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# THE INFLUENCE OF THE EXPLOITATIONAL RELIABILITY OF MINE WINDING GEARS ON THE CAPACITY OF SHAFT TRANSPORT SYSTEMS

Summary. The problems of exploiting the transport capacity of some elements of the mine transport machinery systems are presented in the paper. Particular attention is paid as to what extent the mine winding gears are exploited. Some test results are given from the wide investigation of operational processes of the shaft transport machinery systems. The results presented, illustrate the influence of reliability of the mine winding gears on the output of the shaft transport systems. The conclusions point to the directions of the desirable works which could increase the transport capacity of the existing winding gears.

## 1. INTRODUCTION

The rational exploitation of the machinery systems used in underground coal mining, which comprise the processes of exploitation and maintenance is the problem deserving special attention. To-day there is a great operational potential of the mine machinery systems, worth of billions, whose technological structures are, as a rule, very sensitive to any disturbances of the exploitational processes of their elements and subsystems. A proper and undisturbed operation of those systems decides on the effects of the production process and conditions the production at lowest costs. The production processes in coal mines have a specific character resulting from a considerable influence of the independent, external factors, mainly the geological and mining conditions on their courses. The objects of interest of this paper are the winding gears, operating in coal mines. If the servicing states contained in the disposable time of operation appear in the exploitation process of the mine winding gear it is connected always with the loss of that time and with the reduction of the potential winding capacity.

One of the conditions of eliminating or minimizing the time intervals of failures is a through knowledge of the operating processes of the objects investigated. The lack of a precise discernment of the exploitational processes and the unacquaintance of the factors characterizing them brings about some negative consequences, in the first place the following ones: disregarding the reliability in the designing phase, lack of a suitable prophylaxis concerning the durability and reliability control, inability of optimizing the exploitational costs and carrying out the groundless replacements of elements which, from the technical point of view, would be suitable for further operation, but their replacement is forced by the regulations.

## 2. THE EXTENT OF EXPLOITING THE TRANSPORT ELEMENT CAPACITIES OF THE MINE TRANSPORT MACHINERY SYSTEMS

The machinery system of a mine consists of a large number of machines primarily for coal transport, cooperating most frequently in series. The structures of machinery system have a dynamic character. During the exploitation of a coal mine the length of transport roads and the number of elements in operation alter due to starting the new coal faces and clearing the old ones. In many cases the elements composing the system change their parameters because of the implementation of the more and more productive and reliable cutter-loaders, chain conveyors, belt conveyors etc. Contrary to this the capacity of the winding gear is set for many years, because the high costs of shaft sinking, especially in the deep mines, and the costs of the winding gear equipment permit neither the frequent modernization, nor keeping the high capacity reserve idle.
The production of the coal mine is then, in many cases, determined by the winding capacity, which in turn depends on the continuity of the winding gear operation. Considering the winning of coal nowadays, great differences are noticed between the theoretical productivity of coal faces, the road transport and the actual daily production of the mine. The operational investigation of the shaft transport machinery systems - STMS - have shown [1], that there is a trend of prolonging the disposable time of shaft operation while the down time of the winding gear due to the lack of coal delivery to the shaft bottom is increasing. The investigation of the machinery system elements of the road and shaft transports disclose great differences between the production and the theoretical transport capacities [2].

The exemplary mean values of production to transport capacity ratio for some of the mine transport elements are as follows [2]:

- chain conveyor "Grot" - M = 35,36%
- chain conveyor "Śląsk 67" - M = 38,87%

- belt conveyor "PTG-50/800" - M = 25,01%
- belt conveyor "PT-50/1000" - M = 29,40%.

The corresponding values for the systems of the main road and shaft transport are:

- machinery system of car transport - M = 49,16%
- machinery system of shaft transport - M = 81,47%

From the above results it is seen, that the exploitation degree fo the elements of the road transport machinery system is small.
For all the selected elements it does not exceed 50%. Much better values are for the exploitation degree of the shaft transport machinery systems. Then shaft transport machinery systems [1] were throughly investigated which give an exact assessment of the operational processes of those objects.
In figs. 1 and 2 some exemplary results are presented of the balances of the calender times investigated for the two STMS.

