2009 American WJTA Conference and Expo
August 18-20, 2009 • Houston, Texas

Paper

JET ASSISTED SHEARER FOR CUTTING

THE PHOSPATE AT ABU TARTOUR DEPOSIT (EGYPT)

S.I. Youssef*
Tabbin Institute For Metallurgical Studies
Helwan, Egypt

ABSTRACT

The mentioned deposit is located at the western desert, 45 km from El Gharaga Oasis, Egypt. The proved reserves reach 888.5 million tons. The phosphate bed is horizontal (Dip = 4^o) with a thickness of 3.4m at a depth of about 150 m from the earth surface. Mechanized long wall mining using drum shearer and powered supports was designed and implemented by Russians and Sophramine. The troubles of the shearer were the main cause for shutting the mentioned mine unless some mining operations at the outcrops. The troubles include low production, collapse of equipment, high level of vibrations. Jet parameters such as nozzle diameter, jet pressure and power will be analyzed. Relations between rock properties with jet parameters will be discussed. Finally, jet parameters that can suit the mentioned deposit are calculated. A jet pressure of 700 bar, nozzle diameter of 0.5 mm and a power of 100 kw are recommended. It is believed that assisted shearer is the only way to re-open this deposit.

1. INTRODUCTION

Abu Tartour phosphate deposit is located at the western Desert, 45 m from El Kharga Oasis, Egypt. The key map location of this deposit is shown in Figure 1. The reserves of this deposit reach a value of 888.5 million tons. [5]

The phosphate bed has a thickens of 3.4m. It is nearly horizontal with a dip of 4^o. It is covered by 28-45m of book clays, then 103m of clays and 52m of lime stones. The stratigraphic column is shown in Figure.2. [5]

The phosphate bed consists of grained phosphate with a thickness of 2.55m, dolomitic phosphate with a thickness ranging from 0.3-0.8m and clay inter layer with a thickens ranging from 0.1 to 0.5m. The dolomitic phosphate is intercalated in the upper half of the grained phosphate.

The mechanical properties of the phosphate bed can be given as follows;

The compressive strength of the grained phosphate ranged from 10-40 Mpa, with an average value of 27.3 Mpa. The compressive strength of dolomitic phosphate ranged from 50-75 Mpa. The cutting resistance of grained phosphate was 3KN/cm while the corresponding figure for dolomitic phosphate was 7.0 KN/cm. [1]

An experimental mine was designed by Russians. The layout consists of driving outer ring way (12 m^2), radial ways (14m^2) and inner ring way (16 m^2). Trapezoidal and arched steel supports were used to support the mentioned above openings as shown in Figure 3. Panels of 60 m width were developed by main, tail entries (10 m^2) and chain pillars as shown in Figure 4. This design caused the caving of the immediate roof and forming the cracks behind the face except crack D, Figure 5 Crack (D) as located in front of the face caused equipment collapse. The target production was 2800 tons / day i.e 1400 tons/shift, however it actually ranged from 77.36 tons/shift to 181.63 tons/shift using single drum shearer.

Furthermore, a producing mine was designed by Sophramine with a panel width of 150m. Double drum shearer was applied (1 k III Э Russian type). It has a diameter 1.8m, 0.64 m web, three vanes, Each vane carries 10 point attack picks and a back plate ring carries 12 picks arranged in 4 cutting lines, A, B, C, and D. See Figure 6. [2]

The double drum shearer was subjected to severe vibrations that caused frequent break down of the machine. Very low productivity was obtained using the mentioned shearer as the production per shift ranged from 200 to 267 ton/shift. Unfortunately, the mine was shut down unless some mining operations are carried out at the outcrops.

One can conclude that the shearer was behind the problems of the mentioned mine. A unique solution is to use jet assisted shearer.

This paper aims to:

i) Review jet parameters, the effect of rock properties needed to select jet pressure and analyze the practice of jet assisted shearers.
ii) Calculate jet parameters that could be recommended to assist the shearer to be applied in the mentioned above mine.

