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RESULTS OF RESEARCH RELATED TO REDUCING ENERGY CONSUMPTION IN THE ROCK WINNING PROCESS

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Abstract

Energy consumption is the main parameter describing the efficiency of the rock winning process in mechanical excavation. Because the rock winning process is a very complex one, the strength properties of rocks prescribed by classical rock mechanics is not sufficient: Knowledge of cutting forces values, and of the shape and volume of removed chips – based on tool geometry and cutting head kinematics – has significant importance in the optimal design of winning machines, and in improving their operating parameters. The paper deals with some results in research performed at the University of Petroșani on these issues, both in theoretical findings and experimental assays in laboratory and on site.

Keywords*: rock cutting, energy, mechanical excavation, mining machinery.*

1. Foreword

Establishing the characteristics of the extraction of various rocks or useful minerals by excavators (**Fig. 1**), shearer-loader (**Fig. 2**), roadheader (**Fig. 3**) etc. is an important task that leads to the understanding of the phenomenon of rock cutting, the determination of the geometric and technological parameters of the excavation tool, the parameters of the removed rock chips and the relationships between the parameters of the process.

Knowing the laws of interaction between parameters, in practice it is possible to develop such excavation machines and technology that require minimal specific energy consumption, using the maximum efficiency of the machine, in different specific cases.

Mechanical excavation consists of the decomposition of the rock from its natural state in the rock mass.

The chips are separated from the rock by means of a sharp working tool, with suitable geometry and strength (**Fig. 4**) .

Fig. 1. *Bucket Wheel Excavator.*

Fig. 2. *Shearer loader.*

Fig. 3. *Roadheader.*

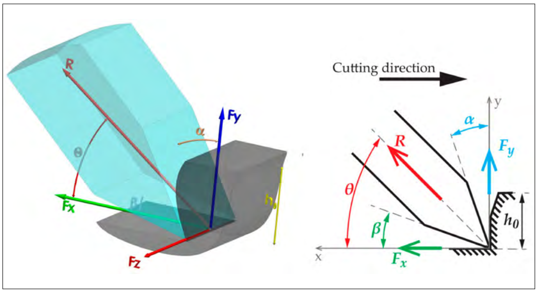

Fig. 4. *Geometric characteristics of the cutting tool (α – face angle, β – back angle, θ – cutting angle, h_0 – depth of cut) and forces acting on it (F_x – cutting force, F_y – pushing force).*

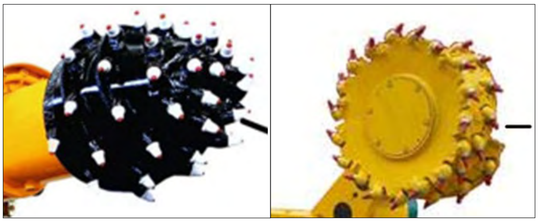

Fig. 5. *Different types of cutting head units.*

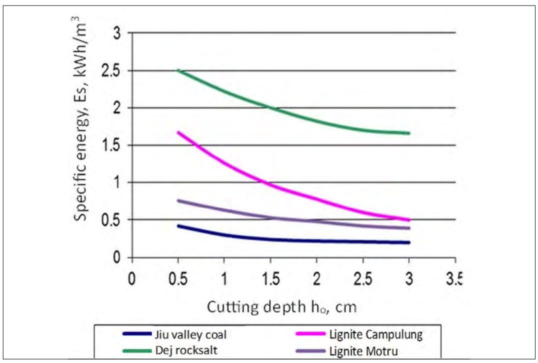

Fig. 6. *Specific energy consumption for the studied rocks as a function of the cutting depth.*

The working tools are placed according to an appropriate placement system on a rotary cutting head unit (**Fig. 5**), so that the machine can decompose the entire rock mass due to the spatial kinematics of the cutting head movement performed by a manipulator (arm).

In the case of coal, rock salt or other beneficial minerals and rocks, it is not enough to determine the strength of these by various conventional rock mechanics tests (compressive, tensile, shear strength, etc.), since excavation is a very complicated process that depends on the influence of many factors.

Its characteristics include: forces acting on the working equipment (drag bit, demolition tooth, cutting edge, etc.) (**Fig. 4**), specific cutting force, specific energy demand, required propulsion power, etc.

The cutting forces acting on the cutting device (tooth or drag bit), mainly the tangential cutting force and the normal force (**Fig. 4**), are the basic parameters used to calculate the torque of the cutting head, engine power and rock excavation efficiency.

On the other hand, the specific cutting energy is usually used to assess the cuttability of rock, which is one of the most significant parameters used both for performance evaluation and for evaluating the efficiency of excavation systems.

2. Analysis of the energy demand of various rocks

Fig. 6 shows the curves of specific energy consumption for the materials already mentioned, as a function of the cutting depth, which were plotted based on the results of laboratory measurements.

These curves are hyperbola-like, similar in shape, but significantly different in values.

It can be observed that in the case of rock salt the specific energy consumption is 1.5...2.5 kWh/m^3, in the case of the hardest domestic lignite it is 0.5...1.5 kWh/m^3, but in the case of hard coal it is only 0.25...0.5 kWh/m^3.

Since the difference between the analysed rocks is not so great as far as cutting factors are concerned, harder and softer materials were also taken into account as examples.

