Original Article: Evaluation of Executive Quality of Drilling Machines in Iran's Oil Industry

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ABSTRACT

With the advancement of science and progress in the construction of drilling machines, the use of drilling machines instead of fire operations for underground drilling has widely increased. In mechanized drilling, tools and machines are used to dig underground spaces and its main goal is to achieve high speed in the construction and digging of these spaces. Drilling operation is one of the costliest operations in underground excavations. On the other hand, there is a lot of limitation in choosing a drilling machine. In other words, there is no flexibility in choosing a drilling machine, i.e. in one project, using several drilling machines is less used due to economic discussion and high cost of drilling machines. Therefore, the type of machine and drilling machinery must be specified before the operation. In choosing the type of drilling machine, its study and efficiency is one of the most important factors. As a result, studying the performance and efficiency of each drilling machine is one of the most vital factors in underground excavations. Here, the discussion is not about the determining factors in choosing the type of device, but the performance of intestinal drilling rig and TBM has been studied separately.

Introduction

Factors affecting the performance of drilling operations can be broadly divided into four main groups (Fig. 1), as follows:

- **Parameters of rock material:** This category includes compressive and tensile strength of rock, percentage of hardness and abrasive minerals (quartz), type of texture and matrix of rock, presence of directional mechanical properties in mineral composition and elastic behavior of rock materials, energy properties of rock such as stiffness index, energy release rate Critical [1-4].

- **Rock mass parameters:** such as degree of jointing (RQD), number of joints, direction of discontinuities (the closer the angle of contact

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of these discontinuities with the tunnel axis to the vertical, the easier it is to dig the tunnel), and the position of joints (closed joints). It does not penetrate, but open joints are very effective. Tensile joints in walls, which are sometimes welded, also have a positive effect on increasing the drilling rate, i.e. groundwater, fault zones, complex working site position, ground retaining stratification, general retaining stratification [5-9].

- **Characteristics of the machine:** This group includes weight, tiller strength, machine forces, type of winning tool, number, order of winning tool and capacity of the support system [10].
- **Operational parameters:** These parameters encapsulate shape, size and length of opener, slope, route arch, drilling order, widening operation, number and number of rock formations in the tunnel route, land maintenance method, work schedule, meaning the number of work shifts per day and days of the week. A combination of these parameters determines the production capacity of a particular machine in a formation and determines the rock conditions. Among these parameters, there are some parameters that cannot be controlled. They include the condition of the ground and rock and some operational parameters. In other words, in a tunneling project, the only controllable parameters are the machine parameters [11-13].

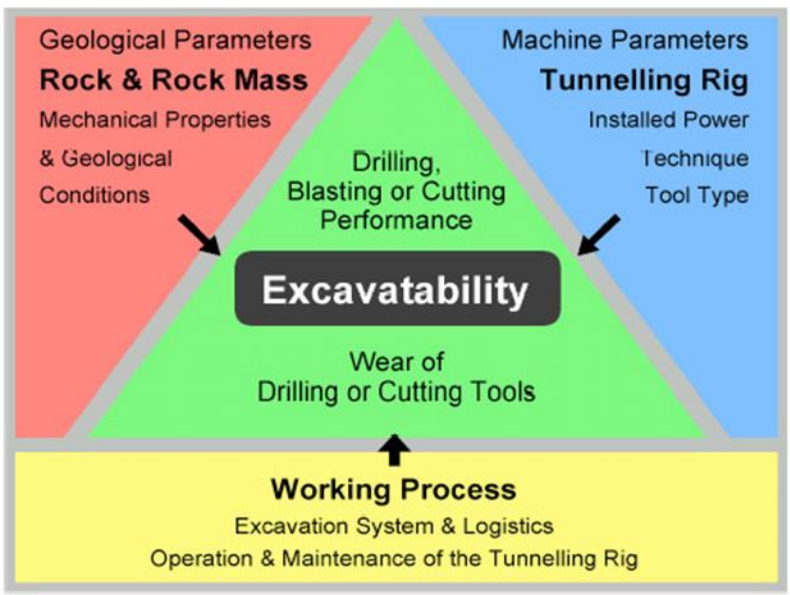

Figure 1. Factors affecting drilling operations [14]

As can be seen in Figure 1, many factors affect the performance and efficiency of drilling machines, so it cannot be quantitatively evaluated the performance of a drilling machine, so all the diagrams presented are qualitative [15-19].

