# STUDY REGARDING THE SPECIFIC ENERGY CONSUMPTION USED DURING LIGNITE AND OVERBURDEN ROCK EXCAVATION IN JILT OPEN-PIT MINE

**OVIDIU-BOGDAN TOMUŞ**[1]

**Abstract:** The paper deals with the experimental and laboratory assay results regarding the mechanical cutting of overburden rocks and lignite from Jilț open pit mine, with special accent on the dependence of break-out angle and specific energy consumption on the geometric parameters of teeth in view to optimize them, for lignite and overburden rock efficient cutting.

**Keywords:** open pit mining; energy; break-out angle; rocks; cutting; Jilt;

## 1. GENERAL CONSIDERATIONS

The non-homogenous material cutting theory in general, and the lignite and overburden rock cutting in particular, highlights that dislocation occurs as the result of the interaction between the cutting tool and solid, characterized by a resultant force which breaks down into three components acting on the main directions (tangent, normal and binormal) compared to the trajectory of the tool. Research conducted to date in this area, both worldwide and in our country, revealed that the cutting phenomenon has a strong random character, defined by random variables and their appropriate probability functions.

For the experimental determination of the cutting characteristics of the rocks, the laboratory method was chosen. In order to conduct the experimental research, proper work methodology and experimental data processing and capitalization methods were established. It was proven, both theoretically and experimentally, that application of modeling and geometric similarity methods - in the study of cutting characteristics of lignite and overburden rock - is accurate enough so that the values obtained in the laboratory are translated into real linear equations.

[1] *Lecturer Eng. Ph.D., University of Petrosani, tobogdan2002@yahoo.com*

## 2. DETERMINATION OF THE BREAK-OUT ANGLE OF THE CHIP

Both technical literature and our own experience show that all non-homogeneous materials break from the solid at a certain angle not related to the shape of the cutting tool. If the break-out angle is $\psi$, as shown in figure 1, the value of this angle varies $\psi$ = 20...80° for different material and working conditions.

Determining the most probable value of this angle $\psi$ is very important because it affects the cross-section area of the chip, the volume of material cut from the solid and the specific energy consumption at cutting. Moreover, it is used to define the distance and position of teeth on the excavator bucket.

The break-out angle of the chips $\psi$ has a random variation, like all the other variables of rock cutting characteristics. Therefore, during experimental trials we determined the median value of the angle, with the highest probability to happen in real life conditions.

First, the cross-section area of the displaced (cut) chip is calculated using the relation:

$$S_0 = \frac{V}{L}, \ [cm^2] \tag{1}$$

where $V$ is the volume, in $cm^3$, and $L$ is the length, in cm, of the cut, experimentally determined using the method of modeling clay molds.

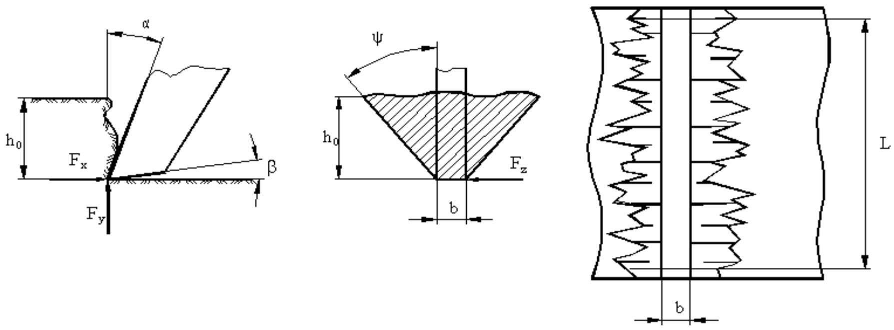


**Fig. 1.** Determination of the break-out angle ψ

Based on the values of $S_0$ we can calculate the break-out angle of the chips $\psi$ using the equation:

$$\psi = arctg\left(\frac{S_0}{h_0^2} - \frac{b}{h_0}\right) \tag{2}$$

where: $b$ – is the width of the chip, in cm;
$h_0$ – is the thickness of the chip, in cm.

Based on the values obtained during the experimental tries and using the methodology described above, the empirical values of the break-out angle ψ were determined.

