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Impact of setting load on bearing capacity of props in a powered support unit

Experience acquired for a number of years proves that the fluidity of production processes in longwalls depends on proper support of the excavation roof. A properly matched power support unit is not enough to guarantee good support of the excavation roof, particularly in its face part. Irregularities in the maintenance of the longwall roof may be related to some errors in the control of the power support unit, mainly in setting the unit with too low initial pressure. With respect to the above issues, the article features an analysis of the setting load impact on the bearing capacity of props in a power support unit.

Key words: *powered support unit, setting load, load bearing capacity*

1. EXPLOITATION FACTORS WHICH IMPACT LOAD BEARING CAPACITY OF POWERED SUPPORT UNIT

The following exploitation factors significantly impact the load bearing capacity of a powered support unit: achieved setting load, different setting of props in the unit and in neighbouring units, and the load on the shield caused by chaotic blocks of rocks.

A properly matched powered support unit, for which the height of the longwall complies with the exploitation range while the support resistance and setting load are determined based on the expected load of the rock mass, does not guarantee proper maintenance of the excavation roof, particularly in its face part. Irregularities in the maintenance of the longwall roof may result from the following:

- structure of the powered support unit resulting in an improper distribution of the load exerted by the roof bar onto the roof; this may lead to a situation when active support of the roof ends in a certain distance from the end of the roof bar,
- improper rigidity of hydraulic props and air-locking of the under-piston compartment of the props,
- loose rock rubble on the roof bar and/or under the floor bar, which leads to uncontrolled convergence of the excavation,
- errors in the control of powered support units related to the unit setting with too low initial pressure and to uneven setting of props and neighbouring units.

Control errors are very important as the value of the setting load impacts the achievement of the assumed convergence of the excavation which ensures proper co-operation of the powered support unit with the rock mass. The unit setting with too low initial pressure can also result from too low supply pressure.

The setting load, understood as an impact of the roof bar on the roof, achieved in the moment when the unit setting is completed, should be determined according to the given roof conditions and should be strictly obeyed by the unit operators. Too big setting load causes damages in the rocks of the immediate roof, particularly when the rocks are weak. While too small setting load leads to a faster roof subsidence, its loosening and reduced setting of the immediate roof.

2. TESTING METHODOLOGY

In order to determine the impact of setting load on the load of the powered support unit, a testing procedure was worked out. The objective of the procedure was to analyze setting load achieved with the use of manual control [3]. The analysis was carried out based on time series of pressure changes in the under-piston parts of props in the powered support unit.

Exploitation tests were conducted in a 1.65÷1.85 m high longwall exploited with a roof fall. The longwall was equipped with XXX-10/20-POz powered support units and a wireless pressure monitoring system which registered pressure in all props.

For the purpose of the analysis, the units selected for testing were those from the central part of the longwall, located in the distance of one-third of the lowgwall length from the longwall gallery. This way it was possible to avoid the impact of neighbouring longwall galleries.

Thanks to constant monitoring of pressure in working areas of the props, time series of pressure changes were achieved – for further analysis. From the achieved time series it was possible to read data about initial pressure p_w and final pressure p_k in each load cycle of the selected powered support units (Fig. 1).

