Drilling technology in mining industry

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Abstract

The fundamental problem in rock working is the breakage of fragments out of the face of a solid rock wall rock. Mechanically, this can be done only by forcing a tool into the rock surface, after the manner of an indenter is commonly used in the testing of surface hardness. Since the process breaks rather than cuts the solid rock into small fragments of assorted sizes, it can be regarded as the essential one in crushing. As in the crushing processes generally, energy volume relationships are therefore of interest. The specific energy, defined as the energy requierd to excavate an unit volume of rock is a useful parameter in this context and many also take it as an index of the mechanical efficiency of rock-working processess.

In drilling data from a number of sources, its minimum value appears to be very roughly correlated with the crushing strength of the medium drilled in for percussive-rotary. The implications of this are discussed

Key words: *drilling technology, rockpercussive rotary*

Introduction

Drilling and drilling technology play a major role in the Algerian mining industry. In fact, it would be fair to say that the optimization of drilling parameters is an integral part of the economic success or failure of any mining operation. Operators and manufacturers are continually exploring ways of reducing costs and increasing the productivity by enhancing drill penetration rates and decreasing the perforation drill bit wear.

Drilling and rock cutting are the basic concerns in all underground and surface mining operations as well as in the oil petroleum industries (Bullock, 1984). In open cut operations, the need to be competitive with world markets places a strong demand on the excavation technology, placing a solid weighting on the necessity to be able to drill and blast considerable tonnages of ore in the quickest possible times. Underground operations rely on the excavation technology to increase the production of continuous miners and longwall shearers in collieries as in jumbo and stope drilling machines in metalliferous mines. In recent years, the need for increasingly deeper boreholes and the introduction of higher formation temperatures have placed a heavy reliance on the drilling industry to focus a more attention on improving the technology of drilling and drilling fluids for the oil and petroleum industries (Nistimatsu, 1972).

Improvements to the drilling technology bring about a more efficient, power conserving machines capable of producing larger torques, longer lasting drill bits, and a greater directional accuracy. Investigations of drilling fluids can also serve many significant functions, from cooling drill bits and improving the drillhole stability to increasing the rate of penetration of the drill.

One is confronted with the problem of examining the effects of factors, influencing the drilling efficiency and the challenge of determining the parameters under which the drill performs best. The following work details an investigation of the factors affecting the drilling efficiency and the productivity with a special emphasis placed on the effects of introducing chemical enhancers to drilling fluids. This study discusses any significant variations in experimentally obtained values for both specific energies whilst drilling in granite samples.

Materials and Methods

The investigation in this work required a construction of a fully equipped drilling unit. Many modification and alterations were made to the rig and auxiliary measuring devices in the construction and initial testing phase before the final set up was decided on.

There are still many adjustments that could be made to the structure and its components to increase the ease of operation and the accuracy of results.These will be discussed later.

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The Laboratory Drilling Machine

A laboratory rotary-percussive drill was built to simulate practical drilling operations Fig. 1 and 2 show a schematic representation of the testing layout. Both figures indicate the main components of the operations, which are:

- Drill frame,
- Sample,
- Height adjustment plate,
- Rotary-percussive drill,
- Load cell,
- Load cell digital readout,
- Chart recorder,
- Power supply,
- Flushing fluid systeme,
- LVDT,
- Hydraulic jack,
- Hydraulic pump.

The Drill

Tab. 1. The drill utilized was the bosch 8/65 DCE rotary- percussive drill with the following characteristics.

characteristic	unity	values
Power Input	W	1050
Speed of rotation	Rad/s	12,56 ÷ 26,17
Cadence	Hz	21,7 ÷ 44,2
Energy	J	1 ÷ 7,5
Weight	kg	8

The Rock samples

The sample used in this project was a typical granite stone. The mineralogy of the stone consists of an equigranular array of approximately 70 % Orthoclase, 20 % biotite and 10 % quartz. Samples of the granite were cut to the size no larger than 500 × 500 × 500 mm and cast in conrete to stabilize them.