Theoretical models

The basis of these models is the forces acting on the winning tool or the work done to dig a volume unit of rock (specific energy). The characteristics of these models can be described as follows:

1. Their basis is the balance of power or energy;

2. In the case of failure, both tensile and shear stresses are considered;

3. In these models, homogeneous materials are assumed and the effect of pre-existing fractures is assumed; and

4. The stress distribution mode in two dimensions is considered, such as linear or point loading [20].

These models also have weaknesses. Among the weaknesses of these models the following instances can be mentioned:

1. Poor understanding of the state of stress propagation in rock due to forces and mechanics of failure;

2. Ignoring fractures that already exist in the rock;

3. Failing to consider the three-dimensional stress distribution mode, i.e. the interaction of the winning tool; and

4. In general, lack of sufficient accuracy and hence deviations in the use of these models.

These models sometimes estimate the vertical and rotational forces using the drilling penetration depth and sometimes use these models to predict the drilling depth. Finally, it can be said that these models are more developed for full-length mechanical devices and are less used in the case of intestines.

Experimental models

The use of experimental models has been expanded further due to the limitations and problems inherent in theoretical methods and models. These methods claim that theoretical models do not take into account some parameters affecting performance. The characteristics of these methods include using several fixed and dimensionless parameters, relying on real local information that is recorded in a database, and showing the relationship between rock and machine in a simple way.

The weaknesses of these models include the following instances:

1. It is difficult to collect quality data for these models; and

2. In most cases, empirical relationships cannot be used in two specific places.

So far, the factors affecting performance and types of performance forecasting models have been studied. Since the study of each of these factors in the intestine and the whole cross-section machine is very extensive, we have tried to present all related issues by examining the factors affecting the performance of the bowel machine and experimentally predicting the performance of the whole cross-section machine [21].

Intestinal function

This type of machine has arms for selective drilling. The arms are attached to the drilling machines in different ways. The drilling operation by this machine is in the form of scratching the chest as the arms move in different directions and scratch the chest. The effective power of these machines depends on their weight. So that the application of compressive force for drilling is provided by the reciprocal force caused by the weight of the machine [22].

The maximum thrust and compressive force of the intestinal head is directly dependent on the weight of the machine [23]. The cutters operate either crosswise (perpendicular to the arm) or linearly (along the axis of the arm). This arm has the ability to move up and down the axis as well as left and right and thus can cover the entire chest surface [24].

The excavated material that is poured from the chest is collected by a plate with retractable arms fixed to the front of the machine and carried by a conveyor to the rear of the machine. This method produces a lot of dust that must be controlled in different ways, i.e. spraying and filtering, etc. There is no immediate maintenance in connection with this type of machine. This method of tunnel excavation should be used with one of the maintenance methods that is appropriate to the shape of the tunnel and the ground conditions in which it is used (rock screws, shotcrete, etc.). This type of machine cannot withstand hydrostatic pressure, so some side measures such as building and strengthening the ground, lowering the ground water, etc. may be necessary [25-28].

Figure 2. View of the intestinal machine with cross-sectional drilling method (Weirs Company)

The effect of winner's distance on the head on the performance of the intestinal tract

Among the parameters of the distance of the winning tool in the head are linear distance (SL), circumferential distance (Cs) and the angle of inclination of the winning tool (Fig. 2 and 3). The circumferential distance is measured with a degree scale and the linear distance is measured in centimeters [29].

Here, the equal and unequal distances of the winners at the conical tip are investigated. For this purpose, two types of heads with equal and unequal distances were designed. This study was conducted first theoretically and then in situ [7]. As mentioned, one of the main studies in the performance of the intestinal drilling machine is the amount of vibration generated by the machine. Here, the amount of vibration of drilling heads in different states was studied theoretically.