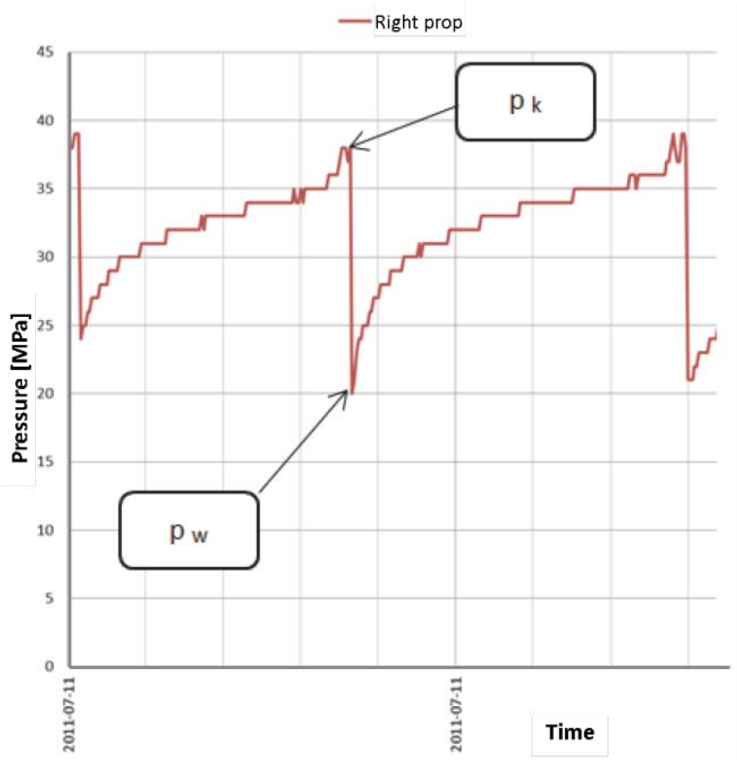

Fig. 1. Pressure values taken for analysis [3]

Based on the recorded pressure values for all verified cases, an analysis was carried out on the dependence of the final pressure of the props on their initial pressure.

2.1. Preparing data for analysis

Two criteria were taken into account to select a unit for analysis: the unit location in the longwall and completeness of measurement data. The latter criterion referred to obtaining the biggest possible number of proper time series of the load of three neighbouring units during the selected month.

For each unit an analysis was conducted of pressure changes in working areas of servomotors in the given period of time. A sample analyzed time series is presented in Fig. 2.

Each load cycle of the unit was analyzed separately with an extended time axis, which allowed to analyze in detail the registered time series. This, in turn, enabled to detect irregularities in the operations of the powered support unit:

- setting the powered support unit with too low initial pressure,
- final load of the unit on the level of setting load (25 MPa).

2.2. Analysis of pressure waveforms in the working area of props with respect to measurement data verification

Initial verification of measurement results was based on the analysis of particular time series of pressure changes in working areas of props and on rejecting those series which indicated failure states of props due to, for example, their leakiness. For further analysis the author qualified those time series of the unit operations which were characterized by pressure increase in both props of the powered support unit, independently of the character of pressure increase in working areas of both props (load cycles of the unit with regular – Fig. 3 or irregular – Fig. 4 setting of props). The load cycles taken into account were both those during which the units were set properly (with initial pressure set for the given unit) and those which began with initial pressure lower than nominal pressure.

For each load cycle qualified for the analysis, the value of initial pressure p_w and the value of final pressure p_k were determined (Fig. 1).

