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THE HYPOTHESIS ON THE ENERGY ASSEMENT AS FOR OPERATIONAL SAFETY OF FUNCTION ELEMENTS IN COAL MINING MACHINES

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ГІПОТЕЗА ПРО ЕНЕРГЕТИЧНУ ОЦІНКУ НАДІЙНОСТІ ВИКОНАВЧИХ ОРГАНІВ ВУГЛЕДОБУВНИХ МАШИН

Purpose. To develop a methodology aimed at determination of the time between overhauls (TBO) for coal mining machines based on the energy intensity of the unworked coal crushing.

Methodology. For specific stopes, where durability indices for augers as function elements were known, the values of specific power inputs for crushing of the unworked coal were calculated and then compared to the actual values as for the auger overhaul life. Based on the data, the graphs of auger TBO were plotted as a function taking into account the power inputs for crushing of the unworked coal in relation to different types of mining machines and augers. The energy resource for the function element was determined as the product of its overhaul life and specific power inputs for crushing of the unworked coal during the operation under specific conditions of resistance of the seam to cutting.

Findings. The research proved that, irrespective of operating parameters of a mining machine, the product of specific power inputs for cutting of the unworked coal and the TBO for the augers of such a design of a function element is a constant value. It is numerically equal to the total energy spent on crushing of coal volume equal to the auger TBO.

Originality. The forecasting of average reliability indices for newly designed and mass-produced function elements can be made based on the established relationship of specific power inputs for cutting of the unworked coal and the TBO for augers.

Practical value. The developed method for estimating the reliability of function elements based on the energy resource allows calculating the TBO for function elements of mining machines in relation to any conditions of their operation as far as coal seam resistance to cutting is concerned.

Keywords*: coal seam, resistance to cutting, energy intensity, energy resource, operational safety, function element, coal cutter-loader*

Observations of work as for coal cutter-loaders during their operation under equal conditions according to the crushing characteristics of the coal-seams showed that the higher (in 1,5÷2,0 times) overhaul life value of the function elements (augers) R_{sor} corresponds to the higher coal cutter-loader feed rates. Such a striking variance in the operational safety of the augers having the same configuration is explained by the difference in operating modes of the employed coal cutter-loaders (1K101, K500U, 2GSH68B, 4LS5, SL500, KGS and others). For example, the coal cutter-loaders 2GSH68B crush the unworked coal with substantially low auger rotating speed as compared with 1K101U. The coal cutter-loaders with high per capita power consumption, like K500U, SL500 and others provide besides this the higher feed rates, combinations of which with low, if compared to 1K101, rotating speed n_{tur} involve the chip thickness h and the cuttings cross-section increase, and consequently the decrease of the operating time in the cutting path T_L per unit of mining. Thus the number of loading cycles as for the units and elements of an executive device decreases, which positively influences their safety. The decrease of the cutting path is pro rata to the increase of the ratio V_n / n_{tur}. On the other hand, with the h increase, the efforts, influencing on an executive device, and consequently the power $\overline{P}_м$, spent on the rock fragmentation, increase either. However, it is known [1] that with the h increase, in spite of the $\overline{P}_M$ increase power inouts per unit on cutting H_{wp} become lower. Hence, the physical interpretation of the

inequality of values $R_{os.}$ under different operational modes of the cutter-loaders is given which implies the following: the coal cutter-loaders being in operation, the part of energy, transmitted from electromotors to executive device`s cutters is spent on friction and deformation of the units and components of the executive device which essentially determines the operational safety level of the latter. The higher power consumption for cutting is, the larger part of energy per unit of production is dispersed within the elements of the executive device and consequently, the lower its operational safety is, being determined, in this case, by the indices $R_{sor.}$. Since if compared with K500U, SL500 under equal conditions of operation, the cuttings/chip thickness in case of 1K101 coal cutter-loader operations is less and the cutting energy-output ratio is, vice versa, higher, so the values R_{sor} in the first case are lower than in the second one.

