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EFFECTIVE ENERGY UTILISATION WITH THE EXCAVATOR WHEEL

EFEKTYWNE WYKORZYSTANIE ENERGII KOPARKI WIELONACZYNIOWEJ

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Abstract:
The optimum utilisation of energy supplied to the excavator wheel rests upon the optimisation of mode parameters of breaking aimed at diminishing the energy demand of the mining process at keeping theoretical efficiency. With bucket wheel excavators, the mining process is subject, similarly to any process in the course of which rock breaking takes place, to general regularities influencing the final effect. Then, theoretical conclusions and practical results can be applied that have been verified in the operation of drilling units and tunnelling machines, in the course of which a considerable energy and thus also economic saving was made by the regulation of mode parameters of breaking. The solution proposed is based on the determination of basic dimensions of the cut mined, especially the width-depth ratio according to the criterion of minimum specific energy by volume.

Key words: *energy efficiency, bucket wheel excavator, optimization*

Słowa kluczowe: *efektywność energetyczna, koparka wielonaczyniowa, optymalizacja*

ANALYSIS OF FACTORS AFFECTING THE CONDITIONS OF WHEEL EXCAVATORS

The final effect of any mining process is achieving the maximum efficiency, which represents, in the case of exploitation by wheel excavators that are part of the equipment complex, efficiency by volume corresponding to the maximum utilisation of all machines included into the equipment complex. The theoretical efficiency of the excavator determining the theoretical volume amount of broken (loose) rock per unit time is a technical parameter of the machine and is directly proportional to the geometrical volume of the bucket and the number of bucket tips [1]. The excavator is able to achieve this theoretical efficiency under optimal conditions of mining, but not in the whole bench under breaking, so that in these cases this efficiency can be regarded as a momentary value. The achievement of the maximum efficiency in the course of working one bench is a primary precondition for the effective mining process, and if digging resistances do not exceed the breaking ability of the wheel, the wheel excavator is able to achieve this maximum efficiency. In the opposite case, the volume of material broken is reduced, the machine is overloaded, the failure rate increases and operational reliability is worsened. The final effect of excavator efficiency is affected by many parameters that are not only technical, as can be seen in fig. 1.

The final effect of the mining process – theoretical efficiency – is influenced, in various degrees, by the mentioned factors, and energy consumption required for achieving it can be of different values.

Digging resistances are a result of rock-wheel interaction; their magnitudes will depend, in addition to the kind of rock broken, on the shape and the size of the cut, on the number of buckets engaged, and thus also on the length of cutting edges. The number of buckets engaged is one of the factors affecting on the one hand the capacity of the excavator, and on the other hand, the breaking force per bucket. The analysis of these factors shows hat from the point of view of energy demand, it is mode parameters determining the shape and the size of the cut mined that can influence markedly the final effect of the mining process – theoretical efficiency.

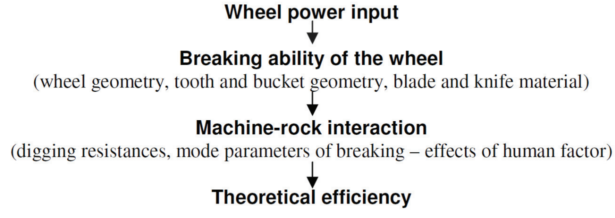

Fig. 1. An overview of factors affecting the theoretical efficiency of excavators
Rys. 1. Przegląd czynników wpływających na wydajność teoretyczną koparki

THE EFFECT OF CRUCIAL PARAMETERS ON THE EFFICIENCY OF WHEEL EXCAVATORS

The efficiency of wheel excavators and energy demand of the mining process are directly proportional to digging