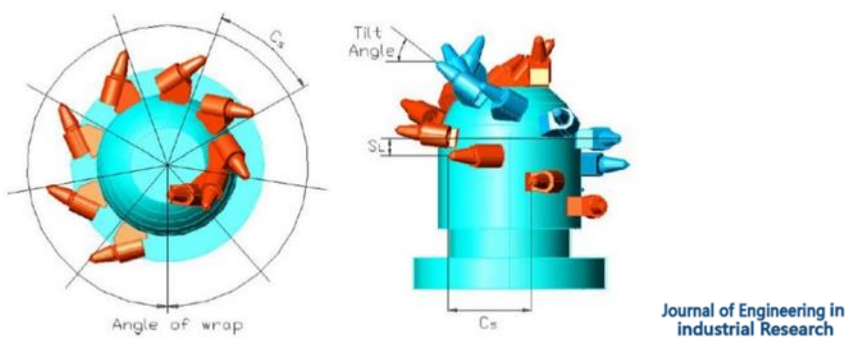

Figure 3. View of the parameters of the distance of the winning tool at the conical tip [7]

From the point of view of how to build, it is easier to make the head with unequal distance, because when the distances are equal, due to the limited space at the head of the head, the winning tool overlaps.

On the other hand, heads with unequal distances have more vibration and consequently more head wear. To compare the effect of equal and unequal distance between the winning tool, four types of heads were designed, which in addition to having different distances, had different light and heavy weights for the winning tool. But in the heavy type there was an overlap between the winning tools and two types of light were used for analysis. The 3D view shows the model of the winning tool in the header [30].

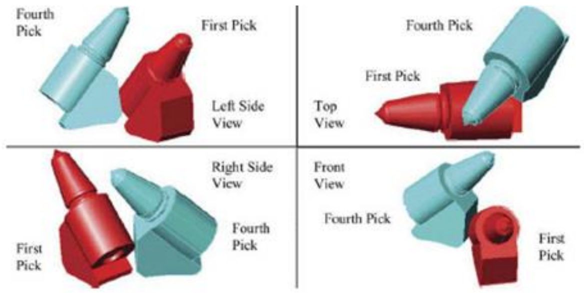

Figure 4. Three-dimensional view of the winning tool model No. 1 and No. 4 in the head with unequal distance [7]

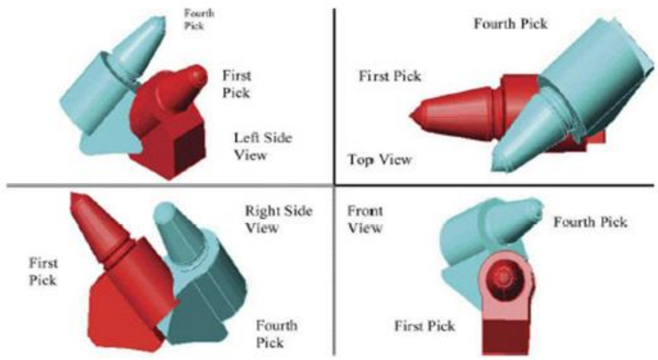

Figure 5. Three-dimensional view of the winning tool model No. 1 and No. 4 in the head with equal distance [7]

Figure 6. View of the head with equal distance [7]

After designing the drill heads, the equilibrium theory showed that the amount of vibration in the head with the unequal cutting tool was more; as a result, the amount of depreciation was higher. For operational investigation, on-site testing was performed in a tunnel with a cross section of 24 m2 with a 0.8 m thick middle layer of silt. The total drilled length equal to the head with the winning tools of the first type and the second type are 275 and 308 meters, respectively.

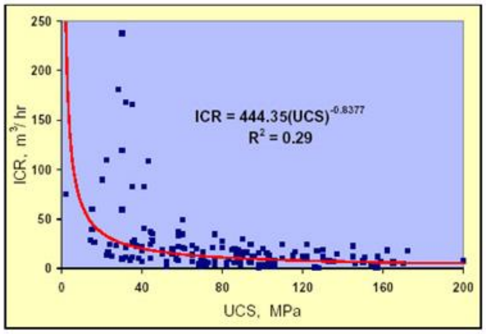

Figure 7. Compressive strength in any geological conditions - instantaneous penetration rate for each type of intestine [10]

As can be seen, there is no precise relationship between uniaxial resistance and the rate of advance, and this is because the rate of advance depends on other factors as well. For this purpose, they should consider other related parameters such as power and weight that are directly related to the rate of advance.