The values of the angle ψ corresponding to the depth of cut $h_0$ for different values of the rake angle of the tooth - *α*, are snowed in figure 2, while the values of the angle ψ corresponding to the rake angle of the tooth - α, for different values of the depth of cut $h_0$, are represented in figure 3.

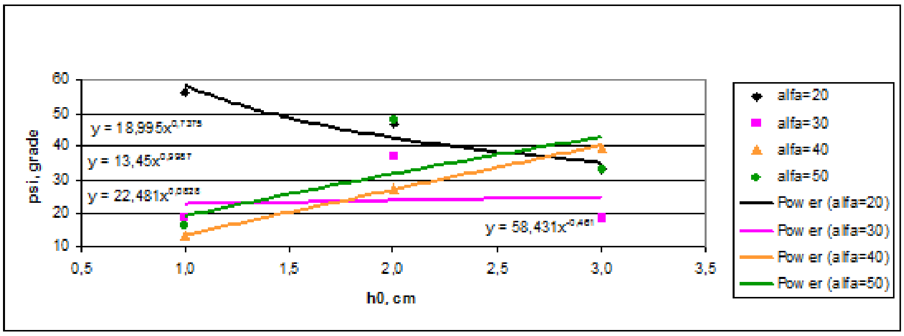


**Fig. 2.** Values of the angle ψ corresponding to the depth of cut $h_0$ for different values of the rake angle of the tooth - α,

In figure 2 we can observe that the angle *ψ* has a curvilinear variation described by a power function, with the variation between 15° and 50°. Values smaller than 25° correspond to smaller depths of cut ($h_0$ < 2 cm), while for values of $h_0$ > 2 cm the angle *ψ* presents values between 25° and 40°. Dependency curves tend to plateau at values of 25 ° to 40 °, regardless of the thickness of the chip displaced.

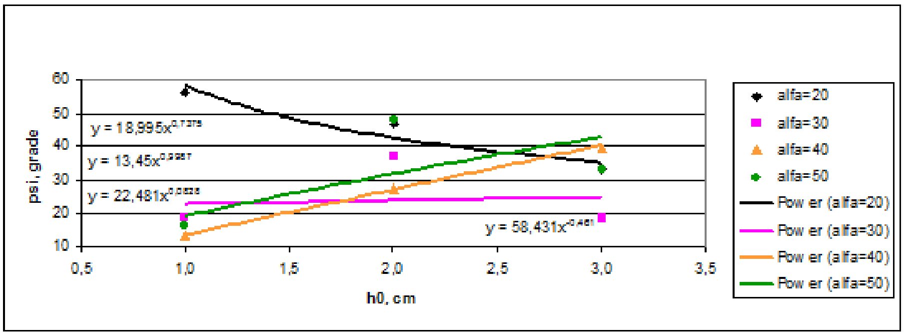


**Fig. 3.** Values of the angle ψ corresponding to the rake angle of the tooth - α, for different values of the depth of cut $h_0$

In figure 3 we can see that the break-out angle of the chip *ψ* is not influenced by the rake angle *α* – of the tooth, especially at depths of cut close to 2 cm. Upon analyzing the results obtained for the break-out angle of the chip *ψ*, for the overburden rock found in the Jilt open pit mine, we can conclude that the most probable break-out angle is between 25° and 40°.

## 3. DETERMINATION OF SPECIFIC CUTTING ENERGY

One of the indicators of digging (cutting) difficulty is the Specific Energy $E_s$. which is described as the electrical energy consumed in cutting unit volume of rock, ore and/or coal. The principle of this indicator is the harder the formation the higher the energy needed to cut it. It is a parameter independent of the bucket size. It can be determined either by recording the measured energy consumption of the bucket-wheel drive and of the cut volume, or by experimental approaches in laboratory or in situ.

Based on the data presented in this paper, the specific cutting energy was calculated using equations (3):

$$E_s^{'} = \frac{F_{xm}}{100 S_o} = \frac{A \cdot h_o}{100 S_o}\text{, } J/cm^3 \tag{3}$$

and (4):

$$E_s = \frac{F_{xm}}{360 S_o} = \frac{A \cdot h_o}{360 S_o}\text{, } kWh/m^3 \tag{4}$$

The values of the specific energy $E_s$ corresponding to the depth of cut $h_0$ is graphically represented in figure 4, and the values of the specific energy $E_s$ corresponding to the rake angle of the tooth - α, is traced in figure 5.

