Türkiye 11 Komur Kongresi Bildiriler Kitabı, 10-12 Haziran 1998, Barlın-Amasra, Türkiye
Proceedings of the 11th Turkish Coal Congress, 10-12 June 1998, Bartın-Amasra, Turkey

DETERMINING THE OPTIMUM STOPE PARAMETERS FOR OVERBURDEN EXCAVATION WITH A BUCKET WHEEL EXCAVATOR SRs-2000

SRS-2000 TİPİ BİR DÖNER KEPÇELİ EKSKAVATÖR İLE ÖRTÜ TABAKASI KAZISI İÇİN OPTİMUM BLOK KAZI PARAMETRELERİNİN BELİRLENMESİ

Ivan LALOV, *University of Mining and Geology, 1100 Sofia, Bulgaria*
Stoyan. HRISTOV and Evtim KARTSELIN, *University of Mmmg and Geology, 1100 Sofia, Bulgaria*

ABSTRACT

The rate of efficiency of a bucket wheel excavator SRs-2000 that excavates the overburden depends on a number of factors Values of stope and web parameters being equal or almost equal to optimum ones is a basic factor Bench stability is necessary for securing a safe and effective work under the conditions of "Maritsa-Iztok, AD" mines Conditions of the task for calculating the optimum values of stope parameters are determined in the paper. An analytic-graphic method is proposed for resolving the task An analytic expression is also proposed for calculating power and electric energy consumed Methods proposed in the paper can be applied to other excavators and other working conditions

ÖZET

Örtü tabakasını kazan SRs-2000 tipi bir doner kepçeli ekskavatörün verimliliği birçok faktöre bağlıdır Blok kazı ve dilim parametre değerlerinin optimum değere eşit veya oldukça yakın olması temel koşuldur 'Maritza-Iztak, AD' işletmesindeki koşullar açısından, basamak duraylığı güvenli ve verimli çalışma açısından bir gerekliliktir Blok kazı parametrelerinin optimum değerlerinin belirlenme koşullan bildiride belirtilmiştir Bu iş için bir analitik-grafik yöntem önerilmektedir. Tüketilen guç ve elektrik enerjisi için bir analitik eşitlik de önerilmiştir Bildiride önerilen yöntemler, diğer ekskavatörlere ve farklı çalışma koşullarına da uygulanabilir

1. INTRODUCTION

Opencast coal mines often use bucket wheel excavators of average and high productivity that form the productivity of the entire technological integration. This involves the realization of opportunities for maximizing the rate of their efficiency. It depends on a number of factors One of them is optimum values of stope parameters.

Furthermore, securing a safe and effective work of the excavator when loose clayey-arenaceous rocks, like those at the "Maritsa-Iztok, AD" mines are excavated requires bench stability.

2. DEFINING THE CONDITIONS OF A TASK FOR OBTAINING OPTIMUM VALUES OF STOPE PARAMETERS

Under the mining conditions of opencast coal mines of "Maritsa-Iztok, AD" and the bucket wheel excavator, SRs-2000, a subject of interest, a height higher but lower than the admissible one increases its productivity but leads to sudden failures and accidents

Then a task originates - determining the optimum stope parameters - stope height H, stope width A, angle of bench slope a and angle of the stope a, . The determined optimum values of the parameters and relations are expected to secure maximum productivity and necessary safety of the system "excavator-stope" under certain mining conditions, i e.

$$H = H_{opt} \leq H_{max}, \; A = A_{opt} \leq A_{max}; \; \alpha_{m\,c.} \leq \alpha = \alpha_{opt} \leq \alpha_{n};$$

$$\alpha_{s.m\,c} \leq \alpha_s = \alpha_{s.opt} \leq \alpha_{s.n} \text{ in case } Q_{tech} = Q_{tech\,opt}, \qquad [1]$$

where $\alpha_{m\,c}$ and $\alpha_{s\,m\,c}$ are the minimum possible values of the angle of slope, of bench and stope respectively, depending on excavator parameters; $\alpha_{ni}=f(H)$ and $\alpha_{sni}=f(H)$ angles of temporary stability of the angle of slope, of the bench and stope, respectively; Q_{tech} - technical productivity of the excavator including the auxiliary operations connected with block excavation. This task can be divided into two subtasks.