2. THEORITICAL PART

2.1. Jet Parameters

- Jet Velocity
- Jet velocity can be obtained as follows,

$$V_j = \sqrt{\frac{2p}{\rho}} \qquad (1)$$

V_j = jet velocity (m/s)
P = jet presure (P_a)
ρ = fluid density (kg/ m^3)

- Flow rate

Jet flow rate can be obtained as follows,

$$Q = \frac{\Pi}{4} C_d \, d_n^2 \; x\, 10^{-6} \; x \sqrt{\frac{2p}{\rho}} \qquad (2)$$

Q = jet flow rate (m^3/s)
C_d = discharge coefficient
d_n = nozzle diameter, mm

- Jet power

The jet power can be obtained as follows,

$$W = PQ = \frac{\Pi}{4} C_d \; x \; P^{1.5} \; x \; dn^2 \; x \; 10^{-6} \; x \sqrt{\frac{2}{\rho}} \; (3)$$

$= 3.51 \, C_d \, P^{1.5} \, dn^2 \, x \, 10^{-8}$ Watt
W = power in watt.
For details see reference [4]

2.2. Effect of Rock and Structural Properties

2.2.1. Uniaxial compressive strength

Matsumoto [4] found that penetration depth to diameter is linearly proportional to the jet pressure and exponentially proportional to uniaxial compressive strength as shown in Figure 7. Cooley [3] found that the specific Energy of excavation was reduced as jet pressure was increased from 1.43 to 3.95 times the uniaxial compressive strength. Optimum values were above 10 times the uniaxial compressive strength. [3]

2.2.2. Tensile strength

Power and Simpson [4] stated that no fracture should occur in the material until that the incident jet pressure exceeded 20 times the rock tensile strength.[3]

2.2.3. Structural properties

The concept of the effect of structural properties had been proposed by Summers as if water penetrates the rock cracks will induce an internal pressure.

2.3. Jet Assisted Shearers

Jet assisted shearers were developed in Soviet Union, U.S.A and U.K.

2.3.1. Soviet Union

A jet assisted shearer was tested in Nagornaya mine kuznetsk basin. The coal seam was 2.3m thick, dipped at 12^o and contained a mud stone layer 0.07m thick. Optimum nozzle diameter was 2.5mm and a jet pressure of 300 bars was used. The haulage force and the power demand were reduced.

2.3.2. U.S.A.

The U.S Bureau of Mines developed Eickhoff shearer that tested in Marl, Germany. The testing resuts indicated an increasing reduction of thrust and cutting forces as a function of cut length with or without jet. [3]

2.3.3. U.K.

The Anderson Strathclyde shearer AB 16 was fitted with a Harben pump to produce 55 1pm at 690 bar, while nozzle diameters were adjusted between 0.5 and 1mm. The shearer was tested in a coal seam 2.3 thick, containing a 0.45 dirt and dipping 1 in 3.5. The machine ran at an advance between 0.047 and 0.076 m/sec with a drum speed of 62 rpm and a pick speed of 3.8 m/s.

3. CALCULATIONS

3.1. Jet Pressure

The compressive strength of dolomitic phosphate ranged from 50-75 Mpa. For our case a value of 75 Mpa is considered. A penetration depth of 20 times the nozzle diameter can be obtained according to Matsumoto diagram shown in Figure 7. A jet pressure of 10 times the compressive strength according to Cooley [3] is 10x75 Mpa (7400 bars) will be needed. Furthermore, a jet pressure 20 times the tensile strength according to Powel & Simpson [3] i.e 20x7.5 Mpa (1480 bars) is needed.

The values of jet pressure obtained according to Cooley or Powel & Simpson are over estimated and the value selected according to Matsomoto diagram can be accepted for the time being.

3.2. Nozzle Diameter

Due to the shortage of under ground water in the mentioned locality a nozzle diameter of 0.5 mm can be accepted.

3.3. Flow Rate

Applying eq.2 to determine the flow rate per nozzle (Q_1) and substituting dn by 0.5 mm the value of Q_1 will be;

$$Q_1 = \frac{\Pi}{4} C_d \times dn^2 \times 10^{-6} \times \sqrt{2p/\rho}$$

$$= \frac{\Pi}{4} \times 0.98 \times (0.5)^2 \times 10^{-6} \times \sqrt{\frac{2 x 700 * 1.01325 x 10^{-5}}{1000}}$$

$$= 7.24 \times 10^{-5} \text{ m}^3/\text{sec}$$

If 50% of vane picks is equipped with jets i.e. 50% x 30 picks, then the flow rate Q_T needed will be;

$$Q_T = Q_1 \times 15 = 7.24 \times 10^{-5} \text{ m}^3/\text{sec} \times 15$$
$$= 1.086 \times 10^{-3} \text{ m}^3/\text{s} \quad (65 \text{ L/min})$$

3.4. Power (W)

The needed power can be obtained using equation (3).