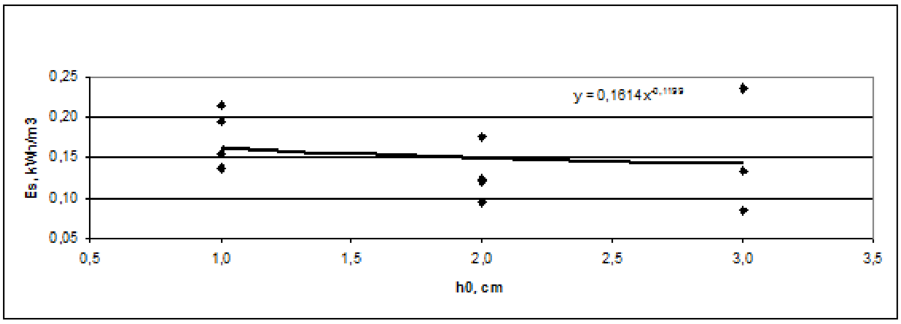


**Fig. 4.** Values of the specific energy $E_s$ corresponding to the depth of cut $h_0$

From the figures above, we can see that the specific energy variation during cutting of overburden rock is between 0,08 and 0,24 kWh/m$^3$.

The dependence curve $E_s = f(h_0)$, presented in figure 4, varies by a power function which decreases proportionally with the increase of the depth of cut, and for values of $h_0 > 2$ cm, it tends to plateau.

Also, the dependence curve $E_s = f(h_0)$, presented in figure 5, shows a decrease of the specific energy consumption proportionally with the increase of the rake angle α of the tooth, with a median value of 0,2 to 0,12 kWh/m$^3$.

In order to stress and analyze the influence of the depth of cut $h_0$, and of the rake angle - α - of the tooth respectively, on the specific energy, the corresponding curves were traced as seen in figures 6 and 7.

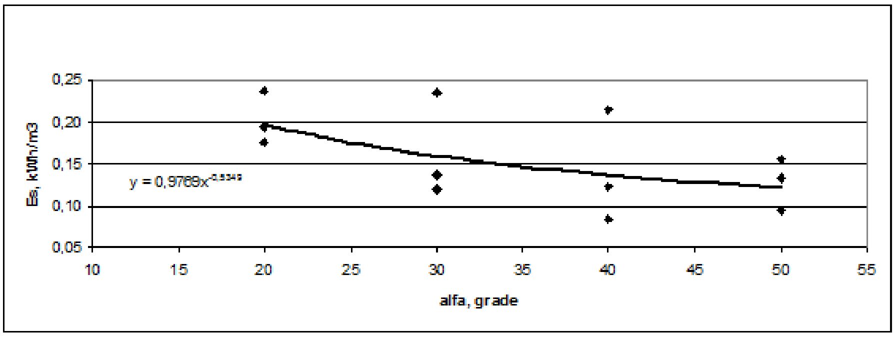


**Fig. 5.** Values of the specific energy $E_s$ corresponding to the rake angle of the tooth - α,

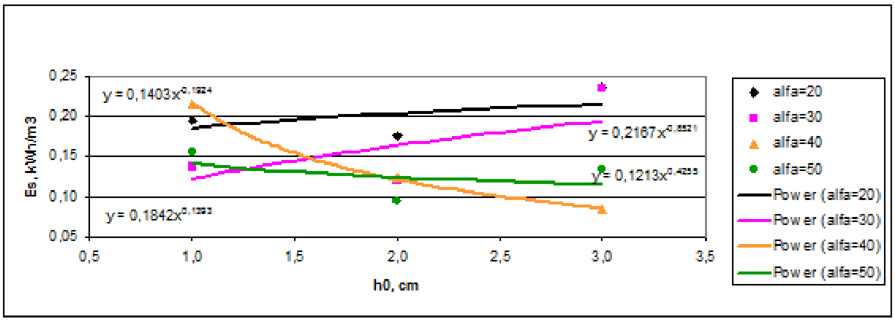


**Fig. 6.** Values of the specific energy $E_s$, corresponding to the depth of cut $h_0$ for different values of the rake angle of the tooth - α