In the first subtask parameters of the stope H, a and a,, are optimized as a function of both geometric constructive parameters of the excavator and physical and chemical properties and rock parameters. This subtask can be formulated as follows' at a constant width A = const, and considering the geometric dimensions of the excavator and mining conditions the values of H, a and a, are equal to optimum ones if they provide a maximum volume of the excavated block Vb, i.e.

$$H = H_{opt} \leq H_{max}, \; \alpha_{m\,c.} \leq \alpha = \alpha_{opt} \leq \alpha_{n}, \; \alpha_{s.m.c.} \leq \alpha s = \alpha_{s.opt} \leq \alpha_{s\,n},$$

$$A = \text{const.} \leq A_{max} \text{ in case } V_b = V_{bmax} \text{ or } V_b \rightarrow \max \qquad [2]$$

In the second subtask the optimum values of $H_{opt.}$, α_{opt} a n$\alpha_{s\,opt}$ r e known and the optimum value of the stope width A = A_{opt} as a function of geometric excavator parameters, height of the most upper layer he of the stope and the main disturbance - variation of volume of sheared V_s web following a cosine law of the angle ϕ of rotation of the upper structure of the excavator towards not yet mined room, i.e. $V_s = V_{s.o.}\cos\varphi$. The determined optimum value of width A = A_{opt} is expected to provide maximum productivity $Q_{tech\,b.} = Q_{tech\,b\,max.}$ In Hie case of give mining and climatic conditions this subtask can be formulated (defined) as follows:

$$A = A_{opt} \leq Amax \text{ in case } Q_{tech.b.} = Q_{tech\,b\,max.};\ H=H_{opt.},$$

$$\alpha = \alpha_{opt} \text{ and } \alpha_s = \alpha_{s\,opt};\ h_c = h_{copt} \text{ and } a_{c\,o} = a_{comax} \qquad [3]$$

3. ANALYTIC-GRAPHIC METHOD FOR DETERMINING STOPE PARAMETERS

The solution of the above problem, determining the optimum values for stope parameters can be obtained by an analytic-graphic method The excavator subject of discussion, SRs-2000 has got the following parameters: $H_{min} = 5,5 \div 7,7$ m, $H_{max} = 28$m, Q_{theor} = 3600/4500m^3/h, k_F = 1110/890 N/cm, A_{max}=55 m.
Determination of the rational stope height is done by the use of fig. 1 depending on theoretical excavator productivity according to condition of minimum consumption for the conditions of "Maritsa-Iztok, AD" mines. The response of Q_{theor} = 3600/4500m^3/h reads H = 23/25 m.

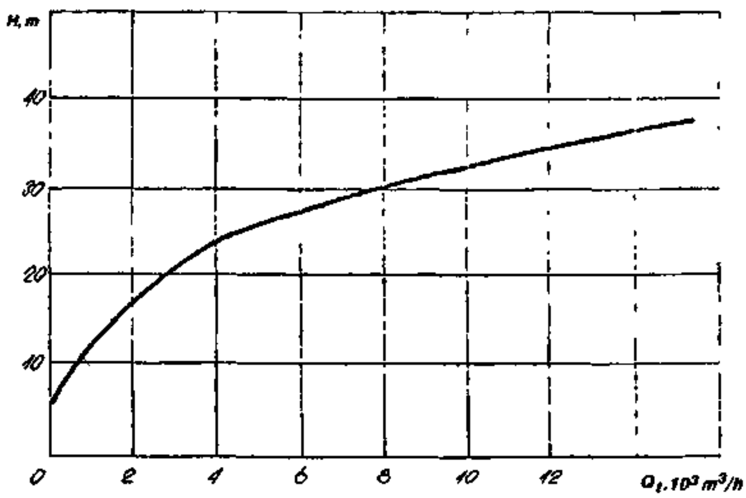

Figure 1. Dependence of stope height from theoretic productivity

Height of the bench (stope) can be determined depending on specific force (shearing effort) of excavator digging. For this purpose using the nomogram in fig. 2 of Q_{theor}=3600/4500m^3/h also H = 23/25m is read, and with respect the specific force of digging H = 25 - 28 m is read With the aim of providing better safety $H_{m,,}$=20,5-21,5 m is assumed and then a =45 s 47° is read in fig 3