The characteristic time values are plotted in the diagrams as follows:

- the assumed, disposable time of STMS operation - that value was determined as the sum of hours of the disposable time of operation in the individual days, months and years,
- the actual disposable time of STMS operation - for individual days that value was determined as the difference between the hour of termination and the beginning of the winding operation. The sum of such calculated values gave the actual disposable time of operation for individual months and years,
- the actual effective time of STMS operation - this was calculated from the number of skips with coal wound up to the surface and the time of one cycle,
- values of excess of the assumed, disposable times of STMS operation - it was calculated as the sums of the positive differences between the assumed and the disposable times of the STMS operation for the individual days, months and years.

The balance of the calender times of the objects investigated show considerable differences of using the disposable time for the effective STMS operation. For the majority of objects there were appreciable fluctuations of the actual affective time of operation in some months during the two years under examination. The exploitation of the actual, disposable time of STMS operation for the effective work was 52,3 to 81,8%. The calculated figures for the individual objects are presented in fig. 3.
It seems, that the effective use of the actual time of operation by the STMS, although higher in comparison to some other elements of the mine transport systems, is unsatisfactory. An alarming thing is the prolongation of the actual disposable time of the STMS operation in respect to the time primarily assumed.

Those time prolongations came out in all the objects analysed and for the majority of the objects the prolongations amounted to a few hundred hours per year. This is connected directly with the reduction of the primarily planned time intended for the renewal of the STMS.
That phenomenon is particularly dangerous in case, if the assumed time intervals intended for the renewal were planned on the level of the indispensable ones needed for inspections, controls, repairs, replacement of parts, maintenance etc.

## 3. THE EXPLOITATIONAL RELIABILITY OF THE SHAFT TRANSPORT MACHINERY SYSTEMS

From an analysis of the actual disposable time intervals of the STMS operation it is possible to determine the main reasons of their unsatisfactory, effective use. A detailed analysis of the exploitational processes of the then STMS in the actual disposable time intervals was made on the level of five subsystems [1], into which the analysed objects were divided (fig. 4).

The following STMS subsystems were distinguished:

No 1 - subsystem realizing the delivery of coal to the shaft bottom
No 2 - subsystem containing all the elements of the shaft bottom
No 3 - subsystem consisting of the winding gear with the headgear and the movable and unmovable shaft elements
No 4 - subsystem containing all the elements of the shaft top
No 5 - subsystem realizing the receipt of coal from the shaft top.

The percentage share of the dwon times of the individual subsystems in the total down time for one of the objects analysed is shown in fig. 5. The greater part of the down time of the STMS operation was produced by the subsystems no 1 and no 2, which perform the delivery of coal to the shaft bottom and the receit of it from the shaft top. Similar results were obtained for the remaining nine STMS investigated in operation. For all the STMS subsystems the factors were determined which characterized their exploitational processes. By means of the statistical data about the STMS exploitation processes a hypothesis could be verified, that the processes of exploiting and servicing the STMS could be treated as the stationary, stochastic processes [1].

The possibility of using the stationary Markov's processes as a mathematical model to describe these processes permitted us to assume four basic factors for the assessment of their course and namely:

$\alpha$ - failure formation rate
$\beta$ - failure decline rate
$\varkappa$ - break dwon factor
$P_o$ - limit probability of proper operation

The most interesting of the above listed factors is the limit probability of proper operation $P_o$, because these values can be interpreted as the probability of the object being in the state of proper operation. The failure formation rate $\lambda$ is the measure of the reliability of both the individual elements and the whole objects and it well characterizes the process of exploitation. The failure decline rate $\beta$ is closely connected with the failure clearing rate, characterizing the process of maintenance. In fig. 6 the exemplary factors are presented which were obtained for the data of one year investigation of the process of no 1 STMS exploitation. The most advantageous factors $\lambda$ and $\beta$ were obtained for the no 3 subsystem i.e. the subsystem consisting of the winding gear and the gearhead with the movable and immovable shaft elements. At the similar level are the factors for the subsystem no 4, but the number of elements contained in this subsystem is much less.