With the overhaul life expressed not in the production volumes $R_{sor}(Q)$ but in the cutting path right until the executive device failure $R_{sor}(L)$ and considered as the reliability index, on the assumption of the fact that with the power /seam thickness growth $\overline{P_M}$ the depth of cuttings/chip thickness increases, we can suggest that failures of the similar design augers when employed in different types of coal cutter-loaders are to take place after passing approximately the same cutting path only in case when the ratio of the feed rate to the auger rotation speed $V_п/_{rot}$ is equal. The given proposal is confirmed by the experimentally stated dependence of the auger overhaul period R_{sor} on the indices equivalent to coal resistance to cutting A_{ew}, given in fig. 1. During pilot researches in mines, the criterion of the marginal state for an executive device on which its overhaul period depends was the definite number of the cutter holder failures (wear and tear of the slot cutter, break-off of the body) and instantaneous failures in a hub**.**

The graph is plotted for the coal cutter-loaders 1K101 and 2GSH68B which, working in equal conditions under indices At_{eq}, provide approximately equal values for the ration $V_п/n_{tur.}$ As seen in fig. 1, the plotted points for both types of coal cutter-loaders are aggregated in the neighborhood of one average curve.

Thus, the performed analysis allows us to draw an important in practical sense conclusion, proving that to increase the auger overhaul period, it is expedient to work, whenever possible, with the operating parameters that provide higher values of the thickness of the cutting (ratio $V_п/n_{tur)}$) and consequently, lower energy intensity of cutting.

The obtained experimental data on the nature and physical essence of auger failures as well as the influence of the modes of the rock fragmentation on the auger overhaul life contribute to the estimates of their operational safety indices based on energy approaches in a new way.

Analyzing the results of our researches, we hypothesized interactions between an overhaul period of the executive device and energy consumption for cutting. The following aspects were the prerequisites for putting forward the given hypothesis. Regarding auger executive devices that directly take the load from the coalface, the voltage level in hubs and elements per se depends on the voltage and consequently, on the energy consumption in the crusher zone. As for the crushing/breaking elements, it can be supposed that with other things being equal, the energy lost in elements of the device is proportional, to the total energy consumption required for fragmentation ($\overline{Э}_R$), which can be calculated [1]. In this case, the characteristics of operational safety for crushing/breaking elements (in particular, their overhaul resource R_{sor}) must be the explicit energy consumption functions, i.e. $R_{sor}=f(\overline{Э}_R)$. Since the value of power inputs required for fragmentation of the unworked coal depends on the parameters of the schemes for arrangement of the instrument on the executive device and on the modes of operation of a cutter-loader (along with the properties of the seam), with the assumption in mind that $R_{sor}= f(\overline{Э}_R)$, it is possible to state that the latter influence on the operational safety of executive devices as well.

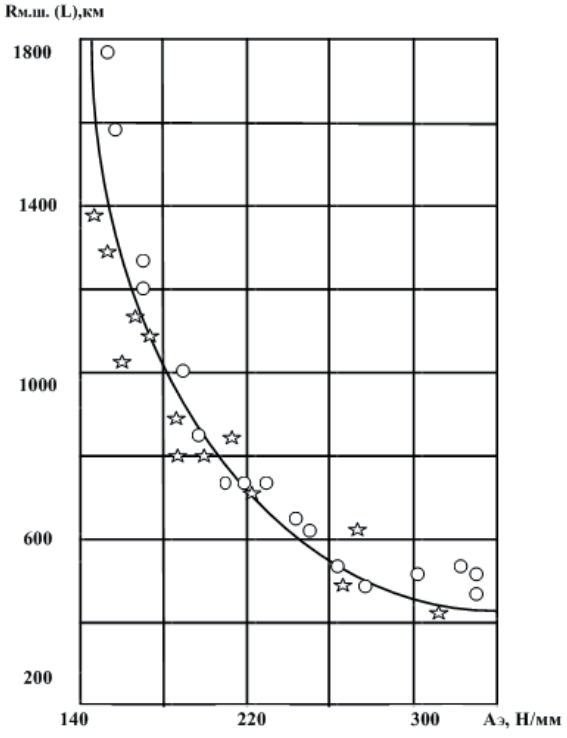

Fig. 1. The graph of the auger overhaul period, in units of the cutting path R_{sor} (L) depending on indices A_{eq}, where: ○ – 1K101 coal cutter-loaders; ☆ – 2GSH68B coal cutter-loaders

