UNDERGROUND MINING ENGINEERING 23 (2013) 59-68 UDK 62
FACULTY OF MINING AND GEOLOGY, BELGRADE YU ISSN 03542904

Original scientific paper

TESTING OF THE RESISTANCE TOWARDS THE CUTTING OF THE COAL MASS BY THE MECHANICAL MEANS ON THE EXAMPLE OF DEPOSIT "KOSTOLAC"

ISPITIVANJE OTPORA PREMA REZANJU UGLJENE MASE MEHANIČKIM SREDSTVIMA NA PRIMERU LEŽIŠTA "KOSTOLAC"

Vidanović Nebojša[1], Vujanović Marko[2], Ognjanović Saša[3], Nikolić Dobrica[1]

Received: November 1, 2013 **Accepted:** December 6, 2013

Abstract: For cutting of the coal mass in the coal mines, in addition to explosive, different machines and devices whose construction has to be adjusted to the working conditions are used. This paper deals with the problems related to the conditions of coal mass cutting and the corresponding resistance based on an examination of a sample from coal basin Kostolac - Field "Drmno", under different conditions and different shapes and sizes of etalon for cutting (different widths, angles...) varying degrees of blockage (blocked, semi blocked and free) and for different depths of cutting. For the purpose of determining the behavior of coal mass from the point of its destruction by mechanical means, as the most appropriate research method, a method of three-component load measuring on the cutting element during the cutting process was used. Based on the simulation of this process in the laboratory the corresponding equations depending on these influential factors in the process of cutting coal were obtained.

Key words: coal, cutting, resistance, Kostolac

Apstrakt: Za razarenje ugljene mase se u rudnicima uglja pored eksploziva koriste i različite mašine i uređaji čija konstrukcija mora da bude prilagođena uslovima rada. U okviru ovog rada obrađena je problematika vezana za uslove rezanja ugljene mase i odgovarajućih otpora zasnovanih na ispitivanju uzorka iz ugljenog basena Kostolac - Polje "Drmno", pod različitim uslovima i različitim oblicima i dimenzijama etalona za rezanje (različite širine, uglovi...), različitim stepenima blokade (blokiran, polublokiran i slobodan) i za različite dubine rezanja. Za potrebe utvrđivanja ponašanja ugljene mase sa stanovišta njenog razaranja mehaničkim sredstvima, kao najpogodnija metoda istraživanja korišćena je metoda trokomponentnog merenja opterećenja na rezni element u toku procesa rezanja. Na osnovu simulacije ovog procesa u laboratorijskim

[1] University of Belgrade - Faculty of Mining and Geology, Djušina 7, 11000 Belgrade, Serbia, e-mails: nebojsa.vidanovic@rgf.bg.ac.rs; dobrica.nikolic@rgf.bg.ac.rs
[2] Siming d.o.o., Obrežje 7D, SI-8261 Jesenice na dolenjskem, Slovenia, e-mail: marko.vujanovic@siming.eu
[3] PE for UEC Resavica, BCM "Jasenovac", Maršala Tita 33, 12316 Krepoljin, Serbia, e-mail: sasa.ognjanovic@jppeu.rs

uslovima dobijene su odgovarajuće jednačine zavisnosti ovih uticajnih faktora na proces rezanja uglja.

Ključne reči: ugalj, rezanje, otpor, Kostolac

1. INTRODUCTION

For the purposes of testing a sample of coal from the deposit "Drmno" coal mine "Kostolac" was taken taking into account that it is a representative of the given environment. Planer at which the cutting is done is also used for sample preparation and for making of cubes dimensions of 25 cm x 25 cm x 25 cm. The cutting of the coal under different regimes was done on it, all in conjunction with three components device for registration of resistance towards the cutting. From the technical parameters that affect the size of the resistance towards the cutting in all three directions of cut by complexity, the most important were examined (Vidanović, 1996; Vidanović and Tokalić, 1999):

- Cutting depth;
- Cutting width;
- Front angle of the pick;
- The degree of cut blockage.

a) Influence of cutting depth on the size of the resistance towards the cutting

To determine the influence of cutting depth on the size of the resistance towards cutting, coal sample is examined under the following cutting regime:

- Cutting width $b = 3$ mm;
- Front angle of the pick $\beta = 0^o$;
- Cutting speed $v = 0.275$ m/s;
- Cutting step t = 30 mm;
- Cut blocked.

b) Influence of the cutting width on the size of the resistance towards the cutting

When examining a sample of coal in order to find the influence of the cutting width on the size of the resistance towards the cutting the following working regime is used:

- Cutting width $b = 5$ mm;
- Front angle of the pick $\beta = 0^o$;
- Cutting speed $v = 0.275$ m/s;
- Cutting step t = 30 mm;
- Cut blocked.

c) Influence of the front angle of the cutting tool on the size of the resistance towards the cutting

To determine dependence of the size of the resistance towards the cutting from the change of the front of the cutting tool angle the following working regime is used:

- Cutting width $b = 10$ mm;
- Cutting depth $h = 5$ mm;
- Cutting speed $v = 0.275$ m/s;

- Cutting step t = 30 mm;
- Cut blocked.

d) Influence of the blockage degree of the cut on the size of the resistance towards the cutting

In determining the influence of the cut blockade degree on the size of the resistance towards the cutting the following working regime is used:

- Cutting width $b = 10$ mm;
- Cutting depth $h = 5$ mm;
- Front angle of the pick $\beta = 0^o$;
- Cutting speed $v = 0.275$ m/s.

2. ANALYSIS OF THE INFLUENCE OF THE BASIC PARAMETERS OF THE CUT ON THE RESISTANCE TOWARDS THE CUTTING FOR CONDITIONS OF VERTICAL CUTTING TO THE LAYERS

The greatest load on the element which performs cutting of the coal mass is in conditions of the blocked cut and when cutting vertical to the layering. Since these are the most unfavorable conditions for devices and machines that perform cutting, it is rational for these conditions and to calculate the most important influential parameters, such as: the influence of the cutting depth on the resistance towards the cutting, the influence of the cutting width on the resistance towards the cutting and the influence of the front angle of the tool pick which is used for cutting on the resistance towards the cutting (Vidanović et al. 1997).

2.1. Defining the resulting values of resistance towards the cutting for the conditions of vertical cutting to the layers

The value of this resistance given as F_R, for different cutting conditions, is given in Table 1.

2.2. Influence of the cutting depth on the resistance towards the cutting

The relationship between resistance towards the cutting and cutting depth can be shown in the form of equation (Jovanović et al. 1996):

$$F_R = A \cdot h^n \tag{1}$$

Where the:

A - coefficient of proportionality that defines the growth of resistance towards the cutting for the depth unit, whose value depends on many factors, and from layer to layer and the basin to basin and ranges from 30 - 300;

n - the exponent which is for its numerical value always greater than 1;

h - cutting depth [cm].

In addition to the previous expression for calculating of the resistance towards the cutting, another form is also used:

Table 1 - The value of the resistance resultant towards the cutting by tested samples

Mark of the semple	Degree of the blockade	Cutting depth h [mm]	Cutting width b [mm]	Front angle of the pick β [°]	The resistance resultant towards the cutting F_R [N]
Kostolac-Polje "Drmno"	blocked	5	10	50	68.53
Kostolac-Polje "Drmno"	blocked	5	10	40	80.83
Kostolac-Polje "Drmno"	blocked	5	10	30	94.49
Kostolac-Polje "Drmno"	blocked	5	10	15	118.53
Kostolac-Polje "Drmno"	blocked	5	10	0	147.02
Kostolac-Polje "Drmno"	blocked	5	10	-15	255.71
Kostolac-Polje "Drmno"	blocked	5	2	0	93.10
Kostolac-Polje "Drmno"	blocked	5	3	0	98.48
Kostolac-Polje "Drmno"	blocked	5	4	0	104.40
Kostolac-Polje "Drmno"	blocked	5	5	0	117.13
Kostolac-Polje "Drmno"	blocked	5	7.5	0	116.14
Kostolac-Polje "Drmno"	blocked	5	10	0	149.56
Kostolac-Polje "Drmno"	blocked	5	12.5	0	178.86
Kostolac-Polje "Drmno"	blocked	2	3	0	47.48
Kostolac-Polje "Drmno"	blocked	4	3	0	72.06
Kostolac-Polje "Drmno"	blocked	6	3	0	80.88
Kostolac-Polje "Drmno"	blocked	8	3	0	112.61
Kostolac-Polje "Drmno"	blocked	10	3	0	192.45
Kostolac-Polje "Drmno"	blocked	12	3	0	375.58
Kostolac-Polje "Drmno"	blocked	14	3	0	415.99
Kostolac-Polje "Drmno"	free	5	10	0	68.38
Kostolac-Polje "Drmno"	half-blocked	5	10	0	86.85
Kostolac-Polje "Drmno"	blocked	5	10	0	126.50

$$F_R = a \cdot h \tag{2}$$

Results of the analysis of influence of the cutting depth d on the resistance towards the cutting for given sample are shown in Table 2.