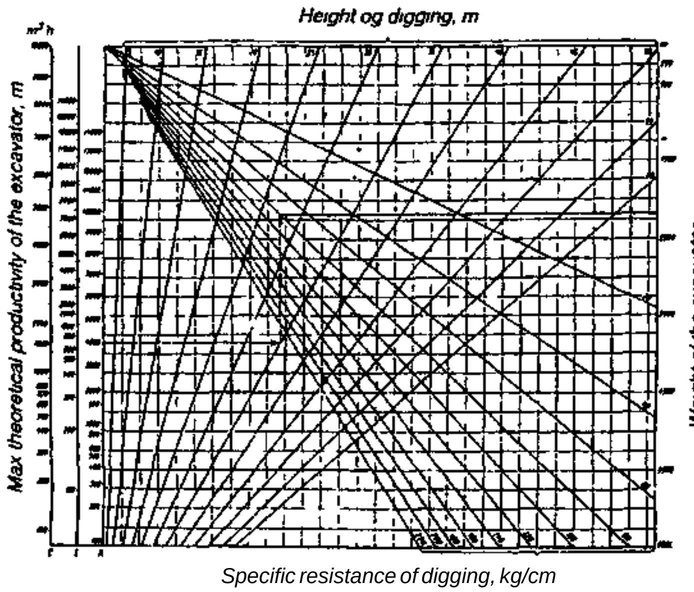

Figure 2 Dependence of the height of digging from the theoretical productivity and weight of the excavator and specific resistance of digging

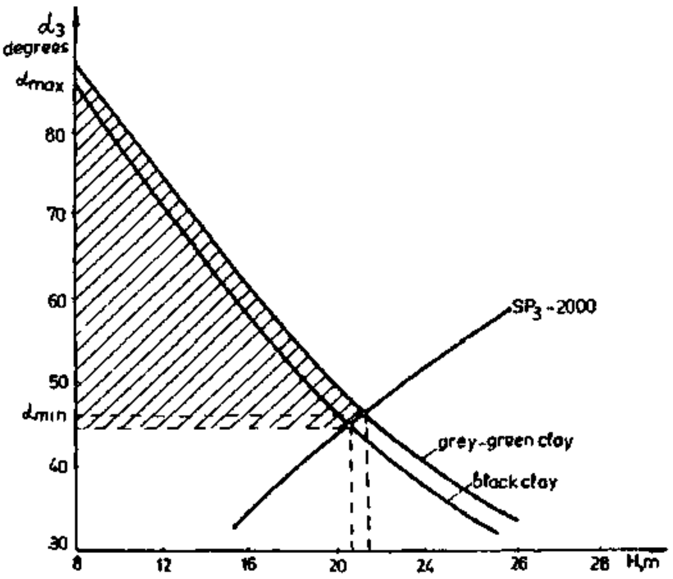

Figure 3 Dependence of stope angle from dench height according to a condition of slope stability and constructive parameters of SRs - 2000

The function a = f(H) can be determined by the response of G L Fisenko (fig 4) Forces of lateral stress in the massif due to its rounded shape and duration of its stay are considered in the determination of stope slope angle For that purpose the increase Aa towards the angle of bench slope is read from the response in fig 5 and the stope angle is determined, i e

ꝏ» = a + Aa = f(H) [4]

