Effect of operating parameters on tricone roller bits used in blasthole drills

Drilling performance is the culture where the decisions and actions needed to achieve improvements in drilling environment are made and driven by detailed analysis of relevant data. Drill bits have been playing a significant role in the rock drilling operations. In order to meet the needs of users, the rock drilling has experienced an impressive technological advancement particularly in the area of bit design and its performance. Today, faster penetration rate is an increasing demand. Bit performance evaluation and bit selection is of paramount importance for the drilling engineers. Rate of penetration (ROP) is one of the most important bit performance indexes. The improvement in ROP will bring increased efficiency to the drilling industry. ROP model such as Bourgoyne and Young's Rate of penetration model have been developed by researchers for roller cone bits. This model can select optimised weight on bit and rotary speed to achieve the minimum cost per unit length of drilling. The penetration rate of a bit tooth depends on the weight on bit, rotary speed, shape and size of the tooth, and the strength of the rock. The aim of this work is to study the operating parameters such as weight on bit and rotation speed of the tricone roller bit to find out the effect of these parameters on the performance of drilling.

Keywords: *Tricone roller bits, rate of penetration (ROP), weight on bit (WOB), pull down pressure, rotation speed, bit life.*

I. Introduction

Tricone rock roller bits are used in blasthole drills. The bit consists of steel body and tungsten carbide inserts. The inserts are the primary cutting points and the steel body holds them in place. Primarily two types or tricone bits are made, milled tooth bits and tungsten carbide insert bits. Milled tooth bits are also called steel tooth bits. In milled tooth bits the cones are completely made of alloy steel and the teeth are formed by milling a mechanical metal cutting process [1-3, 9].

Tricone rollerdrill bits with carbide inserts are commonly used for cutting through hard and abrasive rock formations to reach ore reserves far below the earth's surface. A typical drill bit is shown in Fig.1.[2]. It consists of three cones, a bearing body for each cone, and a bit body. The cones are covered with small teeth, and during drilling cones are rotated on the bearing bodies, forcing the teeth to chip and gauge away the rock face at the bottom of the blasthole [2, 4].

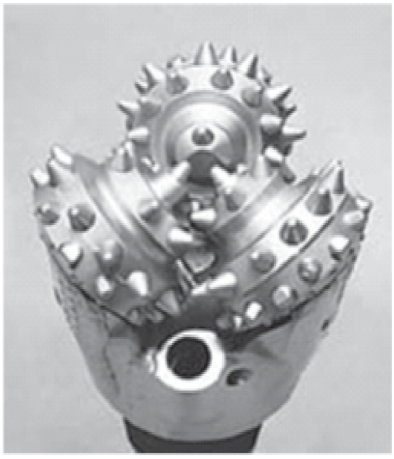

Fig.1 Tungsten carbide insert bit

The efficiency of any drilling operation depends largely upon the choice of a rock bit that is most suitable for a given set of operational conditions. It is important to know the fundamentals of bit design to fully understand its selection. Selecting the appropriate bit for a particular rock formation can improve the performance of drilling. An incorrect bit selection, because of incomplete information or understanding, can increase drilling time and cost [5].

John W. Speer has suggested the controllable factors that affect the bit performance. Drill bit performance depends primarily on five controllable factors: (1) weight-on-bit (2) rate of rotation (3) hydraulic power (4) type of bit and (5) properties of the circulating medium. Although each parameter contributes individually to bit performance, they are closely interrelated and their combined influence governs the degree of drilling efficiency obtained [6]. Four basic types of relationships have been suggested by J W Speer with respect to weight on bit over penetration rate. They are indicated and shown in Fig.2. [6] as: (1) Curves that bend upward, and could pass through the origin only with a reversal in slope; there is not an apparent reason for a reversal in slope for a relationship of this nature, and it is presumed that this relatively small group of data reflects the effect of other factors, specially the variation of rock hardness. (2) Curves that bend upward, and