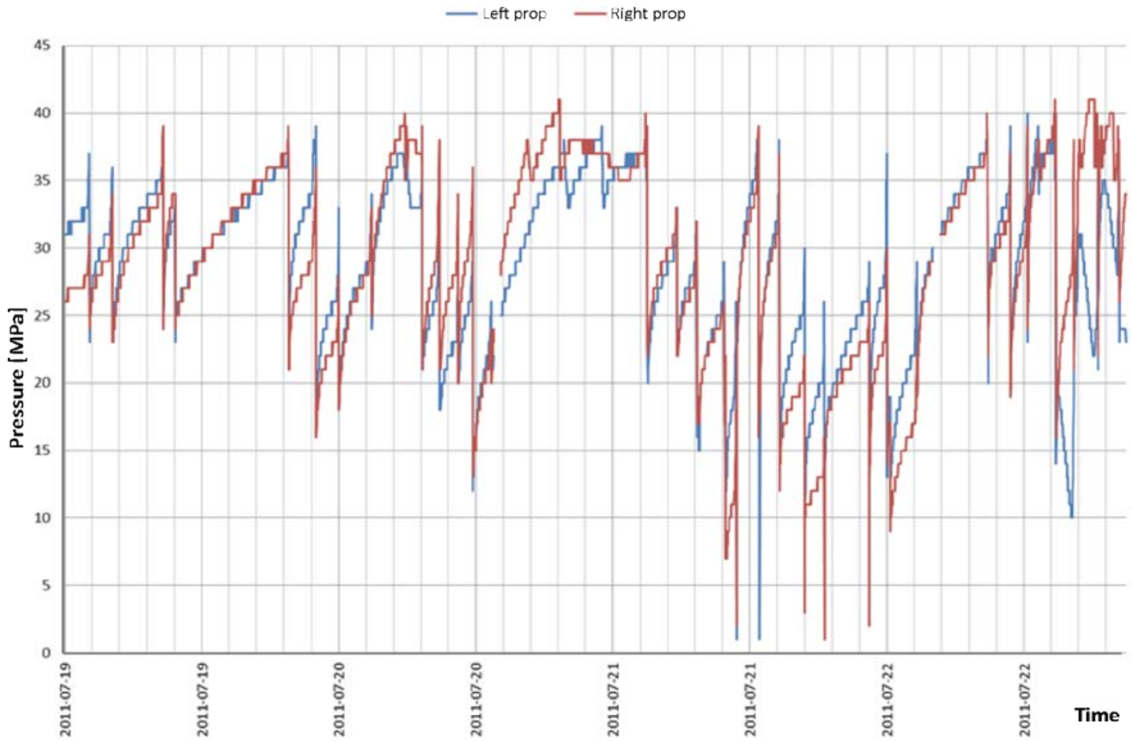

Fig. 2. Sample time series of pressure changes in under-piston compartment of props of the powered support unit during a few successive days [3]