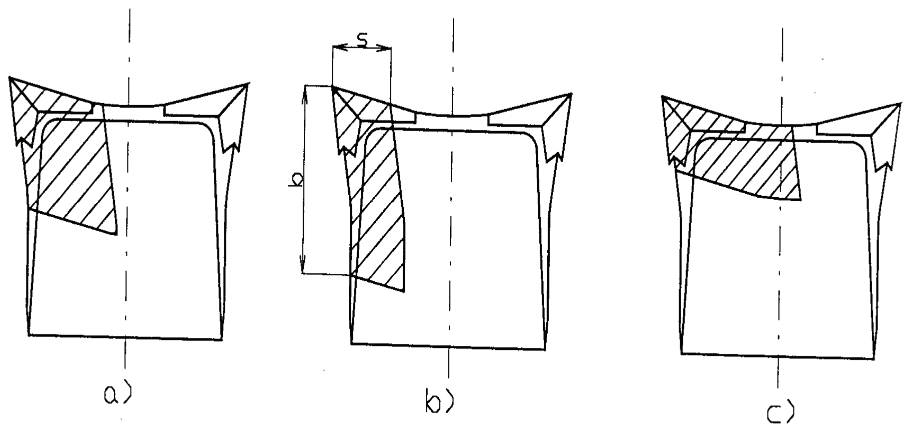

Fig. 2. Shapes of cuts made
Rys. 2. Kształty bruzd

resistances. This technological quantity expressing machine – rock interaction depends on the set of input quantities:

a) constants
   - geological factors (rock) – they are expressed by a set of technical and petrographic properties. As for the technical properties, strength and strain properties are the most important from the standpoint of the breaking characteristic; as for the petrographic properties, it is the mineral composition, especially the content of hard minerals, and the rock structure.
   - the other influences - they are a set of prevailingly non-influenceable factors, to which the stress state of solid mass, the moisture content, chemism and temperature of rocks belong.

b) variables
   - technical factors – they are given by properties of the breaking tool that is determined by a breaking technology. Properties of the tool are conditioned by its geometry and material used. The type of the breaking tool must be selected before its introduction; it is not usually changed when a change in rock conditions occurs.
   - technological factors – are determined by mode parameters (wheel rpm and the rate of turning the superstructure) that condition the shape and the size of the cut of rock under breaking. If the machine is not equipped with full automation, a human factor enters to the breaking process. The factor has a possibility to regulate partially or wholly the mode parameters, and in virtue of its subjective evaluation to set these parameters with a greater or smaller error.

It follows from the analysis of the mentioned factors that merely the technological factors can offer possibilities of solving energy conditions in mining. The measure of efficiency of any breaking process is energy consumption related usually to the unit of volume of rock under breaking. This common viewpoint will be essential when evaluating, from the standpoint of energy, the mining process of bucket wheel excavators.

Mode Parameters of Breaking and the Impact of the Human Factor

Generally, the technical efficiency of bucket wheel excavators depends on basic technical parameters and mining conditions. In reality, the human factor – the driver of the excavator - influences it markedly. On the excavators, many controlling elements are used; however, input values are almost fully dependent on the driver of the excavator who, on the basis of his own subjective estimate, determines the cut size. Thus considerable differences in production arise that manifest themselves in instantaneous efficiencies [2].

Adjustable parameters influencing directly the theoretical efficiency and energy consumption are, in principle, dimensions of the cut produced. As can be seen in fig. 2, the shape of the cut can considerably change and the ratio of sides s/b can be of values different from the optimum value, and thus it can markedly increase the specific consumption on energy at growing digging resistances. It follows from the presented analyses that the human factor affects markedly the efficiency of the mining process. The achieving of optimum mode parameters is conditioned by an adequate information system in the driver's stand.

Operational Measurement and Result Interpretation

Specific Energy by Volume as a Criterion for the Breaking Ability.

It is energy consumption related usually to a unit of volume of rock under breaking that is a measure of efficiency of any breaking process. This general criterion will be crucial to the energy-based evaluation of the mining process of bucket wheel excavators. If we subject the methods of digging resistance determination to the analysis of objectiveness, we shall find out that they, in a larger or lesser degree, do not take into account the whole set of affecting factors, and therefore they decrease their predicability on the real breaking process. The quantification of the evaluating magnitude remains disputable as well.

In virtue of the analysis of completed theoretical and practical researches orientated towards breaking processes and objectiveness proving when used in situ (at drilling and tunnelling), the most objective present-day evaluation quantity is minimised specific energy by volume. This quantity has common validity for dispersion processes, and thus the utilisation of it also in evaluating the breaking ability of the excavator wheel is well-founded.