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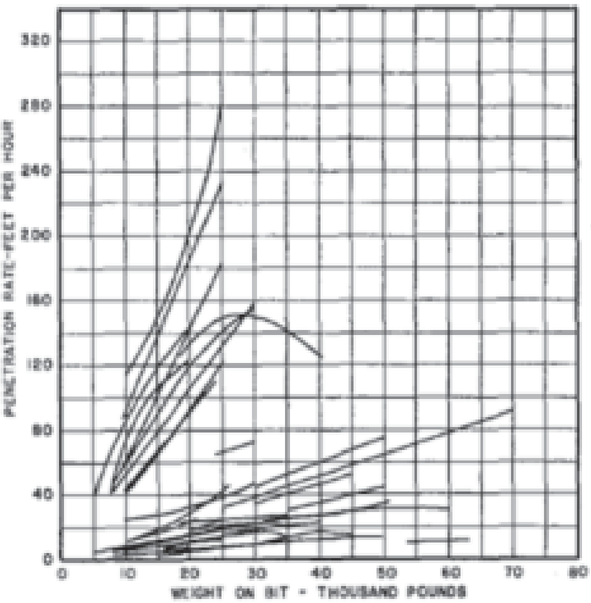
would pass through the origin if extrapolated downward. This relationship is quite reasonable, particularly for hard rock. (3) Curves that bend downward, and could pass through the origin without reversal in slope. (4) Curves that are straight lines, and approximately pass through the origin. This relationship is indicated by the largest group of data and is also the relationship most commensurate with laboratory results [6].



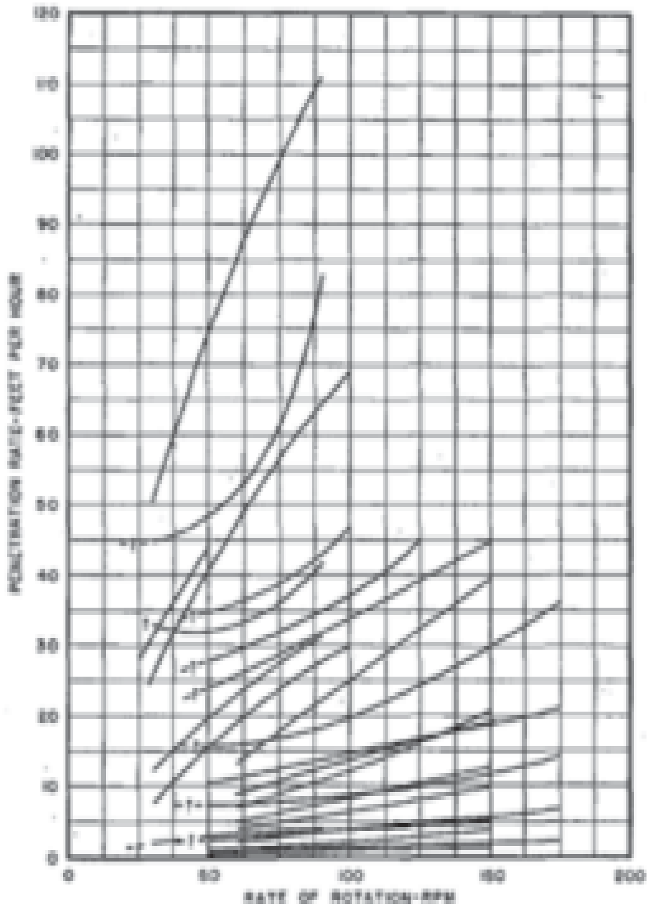
PENETRATION RATE VERSUS WEIGHT ON BIT - ASSORTED FIELD DATA

Fig.2 Penetration rate versus weight on bit

With respect to rotary speed versus rate of penetration, three types of relationships are represented by J W Speer. They are indicated and shown in Fig.3. [6] as: (1) straight-line curves emanating from the origin of the graph, showing directly proportional response of penetration rate to increases of rotary speed; (2) curves that bend slightly upward, showing increasing response of penetration rate to increases of rotary speed; and (3) curves that bend slightly downward, showing decreasing response of penetration rate to increases of rotary speed. Although an average of these results indicates that penetration rate varies in a direct proportion with speed of rotation, the data are too inconsistent to be conclusive [6].