Unfavourable values were obtained for the two subsystems which cooperate with the winding gear i.e. the delivery of coal to the shaft bottom and the receipt of it from the shaft top (No 1 and No 5).

In table 1 are given the factors calculated for some STMS, which characterize the complete objects. The exploitation tests reveal, that there is a correlation between the reliability factors and the actual disposable times of STMS operation. Significant prolongation of the disposable time of STMS operation has a negative influence on the STMS reliability factors. The calculated factors illustrate the influence of the exploitational reliability of the mine winding gears as well as of the rest subsystems on the output of the shaft transport systems.

The most helpful factor for the determination of that influence is the limit probability of proper operation [3]. The reliability factors determined for the mine winding gears take very favourable values in comparison with other elements of the mine transport systems. These values show, that it is necessary to treat the mine winding gears individually when their reliability characteristics are to be determined [1].

From an analysis of the STMS exploitational test results it is evident, that the most effective way of increasing the transport capacities of the existing STMS is to secure the continuity of operation of the winding gears. One of the ways of solving that problem is the application of surge bins both at the shaft top and at the shaft bottom with some definite capacities.

The selection of the capacities of the surge bins for the STMS characterized by certain exploitational reliability factors is given in paper [1]. The $P_o$ values of the limit probability of proper operation of the analysed STMS can be used for calculation of their effective capacities [3], using the following relation:

$$W_{ef} = W_t \cdot P_o \cdot k_v \quad Mg/h$$

where:

$W_t$ - theoretical hourly capacity of the winding gear,

$P_o$ - limit probability of proper operation of the system analysed, which can be calculated from the formula:

$$P_o = \frac{1}{\sum_{i=1}^{m} \frac{1}{P_{oi}} - m + 1}$$

if the limit probabilities of proper operation of the individual subsystems $P_{oi}$ are known, into which the STMS is divided, providing, that the system elements suitable for operation, which are at the standstill are practically not liable to failure,

m - number of STMS subsystems,

$k_v$ - factor of increase of effective productivity, depending on the surge bin capacities, whose value can be determined by means of the simulation test method [1].

The relation mentioned above determines directly the influence of the STMS exploitational reliability on their effective capacity.

## 4. CONCLUSIONS

1. The effect of the exploitational reliability of the mine winding gears on the capacity of the shaft transport machinery systems is much smaller compared with the effect of its other subsystems.
2. To exploit the transport capacities of the winding gears in the most effective way is to secure the continuity of their operation by the rationalization of the exploitational processes of the cooperating subsystems and the application of surge bins of certain capacities.

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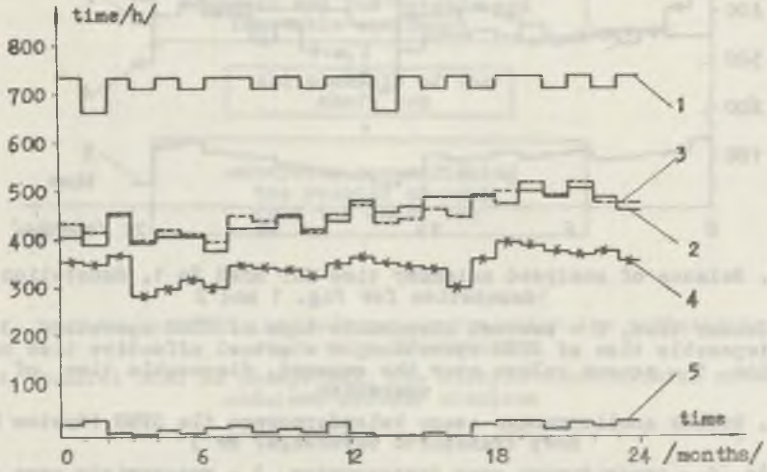


Fig. 1. Balance of analysed calender time for STMS No 1

Rys. 1. Bilans analizowanego czasu kalendarzowego dla STMS (System Maszynowy Transportu Szybowego) Nr 1, gdzie

