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Research Article

STUDY AND DETERMINATION OF RATIONAL OPERATING RATIO FOR PERCUSSION DRILLING MACHINES

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ABSTRACT

In this paper, we have the percussive rotational drilling regime that is determined by the combination of the rotational speed of the tool, the axial force applied on the rock; the optimal values of these parameters depend in particular on the type of tool and on the physico-mechanical properties of the rocks to be felled. The aim of the research is to improve the operating regimes of percussive drilling machines under the conditions of the Algerian limestone quarries (Hadjar-soud quarry) and to obtain a better compromise between the technical and economic indices, in order to ensure a minimum cost price for a meter of drilled hole. The experimental results carried that this methodology, which consists of assuming that under the concrete conditions can find the combination of the setting parameters that ensure the best techno-economic indices, as well as to carpenter the cost price for a meter of drilled holes.

Keywords: Axial force; Rotation and Penetration speed; Properties of the rock, Energy of shock; The tool of progress speed.

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1. INTRODUCTION

The importance of the mining sector for the national economy is capital, in order to reveal the resources which may undergo beneficiation real of the country. The objectives to be reached are numerous: to reduce our dependence with regard to the foreigner, to produce with the lower costs [1].

The objective that our mines and careers must set is that of an optimal exploitation of the Algerian by taking account of the various features, economic and human resources. This gives to reflect on work to realize and among them the process of drilling which is the prevalent factor in the development of exploitation [2].

The essential parts of this work show that whatever the nature of the massif and the optimization of the control parameters, the choice of the machines and the drilling method to be used remains a major concern for the national companies [2].

The aim of this work is to determine the operating regimes of percussive drilling machines under the conditions of the Algerian limestone quarries (Hadjar-soud quarry). In this way, the present paper is organized into eight sections. Section 2 is dedicated to the physico mechanical properties. Section 3 presents the productivity of the drills. Then, the experimental study of productivity is discussed in the following section. in section 5, the depression tool in the rock with shock courses, section 6, present the mathematical method of experiment planning and section 7, about the mathematical model of the cost price of a meter of drilled hole finally, conclusions are given.

2. PHYSICO MECHANICAL PROPERTIES

In this section, we have study the physico mechanical properties of the limestones of the Hadjar-Soud quarries began with the visual observation of the deposit, subdivision of the deposit into number of parts according to the peculiarities of cracking, presence of impurities (figure.1). After doing in several parts, we took a number of samples determined abrasiveness and impression resistances under laboratory conditions [11].

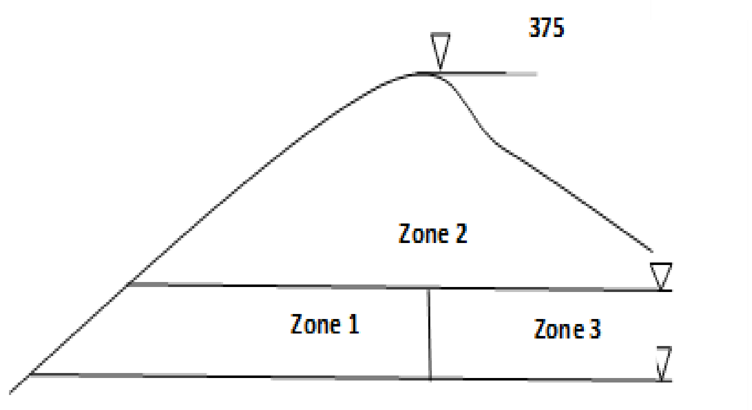

Fig.1. Distribution of solid mass in zones for the study of the physico- mechanical properties, (footprint resistance, abrasiveness)

2.1 The abrasiveness

The test of the rocks on abrasiveness was carried out according to methodology proposed by BARON.L [3]. The most of this one consists in rubbing a steel stem on one of the facets of the sample of the rock and determining the loss of the weight of the stem during the experiment. What amounts saying that the criterion of abrasiveness is a summary loss of weight of a steel stem (mg) during 10 minutes of friction.