The proof of the offered hypothesis was realized in the following way. For the specific stopes, where the safety indices of auger executive devices were known, according to the methods OST12.44.258-84, the values of power inputs necessary for the unworked coal fragmentation $H_{wp.}$ were determined. The feed rate of coal cutter-loaders, parameters of the scheme for the cutting tool and the index A_e applied in the calculation were taken into account according to the actual data. Practically all typical conditions for application of cutter-loader executive devices were considered.

The obtained calculated data of the specific energy consumption H_{wp} were compared with the actual values of the

auger overhaul resources R_{sor}, on the basis of which the graphs $R_{sor}= f(\overline{H}_{wp})$ were plotted. The dependence $R_{sor}= f(\overline{H}_{wp})$ for the augers SHR with the diameter of 0,8 m for the cutter-loader 1K1O1U is shown in fig. 2.

In table 1, the data are given against which the dependence $R_{sor} = f(\overline{H}_{wp})$ was plotted in fig. 2. In the graph, it is clear that with the energy consumption increase required for the fragmentation H_{wp} the auger overhaul resource R_{sor} decreases hyperbolically. This means that the lower specific power inputs for fragmentation of the unworked coal are during the operation of the executive device, the less energy is spent on the production unit (or time unit), though failures in hubs or components still occur, their operational safety is higher.

The analysis showed with high enough exactitude (the variation coefficient 0,104) the total energy spent on the production volume and relevant to the overhaul life for the executive device of the given design is the approximate constant value, i.e.

$$\overline{Э}_R = H_{wp} \cdot R_{миш} \approx const . \qquad (1)$$

In the considered case, the value $\overline{Э}_R$=7520 kw-h. (the variation coefficient is 0,106).

Since the value $\overline{Э}_R$ for the specific configuration of the executive device, regardless of the maintenance conditions, is an approximate constant value, it is possible to assume that

$$R_{миш} = \frac{\overline{Э}_R}{H_{wp}} . \qquad (2)$$

It is stated that there exists the value $A_{e.o}$ lower of which the failure intervals for executive devices are constant and the greatest. Taking into account that $H_{wp.o}$ are the specific power inputs for fragmentation at $A_e \le A_{e.o}$, it is possible to suppose that there exists the auger overhaul resource limit $R_{sor.lim.}$ for the given auger congiguration.

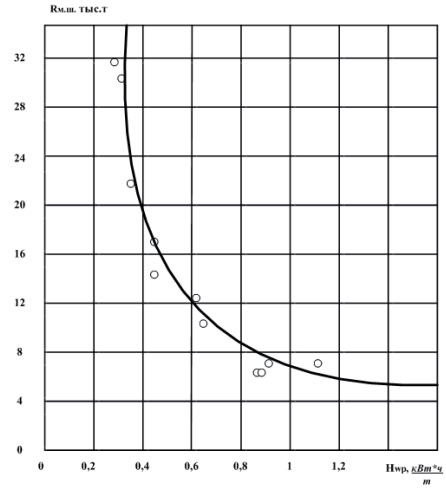

Fig. 2. Dependence of auger overhaul resource (R_{sor}) for the SHR coal cutter-loader 1K1O1U on specific power inputs aimed at seam fragmentation (H_{wp})

Table 1

Data for plotting of the dependence $R_{sor} = f(\overline{H}_{wp})$

Indices of the equivalent seam resistance to cutting A_{eqw}, H/mm	Coal cutter-loader feed rate V_n, m/min	Specific energy consumption during coal mining H_{wp}, kw-h.\t	Auger overhaul resource R_{sor}, thous.t.	Total energy, spent on coal volume fragmentation, equal to overhaul resource $\overline{Э}_R$, kw-h
164	3,50	0,24	35,2	8448
230	3,00	0,42	17,9	7818
320	1,70	1,12	6,5	7280
237	1,73	0,64	13,8	8851
239	1,91	0,93	7,4	6885
183	1,96	0,26	32,2	8557
167	2,04	0,69	10,7	7389
203	1,85	0,47	14,6	6828
294	1,50	1,62	4,2	6802
324	1,80	0,93	7,5	6922
211	2,80	0,32	22,7	7264
313	1,50	0,93	7,8	7254

In order to test the dependence (2), the other data group, obtained under different conditions for the index A_e was used. In calculations, the results of which are presented in table 2, the assumed value is $\overline{Э}_R$ = 7520 kWh, and the value R_{sor}. is calculated by the expression (2).