Table 2 - The values of the resistance towards the cutting obtained for different cutting depths

Constant parameters			The value of the resistance towards the cutting by the analyzed samples F_R [kN]
Cutting depth h [mm]	Cutting width b [mm]	Front angle β [°]	Kostolac - Field "Drmno" (f = 0.62)
2	3	0	0.047
4	3	0	0.072
6	3	0	0.081
8	3	0	0.113
10	3	0	0.192
12	3	0	0.376
14	3	0	0.416

The data from the table allow for the relationship between the cutting depth and resistance towards the cutting to be graphically shown depending on strength coefficient *f*, shown in Figure 1. The analytical form of this dependence is given by the function:

$$F_{R(d)} = 0.041 \cdot h + 0.091 \cdot f - 0.171 \tag{3}$$

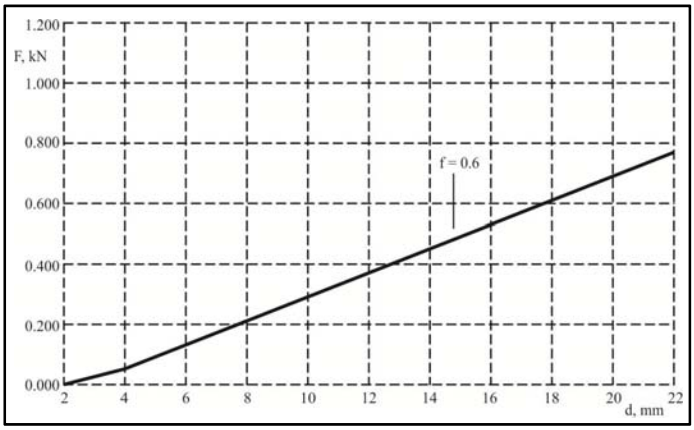

Figure 1 - The nomogram for determining of the cutting force depending on the cutting depth and strength coefficient

2.3. Influence of the cutting width on the resistance towards the cutting

Cutting width is one of the cutting parameters that influences on the size of the resistance towards the cutting. With increase of the cutting width the mass of coal substance also increases, and therefore the energy accumulation ability of the part of the coal mass in the cutting process. With increase of the cutting width the resistance towards the cutting also increases. V.N. Getopanov he carried out research and found that resistance towards the cutting grows more slowly than the increase in the width of the cut, whose results are shown in Figure 2. If the cutting depth is between 2 mm - 15 mm, then with increase of cutting width from 3 mm to 12 mm, an increase of four times, resistance towards the cutting is increased only by 60% - 100% .These changes can be seen in the diagram in Figure 2.

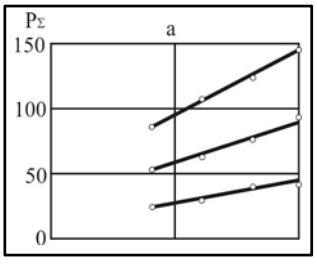

Figure 2 - Dependence of the resistance towards the cutting from the width of the cut: 1) h = 6 mm, 2) h = 4 mm, 3) h = 2 mm

The results are shown in Table 3. Data from Table 3 prevent the relations between the cutting width and resistance towards the cutting in addition to the analytical expression to be shown graphically (Figure 3). The analytical expression of the relationship between the cutting width and resistance towards the cutting with constant cutting parameters depth d and the front angle of the cutting tool β , can be defined:

$$F_{R(b)} = e^{-2.561-0.083b+0.222f}$$

Table 3 - The values of the resistance towards the cutting obtained for different widths of cut

	Constant parameters		**The value of the resistance towards the cutting by the analyzed samples F_R [kN]**
Cutting width *b* [mm]	**Cutting depth *h* [mm]**	**Front angle β [°]**	**Kostolac - Field "Drmno" (f = 0.62)**
2	5	0	0.093
3	5	0	0.098
4	5	0	0.104
5	5	0	0.117
7.5	5	0	0.116
10	5	0	0.150
12.5	5	0	0.179

2.4. The influence of the front angle of the cutting instrument on resistance towards the cutting

The size of this angle β has a great influence on the way the coal mass is cut during the cutting and from this angle depends on whether the cutting parts of the coal mass will be exposed to pressure or tightening. Position of the resultant cutting force F_R depends on the form of the element by which the cutting is done, and this one depends from the front angle of the element itself. Depending on the size of the cutting angle δ position of the resultant force is changed F_R relative to the position of the free surface. If this angle is less than 90°, the resulting cutting force is directed towards the free surface in the zone in front of the cutting instrument the destruction will come in the highest percentage as a result of deformation caused by tightening tension. If the cutting angle is greater than 90° then the resulting force is directed towards the depth of the coal mass and the highest percentage of destruction will be realized as a result of compressive tension. In this case, the destruction requires higher energy and power than in the first case. Figure 3 shows the relationship between the front angle β and cutting force for different types of coal.