II. Influence of operating parameters on bit performance

Pull down pressure expressed in pounds per square inch (psi), is not a completely satisfactory unit for describing operating conditions, particularly if applied to all bit sizes in use; however, it appears to be the unit best suited to this study. As a rule of thumb, low pull down pressure and low RPM produces unnecessarily low penetration rates while high pull down pressure and high RPM produces unnecessarily accelerated wear, both of which are uneconomical [7,12]. Good drilling practice entails selecting the appropriate pull down pressure and RPM to achieve the most economical combination of penetration rate. Another rule of thumb is that soft formations are drilled most effectively at lower pull down pressure and higher RPM levels while it is preferable to drill hard formations at a higher pull down pressure and lower RPM combination [7, 8]. In air flushing, air travels to the drill head from where it enters the rotating drill string through the swivel of the drill head. When compressed air comes out of the nozzles of the drill bit, it impinges on the formation, the cuttings formed by the interaction between the drill bit and formation get lifted from the bottom and starts moving upward, depending upon the forces acting on them. Three forces act on cuttings while flushed are gravitational, buoyant and drag [1-3, 10, and 11].



RATE OF ROTATION VERSUS PENETRATION RATE - LABORATORY DATA (HUGHES & REED LABS)

Fig.3. RPM versus penetration rate

III. Data collection and data treatment

The strata mainly consist of sandy sandstone, coarse grained sandstone, carbonaceous shale, gritty sandstone and shale. The uniaxial compressive strength of rock is varies from 170 kg/cm^2 to 186 kg/cm^2.

A. Drill Machine

The drilling machine is a diesel powered, self-propelled crawler mounted rotary blasthole drill built to adapt to the toughest operating environments in the world. It can be operated by single person and is equipped for drilling 160 mm diameter holes in opencast mine.

B. Drill bit Specifications

Drill bit type is designed to drill abrasive overburden, soft to medium porphyry copper, gold and sedimentary deposits. Typically these deposits include monzonite porphyry, diabase, schist, shale, intrusive breccias, tightly cemented sharp sandstones and precambrian granite. Bit responds best to moderate weights and rpm.

C. Product Specifications

Size:	6 ¼ inch (159 mm)
Bearing type:	Air bearing
Inner/gage rows:	7/3
Inner/gage inserts:	55/47
Pin/bit connection type:	3 ½ inch API
Weight on bits:	10.0 – 33.0 (Lbs. – Min. to Max. (1000's))
Rotation speed (rpm):	75-120

Fig.4 shows the graph between drilling rate and pull down pressure. The variation in drilling rate is due to uniaxial compressive strength of rock. Since rock is inhomogeneous in nature, the compressive strength of the rock changes from one face to another face. The rock type is sandstone and its uniaxial compressive strength varies from 170 kg/cm^2 to 186 kg/cm^2.

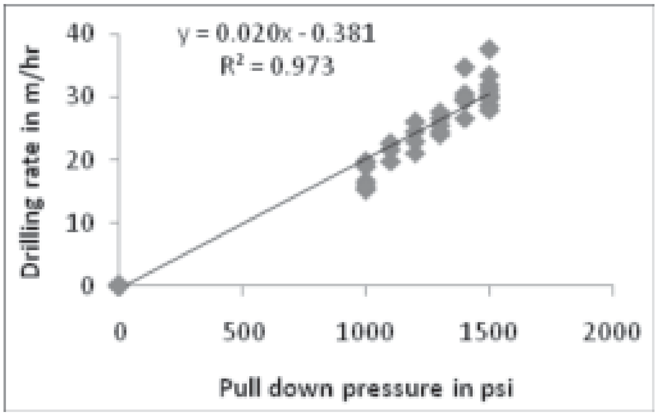


Fig.4 Drilling rate versus pull down pressure

It is extremely difficult to predict the lifetime of accessories and particularly drill bits as it depends upon weight on bit, rotational speed and flushing media as well as the properties of the rock mass being drilled. Evaluating the life of a tricone bit in terms of meter is a very difficult task. Fortunately, most of the bit users and manufacturers keep meticulous records of the drill bit used/supply by them. With such data, the bit manufacturers are the best advisers to a user in his efforts in evaluating bit life in this computer age [1,2,5].The bit shown in Fig.5, failed due to numerous reasons such as air line body