Flushing fluids

Three substances were chosen to be investigated as flushing fluids in order to study their characteristics and any differences which may occur when drilling in samples of granite. The Fluids were water, Aero 3000C Promoter and a sodium chloride solution. It was hoped that Aero 3000C Promoter would act as a hardness reducer in comparison to water, whereas the sodium chloride solution would have the effect of inhibiting drilling.

Testing Procedure

For successful results it was essential to adhere to a rig testing procedure to ensure that all steps were carried out accordingly and also to reduce the effects of human error. As more holes were drilled, minor adjustments were made to the procedure to continuously improve the standard of the results achieved and to increase the speed and simplicity of the operation. The final testing procedure was as follows:

a) Adjust *the vertical position* of the sample relative to the drill. This was accomplished by utilising a two-way hydraulic jack to either or the lower level of the sample plate and then locking into place with lugs in the guide rails. Adjust *the horizontal position* of the sample relative to the drill. The positioning was made by manually pushing the sample, mounted on a sliding plate, sideways to the necessary position and once again stabilising the plate with lugs which slot into the base plate.

b) Zero LVDT. The string of the LVDT was run over the pulley and all slack was taken up to ensure that movement would be immediately registered on the chart recorder.

c) Zero load cell readout. This was simply done with the zeroing dial on the digital readout device.

d) Adjust chart recorder. Both ink pens linked with the LVDT and the load cell were zeroed and set in place.The recording speed was set at 6 cm/min and then the chart driving mechanism was enabled.

e) Flushing system turned on. Flushing rate was 1 L/min for tests with water and kept at 1 L/min for chemical solutions.

f) The wattermeter and the load cell digital readout were constantly monitored throughout each test until the desired depth of drilling had achieved. At the completion of the hole, the steps were as follows:
 1. Release the pressure of drill at the rock face by adjusting the hydraulic pump;
 2. Drive drill backwards;
 3. Switch off drill;
 4. Stop chart recorder;
 5. Remove grah from recorder;
 6. Examine results;
 7. Set up for a next hole.

At the completion of each session of drilling data for each test parameters such as the force, power, depth of drilling, rate of chart movement and the height of chart were entered into the spreadsheet software to calculate the rate of penetration and, ultimately, the specific energy required for each situation.

The corresponding data were then plotted and comparisons could be drawn between tests with regards to differences in flush rates, molarity and concentration of solutions.

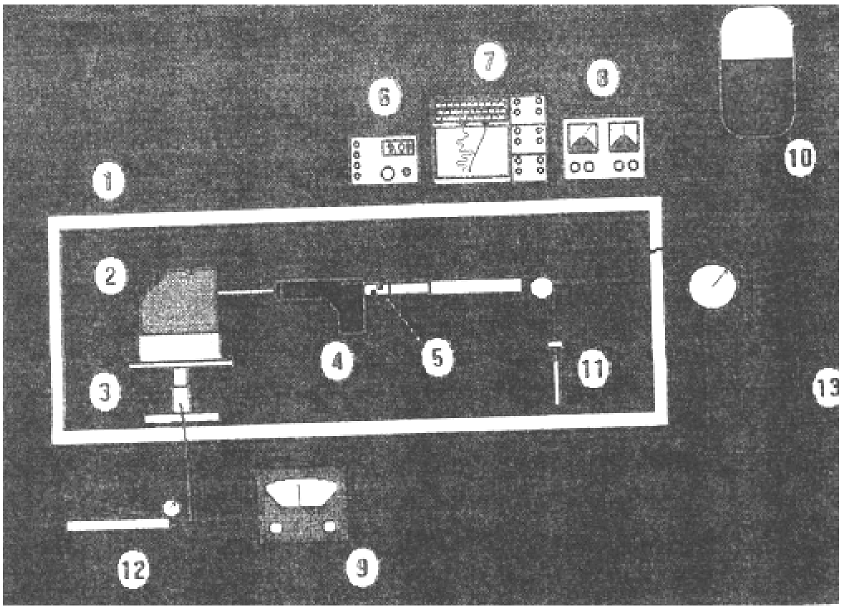

Fig. 1. Schematic representation of drilling operations.