1 - czas, 2 - przewidywany czas dyspozycyjny, 3 - rzeczywisty czas dyspozycyjny, 4 - rzeczywisty czas efektywny, 5 - naddatek czasu dyspozycyjnego ponad wartość przewidywaną

Table 1

Reliability factors for four STMS

| No of STMS | Failure formation rate $\lambda \frac{1}{h}$ | Failure decline rate $\beta \frac{1}{h}$ | Break down factor $\mathcal{H}$ | Limit probability of proper operation $P_o$ |
|---|---|---|---|---|
| 1 | 1,7544 | 7,69 | 0,2281 | 0,8142 |
| 2 | 1,0638 | 2,17 | 0,4902 | 0,6710 |
| 3 | 1,3333 | 4,00 | 0,3333 | 0,7500 |
| 4 | 1,3158 | 2,27 | 0,5796 | 0,6331 |

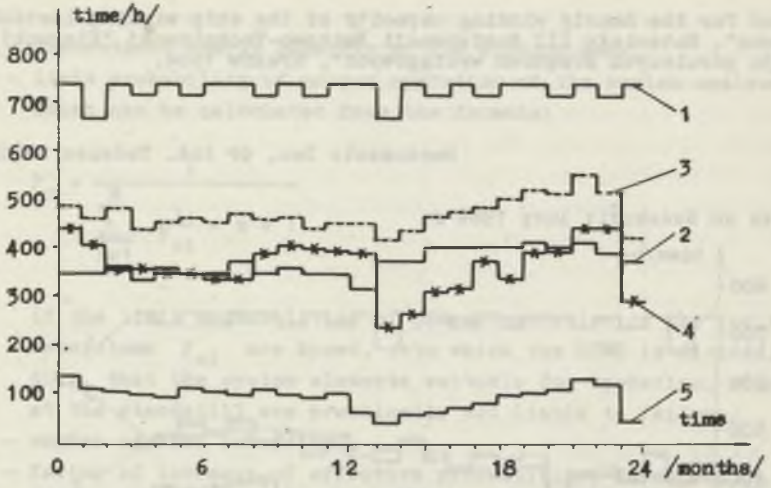


Fig. 2. Balance of analysed calender time for STMS No 1, denotation for denotation for Fig. 1 and 2

1 - calender time, 2 - assumed disposable time of STMS operation, 3 - actual disposable time of STMS operation, 4 - actual effective time of STMS operation, 5 - excess values over the assumed, disposable time of STMS operation

Rys. 2. Bilans analizowanego czasu kalendarzowego dla STMS (System Maszynowy Transportu Szybowego) Nr 3

1 - czas, 2 - przewidywany czas dyspozycyjny, 3 - rzeczywisty czas dyspozycyjny, 4 - rzeczywisty czas efektywny, 5 - naddatek czasu dyspozycyjnego ponad wartość przewidywaną

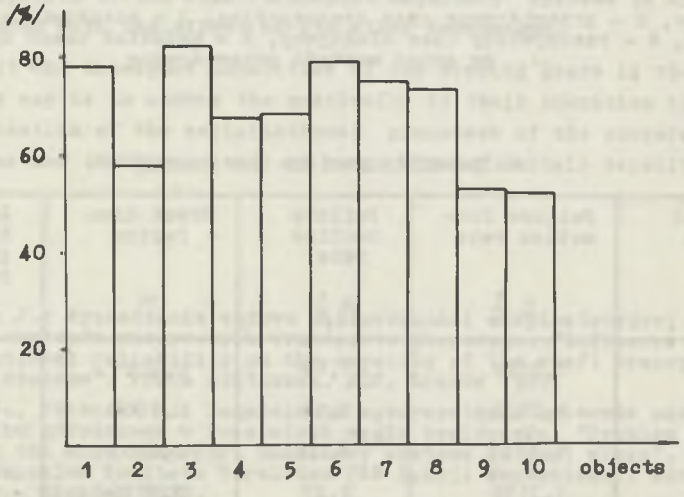


Fig. 3. Exploitation of the actual, disposable time of STMS operation for effective operation