$$W = P \times Q$$
$$= 700 \times 1.0325 \times 10^5 \times 1.086 \times 10^{-3}$$
$$= 77 \text{ kw.} \cong 100\text{kw}$$

3.5. Performance of Jet Assisted Shearer for Our Case

If the penetration depth equals 20 d_n (20x0.5mm) i.e. 10mm per revolution as determined from fig.7, then the shearer advance (a) will be;

a = 10 mm x RPM
RPM = 62 (assumed)

$$= \frac{10x62RPM}{60\sec} = 10.33\ mm/\sec$$

= 0.01 m/sec

The time needed to cut 150 m long wall face is

$$T = \frac{L}{V} = \frac{150m}{0.01\frac{m}{s}} = \underline{15000\sec} = 4.166\ hours$$

Assuming Two shifts per day then,
The advance per shift will be 0.6 m x 2 = 1.2m
Production / shift = advance / shift x bed thickness
x panel length x specific weight
Production per shift = 1.2 x 3.4 x 150 x 2.35
Production per long wall per day = 1438 Ton
The annual production assuming 2 shift/day, 300 day/year and 4 long wall panels will be;
2 x 1438 x 300 x 4 = 3.45 million tons.

The last figure is the required production to produce two million ton concentrate. Assuming the production per development = 0.35 million tons, the recovery = 58%, and moisture content = 8% then the concentre will be (3.45+ 0.35) x 0.92 x 0.58 = 2 million tons.

3.6. Discussions

The value of jet pressure determined by Cooley is far from the spectrum of industrial equipment. While the value of jet pressure determined by Powel & Simpson is over estimated. The value of jet pressure of 700 bar is promising but need in situ verification. Flow rate of 65 L/min is highly accepted and a power of 100 kw is in the spectrum of industrial equipment.

4. CONCLUSIONS

1. A jet assisted shearer with a nozzle diameter 0.5mm, flow rate of 65 L/min and a power of 100 kw is highly recommended.
2. Using the mentioned parameters an annual production of 3.45 million tons (ROM) and 2 million ton concentrate can be produced.

5. ACKNOWLEDGEMENT

To all who taught me…. How to know and to use what I had knew.
Deeply, I am indebted to Engineer "Fikry El Mursey the former director of Abu Tartour project and Dr. Mahoud seliem, the rector of TIMS for their help to work at Abu tartour as a consultant for the miming section.
Also I deeply thank all the responsible of WJTA to present this paper and I hope to help me to do the experimental part at one of the advanced laboratories. This kind help can not be forgotten, This will increase the economics of Egypt which invented the first break- through "fire setting" in Mining.

6. REFERENCE

1. Khovanets, P., Degtarjov, V., Consideration And Analysis of in Mine Investigations of Physico Mechanical properties and cutting forces of Rocks in Abu Tartour Phosphate Depsit", Internal part to Abu Tartour mine, 1993.

2. Mossallam, K., F., Analysis of the First long Wall Drum Shearer used for cutting Hard Phosphate At Abu Tartour Mine. The 9th International Mining, Petroleum and Metallurgical Engineering Conference, Cairo University, Egypt, 2005.

3. Summers, D. A., Water jetting Technology, E & FN SPON, New York, 1995.

4. Wuchao "Lecture of the 2nd international mining workshop, School of Resources and Safety Engineering, Central South University, Changsha, Human, P.R, China, 2002.

5. Youssef. S.I. Abu Tartour Deposit between theory and practice, Tabbin Institute for Metallurgical Studies, Special Issue, 1991.