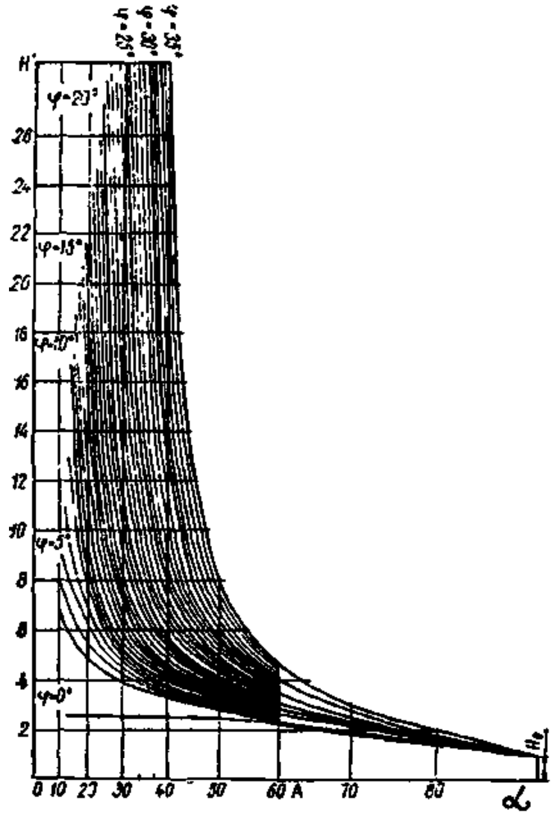

Figure 4 Dependence of the slope angle of the bench from its height at a given angle (p of internal traction ($H'=H/H_a b$)

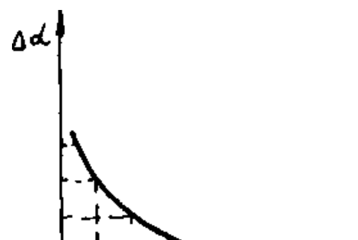

Figure 5 Dependence of the increase Aa from the radius of digging RM of the lowest iager of bench

For the conditions of "Maritsa-Iztok, AD" mines the stope angle is obtained 8° or 10° higher than the angle of bench slope

The dependence a, is obtained from the constructive parameters of excavator SRs-2000 according to its digging from minimum to maximum height and from minimum to maximum radius For that purpose the following formulas are used (fig 6)

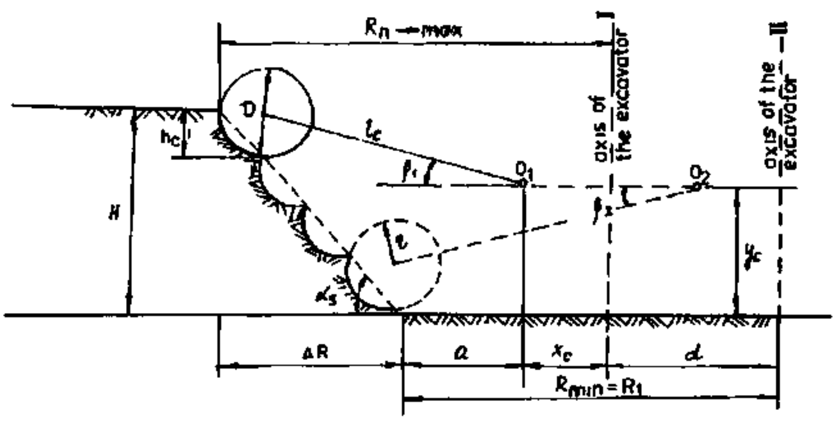

Figure 6 Parameters of the stope and bucket wheel excavator

$$\alpha_s = \mathrm{arctg}\frac{H}{l_c \cos\left(\arcsin\frac{H-y_c}{l_c}\right)+r-a}, \quad [5]$$

or

$$\alpha_s = \mathrm{arctg}\frac{H}{R_{max}-d-R_{min}}, \quad [6]$$

$$\alpha_s = \mathrm{arctg}\frac{H}{\sqrt{l_c^2-(H-y_c)^2}+r-a}, \quad [7]$$

$$a = R_{max}-X_c = l_c \cos\left[\arcsin\frac{H-(h_c-r)}{l_c}+r-H\mathrm{ctg}\alpha_s\right] \quad [8]$$

The distance of excavator movement d is

$$d = l_c(\cos\beta_2-\cos\beta_1)+(H-h_c)\mathrm{ctg}\alpha_s, \quad [9]$$

$$\beta_1 = \arcsin\frac{H-(h_c-r)-y_c}{l_c}, \beta_2 = \arcsin\frac{y_c-r}{l_c}, \quad [10]$$

$$h_c = H_{min} = (0{,}5 \div 0{,}7)D, m, D = 2r, \quad [11]$$

The following relation exists also between parameters of the excavator and the stope

$$H-(h_e-r)ctg\alpha+R_{min}-r=\sqrt{l_e^2-[H-y_e-(h_e-r)]^2-X_e}\ , \qquad [12]$$

The equation can be used for determining the minimum slope angle a at a maximum height of excavator digging or at a certain slope angle the maximum bench height to be calculated

