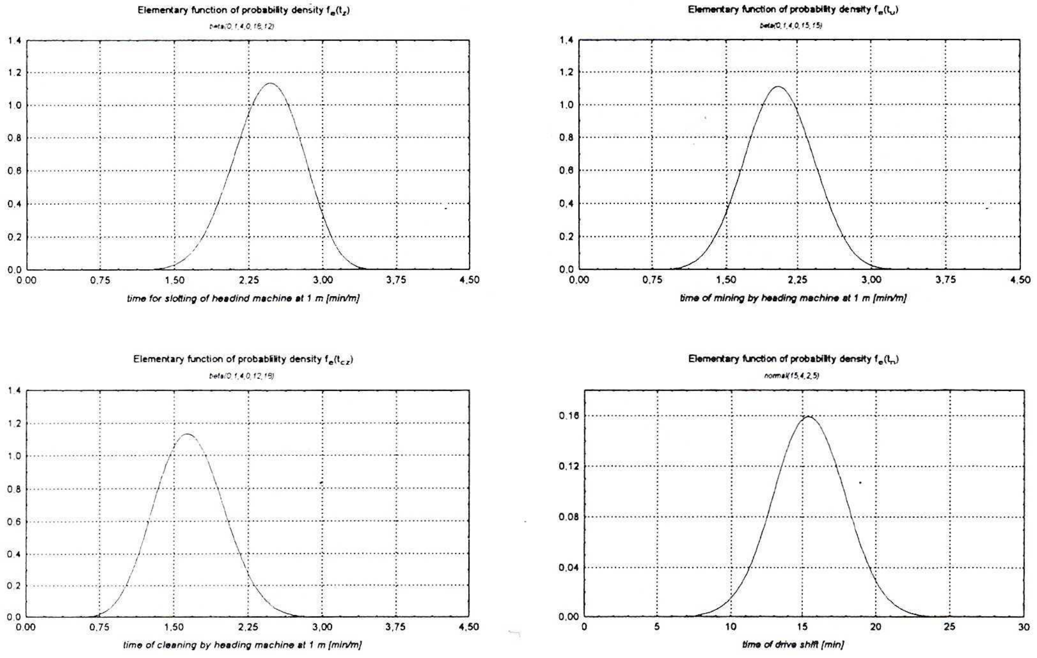

Fig. 3. Elementary functions of probability densities with stable courses for all sample calculations

The size (number) for each sample calculation was set at 740. It resulted from asumptions made by the author and the method described in (Elmaghraby, 1977). The method is based on Kolmogorov-Smirnov test for which it is assumed that the difference between theoretical and empirical distribution functions should not exeed set value D_k for determined value for confidence level α.

The following assumptions were made:

1. Difference between theoretical and empirical distribution functions should not exeed 0.05, i.e. $D_k = 0.05$.

2. Confidence level was set at 0.95, i.e. $\alpha = 0.95$.

For set values D_k and α, value for λ is read from distribution chart for which the following equation is valid:

$$P\left(D_k\sqrt{n} < \lambda\right) = 0{,}95. \tag{4}$$

For value $\lambda = 1.355$ (read from the chart), value for n should be equal at least to 735. On the base of the above given data, the size of the sample was set at $N = 740$. Table shows values for some statistics which were determined on the base of sample calculations.

TABLE

Set of values for statistics which were calculated for results obtained from the sample calculations

		Sample size	Sample calculations				
			2b	2a	1	3a	3b
Duration time of production cycle T_c [min]	Average value	740	279.59	280.54	291.65	303.71	309.96
	Standard deviation		2.87	2.80	2.85	2.89	2.88
Total, average time of breaks in work of heading machine T_{pk} [min]			0.00	0.20	9.80	20.48	26.07

Fig. 4. presents diagrams for functions of probability densities $f_{tc}(t_c)$ for value T_c — duration time of production cycle for sample calculations (positive verification of hypothesis that these functions are normal was made in (Snopkowski, 2000).

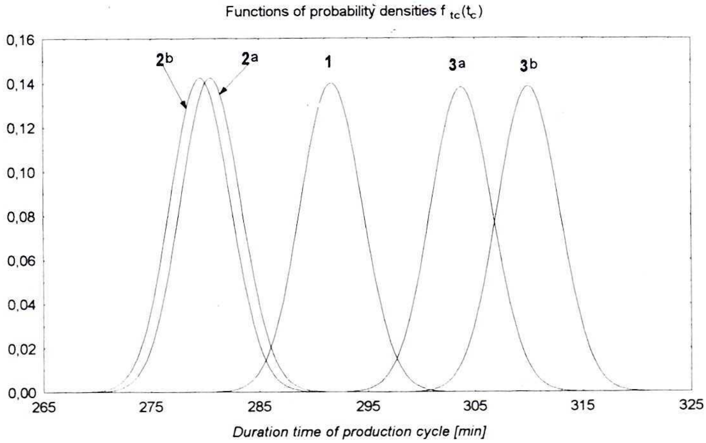

Fig. 4. Functions of probability densities $f_{tc}(t_c)$ for the sample calculations

Interpretation of obtained results leads to conclusion that reciprocal relations between elementary functions of probability densities have substantial influence on the course of function $f_{tc}(t_c)$ for variable T_c — duration time of production cycle. In the sample calculation described by conditions (3), duration time of production cycle becomes longer. The larger the difference which results from inequality in conditions (3), the more unfavourable becomes the situation. It was proved by results of sample calculation 3b. Average total idle time for heading machine work in this sample calculation was 26 minutes. In calculations marked as 2a and 2b the idle time was practically equal to zero.

Conclusions

Determination of relations between elementary functions of probability densities can provide answer for the question whether movement of heading machine can be stopped by other, carried out paralelly (simultaneously) operations of the production cycle.

Therefore, elementary functions of probability densities should meet the following boundary conditions:

$$\begin{cases} \int_a^{+\infty} f_e(t_u)\,dt_u - \int_a^{+\infty} f_{e_1}(t_1)\,dt_1 > 0 \\ \int_a^{+\infty} f_e(t_u)\,dt_u - \int_a^{+\infty} f_{e_2}(t_2)\,dt_2 > 0 \\ \vdots \quad \vdots \quad \vdots \quad \vdots \\ \int_a^{+\infty} f_e(t_u)\,dt_u - \int_a^{+\infty} f_{e_i}(t_i)\,dt_i > 0 \end{cases} \tag{5}$$

for each value "a" >0,
where:

$f_e(t_u)$ — elementary function of probability density for variable T_u – mining time by heading machine on 1 meter distance,

$f_{e_1}(t_1), f_{e_2}(t_2) \ldots f_{e_i}(t_i)$, — elementary functions of probability densities for activities or operations carried out simultaneoulsy (paralelly) with mining by heading machine when realisation of these influence the movement of the heading machine.

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