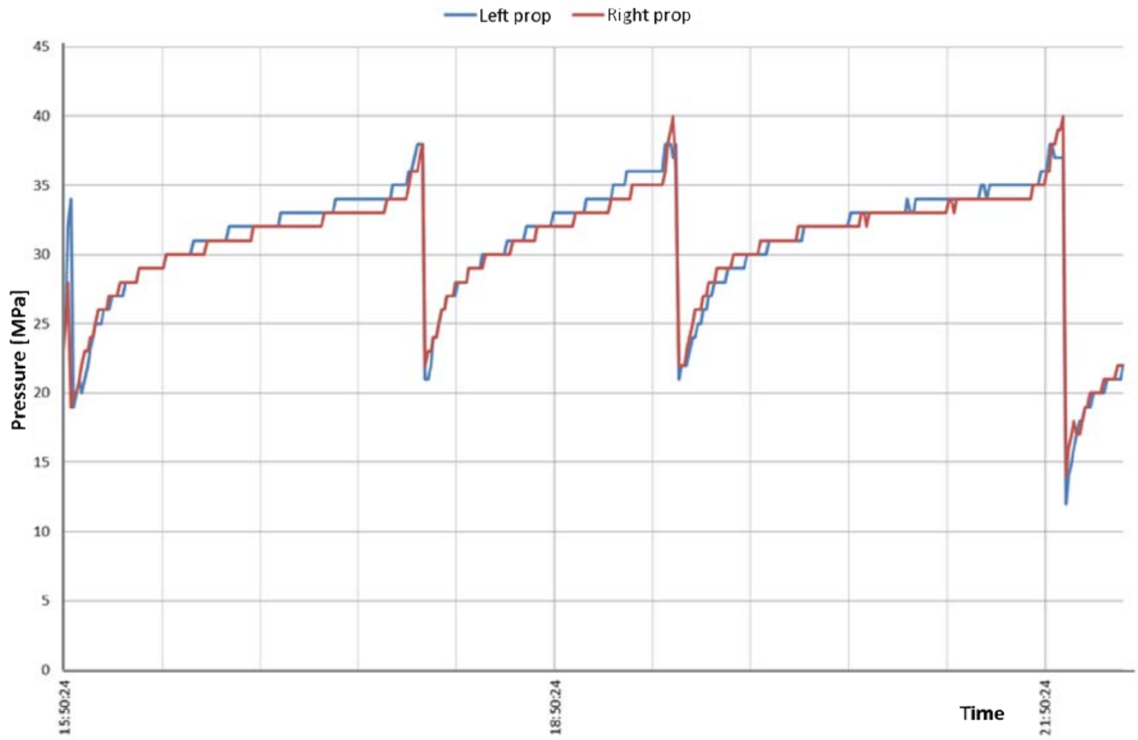

Fig. 3. Regular pressure increase in working areas of both props in the powered support unit [3]

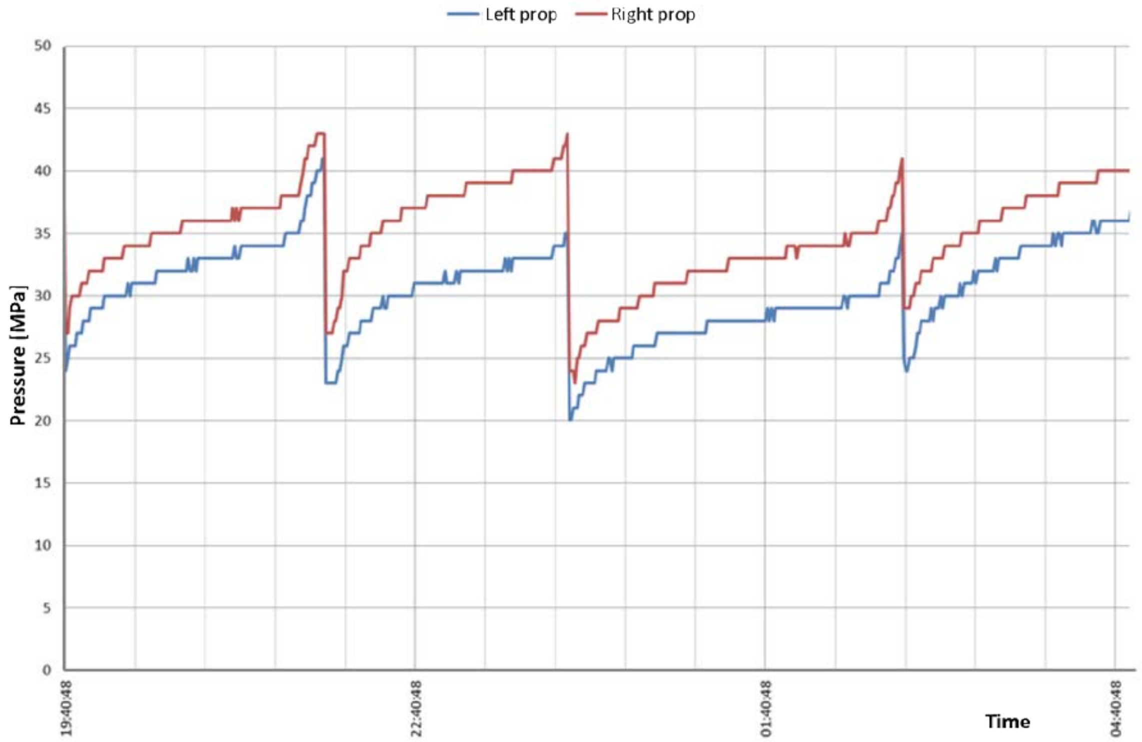

Fig. 4. Load cycles of the unit characterized by irregular setting of props [3]

2.3. Determining the duration of props load cycles

The duration of the unit load cycle depends on the technological process in the longwall. Differences in this duration are visible in a part of the pressure changes time series depicted in Fig. 2. For the purpose of the analysis the times of load cycles tc were determined for the units qualified for the analysis. Then the prevalence layout was prepared (Fig. 5).