On the background of rational calculated parameters α, α_s, H and the final angle of rotation of rotor boom towards bench φ_b and towards mined out room φ_p, the maximum width of stope can be determined

$$A_{max}=R_{max}(\sin\varphi_p+\sin\varphi_b)+l_e(\cos\beta_2+\cos\beta_1)\sin\varphi_p-Hctg\alpha,$$
$$\varphi_p=45\div50^\circ, \varphi_b<90^\circ \qquad [13]$$

Investigations carried out on the base of experience from "Maritsa-Iztok, AD" mines reveal that rational height of the bench for an excavator SRs-2000 varied from 15 to 20 m and a safe operation is secured

4. DETERMINING THE MAIN PARAMETERS OF THE COAL WEB

The method for determining the main parameters of the web and the regime of wheel boom rotation in a horizontal plane is determined depending on control purpose envisaged as well as technical and technological limitations Some of them are formulated as requirements

For the purpose of excavator control the maximum exploitation productivity $Q_{e\,b}=Q_{e\,b\,max}$ of the excavator in case of stope block excavation follows

$$Q_{tech\,b}\rightarrow Q_{tech\,b\,max}, \text{ in case of } C_{k\,b}\rightarrow C_{k\,b\,min}, \qquad [14]$$

where Ckb is the specific consumption for excavation of a stope block

Acquiring of optimum values of these parameters is provided to the highest extent when block and slope parameters tend to optimum values

$$A\rightarrow A_{max},\ Tb\rightarrow T_{b\,max},\ K_{dm}\rightarrow K_{dm\,min}, \qquad [15]$$

where K_{dm} is the coefficient of dynamics representing the ratio of maximum amplitude of loading to average constant value, Tb - length of the excavator block

The criterion of stope block control reveals

$$n_c = \frac{H}{h_{c\,max}} \to n_{c\,min},\ 0{,}5D \le h_c \to h_{c\,max} \le 3D/4, \qquad [16]$$

where n_s is the number of layers of the stope block,

At a level layer, criteria and limitations (technical and technological) are

$$n_{pc} \to n_{pc\,min} \text{ and } K_{dm} \to K_{dm\,min} \text{ in case of } a_{co} \to a_{co\,max} \le 0{,}8h_k \qquad [17]$$

where n_{p0} is number of lines m the web in one layer, hk - height of the bucket, Ik - wide of the bucket

Usually the height of benches is determined in advance In the process of excavation of a stope belt any time when the excavation of a new stope block (SB) begins its actual height H is determined, the height hcn of the upper layer is optimized so that the radius of digging R—»max and considering the longitudinal and cross slopes of the Lower Structure of the Excavator (LSE) and the upper horizon, $\delta_{лс}, \varepsilon_{лс}$ and $\delta_{uh}, \varepsilon_{uh}$ respectively The height of the "n" web at its shearing is h_{cns}

$$h_{cns} = h_{c\,max} - R_s \left\{ (tg\delta_{лс} - tg\delta_{uh})(\cos\varphi^m - \cos\varphi^s) + (tg\varepsilon_{лс} - tg\varepsilon_{uh})^2 (\sin\varphi^m - \sin\varphi^s) \right\} \qquad [18]$$

where $\Delta h_{cn\,max}$ - maximum value of variation of the -"n" web (layer) due to the difference in the slopes of the Lower Structure of the Excavator (LSE) and the upper horizon, φ^m - value of the angle where $\Delta h_{cn} = \Delta h_{cn\,max}$, φ^s - value of the angle where the next new web of the new stope block is sheared, $\delta_{дс}, \varepsilon_{дс}, \delta_{uh}, \varepsilon_{uh}$ the longitudinal and cross slope, respectively of the lower and upper structure of the excavator
The value of φ^m is determined as a first derivative of Ahc„ i e

$$\varphi^m = \text{arctg}\frac{tg\varepsilon_{лс} - tg\varepsilon_{uc}}{tg\delta_{лс} - tg\delta_{uc}} \pm \varepsilon_u, \qquad [19]$$

Where ε_u is the argular displacement of excavator from stope axis
Then

$$\Delta h_{cn\,max} = R_s \left[(tg\delta_{лс} - tg\varepsilon_{uh})\cos\varphi^m + (tg\varepsilon_{лс} - tg\varepsilon_{uc})\sin\varphi^m \right] \qquad [20]$$