7. GRAPHICS

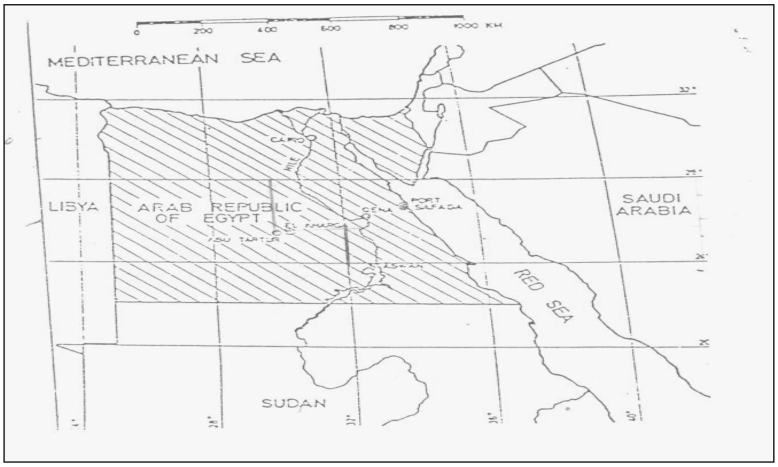

Figure 1. Key Map location of Abu Tartour deposit

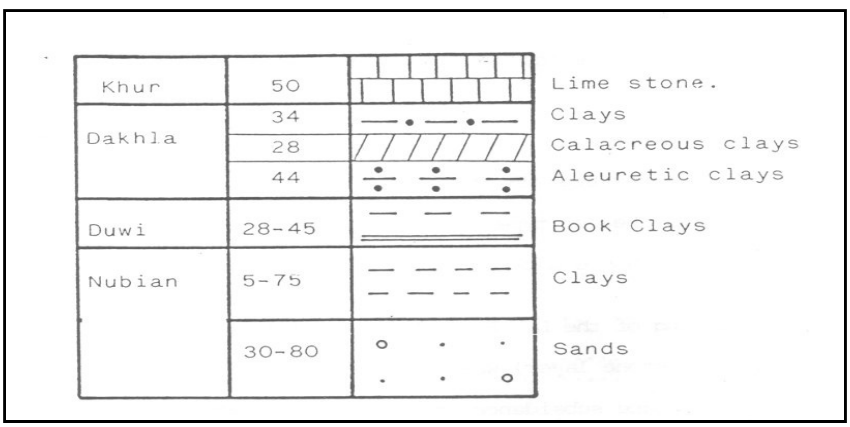

Figure 2. Stratigraphical section of Abu Tartour deposit

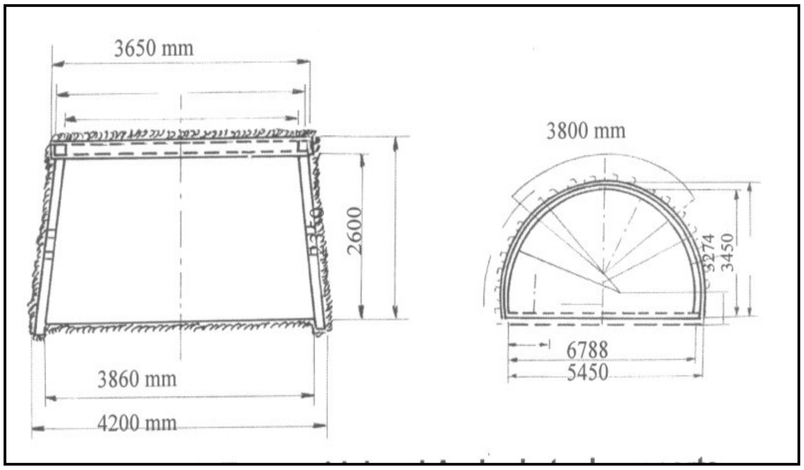

Figure 3. The trapezoidal and arched steel supports

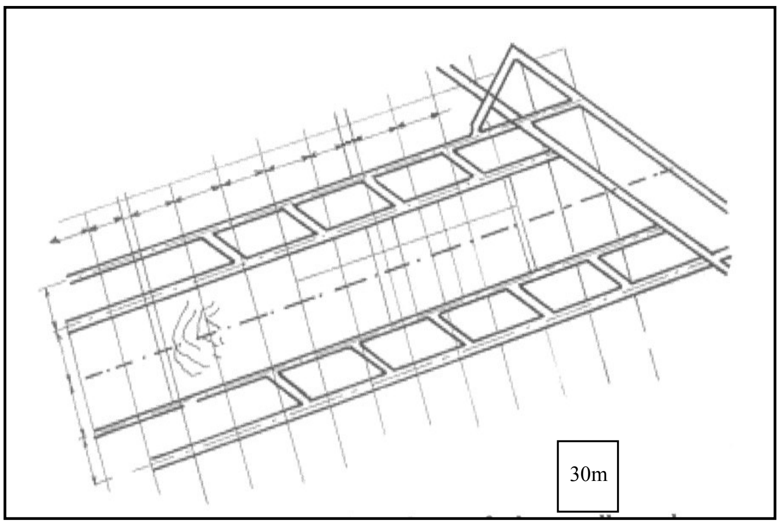

Figure 4. The layout of the experimental mine