As follows from table 2, the error of the calculated values for R_{sor} does not exceed 9,7%, , which testifies the high exactitude of the presented method aimed at operational safety evaluation of executive devices.

The similar analysis was performed for the serial auger type SHR, applied in coal cutter-loaders 2K52MU, 1GSH68 and KSH3M, different in their operating parameters. The aggregate data are given in table 3. The data on the specific energy consumption for the seam fragmentation were determined experimentally on the basis of observation of the energy consumed by the coal cutter-loader and its subsequent division by the value of the mined coal volume during the experiment period under the concrete operation conditions. In order to broaden the range of researches, the feed rates of coal cutter-loaders were set by an operator forcibly, in terms of the conditions of the mine experiment.

Table 2

The comparison of the actual and calculated values of the auger overhaul resource

Indices of the equivalent resistance of the seam to cutting A_{eq}, H/mm	Coal cutter-loader feed rate V_n, m/min	The specific energy consumption during the coal mining $H_{wp.}$, kWh./t	Augers overhaul resource thous. t.		Error E, %
			calculated $R_{sor.cal.}$	actual $R_{sor.act.}$	
215	2,5	0,42	17,9	16,8	6,0
211	1,6	0,51	14,7	14,2	2,8
312	1,7	1,30	5,8	5,5	3,6
183	2,9	0,26	28,8	27,8	3,6
338	1,0	0,97	7,7	8,3	7,2
231	2,1	0,59	12,7	12,0	5,8
335	1,2	0,78	9,6	9,3	3,2
154	2,3	0,46	16,3	17,6	9,7
300	1,1	1,58	4,8	5,3	9,4

Analyzing the data given in table 3, it is clear that the results obtained with satisfactory accuracy confirm the determinacy of the expressions (1) and (2) for the other coal cutter-loader types as well (the variation coefficient 0,106–0,170)

If compared, the data presented in table 3 show that auger application of the type SHR approximately of the similar configuration for the coal cutter-loader1K101U, on the one hand, and 1GSH68, on the other hand, fundamentally different in their operating parameters and specific energy consumption H_{wp}, does not influence on the value $\overline{Э}_R$, though the value R_{sor} for these augers differs in compared conditions at A_e.

This fact is caused by the energy nature of executive device failures: the higher the energy intensity for fragmentation is, the less is R_{sor} and vice versa, a longer overhaul life in mining corresponds to less energy consumption for cutting. In other words, the equality of values $\overline{Э}_R$ retains in this case at the expense of the compensation of the increase (decrease) H_{wp} by the decrease (increase) $R_{sor.}$.

Thus, in such a way the overhaul resource of the executive device of such configuration is explicitly determined by the values of the total and specific power inputs required for the coal fragmentation.

Table 3

The results of energy assessment for the auger operational safety

The coal cutter-loader type	The auger marking	The observation numbers	The rangeability			The average value of the total energy for fragmentation $\overline{Э}_R$, кWt \h	The specific power inputs for coal fragmentation H_{wp}, kWh/т	The variation coefficient V_r
			A_e, H/mm	V_n, m/min	R_{sor} thousand tons			
1K1O1U	SH88R	24	1541-338	3,5-1,0	35,2-4,2	7520	0,23-1,62	0,106
1GSH68	SH116R, SH126R	16	145-387	5,0-1,0	79,4-4,9	7266	0,13-1,9	0,120
KSH3M	SH166K	12	150-290	2,5-2,1	40,6-19	12218	0,38-0,47	0,130
КАН3М	SH186K	22	106-263	2,5-1,8	38,0-20,1	13651	0,34-0,63	0,170

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Линник Ю.Н. Расчет параметров исполнительных органов очистных машин на основе электронного банка данных о характеристиках разрушаемости угольных пластов / Ю.Н. Линник, В.Ю. Линник // Горное оборудование и электромеханика – М.: Новые технологии, 2011. – С. 42–49.