On the basis of expressions (19) and (20) hc_{ns} and number of layers (n-1) is determined, **i e**

$$h_{cns} = 3D/4 - \Delta h_{cn\,max},\ (H - h_{cn})/(3D/4) = (n-1)_1 \qquad [21]$$

Height of other layers is obtained from the expression

$$h_{c1} \div h_{c(n-1)} = (H - h_{cn})/(n-1),$$ [21']

Maximum values of a $b_{c\,max}$ and the number of sheared spits np $_c$ in one layer is

$$b_{c\,max} = 0{,}5l_k,\ n_{pc} = T_b/(0{,}8h_k) - (n_{pc})_{\delta+},\ a_{c\,\delta} = T_b/(n_{pc})_{\delta-}$$ [22]

At a given $K_{a\,max} = a_{co\,max}/b_{co}$ or the thickness $a^{\wedge}_{omm}$ the following models are used

$$a_{c\,o\,max} = [(q_b K_{fb\,max} K_{a\,max})/(K_{sb}\,h_c)]^{0.5} \le 0{,}8h_k,\ b_{co} = a_{c\,o\,max}/K_{a\,max}$$ [23]

$$V_p = (w_r n_k b_{co})/(2\pi\cos\varphi),\ w_p = z_{bc\,o}/(R+r)\cos\varphi$$ [24]

K_{fb}, K_{sh} are coefficients of filling and swelling of the mining mass in the buckets of the wheel, $b_{c\,o}$, $a_{c\,o}$ - width and thickness of the sheared web at an angle of rotation of the Upper Structure of Excavator (USE) $\varphi = 0$, Z - number of released bucket for unit time, n_k number of buckets on the wheel, ω_r, ω_p - angular speed of the wheel and the Upper Structure of Excavator (USE), respectively

The expressions (23) and (24) are used for determining the maximum angle of wheel boom rotation in a horizontal plane which provides filling of the buckets up, i e

$$\varphi_{max\,f} = \arccos\sqrt{\frac{K_{a\,min}}{K_{a\,max}}} = \arccos\sqrt{\frac{0{,}4 \div 0{,}333}{a_{co}^2 h_c K_{sb}} q_k K_{fb\,max}} \le \varphi max$$ [25]

The maximum periphery $V_{p\,max}$ or a n g u l $\omega_{p\,max}$ e e d when the buckets are filled up is determined from the expressions

$$V_{p\,max} = \frac{zb_{co}}{\cos\varphi_{max\,f}},\ w_{p\,max} = \frac{zb_o}{(R+r)\cos\varphi_{max\,f}}$$ [26]

The value obtained for V_{pmax} Is compared to the maximum admissible $V_{pmax.g}$.

In case that $V_{pmax.f} < V_{pmax\,g}$ the boundary angle $\varphi_{gr\,nar}$ of the increase of V_n is determined, i e

$$\varphi_{gr\,nar} = \arccos\frac{b_{co}}{V_{p\,max.g}}$$ [27]

After reaching of $\varphi_{gr\,nar}$, i e of $V_{pmax.g}$ the speed remains constant to reaching the internal angle $\varphi = \varphi_{p\,max}$ of rotation and the productivity, i e the coefficient of filling K_{fb} reduces following a cosine law, i e

$$K_{fb} = K_{fb\,max}\cos(\varphi - \varphi_{gr\,nar}) \text{in case} (\varphi - \varphi_{gr\,nar}) > 0$$ [28]

When

$$V_{p\,max\,f} = V_{p\,max\,g}, \text{if } \varphi_{gr\,nar} = \varphi_{max\,n}, \qquad [29]$$

Then

$V_{p\,max\,f} > V_{p\,max\,g}$ is necessary to be assumed

$$\varphi_{max\,f} = \varphi_{gr\,nar}, V_{p\,max\,f} = V_{p\,max\,g} \qquad [30]$$

5. CONCLUSION

The definitions proposed and the analytic-graphic method for optimum stope parameters as well as the method for determining the optimum values of layers, of the excavator block, number of webs in one layer, and thickness and wide of the web can be applied to other types of bucket wheel excavators

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