The experiment is done with a thrust load of 15 kgf and a number of revolutions equal to 400tr/min creating the friction of the stem.

The tests are carried out using stand represented on (figure.2), whose principle of operation is illustrated in the following way: the test-tube of the rock (1) is tight between the trimmings (3) of a device (2) rests sour one of the two facets. During the test, a tigemesure (4) fixed in a chuck (5) of a drilling machine goes down on the sample after having started the engine (7) of the machine tool. The required thrust load is ensured by the load (6). The stem of measurement is manufactured out of steel soft centre. Before the test, the stem is weighed using an analytical balance with the accuracy of 0.1 mg. After having carried out the tests during 10 minutes we move the stem so that it is turned over other end, then we remake the operation during 10 minutes [4].

Abrasiveness is calculated from the formula:

$$a = \frac{(P_{2i} + P_{1i})}{2N};(mg) \qquad (1)$$

Where: N: Number of tests of each sample

P_{2i}: Initial mass of the sample

P_{1i}: Final mass of the sample

According to the tests carried out, we got the following results (table 1),

Table 1. Property of Abrasiveness

Parts of the deposit	Test results, mg
1	3
2	2.5
3	2.7

By comparing these results with the recommendations of the classification suggested by BARON.L [3] we can say that lime stones of the career of Hadjare-Soud refer to the first class, i.e. of a very low abrasiveness.

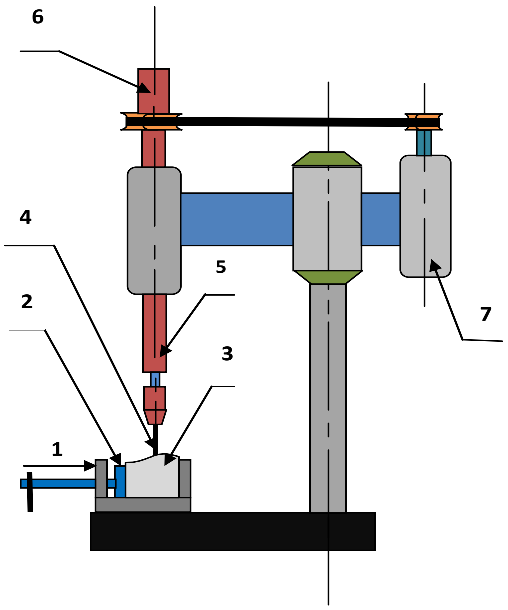

Fig.2. Stand for the determination of the abrasiveness of the rocks

2.2 Resistance to the fingerprint

The determination of the index of resistance to the print was carried out by means of a power press of type – HRC [13].

The press represented on (the figure.3 a), is composed of a base (1) where one installs all necessary equipment and of two Edges (2) length whose a plunger (3) moves. On the higher table of the press we place, a sample (4) which is charged with a stamp (5) fixed in a chucking device (6). The stamp (figure.3 b) is out of tempered steel.

At the time as of tests, we increase the load on the stamp until the formation of a seed hole in the sample [4].

The fingerprint resistanceis determined using the following formula:

$$P_k = \frac{\sum F_i}{N \times S_i}; \left(kgf / mm^2\right) \quad (2)$$

Where: F_i: load at the time of the formation of the seed hole, (kgf);

S_i: surface of the cross section of the stamp, (mm^2);

N: many tests of each sample.

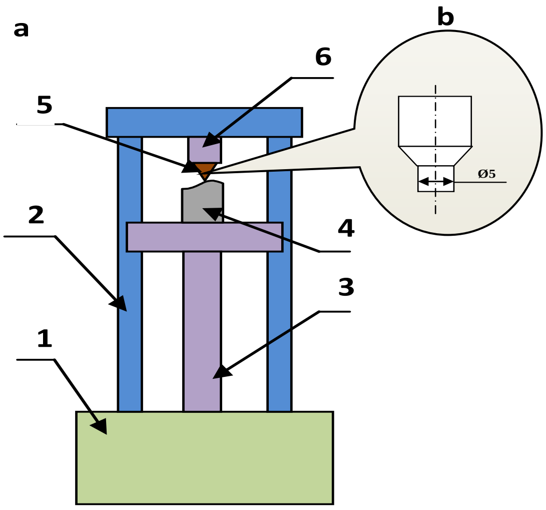

Fig.3. Stand for the determination of the fingerprint resistance (A) and the stamp of measurement (b) [4]