Then the digging resistance will be defined as "the amount of energy consumed by breaking the unit volume of rock per unit time and by overcoming other resistances on the wheel, while mode parameters are regulated to ensure the minimisation of this specific energy" [3]. The digging resistance defined in this manner is quantified in J*m^{-3}.

Measurement on Wheel Excavators.

To verify the influence of mode parameters on the final effect of the mining process, many operational measurements on wheel excavators KU 800 and KU 300 were made. Measurements in situ were taken in localities [4, 5], from the extensive set of evaluated measurements, one example of the dependence of specific energy by volume on the volume of rock mined (fig. 3) was selected from measuring made on the excavator KU 800.

The optimum value Vtj for the excavator KU 800, at which the excavator achieves the theoretical efficiency and the value of the specific energy by volume is minimum, can be determined in virtue of technical parameters of excavators and the swell factor of 1.2 as follows:

$$V_{tj\,\max} = n_v \cdot V_k \cdot \frac{1}{k_n} = \frac{93}{60 \cdot 1 \cdot 2} \cdot 1 = 1{,}29 m^3 \cdot s^{-1} \qquad (1)$$

where:

n_v = 93 min^{-1} - the number of tips

V_k = 1 m^3 - geometric volume of the bucket

k_n = 1,2 - swell factor

It follows unambiguously from this figure that the mining process takes place prevailingly in an area that cannot be called effective. The quantity mined varies in the range of about 45-75% of capacity. With KU 800 specific energy by volume is about 160-250% of the corresponding minimum measured value. Measured values are graphed to make a curve the shape of which confirms the expected behaviour with the minimum of specific energy by volume – fig. 4.

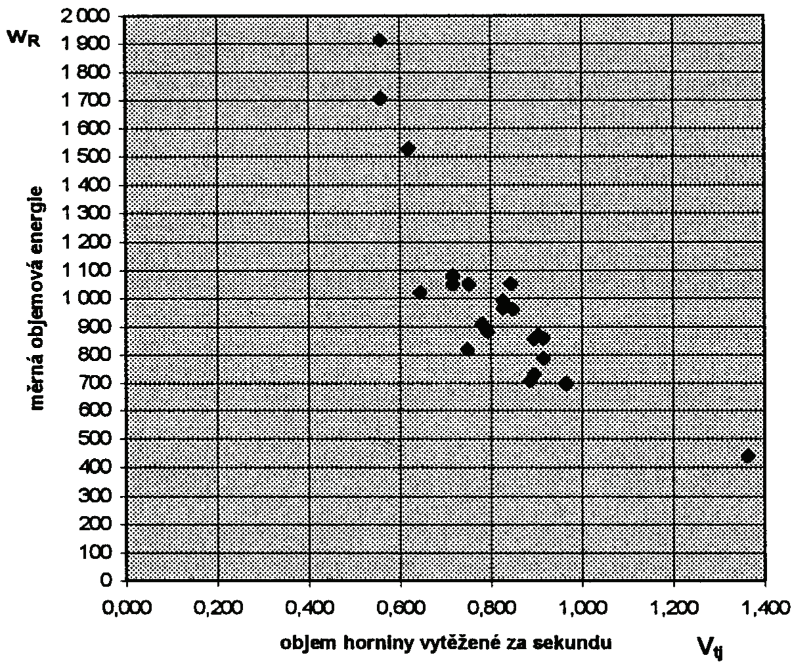

Fig. 3. Values calculated for KU 800 – block I, bench 3
Rys. 3. Wartości obliczone dla KU 800