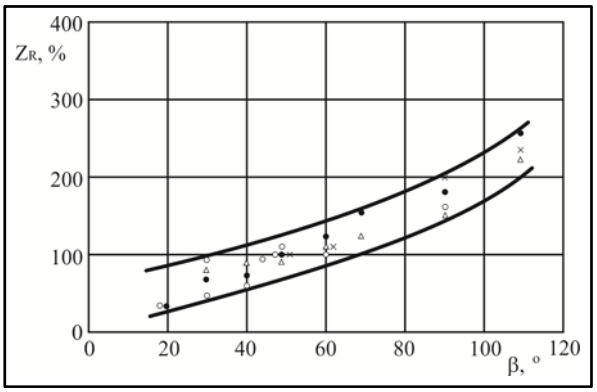

Figure 3 - The dependence of the resulting force in % on the front angle

Data from Table 4 allow the relationship between the size of the front angle of the cutting element β and resulting resistance of the coal mass during the cutting to be expressed graphically and analytically.

Table 4 - The values of the resistance towards the cutting obtained at different front angles of the cutting element

	Constant parameters		**The value of the resistance towards the cutting by the analyzed samples F_R [kN]**
Front angle β [°]	**Cutting width b [mm]**	**Cutting depth d [mm]**	**Kostolac - Field "Drmno" (f = 0.62)**
50	10	5	0.069
40	10	5	0.081
30	10	5	0.094
15	10	5	0.119
0	10	5	0.147
-15	10	5	0.256

Graphical view of the dependence between cutting resistance on the change of the front angle β is shown in Figure 4, and its analytical form is shown by the expression:

$$F_{R(\beta)} = e^{-1.854-0.019\beta+0.2f}$$

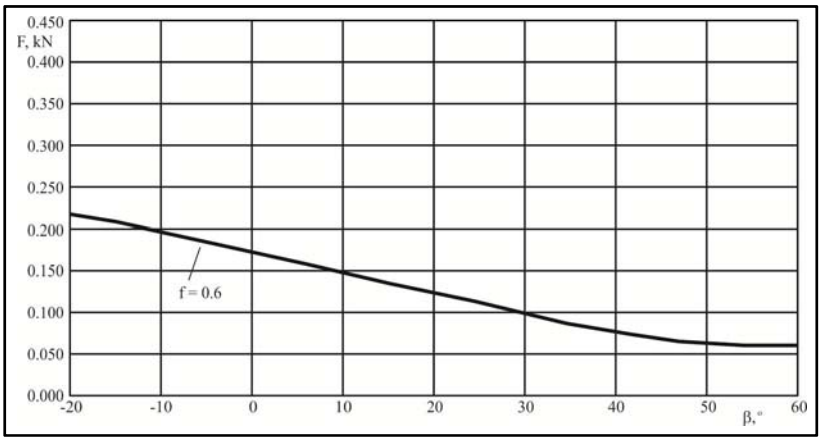

Figure 4 - The nomogram for determining of the cutting force depending on the front angle of the cutting tool and the strength coefficient *f*

2.5. The influence of the blockage degree of the cut on the size of the resistance towards the cutting

For the size of the cutting force it is essential if the cutting is performed in the conditions of blocked, semi blocked or free or cut. The influence of the cutting step on the cutting conditions can be expressed by the coefficient of the blockade K_{bl}, of which values are given in Table 5.

Table 5 - Values of the coefficient of the blockade K_{bl} depending on the cutting step

Cutting step *t*	h	2h	3h	4h
K_{bl}	0.45 - 0.65	0.6 - 0.85	0.9 - 0.95	1

Values of the coefficient of the blockade for different blockade degrees are given in the following tables:

Table 6 - Coefficient of the blockade K_{bl} depending on the blockade degree of the cut

Type of the cut	Free cut	Semi-blocked cut	Blocked cut
K_{bl}	0.4 - 0.9	1.2	1.4

Table 7 - Coefficient of the blockade *S* depending on the blockade degree of the cut

Type of the cut	Free cut	Semi-blocked cut	Blocked cut
S	1	1.61	2.35

The sizes of the cutting force are shown in Table 8, and graphical view of the influence of the blockade degree of the cut on the size of the resistance towards the

cutting is shown in Figure 4 the analytical form of dependence is given by the expression:

$$F_{R(S)} = e^{-3.201+0.642S+0.193f}$$

Table 8 - The values of the resistance towards the cutting obtained for different blockade degrees of the cut