The obtained layouts are close to the normal one. A large majority of the cycles fall into the range of 60÷180 min. The unit load cycles within this range correspond to the average speed of the cutter-loader advance – 1.3÷4 m/min, at the longwall of 235 m, i.e. to a normal technological process in a low longwall.

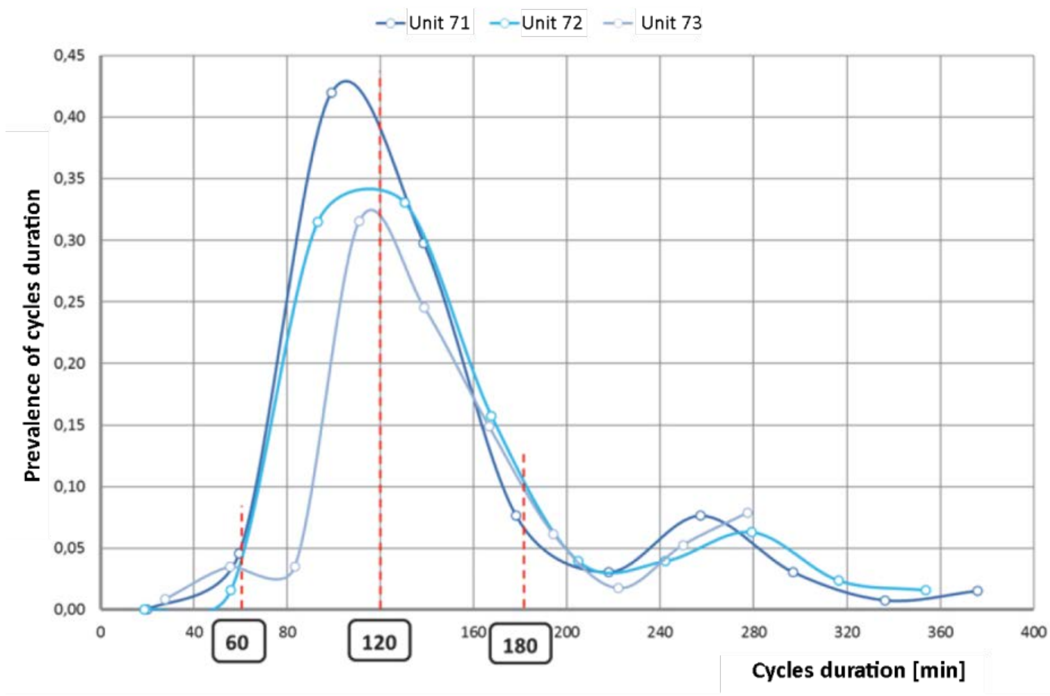

Fig. 5. Cycles duration t_c for three neighbouring units 71, 72 and 73 of the powered support unit [3]

The load cycles of the unit that were shorter than 60 min were about 4% of all analyzed cycles. During these cycles some auxiliary operations were performed, related mainly to the longwall alignment in order to obtain a rectilinear longwall. The cycles longer than 180 min, in turn, were related to longer stopovers resulting from damages of technological equipment or organizational factors. They constituted about 16% of all analyzed unit load cycles. As the subject of the analysis is the load of the unit during an undisturbed technological process, the cycles shorter than 60 min and longer than 180 min were not analyzed.

The time series for two groups of cycles, 60÷120 min and 120÷180 min, served to analyze the bearing capacity dependence on the setting load of props in the powered support unit.