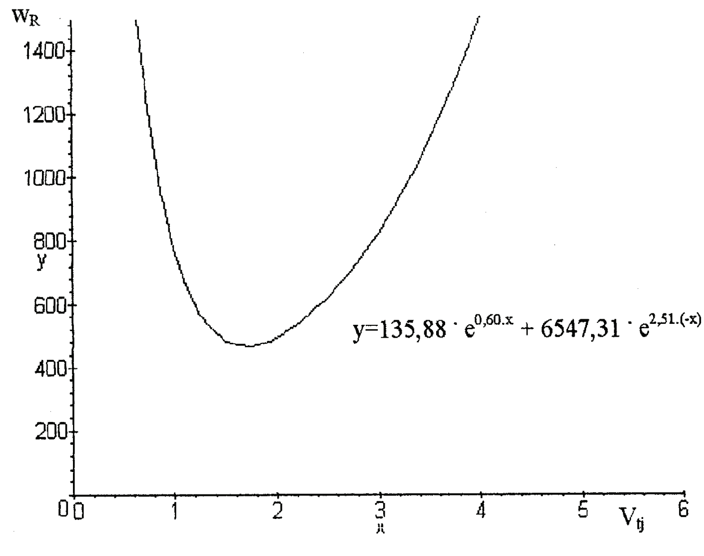

Fig. 4. Expected dependence of $w_R = f(V_{tj})$ with the excavator KU 800
Rys. 4. Oczekiwana zależność $w_R = f(V_{tj})$ dla koparki KU 800

CONCLUSION

Thanks to new knowledge, limits of more effective utilising the technology of breaking, in this case breaking by the bucket wheel excavator, will more and more broaden, or extend to the area of more rigid rocks. In accord with this fact, supplied energy must be utilised more effectively, and the operational reliability of machines must be improved. Problems discussed in this contribution do not go without extensive measurements made directly on the bucket wheel excavator, and with reference to a large number of input parameters the objectivity of results is usually a subject of careful analyses. The analysis of factors affecting the energy demand of the mining process with bucket wheel excavators proceeds from the latest knowledge in the area of mining by bucket wheel excavators, and on the basis of presented results of our own studies, individual factors are evaluated, the order of their importance is determined, and trends in the next research are proposed.

A priority property characterising the rock – machine interaction is a technological property called digging resistance. To be able to fulfil the evaluating and comparing function, this property must be defined by an objective quantity that will enable its quantification [6; 7; 8]. Accepting the quantity of minimum specific energy by volume as a criterion for evaluating the digging resistance made it possible to form a new and more objective opinion on the impacts of particular factors affecting the final effect of the mining process – theoretical efficiency, namely from the point of view of energy demand.

Operational measurements on bucket wheel excavators and their interpretation have proved that the specific energy consumption of the excavator wheel falls:

- with the size of the mined cut, and thus with the mined quantity,
- with a diminishing ratio of cut dimensions, s/b.

In the concrete, the case of the excavator KU 800 may be taken. An approximate saving on energy consumption may be quantified by the following consideration. Installed power input of the excavator wheel is 2x800 kW. Measured values of the power input consumed moved in the range from 800 to 1200 kW. The amount mined ranges from about 45 to 75% of capacity. The operation of the excavator is continuous, with the time utilisation of about 10 hours daily in two-shift 12 hours' operation. The relation below is used for calculation:

capacity loss x min. power input demanded x time utilisation

a) minimum saving:

$$0.25 \cdot 800 \cdot 10 = 2000\ \mathrm{kWh} \cdot \mathrm{day}^{-1}$$

b) maximum saving:

$$0.55 \cdot 1200 \cdot 10 = 6600\ \mathrm{kWh} \cdot \mathrm{day}^{-1}$$

In addition, the optimisation of the ratio of cut sides s/b has a positive effect on these values. Thus the impact of the human factor on the economics of the mining process is unambiguously proved and energy savings approximately quantified give a picture of the importance of optimising the control of mode parameters of mining.

Thus, what is a decisive factor for economical mining is a human factor that at present influences the dimensions of the cut mined without objective information on the breaking process, and thus influences the efficiency and energy demand of mining. To eliminate a negative effect of the driver of the excavator, the installation of an information system is necessary. In virtue of the minimisation of specific energy by volume, the system will make it possible to determine needful dimensions of the cut, and thus will enable the optimum regulation of excavator efficiency; naturally, all above mentioned being in accordance with other control and protective elements of the excavator.

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