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Improvement of the Hammer Drill Performance (Algerian Quarries Conditions)

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Abstract: The factors which influence the performance characteristics of a hammer drill are examined; drilling data are analyzed to determine these factors. Methods for selecting the appropriate drilling are also highlighted. Two models are used in order to compare optimal drilling parameters. The main one is the machine output.

Keywords: Adjustment parameter, axial force, drilling speed, rock, productivity.

1. Introduction

Because of mining industry importance in the national economy, many researchers started to work to increase the production. It is impossible to speak about underground careers or mines, nor even tunnels, without speaking about the drilling machines [1], [2], [3]. Their role is significant and effective for and to the improvement of the production [4]. Several factors can affect drilling performances, which can be divided into controllable factors (rotation speed, air compressed forces) and factors which cannot be controlled (rock properties and geological patterns) [5], [6]. Thus, there have been improved the factors which make it possible to control and link the rate of penetration and the characteristics of the rocks, because the force of drilling and the speed excess influence the drilling tools' wear [7], [8], [9], [10] and thus increase production cost [11].

2. Nomenclature

D: Piston diameter (mm);
d_1: Diameter of the piston rod (mm);
d_2: Diameter of the helical rod (mm);
G: Weight of the piston (kgf);
l_a: Stroke of the piston (mm);
s_a: The useful surface of the piston to carry outward journey;
s_r: The useful surface of the piston to carry return journey;
p_a: Compressed air pressure in the cylinder inlet chamber. It is equal to the pressure in the supply network (kgf / cm^2);
p_e: Compressed air pressure in the exhaust Chamber. We take 0.8 to 1.2 (kgf / cm^2);
k_1: Coefficient taking account of the losses by friction between the piston and the cylinder (k_1 = 0.85 to 0.95);
T_{aux}: Downtime of the puncher due to technical causes (min);
h: Height of the drilled hole (m);
T_{org}: Loss of time due to work organization;
T_f : productive working time of a rotary hammer during a cycle, (min);
k_2: Coefficient taking into account friction and rotation losses of the foil (k_2 = 0.5 to 0.7);
F_a: The force applied to the piston during the outward journey (kgf);
E_{ou}: The energy of a piston stroke (kgf·m)
σ_d: Specific resistance of rock drilled according to the scale of Prof. Protodiakonov;
d_f: Drilling diameter (44 mm);
ξ_e: Efficiency of the energy transmission from the foil to the rock. We take (0.4 to 0.7);
f: The hardness of the rock
u_1: Coefficient of friction between the cutter and the rock (0.3 to 0.5);
C_e: Blunt coefficient (1.2 to 1.3);
α: Sharpening angle, degree;
z: Number of cutting edges (1 to 3);
K_{tec}: technical coefficient of a hammer drill;
$V_{f\,exp}$: experimental forging speed (m/min);
L: Footage of the drilled hole, (m);
K_{exp}: Operating coefficient of a hammer drill
σ_{com}: Compressive strength.

3. Basic functional parameters of the pneumatic perforator

It is assumed that the compressed air pressure in the cylinder chambers at the inlet and during its exhaust is constant.

The basic parameters of the perforator are as follows:

- Number of piston strokes per minute, n_c (coups/min);
- Number of foil turns per minute, n_r (tr/min);
- Energy from a stroke of the piston, E_c (kgf·m);
- Specific consumption of compressed air, C_{air} (m^3/min).

Determination of the forces applied to the piston

The useful surface of the piston for carrying out the outward journey is:

$$s_a = \frac{\pi}{4} \cdot \left(D^2 - d_2^2 \right). \qquad (1)$$

And for the return journey:

$$s_r = \frac{\pi}{4}\left(D^2 - d_1^2\right). \tag{2}$$

The force applied to the piston during the outward journey is equal to

$$F_a = \left(s_a \cdot p_a - s_r p_e\right) \cdot k_1. \tag{3}$$

The energy of a piston stroke is equal to its kinetic energy of the piston

$$E_{ou} = F_a \cdot l_a . \tag{4}$$

4. Choice of the rational operating regime of percussive drilling machine

The best selection of the perforators depends mainly on the mining conditions, but it depends also on the rock properties and the tools' quality and machine performance. Many researchers have investigated (theoretically or experimentally) the percussion drilling, the researchers carried out tests of exploitation and laboratory tests for the goal to determine the indices of exploitation and the design features, Among researchers Karbatchev and Semenov studied the operation of the mining machinery [13].