3. ANALYSIS OF SETTING LOAD IMPACT ON LOAD BEARING CAPACITY OF PROPS IN POWERED SUPPORT UNIT

In order to determine the impact of setting load on the bearing capacity of props, the load cycles of unit 72 were used. Their duration was within the ranges of 60 ÷ 120 min and 120 ÷ 180 min. The values of initial pressure pw and final pressure p_k of props in particular cycles were referred to power supply pressure p_{zas} and working pressure p_r respectively. This facilitated further analysis thanks to the division of the range of relative values of final pressure p_k/p_{rob} and initial pressure p_w/p_{zas} into four parts marked I, II, III and IV (Fig. 6 and 7) with respect to threshold values of both parameters. The figures show an approximate distribution of points for load cycles characterized by different durations.

It was found out that the smaller is the value of setting load, the bigger is the range of changes in support resistance corresponding to the given value of setting load. The dispersion of the points is smaller when the initial pressure is rising. When the pressure value corresponding to the relation of p_w/p_{zas} equal to 0.6 is exceeded, the dependence of relative final pressure on relative initial pressure can be described by a linear dependency.

On the basis of the dispersion of points obtained from the analyzed time series, the threshold values of pressure were determined: p_w/p_{zas} = 0.6 and p_k/p_{rob} = 0.6. These values allowed to divide the area into the above mentioned parts. In parts I and III the points are distributed at random, so it is not possible to determine relations between the analyzed parameters. In part IV there are only few points, which means that this kind of relation between setting load and support resistance happens sporadically.