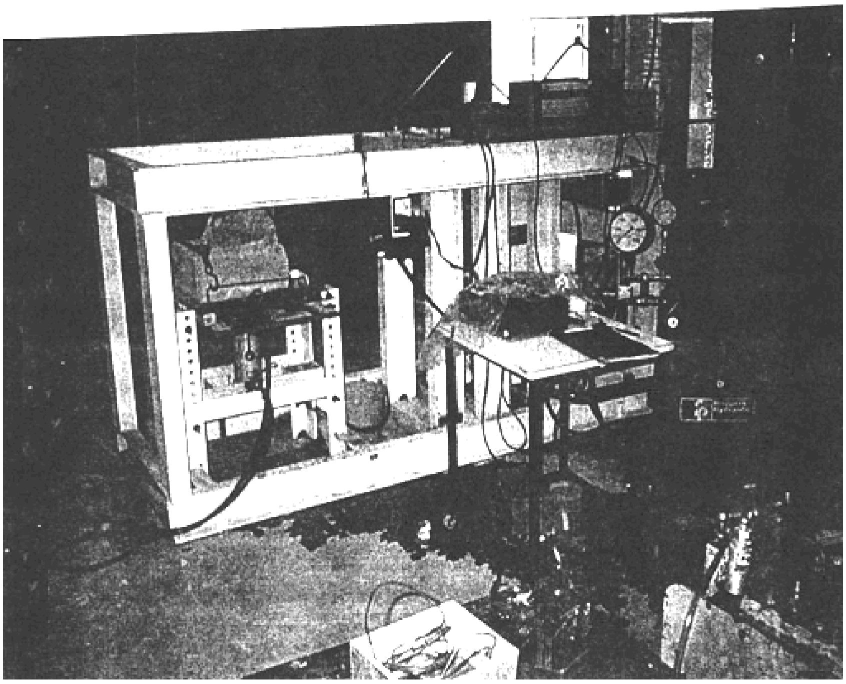

Fig. 2. The testing machine set-up.

Tab. 1.Combined Test Resuts with water as flushing [1 L/min] , Areo 3000C Promoter [1 M] and Sodium Chloride [1 M].

Depth [mm]	**Force** [N]			**Power** [W]			**Chart Height** [mm]	**Chart Rate** [mm/min]	**Penetration Rate** [mm/min]	**Specific energy** [MJ/m^3]
	F_{max}	F_{min}	F_{mean}	P_{max}	P_{min}	P_{mean}				
Water as flushing [1 L/min]										
80	220	140	180	379	353	365	160	60	30	4131
82	200	120	160	385	355	370	150	60	33	3807
85	180	100	140	390	360	375	142	60	36	3537
88	150	90	120	395	365	380	135	60	39	3308
94	145	55	100	400	380	390	130	60	44	3010
Sodium Chloride [1 M]										
85	220	140	180	370	340	355	155	60	33	3653
88	200	120	160	375	355	365	148	60	36	3443
94	180	100	140	380	360	370	142	60	40	3141
100	150	90	120	400	364	382	138	60	43	3016
106	145	55	100	408	384	396	135	60	47	2861
Areo 3000C Promoter [1 M]										
98	220	140	180	365	355	350	140	60	42	3000
102	200	120	160	380	360	370	135	60	45	2773
114,5	180	100	140	390	370	380	132	60	52	2500
123,5	150	90	120	400	370	385	130	60	57	2300
135,5	145	55	100	410	390	400	125	60	65	2100

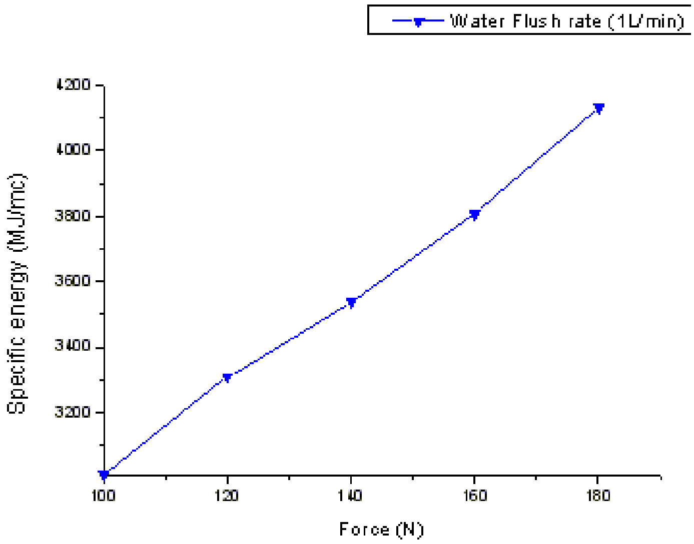

Fig. 3. Specific Energy Es Force [Water 1 L/min].