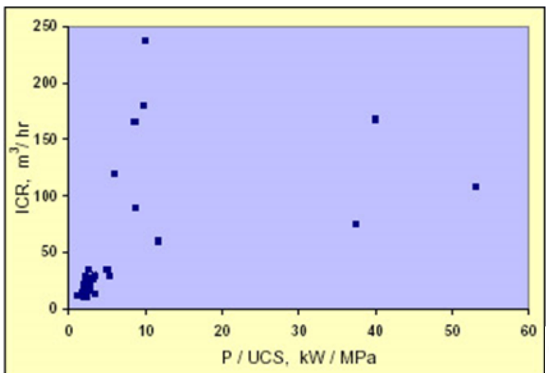

Figure 8. Instantaneous penetration rate diagram with respect to P / UCS ratio [10]

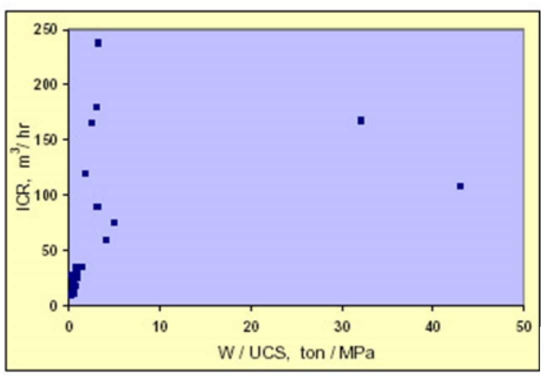

Figure 9. Instantaneous penetration rate diagram with respect to W / UCS ratio [10]

Effect of adhesive zone

To show this effect, we can refer to the case study presented in Turkey. To check this parameter, consider two zones 2 and 3. The amount of water seepage in zones 2 and 3 is 11 l / min, while the percentage of Al2O3 for zones 2 and 3 are 2.68% and 15.1%, respectively, and the water absorption for zones 2 and 3 is 3.8% and 18.1%, respectively. Also, by XRD test, the amount of clay minerals in the two zones has been determined. Kaolite (high in Al2O3) has been observed in zone 3.

However, the rate of instantaneous advance in zones 2 and 3 is 20 solid bank / cutting hour and 50, respectively [31].

Figure 10. View of the effect of adhesives on the head. [10]

Effect of abrasives on drilling performance

As it is known, this parameter is a microscopic parameter of the rock characteristics. To investigate this parameter, microscopic analysis is performed and by determining the percentage of rock constituents, the effect of this parameter on the performance of the drilling machine is determined. Quartz is one of the effective minerals in drilling performance.

Some researchers use the mouse table to check the percentage of abrasives. Thus, in the percentage of minerals with more hardness and equal to quartz, they are equal to the percentage of quartz [32].

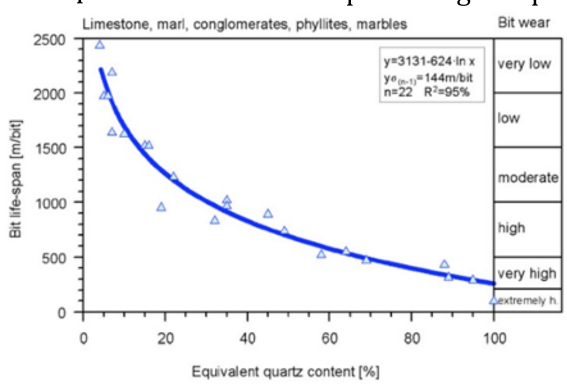

Figure 11. Effect of equivalent percentage of quartz on the life of the head [11]

As can be seen, this difference can be due to the spacing of the joints, the tensile and compressive strength, the texture of the rock or any of the factors as shown in Figure 3 to 11.

However, if we are consent with just classifying the RMR, we cannot make an accurate prediction of the performance of the full-section machine. As a result, we need to normalize this RMR index due to some nuances. The importance of these coefficients is based on sensitivity analysis.

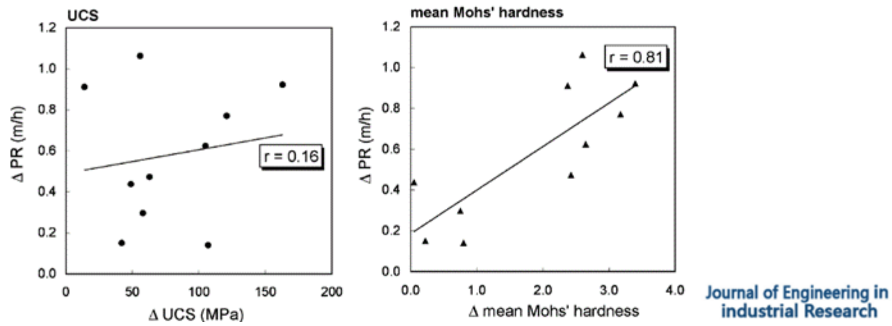

Figure 12. Penetration rate changes for mouse stiffness show a better relationship than uniaxial compressive strength. 10 data from five different types of rocks from my tunnel have been used for this analysis [12]

Comparison with performance forecasting methods

In fact, the obtained results have been compared with two methods of empirical performance prediction, namely QTBM and RSR.