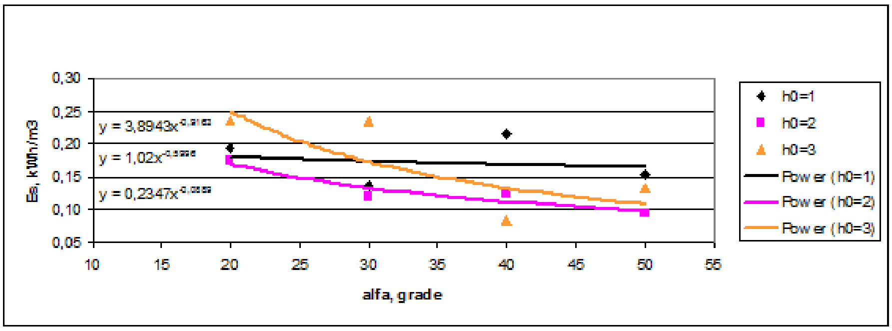


**Fig. 7.** Values of the specific energy $E_s$, corresponding to the rake angle of the tooth – α, for different values of the depth of cut $h_0$

If we take into consideration, as a parameter, the rake angle of the tooth $\alpha$, then the specific energy $E_s = f(h_0)$ will be a family of curves where we can observe the increase of specific energy, when overburden rock is cut, corresponding to $h_0$ for small rake angles, and a decrease of the specific energy when overburden rock is cut, corresponding to $h_0$ for large rake angles. Likewise, if the depth of cut $h_0$ is considered a parameter, then the specific energy $E_s = f(\alpha)$ will show the same tendencies : decrease of the specific energy $E_s$ corresponding to the angle $\alpha$, for different values of $h_0$.

## 4. CONCLUSION

Experimental trials were conducted using samples of both lignite and overburden rocks, taken from various open pit mines. Using measuring and recording devices, we obtained diagrams of cutting forces, penetration forces and lateral forces acting on the standard teeth variations over time.

Based on the empirical data obtained, the specific cutting resistance and the specific energy when cutting were determined, and then links and rules were established between the cutting regime parameters and the parameters of the teeth and chips displaced from the field.

## REFERENCES


[1]. **Dinescu, S., Andraș, A.,** *Modeling And Simulation of the Complex Mining Production Systems for Coal Extraction,* 248 Proceedings of the 1st European Conference of Mining Engineering (MINENG '13), Antalya, Turkey, (October 8-10, 2013).

[2]. **Kovacs, I., Iliaş, N., Nan, M.S**., *Regimul de lucru al combinelor miniere*, Editura Universitas, Petroşani, (2000).

[3]. **Kovacs, I., Nan, M.S., Andraş, I., Jula, D.,** *Stabilirea regimului extrem de funcţionare a excavatoarelor cu roată portcupe*. Lucrările ştiinţifice ale Simpozionului Internaţional „Universitaria ROPET 2002”, Petroşani – Inginerie mecanică, (17-19 oct. 2002).

[4]. **Kovacs I., Nan M.S., Jula D., Tomus O.B.**, *New Buckets Mounted on Rotor Excavators, as a Result of Dislocation Tested Process –, International Conference on Applied Computer Science,* Malta September 15-17, 2010,

[5]. **Kovacs, I., Andraș, I., Andraş, A., Tomuş, O.B.**, *Overview Of The Results Obtained In The Field Of Rock Cutting In Underground And Open Pit Conditions,* Monografia Nowoczesne Metody Eksploatacji Wegla I Skal Zwiezlych. pag. 9 – 16, Akademia Gorniczo-Hutnicza. Krakow 2013.

[6]. **Tomuș O.B.**, *Studiul posibilităților de creştere a performanţelor rotorului excavatoarelor utilizate în carierele de lignit*. Teză de doctorat, Petroșani, 2009.

[7]. **Tomuş O.B., Voicu G.V., Grigorie P., Poiana L.,** *Research Regarding The Use of CAD Methods on the design of Bucket Wheel and Excavator Teeth and Bucket Based on real Working Conditions*. – microCAD 2010, International Scientific Conference Miskolc, 18-20 march 2010