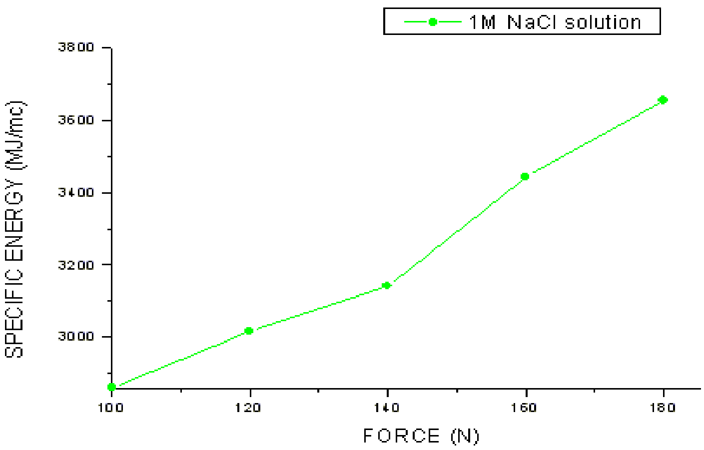

Fig. 4. Specific Energy Es Force [1 M NaCl Solution].

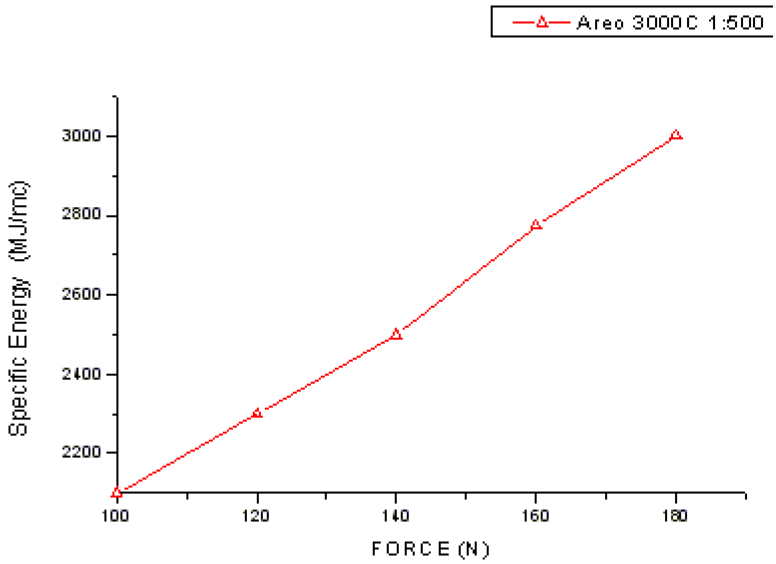

Fig. 5. Specific Energy Es Force (Areo3000C 1:500).