RSR model

As stated before, the relationship between infiltration rate and uniaxial strength and RSR rock mass classification is as follows.

(1) $$PR = 40.41UCS^{0.44} + 0.047RSR + 3.15$$

On the other hand, RSR = 0.77RMR + 12.4.

Here, having the RMR value, the RSR value is calculated and then the graph of the difference between the actual penetration rate and simulated by the RSR method is calculated as a function of the RMR. As shown in the figure, the difference in the predicted penetration rate is large and this is due to the lack of attention to the full-section machine parameter in relation to the RSR classification.

QTBM model

As explained in the previous sections, this method was proposed by Barton (1999). Since the tunneling time was between 1998 and 2000, the data calculated for QTBM were in accordance with the Q classification. This has caused problems in predicting drilling performance by the QTBM method. To solve this problem, the parameters RQD0, Jr and Ja were modified according to the QTBM method.

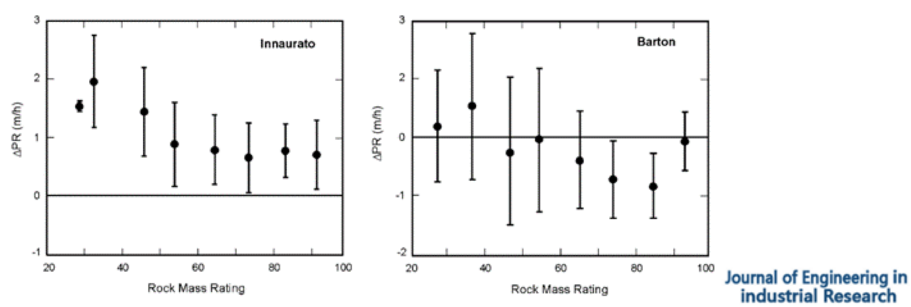

Figure 13. Prediction of full cross-section machine performance by RSR (left) and QTBM (right) methods [12]

As presented in the previous sections, the advance rate predicted by the QTBM method is AR = PR Tm. Where m is a negative number. As can be seen from the figure, in our tunnel, the rate of advance is less than other tunnels, and the main reason for this can be considered as the slope of the tunnel. However, according to the formula for the coefficient m, this factor has no effect on it [33-35].

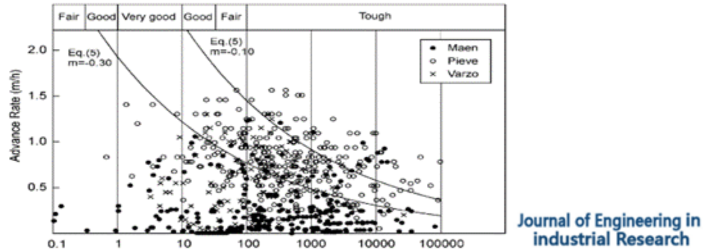

Figure 14. Comparison of penetration rate data for the three tunnels according to the QTBM method [36]

Conclusion

On the basis of the results of this study, it can be concluded that:

1. Investigating the performance of drilling machines has an important role in the schedule and execution cost of drilling operations.

2 - Factors affecting bowel function are machine parameters, geotechnical specifications and operational parameters.

3- Because the performance of the drilling machine depends on a wide range of parameters, performance forecasting in theory is usually inconsistent in practice.

4- One of the ways to study the performance of drilling machines is to study the amount of vibration and vibration (Torque due to incoming forces).

5- From progress rate charts and quantitative conclusions cannot be drawn based on a parameter (Uniaxial Resistance).

6- In designing the winning tool, there is a distance limit in the conical tip of the intestine and its construction is easier based on the irregular distance but the amount of vibration is more.

7- The studies performed on the prediction of the performance of the full-section machine based on the RMR classification show that the advance rate is maximized in the range of 40 <RMR <70.

8- The sensitivity of the percentage of abrasives to the uniaxial resistance is more to predict the penetration rate.

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