4.1. Drilling speed

A: by the first method (A. Karbatchev):

$$V_f = \frac{4 \cdot E_{ou} \cdot n_c}{\pi \cdot d^2 \cdot \delta_{comp} \cdot \left(\operatorname{tg}\frac{\alpha}{2} + u_1\right) \cdot c_e}; \tag{5}$$

B: by the second method (V. Semenov):

$$V_f = \frac{1.3 \cdot E_{ou} \cdot n_c}{d_f^2 \cdot \sigma_d} \cdot \xi_e . \tag{6}$$

4.2. The productivity of a rotary hammer

Theoretical productivity is the number of meters of holes drilled during the time unit:

$$Q_{theo} = 60 \cdot V_f \cdot T_P . \tag{7}$$

The operating productivity depends on the degree of use of the technical possibilities of a rotary hammer under the concrete conditions of the exploitation:

$$Q_{\exp} = Q_{tech} \cdot k_{\exp} \cdot T_P \,. \tag{8}$$

5. Results and discussion

Table1: Technical characteristics of the Atlas Copco pneumatic perforator type (RH658 L) [12]

Parameters	Indices	Values
Piston diameter	D, mm	65
Piston rod diameter	d_1, mm	40
Diameter of the helical rod	d_2, mm	30
Weight of piston	G, kgf	2.4
Piston strokes	l_a, mm	36
Punch mass	M, kg	23

Table 2: The input parameters of a rotary hammer

s_a (cm^2)	2610
s_r (cm^2)	2060
n_c (coups/min)	2222

Table3: The variation of the energy of a stroke of the piston as a function of the pressure of the compressed air

Test nr.	P_a (kgf/cm^2)	E_{ou} (kgf·m)
Test 1	2	0.85
Test 2	2.5	1.205
Test 3	3	1.55
Test 4	3.5	1.91
Test 5	4	2.26
Test 6	4.5	2.614
Test 7	5	2.96
Test 8	5.5	3.319
Test 9	6	3.67
Test 10	6.5	4.024
Test 11	7	4.37

Table4: The variation of the drilling speed as a function of the compressed air pressure by the two methods (A. Karbatchev, V. Semenov)

Test nr.	P_a (kgf/cm^2)	V_{fs} (m/min)	V_{fk} (m/min)
Test 1	2	0.093	0.17
Test 2	2.5	0.132	0.24
Test 3	3	0.170	0.31
Test 4	3.5	0.210	0.39
Test 5	4	0.248	0.46
Test 6	4.5	0.287	0.53
Test 7	5	0.325	0.60
Test 8	5.5	0.364	0.68
Test 9	6	0.403	0.75
Test 10	6.5	0.442	0.82
Test 11	7	0.480	0.89

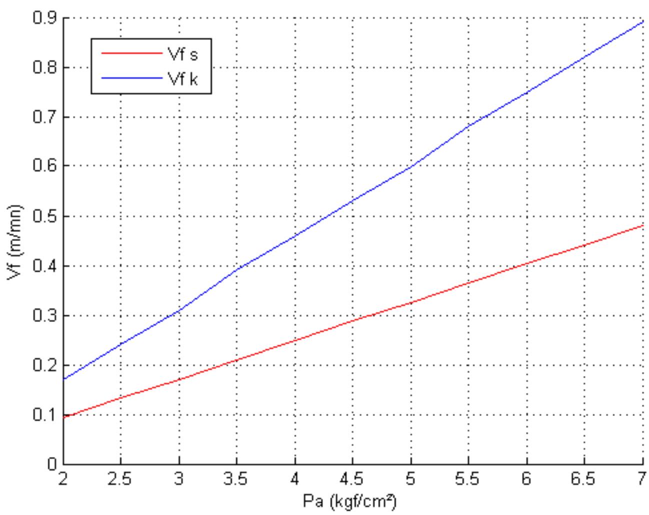

Figure 1: The variation of the drilling speed as a function of the compressed air pressure by the two methods (A. Karbatchev, V. Semenov)

During the experimental experiments the axial force varies, the time and the length are measured; the drilling speed is calculated by the following formula:

$$V_{f\,\exp} = \frac{L}{T_f} \quad {}^{\text{m}}\!/\!_{\text{min}} \,. \tag{9}$$

To process the results, we used the least squares method and checks with the correlation coefficient (see *Fig. 2*)

Table5: Result of the experimental study of a hammer drill working in the conditions of the (Hadja-Soud) quarry (Algeria)

Test nr.	P_a (kgf/cm^2)	$V_{f\,exp}$ (m/min)
Test 1	2	0.10
Test 2	2.5	0.13
Test 3	3	0.56
Test 4	3.5	0.28
Test 5	4	0.24
Test 6	4.5	0.38
Test 7	5	0.62
Test 8	5.5	0.40
Test 9	6	0.32
Test 10	6.5	0.36
Test 11	7	0.44

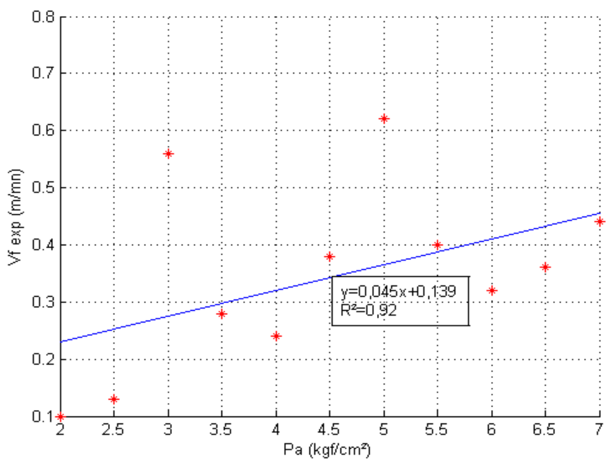

Figure2: the variation of the experimental forging speed as a function of the compressed air pressure

The results obtained from the productivity (yields) of a rotary hammer under the conditions of the (Hdjar -soud) quarry (Algeria).