Table 2. Property of Resistance to the Print

Nature of the limestone sample	Nº of sample to the test	N⁰	Test results			
			F ; kgf	S_i ; mm^2	P_k ; kgf/mm^2	$\overline{P_k}$
Gray	I	1 2 3	2000 2200 2000	20.66 18.78 20.66	100 100 110	103
	II	1 2 3	2500 2300 2100	18.4 21.9 20	125 105 115	115
	III	1 2 3	2000 2200 2000	20.66 18.78 20.66	100 100 110	103
Reddish	I	1 2 3	1500 2000 1700	23.11 17.33 20.39	75 85 100	86.6
	II	1 2 3	2500 2300 2500	20 21.73 20	125 125 115	121
	III	1 2 3	1500 1800 2000	23.55 18.27 17.66	75 100 90	88
Chestnut-gray	I	1 2 3	2000 2000 2300	21 18.26 21	100 100 115	105
	II	1 2 3	2300 2100 2100	18.84 20.63 20.63	115 105 105	108
	III	1 2 3	2000 2400 2200	22 18.33 20	100 120 110	110

According to the results of the tests presented in the table.2, the studied rocks have a resistance to the average print of 105 kgf/mm^2, according to the classification of BARON L and GLTMAN. L [5] these rocks refer to the class called “average hardness”.

3. THE PRODUCTIVITY OF THE DRILLS

The theoretical productivity corresponds to the mechanical speed of drilling,

$$Q_{theo} = V_f ; (m/\min) \tag{3}$$

The technical productivity must take into account the influence of the technical imperfection of the sounder envisaged on its productivity and is expressed by the following formula:

$$Q_{tech} = 60 \times Q_{theo} \times \mathrm{K}_{tech}; (m/h) \tag{4}$$

Where: K_{tech}: coefficient of the technical imperfection of the drill.

$$\mathrm{K}_{tech} = \frac{\mathrm{T}_f}{T_f + T_{aux}} \tag{5}$$

Where: T_f: productive working time of the drill during a cycle, (min):

$$\mathbf{T}_f = \frac{L}{V_f} \tag{6}$$

Where: L: measuring of the borehole, (m);

Taux: summary losses of time to the realization of auxiliary work at the down times of the drill because of its imperfection, (min).

$$\mathrm{T}_{aux} = \mathrm{T}_{man} + \mathrm{T}_{al} + \mathrm{T}_{dep} + \mathrm{T}_{rep} + \mathrm{T}_{remp} \tag{7}$$

Where: T_{man}: preliminary handling time before the drilling of each hole,

T_{al}: time of extension and lifting of the train of the stems,

T_{dep}: time of displacement of the drill to the new hole,

T_{rep}: time of repair of the drill,

T_{remp}: time of replacement of the tool for drilling,

- Operational productivity depends on the degree of utilization of the technical capabilities of a sounder in the actual conditions of the operation.

$$Q_{exp} = 60 \text{ x } Q_{theo} \,.\, K_{exp}, \text{ (m/h)} \tag{8}$$

Where: K_{exp}: coefficient that takes account of the continuous work of the drill during its exploitation.

$$\mathrm{K}_{tech} = \frac{\mathrm{T}_f}{T_f + T_{aux} + \mathrm{T}_{org}} \tag{9}$$

Where: T_{org}: wastes of time because of the organisation of work, (min).

4. EXPERIMENTAL STUDY OF PRODUCTIVITY

In this section, we have presented an experimental stady of influencing factors on the productivity of roto-percussion soundersfor example in the career of Hadjar-Soud they are the drills Ingersoll-Rand and Atlas-Copco used for the drilling of the rock.