Rys. 3. Eksploatacja rzeczywistego, dyspozycyjnego czasu dla STMS (System Maszynowy Transportu Szybowego)

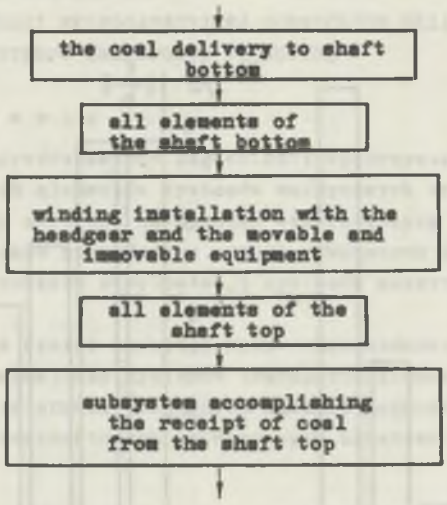


Fig. 4. Division of STMS into subsystems for which the reliability factors were determined

Rys. 4. Podział STMS na podsystemy, dla których współczynniki niezawodnościowe zostały ocenione

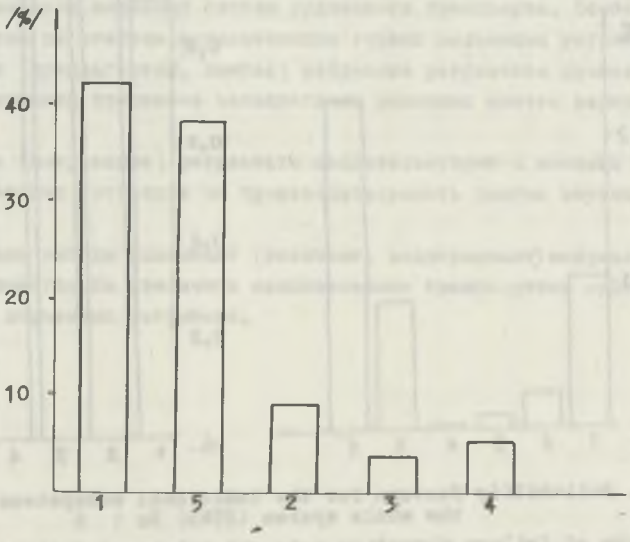


Fig. 5. Percentage share of the down times of the individual subsystems of the total down time of the No 1 STMS operation

Rys. 5. Procentowy udział czasów postoju poszczególnych podsystemów w całkowitym czasie postoju dla STMS Nr 1