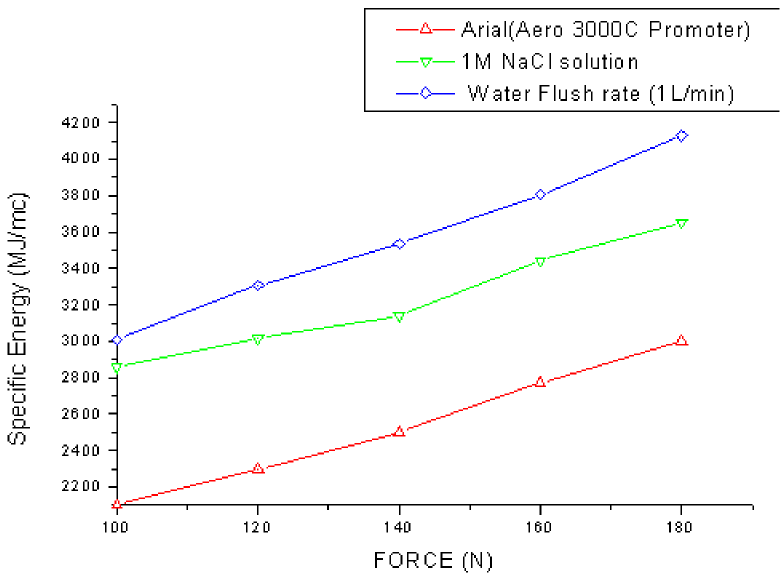

Fig. 6. Combined Results (All Tests).

Assessment of results

Results with Water

25 tests were completed with water as the sole flushing fluid. The results tabulated in Tab. 2. The Error test due to mechanical failure, sample failure, etc have been exluded from this table. A graph from these tests is in Fig. 3.

Results with NaCl

25 tests completed with sodium chloride are given in Tab. 2. A graph of these values is in fig. 4.

Results with Areo 3000C Promoter

25 tests were completed with Aero 3000C Promoter at the concentration of 1:500 aqueous solution. The results are summarized in Tab. 2. The graph of these tests is in Fig. 5.

Comparisons of all results

Comparisons between values obtained for the specific energy with water as a drilling fluid, solutions containing sodium chloride and Aero 3000C Promoter, have been made individually and graphed accordingly. Fig. 6 shows the results of all flushing fluid compositions and flush rates used in this project to obtain a perspective of all the combined tests. From the graph obtained (Fig. 6) it can be seen that the Aero 3000C Promoter solutions and sodium chloride solutions actually faired better than water as a flushing fluid for all force increments.

Discussion and conclusion

The primary objective of this project was to investigate the cutting efficiency of a drill with respect to the drilling fluid composition by determining and comparing experimentally obtained values of the specific energy. By utilising three primary flushing agents, namely water, soduim chloride solution and Aero 3000C Promoter solution in granite, definite variations in the specific energy were noticed throughout the entire range of performed tests. When compared to water, it would appear that the two other drilling fluids either reduce the hardness of the sample or even inhibite the normal drilling efficiency. An investigation of the method of testing as well as the physical and chemical processes involved in the course of drilling may help us to understand what was the case.

Conclusion

It is hard to draw a clear cut conclusion as to the effectiveness of this project based on the strength of the obtained results. As this was the first project of this kind undertaken at our institution, it was more a learning experience and exercise to establish a best drilling practice for the future work.

The results obtained stand for themselves but it will take a more extensive testing to be able to rightfully say whether the level of accuracy attained was actually acceptable. From the investigation of graphs of specific energy vs force for each phase of testing, apparent conclusions are:

- the graphs of specific energy versus drilling follow approximately linear funtions (Fig. 3, 4 and 5);
- water at the same flush rate had consistently higher values of the specific energy than these of sodium chloride solutions;
- water at the same flush rate had consistently highest values of the specific energy than these of Aero 3000C Promoter solutions;
- sodium chloride solutions had generally the higher values of the specific energy than these of Aero 3000C Promoter solutions
- water at the same flush rate had consistently highest values of the specific energy than these of sodium chloride solutions and Aero 3000C Promoter solutions (Fig. 6).

As with all laboratory exercises, a experience in this particular field grows, so does the quality of results achieved. Whilst it is my opinion that additives to flushing fluids in metalliferous and coal mining drilling operations will never be of economic advantage, it has been proven that the research such as this is absolutely vital in the petroleum industry. Whilst drilling fluids in these situations are highly complex, improvements can only be made in very small steps similar to this project.

The first problem to overcome in understanding these results lies in the degree of accuracy with which they were obtained. Obviously, even idealistic results are unbelievable if no attention is paid to eliminating errors of both the mechanical and human origin.A number of major and minor problems were faced during the testing process, each having a different degree of influence on the quality of acquired results.

The first problem was the fact that the testing machine utilizsed the 25 t capacity jack to deliver drill forces no larger than 1000 N; in fact it would be fair to say that the jack was operated at only 0,1 – 0,2 % of its capacity for the majority of tests (Clark, 1982 a,b).

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