Table 3. Determination progress drilling

Name of the Sounder	L, (m)	T_f, (min)	V_f, (m/min)
Ingersoll-Rand	52.5	206	0.255
Atlas-Copco	45	200	0.225

Where: L: Total depth of the boreholes.

T_f: Time of drilling.

V_f: Speed of drilling.

Computation results got using the formulas (4), (6) and (8) are indicated in table 4.

Table 4. Result of calculations of the productivities

Name of the Sounder	V_f m/min	$Q_{théo}$ m/h	K_{tech}	Q_{tech} m/h	k_{exp}	Q_{exp} m/h
Ingersoll-Rand	0.255	15.3	0.80	12.24	0.43	5.26
Atlas-Copco	0.225	13.5	0.82	11.07	0.42	4.64

After read and analysing the obtained results in previous table, we notice that, the spite of the technical imperfection with the drill Ingersoll-Rand, which is confirmed by the value of coefficient (K_{tech}), the drill Ingersoll-Rand ensures a greater technical productivity than drill Atlas-Copco. That is explained by the possibility of obtaining in the first case a high speed of drilling, which at the same time determines larger productivity exploitation.All that is affirmed by the curves of dependence $Q_{theo} = f(V_f)$, $Q_{tech} = f(V_f)$, and $Q_{exp} = f(V_f)$ plotted assuming that it is possible to change the drilling speed (figure 4).

a) b)

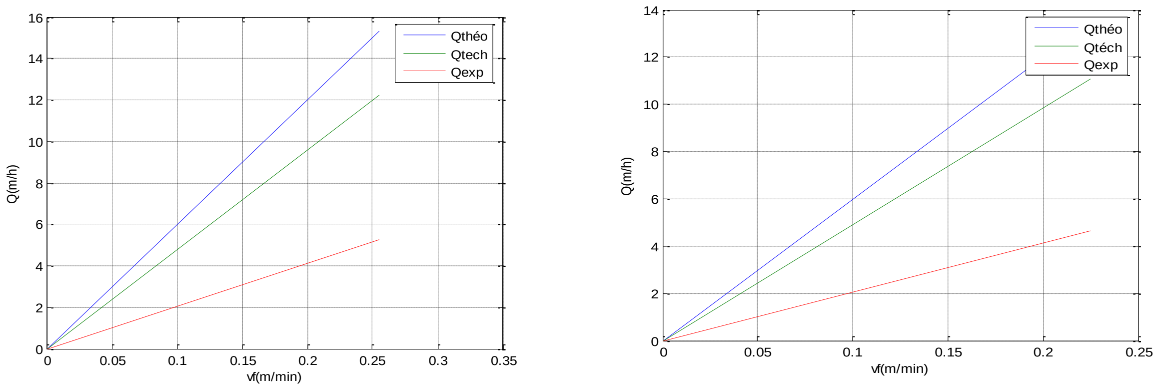

Fig.4. Dependence of the productivities Qthe, Qtech, Qexp according to the progress drilling, (A) Ingersoll-Rand, (b) Atlas-copco

The analysis of the results according to the dependence curves of the theoretical, technical and exploitation productivity as a function of the drilling speed allows us to say that the productivity depends primarily on the parameters of the drilling regime because they determine the value the drilling speed. Thus, it can be concluded that the drilling speed has a considerable influence on the productivity of the sounders.

5. THE DEPRESSION TOOL IN THE ROCK WITH SHOCK COURSES

In this section, we propose an analytical method that supposes that kinetic energy T of the striking ball passes completely to the potential energy U of the deformation of the rock [5]:

$$T_1 = U \tag{10}$$

The kinetic energy of the striking ball is measured by carried out work and is equal to the energy of the shock carried [5]:

$$T_1 = A \tag{11}$$

The potential energy in the case considered is equal to:

$$U = \frac{1}{2} \times Q \times h; (kgf.m) \tag{12}$$

Where: h: penetration of the tool, (m),

Q: force acting on the ball, (kgf).