The previous frame was extended with clay, softer lignite and sandstone. Since the differences are already greater, we were forced to use the logarithmic scale, as can be seen in **Fig. 7.**

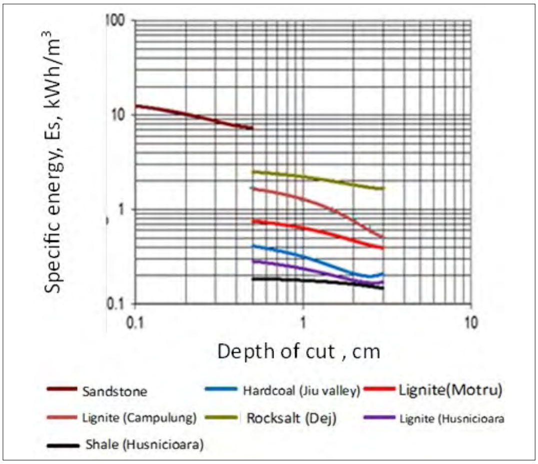

Fig. 7. *Specific energy consumption for the studied rocks as a function of the cutting depth.*

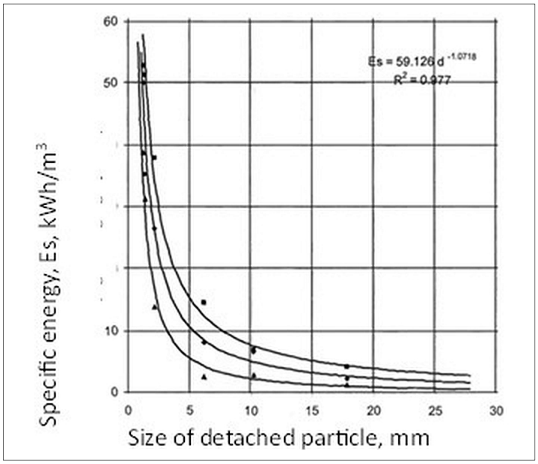

Fig. 8. *Dependence of specific energy on particle size.*

Based on the curves shown in Fig. 7 the specific energy consumption was compared for the materials already listed.

Here, too, the order from clay to sandstone stands out, as the curves of rock salt and carbons are in between.

If we make the comparison, in terms of specific energy demand, it can be noticed that sandstone has a specific energy demand of 7...13 kWh/m³, rock salt 1.8...2.6 kWh/m³, hard lignite 0.5...1.8 kWh/m³, coal 0.25...0.5 kWh/m³, while clay has a specific energy demand of only 0.18...0.2 kWh/m³.

It follows from the same source that the mechanized production of salt from Dej requires 4...5 times less energy than sandstone, which cannot be obtained on an industrial scale by cutting, but is 1.5...7 times more for coals and 10...13 times more for clay.

One of the main parameters describing the excavation process is the specific energy demand, which is a measure of the energy intensity of the ongoing process.

The author of paper [3] used more than 11,000 rock extraction experiments of extraction with blast and use of different machines (cutting machines, tunnel boring machines, shearer loaders, drilling rigs, etc.) establishing the dependence of specific energy consumption and removed particle size.

The measured or calculated, specific energy consumption E_s and the average dimension of the detached materia d the experimental point cloud is located within a band between two curves that approach the equilateral hyperbola. (Fig. 8), in which the function $E_s = f(d)$ is plotted.

Its descriptive regressive equation is:

$$E_s = 59{,}126\ d^{-1{,}0718}\ kWh/t \qquad (1)$$

As it can be seen, the exponent is -1.0718, which characterizes a quasi-equilateral hyperbola. On the other hand, it means that the product of specific energy consumption by the size of the particles (chips) produced is constant, regardless of the process used, i.e.:

$$E_s \cdot d \approx constant \qquad (2)$$

In previous papers [1] and [2] it has been proved that this invariant corresponds to the specific cutting force.

Thus, the relationship between the two essential parameters – specific energy consumption and specific cutting force – and based on this, the specific energy demand, can be calculated based on the specific cutting force, which can be determined by experimental means.

3. Conclusions

Energy demand is the main parameter that describes the efficiency of the rock winning process in mechanical extraction.

Knowledge of its parameters and of those influencing it plays an important role in the optimal design of extraction machines and in the improvement of their operating parameters.

We plotted the curves of the specific energy consumption of coal, two types of lignite and rock salt as a function of the cutting depth, the values of which were determined based on the results of laboratory measurements.

We did the same analysis for harder and softer rocks, because the differences are already greater, we were forced to use the logarithmic scale for comparison.

It has been proven, based on the processing of experimental results, that the product of specific energy consumption by the size of the particles (chips) produced is constant, regardless of the process used, and that this invariant corresponds to the specific cutting force.

Thus, starting from the relationship between the two essential parameters, it is possible to calculate the specific energy consumption based on specific cutting force, which can be established experimentally.

References

[1] I. Andras, M. Lazar, A. Andras: *The Correlation between Physical-Mechanical Properties and the Cutting Characteristics in the Case of Unminable Rock Formations From Husnicioara Lignite Open Pit*. 17th International Multidisciplinary Scientific GeoConference SGEM 2017, Sofia, 869–876. https://doi.org/10.5593/sgem2017/13/S03.110

[2] M. S. Nan, I. Kovacs, I. Andras, D. Jula: *Study of the Working Regime of the Bucket Wheel Excavators in the Conditions of Romanian Open Pit Lignite Mines*. 8th WSEAS International Conference on Simulation, Modelling and Optimization (SMO '08), Santander, Cantabria, Spain, September 23-25, 2008. 83–88. https://www.researchgate.net/publication/262329172_Study_of_the_working_regime_of_the_bucket_wheel_excavators_in_the_conditions_of_Romanian_open_pit_lignite_mines

[3] L. Ozdemir: *Comparison of Cutting Efficiencies of Single-Disc, Multi-Disc and Carbide Cutters for Microtunneling Applications.* No-Dig Engineering, 2/3. 2002.