Table 6: Productivity (yields) by the method of (V. Semenov)

Test nr.	$V_{f\,s}$ (m/min)	h (m)	Q_{theo} (m/post)	K_{exp}	Q_{exp} (m/post)
Test 1	0.093	300	39.06	0.95	37.107
Test 2	0.13	250	54.6	0.93	50.77
Test 3	0.17	230	71.4	0.90	64.26
Test 4	0.21	200	88.2	0.87	76.73
Test 5	0.24	180	100.8	0.84	84.67
Test 6	0.28	170	117.6	0.81	95.25
Test 7	0.32	160	134.4	0.78	104.83
Test 8	0.36	150	151.2	0.75	113.4
Test 9	0.40	140	168	0.72	120.96
Test 10	0.44	130	184.8	0.68	125.664
Test 11	0.48	100	2016	0.60	120.96

Table 7: Productivity (yields) by the method of (A. Karbatchev)

Test nr.	$V_{f\,k}$ (m/min)	h(m)	Q_{theo} (m/post)	K_{exp}	Q_{exp} (m/post)
Test 1	0.17	300	39.06	0.92	65.68
Test 2	0.24	250	54.6	0.88	88.70
Test 3	0.31	230	71.4	0.84	109.36
Test 4	0.39	200	88.2	0.79	129.40
Test 5	0.46	180	100.8	0.74	142.96
Test 6	0.53	170	117.6	0.70	155.82
Test 7	0.60	160	134.4	0.66	166.32
Test 8	0.68	150	151.2	0.62	177.92
Test 9	0.75	140	168	0.58	182.7
Test 10	0.82	130	184.8	0.54	185.97
Test 11	0.89	100	201.6	0.45	168.21

Table 8: Productivity (yields) by the method of (experimental)

Test nr.	$V_{f\,ex}$ (m/min)	h (m)	Q_{theo} (m/post)	K_{exp}	Q_{exp} (m/post)
Test 1	0.23	300	96.6	0.90	86.94
Test 2	0.252	250	10.5	0.88	92.4
Test 3	0.275	230	113.4	0.86	97.52
Test 4	0.297	200	121.8	0.83	101.09
Test 5	0.32	180	134.4	0.80	107.52
Test 6	0.342	170	142.8	0.78	111.38
Test 7	0.365	160	151.2	0.76	114.91
Test 8	0.387	150	159.6	0.74	118.10
Test 9	0.41	140	172.2	0.71	122.26
Test 10	0.432	130	180.6	0.96	124.61
Test 11	0.455	100	189	0.62	117.18

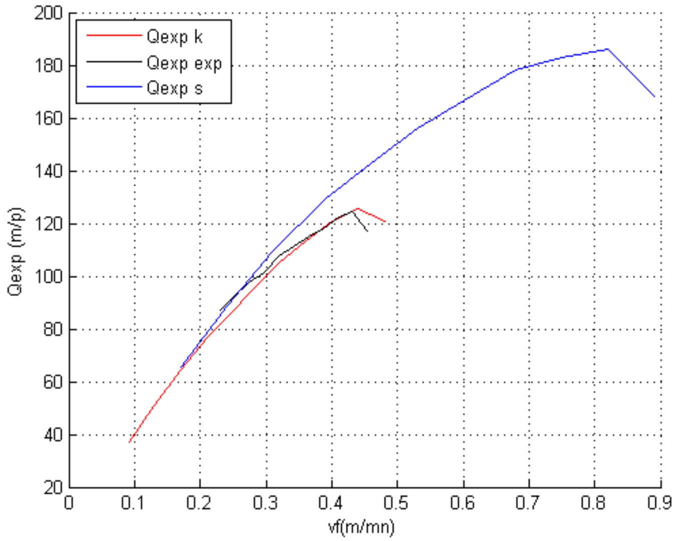

Figure3: Graphical comparison of the results of calculation of the productivity (yields) of exploitation by the three methods (A. Karbatchev, V. Semenov, experimental)

6. Conclusion

The rational parameters of the operating regime of percussive drilling machines in the (Hdjar -soud) quarry conditions are presented in *Table 9*.

Table 9: Optimal parameters of a hammer drill

P_a Kgf/cm^2	E_{ou} (kgf·m)	V_f (m/min)	productivity	
			Q_{the} (m/post)	Q_{exp} (m/post)
6.5	4.02	0.44	184.8	125.664

The main objective of the present work is to underline the importance of the functioning parameters of the drilling machines and the choice of their quality. Based on the results obtained, it can be drawn that the Karbatchev method is better than Semenov one.

According to the results obtained from the regression model proposed, it can be concluded that there is a strong linear correlation between the speed and air pressure (correlation coefficient values $R \geq 0.92$). A good agreement between theory and experiment is clearly expressed.

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