In our case, the force Q can be presented as follows:

$$Q = C_1 \times S; (kgf) \tag{13}$$

Where: C_1: proportionality factor which takes account physic mechanical properties of the rock, surface quality external of the sample and other factors;

S: surface of the ball being in contact with the rock.

$$S = \pi \times d \times h; (m^2) \tag{14}$$

Where: d: diameter of the ball, (m).

As the physical direction of the studied process is analogical with the process of depression of the stamp during the measurement of the resistance to the print of the rock, we take

$$C_1 = K \times P_k \tag{15}$$

Where: K: coefficient which takes account of the brittleness of the surface deposit as well as characteristics of the dynamic action of the tool, (K=1.2÷1.3).

P_k: resistance to the print of the rock, (kgf/mm^2).

In a final form we write:

$$A = \frac{10^6}{2} \times K \times P_k \times \pi \times d \times h^2; (kgf.m) \tag{16}$$

So:

$$h = \sqrt{\frac{2 \times 10^{-6} \times A}{K \times P_k \times \pi \times d}}, (m) \tag{17}$$

Using the formula suggested (17); we can find the depth of the crushing of the rock provided with a ball. But we know that normally the tool is charged by some balls of which the number is equal to N, this is why the formula according to which we determine the depression of the tool in the rock during a shock is the following one:

$$h = \sqrt{\frac{2 \times 10^{-6} \times A}{K \times P_k \times \pi \times d \times N}}, (m) \tag{18}$$

Knowing the number of blows of the piston of the striker lasting a turn nc or the number of blows lasting a minute nm, we find in conformity the total depression for a turn or a minute.

$$h_0 = h \times n_c; (m/cp) \tag{19}$$

$$h_m = h \times n_m; (m/\min) \tag{20}$$

Formulas suggested (18), (19) and (20) could be used to determine the productivity of the drills their rational modes of operation.

6. MATHEMATICAL METHOD OF EXPERIMENT PLANNING

The mathematical method of planning of experiment makes it possible to obtain the mathematical model of the process of drilling and to decrease the number of experiments. The research of following stages [9]:

- Planning of the experiment,
- Realisation of the experiment,
- Checking of the reproducibility of the experiment,

-Checking of the reproducibility of the experiment,

- Obtaining the model of the process with the checking of the significance of the regression equation,

- Checking of the adequacy of the model.

We chose the mechanical speed of drilling, the studied factors (number of revolutions of the train of stem n, thrust load applied P) represent the regulated digital values, during experimental drilling we can give them given values.

The experimental design is presented in (table 5).

Table 5. Experimental design

Indices	Studiedfactors	
Basiclevel, X_0	450	65
Intervalofvariation, S	50	10
Higherlevel, +1 = X_0 +S	500	75
Lowerlevel, -1 = X_0 - S	400	55

The studied factors represent the values of the variables in the field of which the study of the process of goal begins to obtain the values optimal as of these factors [10]:

The choice of the basic level and the interval of variation were made by taking account of the technical possibilities of the studied drill (Ingersoll-Rand).

When we use the experiment supplements, we not carry out all the combinations repeating of the studied factors, ofwhich each one varies on two levels.

The number of such combinations is given according to the formula: $N = 2^k$,

Where: k: many studied factors (inourcase k =2),

2: many levels, $N = 2^2 = 4$, experiments,

Using (table 6), we determine the continuation of the experiments, to realize.

Table 6. Experiment matrix

Experiments	**Levels of the studied factors**	
	P (X_1), kgf	**n(X_2), tr/min**
1	400 (-1)	55 (-1)
2	500 (+1)	55 (-1)
3	400 (-1)	75 (+1)
4	500 (+1)	75 (+1)

The presentation of the values of the level of the factors in the form (+1) and (- 1) will make it possible to facilitate the treatment of the got results.