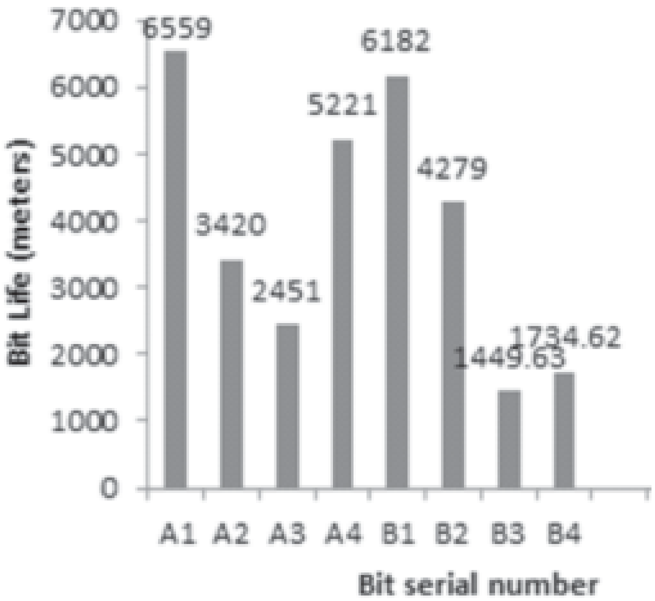


Fig.5 Bit life

damage, drill bit worn out, bearing failure and drill rob fell down in hole with bit and bit sub.

According to Table I, we observe the blasthole drill data for bit serial no. A1. In Fig.6, it can be seen that till the penetration rate was about 1.485 m/min (which corresponded with pull down pressure of 1200 psi) the curve was a straight line, but when higher and higher pull down pressure was exerted on the drill bit while keeping the same rotary speed, the penetration rate became successively lower than the one predicted by the straight line. It can be assumed that penetration rate varies approximately in direct proportion with pull down pressure, if sufficient fluid circulation is provided to insure clean bottom-hole conditions. According to Table II, we observe the blasthole drill data for bit serial no. A1. From Fig.7, if the speed of rotation of the bit increases, the teeth of the bitif the speed of rotation of the bit increases, the teeth of the bit will penetrate into the formation more frequently.

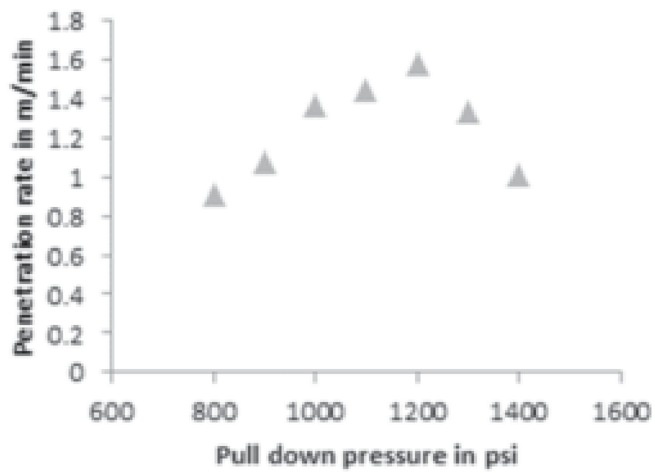


Fig.6 Pull down pressure versus rate of penetration

Table I. Blasthole drill data for bit serial no. A1

Pull down pressure (psi)	Meters drilled	Time (minutes)	Air discharge (kg/cm^2)	Penetration rate (m/min)
800	7.5	8.83	6	0.848
900	7.5	7.35	6	1.02
1000	7.5	5.83	6	1.286
1100	7.5	5.505	6	1.362
1200	7.5	5.05	6	1.485
1300	7.5	6	6	1.25
1400	7.5	7.85	6	0.955