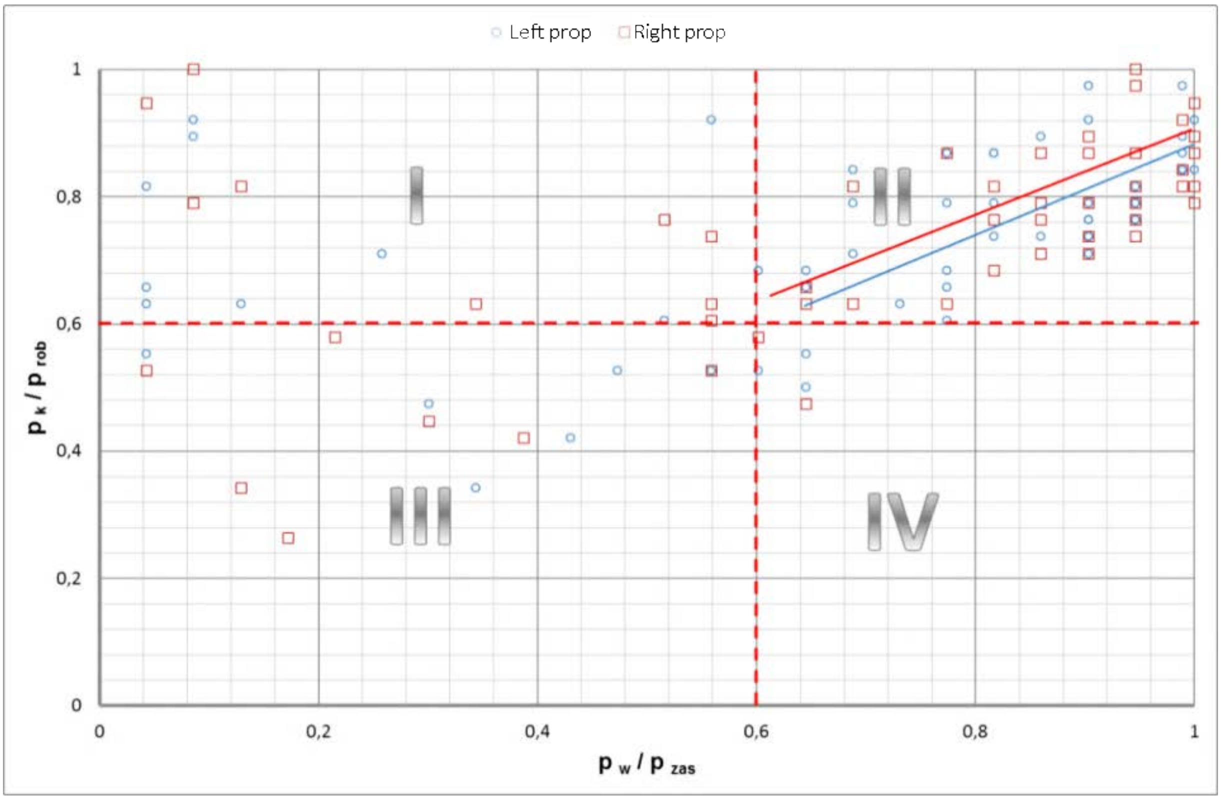

Fig. 6. Dependence of load bearing capacity on setting load $p_k/p_{rob} = f(p_w/p_{zas})$ of props in powered support unit 72 for t_c = 60 ÷120min [3]

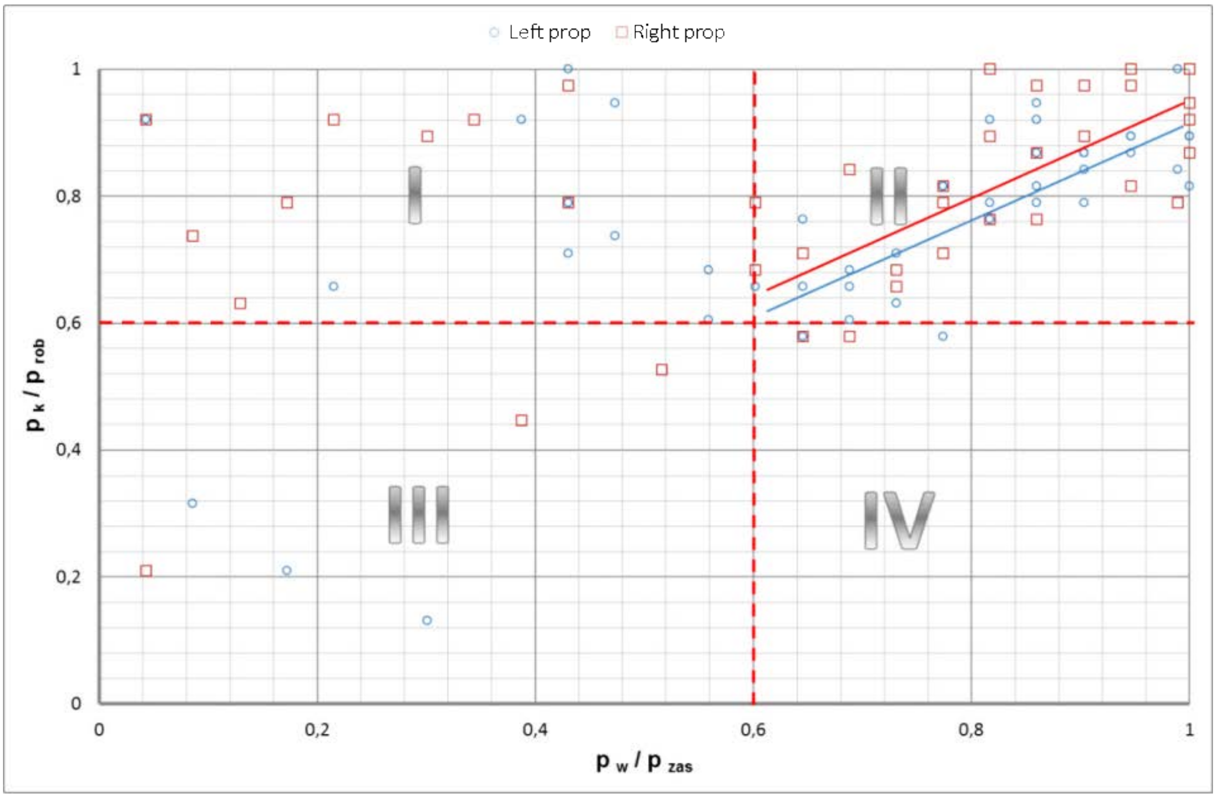

Fig. 7. Dependence of load bearing capacity on setting load $p_k/p_{rob} = f(p_w/p_{zas})$ of props in powered support unit 72 for t_c = 120 ÷180min [3]

When setting load is bigger than 60% of supply pressure and the achieved load bearing capacity is bigger than 60% of support resistance (part II), the relation between the analyzed parameters for unit 72 for the selected cycle durations is best described by simple regression equations, presented in Table 1. For particular props and cycle durations in particular ranges, the author checked the relevance of the analyzed dependency correlation by means of the t-Student test, on the relevance level equal to 0.05.