Мета. Розробка методики визначення міжремонтного ресурсу виконавчих органів вугледобувних машин на основі енергоємності руйнування вугільного масиву.

Методика. Для конкретних очисних вибоїв, в яких були відомі показники надійності шнекових виконавчих органів, розраховувалися значення питомих енерговитрат на руйнування вугільного масиву, які зіставлялися з фактичними значеннями міжремонтного ресурсу шнеків. Потім на підставі цих даних будувалися графіки залежності міжремонтного ресурсу шнеків у функції від енерговит-

рат на руйнування масиву для різних типів комбайнів та шнеків. Визначався енергоресурс виконавчого органу як добуток його міжремонтного ресурсу й питомих енерговитрат на руйнування вугільного масиву під час експлуатації в конкретних умовах за показником опірності пласта різанню.

Результати. Встановлено, що, незалежно від режимних параметрів вугледобувного комбайну, добуток питомих енерговитрат на різання вугільного масиву та міжремонтного ресурсу для шнеків цієї конструкції виконавчого органу є незмінним, чисельно дорівнює повній енергії, витраченій на руйнування об'єму вугілля, рівного міжремонтному ресурсу шнека.

Наукова новизна. Наукова новизна запропонованого в роботі методу – прогнозування середніх показників надійності новопроектованих та випущених серійно виконавчих органів можна здійснювати на основі встановленого взаємозв'язку питомих енерговитрат на різання вугільного масиву та міжремонтного ресурсу шнеків.

Практична значимість. Розроблений метод оцінки надійності виконавчих органів на основі енергоресурсу дозволяє розраховувати міжремонтний ресурс виконавчих органів комбайнів стосовно будь-яких умов їх експлуатації по опірності пласта різанню.

Ключові слова: *вугільний пласт, опірність різанню, енергоємність, енергоресурс, надійність, виконавчий орган, вугледобувний комбайн*

Цель. Разработка методики определения межремонтного ресурса исполнительных органов угледобывающих машин на основе энергоемкости разрушения угольного массива.

Методика. Для конкретных очистных забоев, в которых были известны показатели надежности шнековых исполнительных органов, рассчитывались значения удельных энергозатрат на разрушение угольного массива, которые сопоставлялись с фактическими значениями межремонтного ресурса шнеков. Затем на основании этих данных строились графики зависимости межремонтного ресурса шнеков в функции от энергозатрат на разрушение массива для различных типов комбайнов и шнеков. Определялся энергоресурс исполнительного органа как произведение его межремонтного ресурса и удельных энергозатрат на разрушение угольного массива при эксплуатации в конкретных условиях по показателю сопротивляемости пласта резанию.

Результаты. Установлено, что, независимо от режимных параметров угледобывающего комбайна, произведение удельных энергозатрат на резание угольного массива и межремонтного ресурса для шнеков данной конструкции исполнительного органа есть величина постоянная, численно равная полной энергии, затраченной на разрушение объема угля, равного межремонтному ресурсу шнека.

Научная новизна. Научная новизна предложенного в работе метода – прогнозирование средних показателей надежности вновь проектируемых и выпускаемых серийно исполнительных органов можно производить на основе установленной взаимосвязи удельных энергозатрат на резание угольного массива и межремонтного ресурса шнеков.

Практическая значимость. Разработанный метод оценки надежности исполнительных органов на основе энергоресурса позволяет рассчитывать межремонтный ресурс исполнительных органов комбайнов применительно к любым условиям их эксплуатации по сопротивляемости пласта резанию.

Ключевые слова: *угольный пласт, сопротивляемость резанию, энергоемкость, энергоресурс, надежность, исполнительный орган, угледобывающий комбайн*

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