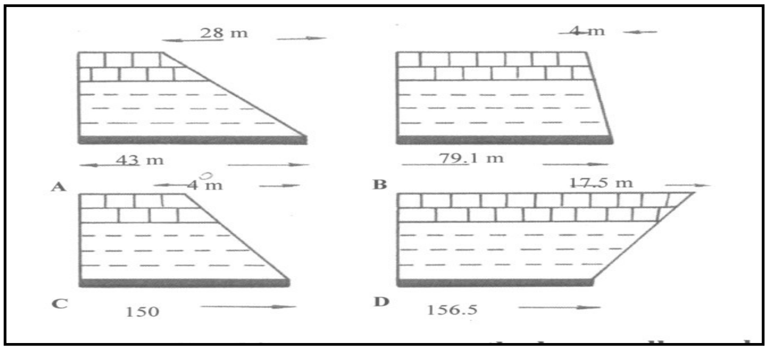

Figure 5. Crack locations behind the shearer (A,B,C) exfept crack D infront of it

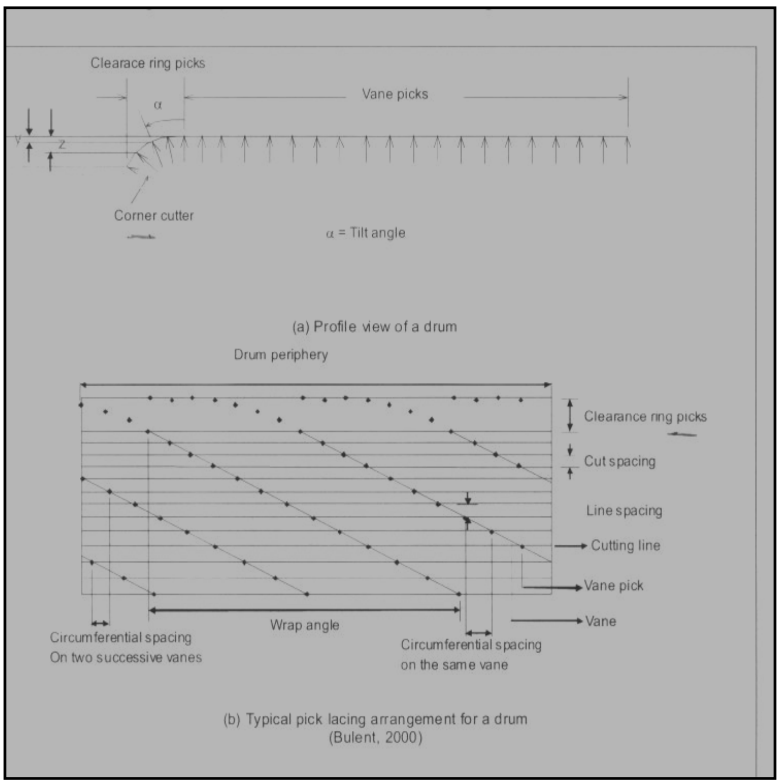

Figure 6. The details of double drum shearer (1k111)

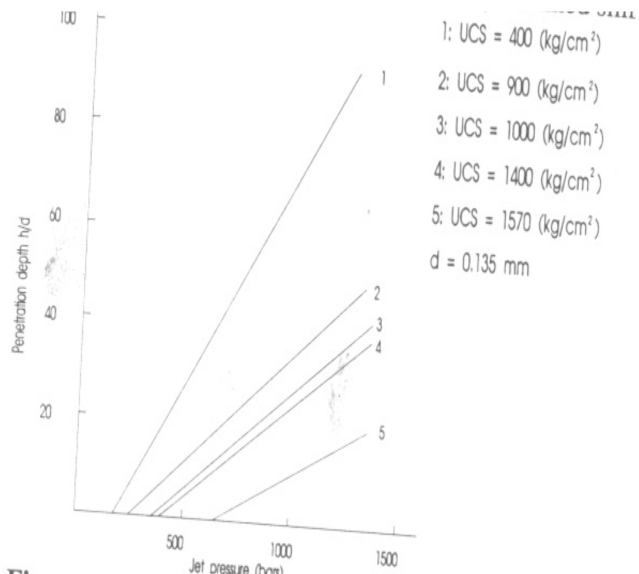

Figure 2.1 Effect of Jet Pressure on Penetration (After Matsumoto, 1972)

Figure 7. Effect of jet pressure on penetration for different rock (After Matsumoto,1972) [4]