Table 7. Results of determination progress drilling

Experiments	**Parameters of optimization**		
	$V_{f1}(Y_{1u})$**,m/min**	$V_{f2}(Y_{2u})$**,m/min**	$V_f(\bar{Y}_u)$**,m/min**
1	0.06	0.05	0.055
2	0.1	0.12	0.11
3	0.12	0.16	0.14
4	0.25	0.20	0.225

The results treatment for the determination speed of drilling is carried out by supposing that the regression equation arises in the form [12]:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_{12} X_1 X_2 \tag{21}$$

The coefficients of this equation are determined according to the formulas [12]:

$$b_0 = \frac{1}{N} \sum_{U=1}^{N} \bar{y}_U \tag{22}$$

$$b_1 = \frac{1}{N} \sum_{U=1}^{N} X_{1U} \times \bar{y}_U \tag{23}$$

$$b_2 = \frac{1}{N} \sum_{U=1}^{N} X_{2U} \times \bar{y}_U \tag{24}$$

$$b_{12} = \frac{1}{N} \sum_{U=1}^{N} X_{1U} \times X_{2U} \times \bar{y}_U \tag{25}$$

Where: $\bar{Y}_u$: Median value progress drilling in each experiment;

X_{1u}, X_{2u}: are respectively the values of the factors studied (thrust load applied; number of revolutions) in the form of Variable code [6], u=1, 2, 3 and 4: sequence numbers of experiment. The resolution of the coefficients allows us to presentthe equation (26) in the form:

$$Y = 0.1325 + 0.035 X_1 + 0.05 X_2 + 0.0075 X_1 X_2 \tag{26}$$

The checking of the coefficients of this equation is carried out by its statistical analysis, which understands three stages:

-Appreciation of the dispersion of the reproducibility orappreciation of the error of experiment,

- Appreciation of significance of the coefficients of theregressions equations,

- Appreciation of the adequacy of the model taken.

The error of the experiment is estimated according to theParallel experiments.

For this goal S_U^2 we calculate dispersions by line, andwe checked their homogeneity.

$$S_U^2 = \frac{1}{m-1}\sum_{k=1}^{m}\left(Y_{uk} - \overline{Y}_u\right)^2 \tag{27}$$

Where: m: number of experiment parallels (inour casem=2), k=1, 2 parallel numbers of experiments, calculate allowed the following values:

S_1^2 = 0, 00005, S_2^2=0, 0002, S_3^2=0, 0008, S_4^2 =0, 00125,

The checking of thehomogametic of dispersions S_U^2 is done according to the criterion of COHREN. Gt [8]. $G_p \leq G_t$.

$$G_P = \frac{S_{u\max}^2}{S_u^2} \tag{28}$$

$S_{u\max}^2$ Dispersion by maximumline,

$$S_{u\max}^2 : 0.00125$$

$\mathbf{S_u^2}$ Total sum of dispersions by N lines,

$$S_u^2 = S_1^2 + S_2^2 + S_3^2 + S_4^2 = 0.0023$$

We have: G_p = 0, 5434

If the underlying condition $G_p \leq G_t$ checked, the assumption on the homogeneity of dispersions is retained.

The criterion of COHRENE Gt is given according to table [8] for the degrees of freedom f_1 = m-1, f_2= N and the level of significance q. For our case, f_1=1, f_2=4, q= 0, 05, Gt = 0, 9065, thus the assumption on the homogeneity of dispersions is retained h.

The determination of the error of the experiment is carried out according to the formula:

$$S_0^2 = \frac{1}{N}\sum_{u=1}^{N} S_u^2 \tag{29}$$

The appreciation of the significance of the coefficients of the regression equation is established in the following way:

First of all, we determine the dispersion of the regression coefficients:

$$S_{b1}^2 = \frac{S_0^2}{4} \tag{30}$$

Then we use the bi confidence interval which is expressed by:

$$\Delta b_1 = \pm t_t \times S_{b1} \tag{31}$$

Where: t_t: criterion of STUDENT, [8] for our case t_t=2.78

One appreciates the significance of the coefficients by comparing their absolute values compared to confidence interval.

$$|b_i| \rangle |\Delta b_i| \tag{32}$$

The comparison enables us to eliminate the coefficient b_{12} owing to the fact that it is not significant.The regression equation takes the following shape:

$$Y = b_0 + b_1 X_1 + b_2 X_2 \tag{33}$$

The following stage consists in checking the adequacy of the regression equation. For this goal, we compare two dispersions. The first is called the dispersion of adequacy and is determined according to the formula:

$$S_{ad}^2 = \frac{m}{N-L}\sum_{u=1}^{N}\left(\overline{y_u} - \tilde{y}\right) \tag{34}$$

Where: L:number of members in the regression equation retained after appreciation of significance,

ỹ: value of the parameters of optimizations found according to the regression equation.