	Constant parameters			The value of the resistance towards the cutting by the analyzed samples F_R [kN]
Blockade degree	**Front angle β [°]**	**Cutting width b [mm]**	**Cutting depth d [mm]**	**Kostolac - Field "Drmno" (f = 0.62)**
Free	0	10	5	0.068
Semi-blocked	0	10	5	0.087
Blocked	0	10	5	0.125

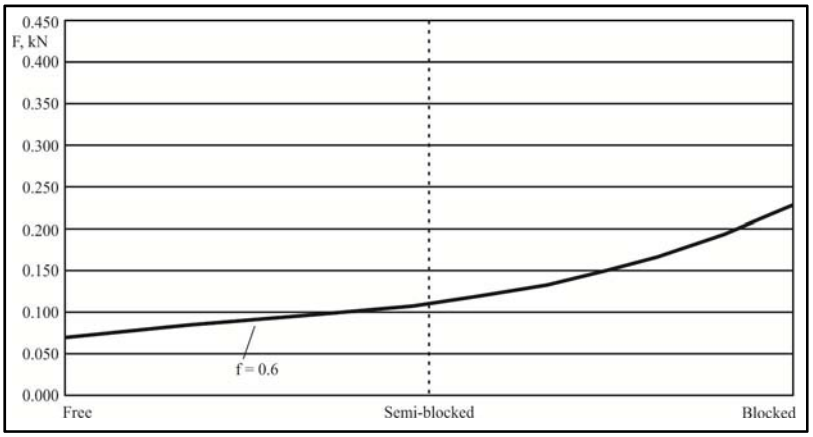

Figure 5 - The nomogram for determination of the cutting force depending on the blockade degree of the cut and strength coefficient f

7. CONCLUSION

In this work, the resistance towards the cutting of the coal mass was studied and the proper dependencies between the resistance towards the cutting of the coal mass and most important geometrical parameters of the cut in different regimes and conditions of cutting were established.

Legality of the relationship between the resistance towards the cutting and appropriate individual cutting parameters are expressed by mathematical laws and defined in the form of the corresponding functions. Obtained results are:

- The influence of the cutting depth: $F_{R(d)} = 0.041 \cdot h + 0.091 \cdot f - 0.171$
- The influence of the cutting width: $F_{R(b)} = e^{-2.561-0.083b+0.222f}$

- The influence of the front angle of the cutting tool: $F_{R(\beta)} = e^{-1.854-0.019\beta+0.2f}$
- The influence of the blockade degree of the cut: $F_{R(S)} = e^{-3.201+0.642S+0.193f}$

In Figures 1, 4 and 5 nomograms are presented on the basis of which it is possible to determine the cutting force depending on the corresponding cutting parameter and the strength of the coal mass.

The aim of this paper is to provide a methodology based selection of the appropriate devices - machines for cutting of the coal mass for specific conditions and thereby to help design engineers and to significantly avoid subjective evaluation.

ACKNOWLEDGEMENT

This paper was realized as a part of the project "Study of Possibilities for Valorization of the remaining Coal Reserves to Provide Stability of the Energy Sector of Republic of Serbia" (TR 33029) financed by the Ministry of Education, Science and Techonological Development of the Republic of Serbia within the framework of Programme of research in the field of technological development for the period 2011-2014.

REFERENCES

[1] VIDANOVIĆ, N. (1996) *Izučavanje ponašanja ugljene mase sa stanovišta njenog razaranja mehaničkim sredstvima*. (PhD), Rudarsko-geološki fakultet, Beograd.

[2] VIDANOVIĆ, N. et al. (1997) Determination of the cutting resistance of lignite from the "Dobro Selo" deposit. ergetski pokazatelj mehaničkih svojstava radne sredine. *Underground Mining Engineering*, 7, pp.115-120.

[4] VIDANOVIĆ, N. i TOKALIĆ, R. (1999) Dosadašnja iskustva o otporu prema rezanju uglja i izbor odgovarajućeg modela. *Zbornik radova V jugoslovenskog simpozijuma sa međunarodnim učešćem "Aktuelni problemi razvoja i primene mehanizacije u rudarstvu", Beograd, decembar 1999*. Beograd: Rudarsko-geološki fakultet, pp.174-177.

[5] JOVANOVIĆ, P. et al. (1996) Effects the cutting depth on the magnitude of catting resistance. *Underground Mining Engineering*, 5, pp.91-94.