It was proved that the correlation coefficient r is statistically relevant for all analyzed cases $|t| \geq t_{0,05,n-2}$, while the force of the correlation is strong and falls within the range of 0.73÷0.80 [1, 5].

In the next stage the author checked the hypothesis that regression straights for the compared populations (of particular props) have the same regression coefficient, i.e. the same incline. For all compared regression straights on the relevance level of 0.05 there were no grounds to reject the hypothesis about their parallelism.

The presented analysis proves the importance of proper selection of setting load nominal value. It also shows that it is important to ensure that this value is achieved in the longwall. On this basis it was ascertained that in order to maintain properly the excavation roof it is necessary to achieve, in each cycle of the unit operations, the setting load on the assumed supply pressure level. Then the load bearing capacity of the unit increases in the manner described by the model of the powered support unit load. Based on the acquired measurement data it was stated that there are unit load cycles where initial pressure is 5÷10 MPa. This worsens the state of the excavation maintenance and may lead to downfalls in the face part of the longwall.

Table 1.

Regression lines for the 72nd unit and their statisical description

Prop / cycle duration	Regression equation	Correlation coefficient r	Statistical test $t = \frac{r \cdot \sqrt{n-2}}{\sqrt{1-r^2}}$	Critical value $t_{0,05,n-2}$
left / 60÷120	0.7225x + 0.1518	0.74	6.742	2.022
right / 60÷120	0.7154x + 0.1734	0.73	6.588	2.022
left / 120÷180	0.7688x + 0.1594	0.80	7.360	2.035
right / 120÷180	0.7668x + 0.1946	0.75	6.333	2.035

Table 2.

Comparison of regression line coefficients for props in the same units

Prop / cycle duration	Regression equation	Statistical test $\|t_1\|$	Critical value t_γ
left / 60÷120	0.7225x + 0.1518	0.047	1.993
right / 60÷120	0.7154x + 0.1734		
left / 120÷180	0.7688x + 0.1594	0.012	1.998
right / 120÷180	0.7668x + 0.1946		
left / 60÷120	0.7225x + 0.1518	0.308	1.995
left / 120÷180	0.7688x + 0.1594		
right / 60÷120	0.7154x + 0.1734	0.318	1.995
right / 120÷180	0.7668x + 0.1946		

4. CONCLUSIONS

One of the conditions to maintain properly the excavation roof is to achieve, in each cycle of the unit operations, the setting load on the level of the assumed initial pressure. The smaller is the value of the setting load achieved by the powered support units, the bigger is the range of changes in the unit load bearing capacity. And the range corresponds to the given value of the setting load. This has negative impact on the conditions of proper maintenance of the excavation roof, as the diversity of the load bearing capacity of the powered support unit results in worsening conditions of the roof maintenance due to its bending along the longwall.

The real value of the setting load impacts significantly the speed of pressure increase in props. The lower is the initial pressure (in the range below the pressure equal to $0.6 \cdot p_{zas}$), the faster is the increase of pressure in props, as a result of the subsidence of the roof part of the rock mass. When the initial pressure is close to the supply pressure, there is smaller distribution of measurement points which characterize the final load bearing capacity of the powered support unit. The above statements show that achieving setting load whose value is close to that of the supply pressure allows to predict pressure increase in hydraulic props and leads to good maintenance of the excavation roof.

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