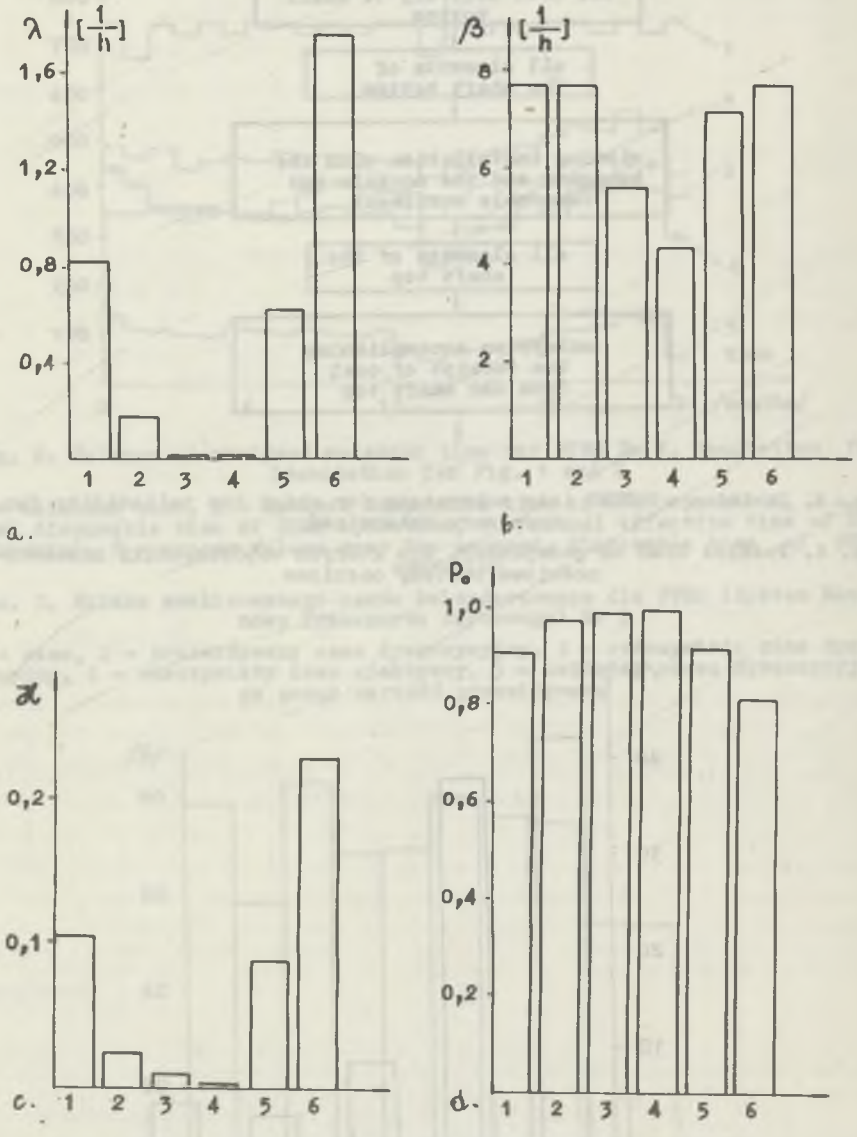


Fig. 6. Reliability factors for the individual subsystems (1-5) and for the whole system (STMS) No 1 6

a) values of failure formation rate, b) values of failure decline rate, c) break down factors, d) limit probability of proper operation

Rys. 6. Współczynniki niezawodności dla poszczególnych podsystemów (1-5) i dla całego systemu (STMS)

a) wartości intensywności powstawania uszkodzeń, b) wartości intensywności zanikania uszkodzeń, c) współczynnik uszkodzeń, d) prawdopodobieństwo prawidłowego działania

WPŁYW NIEZAWODNOSCI EKSPLOATACYJNEJ GORNICZYCH URZADZEN WYCIAGOWYCH NA WYDAJNOSC SYSTEMOW TRANSPORTU PIONOWEGO

S t r e s z c z e n i e

W referacie przedstawiono zagadnienie wykorzystania zdolności transportowych niektórych elementów systemów maszynowych transportu kopalnianego. Szczególną uwagę zwrócono na stopień wykorzystania górniczych urządzeń wyciągowych. Podano przykładowe wyniki wykonanych obszernych badań eksploatacyjnych procesów eksploatacji systemów maszynowych transportu pionowego.

Przedstawione wyniki obrazują wpływ niezawodności górniczych urządzeń wyciągowych na wydajność systemów transportu pionowego. Sformułowane wnioski wskazują na kierunki pożądanych działań mogących zwiększyć wykorzystanie zdolności transportowych istniejących urządzeń wyciągowych.

ВЛИЯНИЕ ЭКСПЛУАТАЦИОННОЙ НАДЁЖНОСТИ ГОРНЫХ ПОДЪЕМНЫХ УСТРОЙСТВ НА ПРОИЗВОДИТЕЛЬНОСТЬ СИСТЕМ ВЕРТИКАЛЬНОГО ТРАНСПОРТА

Р е з ю м е

В докладе представляется проблема использования транспортных способностей некоторых элементов машинных систем рудничного транспорта. Особенное внимание обращается на степень использования горных подъемных устройств.

Представляются (предлагаются, даются) избранные результаты проведенных значительных испытаний процессов эксплуатации машинных систем вертикального транспорта.

Предоставленные (полученные) результаты свидетельствуют о влиянии надёжности горных подъемных устройств на производительность систем вертикального транспорта.

Сформулированные выводы указывают (называют, подчеркивают) направления работы, которые помогли бы увеличить использование транспортных способностей существующих подъемных устройств.