The second dispersion is the error of the experiment. One checks the adequacy according to the criterion of FISCHER $F_p \leq F_t$

$$F_p = \frac{S_{ad}^2}{S_0^2} \tag{35}$$

If this condition $F_p \leq F_T$ is checked, the regression equation is adequate, for our case:

F_p = 1,075, while F_T = 7, 71 [8].

After having appreciated the significance of the adequacy of the regression equation in which appear the coded variables, we pass to the regression equation to the real variables, and this passage gives us the following regression equation [8]:

$$Y = V_f = -0.215 + 0.0007P + 0.0005n \tag{36}$$

The equation obtained is checked for the scope of application of the thrust load applied of 400÷500kgf and number of revolutions of 55÷ 75 tr/min.

At the same time, it is to be announced that this equation does not reflect the influence of the energy of a shock and the frequency of blows, because at the time as of experiments us, did not change the pressure of the compressed air at the entrance of striker.

7. MATHEMATICAL MODEL FOR THE COST PRICE OF A METER OF DRILLED HOLE

The cost price's structure for a meter of the borehole is composed of two parts, expenditure depending on time related to the labor productivity of drilling like to measuring for the tool. For this, it is appropriate the criterion that takes account of the technical level of the used machines and the organisation of work [7].This last is given according to the following formula [10]:

$$C = \frac{C_p}{Q_{\exp}} + \frac{C_{ou}}{H}; DA/m \tag{37}$$

Where: Q_{exp}: productivity by post office of the drill at the time of drilling under the conditions determined with the constant combination of the parameters of drilling, (m/poste).

$$Q_{\exp} = 60 \times V_f \times T \times K_{\exp} \tag{38}$$

Where: K_{exp}: Operating ratio.

T: The time of a station (hour).

$$K_{\exp} = \frac{1}{1 + \frac{T_{aux} + T_{org}}{T_f}} \tag{39}$$

Where: C_{ou}: Price of the tool, (DA).

H: measuring of the boreholes referring to a tool ;(m).

C_p: expenditure referring to the exploitation of the machine of drilling, DA/poste.

$$C = \frac{C_p}{60 \times T \times V_f \times \frac{1}{1 + \frac{T_{aux} + T_{org}}{L} \times V_f}} + \frac{C_{ou}}{H} \tag{40}$$

Let us pose:

$$\alpha = 60 \times \mathrm{T}$$

$$\gamma = \frac{T_{aux} + T_{org}}{L}$$

$$C = \frac{C_p (1 + \gamma + V_f)}{\alpha \times V_f} + \frac{C_{ou}}{H} \tag{41}$$

According to the results of experiments carried out, we did not establish the influence of the parameters of adjustment on the measuring drilled by a tool. This related to the characteristics of the tool for drilling to pastilles:

$$\frac{C_{ou}}{H} = const \tag{42}$$

Same experiments, it should be stressed that the progress drilling is a function with two variables P and n.

We determine the extreme values of the function C = *f* (P, n) by applying the following dependences:

$$\frac{\partial C}{\partial P} = 0, \frac{\partial C}{\partial n} = 0 \tag{43}$$

In this case:

$$\frac{\partial C}{\partial P} = \frac{\partial \frac{C_p (1 + \gamma \times V_f)}{\alpha \times V_f}}{\partial P} = \frac{C_p}{\alpha} \left(\frac{V_f \times \gamma \frac{\partial V_f}{\partial P} - \frac{\partial V_f}{\partial P} (1 + \gamma + V_f)}{V_f^2} \right) = 0$$

$$\frac{\partial C}{\partial P} = \frac{C_P}{\alpha} \times \left(\frac{(\gamma \times V_f - 1 - \gamma \times V_f) \times \frac{\partial V_f}{\partial P}}{V_f^2} \right) = -\frac{C_P}{\alpha V_f^2} \times \frac{\partial V_f}{\partial P} = 0$$

$$\frac{\partial C}{\partial P} = -\frac{C_P}{\alpha V_f^2} \times \frac{\partial V_f}{\partial P} = 0 \tag{44}$$