Table II. Blasthole drill data for bit serial no. A1

RPM	Meters drilled	Time (minutes)	Air discharge (kg/cm^2)	Rate of penetration (m/min)
70	7.5	5.68	6	1.32
75	7.5	5.35	6	1.4
80	7.5	5.17	6	1.45
85	7.5	4.68	6	1.6
90	7.5	4.36	6	1.72

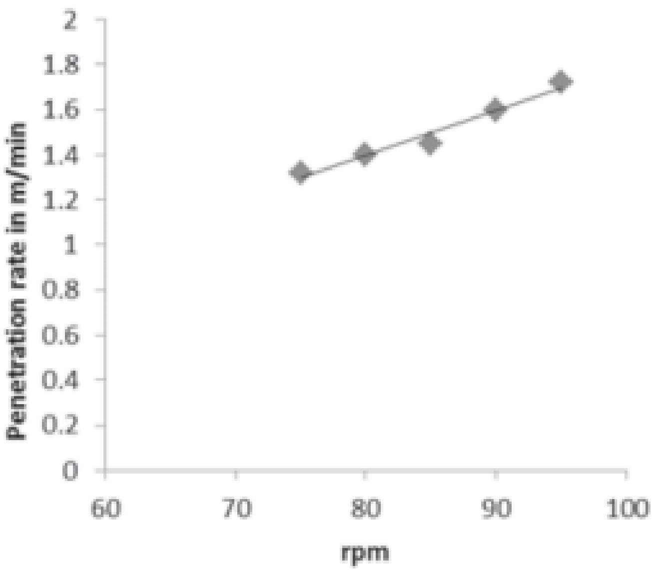


Fig.7 RPM versus rate of penetration

Hence the penetration rate is likely to increase with increasing rotary speed.

Fig.8 illustrates the effect of pull down pressure of bit serial no A2 and bit serial no A3 has on the ROP (rate of penetration). The RPM value for the upper curve is 110 whereas for the lower curve, it is 90 RPM.

IV. Conclusions

It has been observed that, the pull down pressure is directly proportional to penetration rate i.e. the curve was a straight line, but when higher and higher pull down pressure was exerted on the drill bit while keeping the same rotary speed, the penetration rate became successively lower than the one

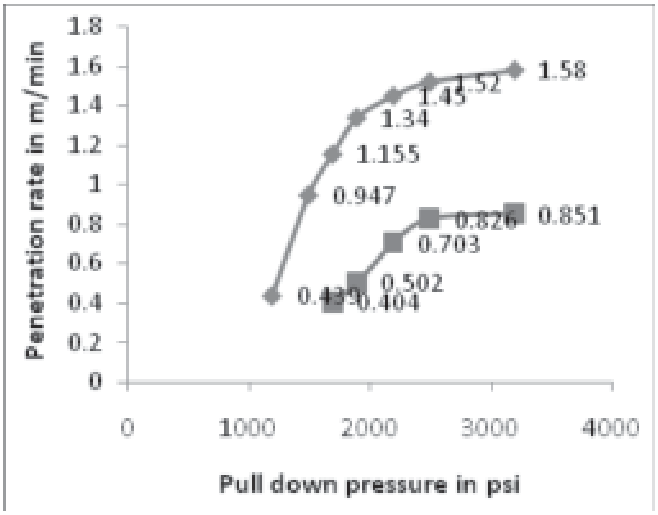


Fig.8 Pull down pressure versus penetration rate

predicted by the straight line. If the speed of rotation of the bit increases, the teeth of the bit will penetrate into the formation more frequently. Hence the penetration rate is likely to increase with increasing rotary speed. It appears the total drilling cost should depend upon the particular combination of bit weight and rotary speed that is used. Harder formations are generally drilled at higher WOB levels than softer formations. Drilling optimization is very important during drilling operation. This is because it could save time and cost of operation thus increases the profit. There is a need to develop a rate of penetration (ROP) model and to study the important parameters such as bit geometry, rock properties, bit weight, rotary speed and fluid velocity.

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IMPROVING EFFICIENCY OF HYDROSTATIC STEERING SYSTEM USED IN OFF-ROAD VEHICLES USING ACCUMULATOR

(Continued from page 168)

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