Notice: $-\frac{C_P}{\alpha} \neq 0$

Analogically we have:

$$\frac{\partial C}{\partial n} = -\frac{C_P}{\alpha V_f^2} \times \frac{\partial V_f}{\partial n} = 0 \tag{45}$$

After the transformations of the formulas (45) and (46), we obtain the system of equation according to:

$$\begin{cases} \dfrac{1}{V_f^2} \times \dfrac{\partial V_f}{\partial P} = 0 \\ \dfrac{1}{V_f^2} \times \dfrac{\partial V_f}{\partial n} = 0 \end{cases} \tag{46}$$

$$V_f = -0.215 + 0.0007P + 0.0005n$$

We will have the system of equation according to:

$$\begin{cases} \dfrac{0.0007}{(-0.215 + 0.0007P + 0.0005n)^2} \approx 0 \\ \dfrac{0.0005}{(-0.215 + 0.0007P + 0.0005n)^2} \approx 0 \end{cases} \tag{47}$$

The analys is of the system (47) shows that thefunction C=f (p, n) does not have minimum, of maximum final, i.e. increases, and decreases infinitely. However, if we consider this function in the limited field, this one obtains its minimal values when P=max and n=max, in figure 5 which shows the extreme values of this function C=f (p, n).

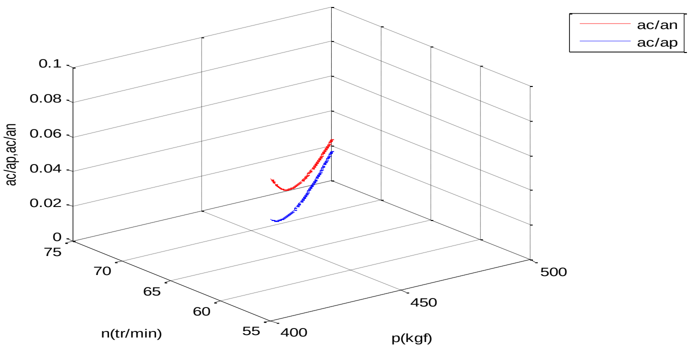

Fig.5. Curves of the extreme values of the function C= f (p, n)

After analyzing the curve of figure 5, which is in order to obtain the best index of the cost price for a meter borehole for our conditions, we recommend to work with the thrust load applied and the number of revolutions of the tool having their maximum values.

In this way, as a result, we conclude that the productivity of drilling rigs depends primarily on the parameters of the drilling regime because this last, it determines the value of the drilling speed. The study of the curves presented in figure (4) leads to a recommendation on the improvement of the work organization, which gives us the possibility of increasing the operating productivity of the drills. As well as the increase of the drilling speed and the improvement of organization's work allow the reduction of the number of drilling rigs used and to improve the technical and economic indices of quarries.

8. CONCLUSION

The statistical treatment of the experimental results made it possible to define the regression equation describing the influence of the control parameters on the drilling speed; we have deduced that the latter increases with the increase in the rotational speed of the tool and the axial force applied.

To ensure the minimum cost of one meter of drilled hole, it is necessary to work with the highest axial force and rotational speed limited to the appearance of the vibrations of the drill and the tool wedging.

The cuttings presence of the bottom of the hole limits the maximum values of these parameters (vibration appearances and the tool jamming). So the first reserve of the improvement of the techno-economic indices is to perfect the evacuation of the excavations.

The study of the existing means for the evacuation of the cuttings made it possible to identify three main methods:

- The periodic blowing of the hole with the corresponding stop of the firing pin.
- The washing by dust sprayer.
- The use of the suction of the cuttings.

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