EFFECT OF CUTTING PICKS AND CUTTING PERFORMANCE ON UNIAXIAL COMPRESSIVE STRENGTH

[1]Cihan DOGRUOZ, [2]Naci BOLUKBASI

[1] Dumlupinar University, Department of Mining Engineering, 43100, Kutahya, dogruoz@dpu.edu.tr
[2] Middle East Technical University, Department of Mining Engineering, 06800, Ankara, naci@metu.edu.tr

ABSTRACT

Sharp picks become blunt due to wear in time and require replacement. Although it is known that the pick blunting affects adversely the rock cuttability, no study exists to show the relationships between the degree of pick wear and the cutting specific energy obtained by standard cutting tests. In this study, standard cutting tests were carried out on different rock types, with picks having varying degrees of blunting and the relationships between the uniaxial compressive strength parameter were established.

Keywords: *Wear flat, uniaxial compressive strength, cutting picks*

KESİCİ UÇLAR VE KESME PERFORMANSININ TEK EKSENLİ BASMA DAYANIMINA ETKİSİ

ÖZET

Keskin uçlar aşınmaya bağlı olarak zamanla körleşmekte ve değiştirilmeleri gerekmektedir. Kesici uçlardaki körleşmenin kayaçların kesilebilirliğini olumsuz etkilediği bilinmekle birlikte, körleşme derecesi ile standart kesme deneyleri sonucu elde edilen kesme özgül enerjisi arasındaki ilişki üzerine bir çalışma henüz bulunmamaktadır. Bu çalışmada, değişik körleşme derecelerindeki kesici uçlar kullanılarak değişik kayaçlar üzerinde standart kesme deneyleri yapılmış ve tek eksenli basma dayanımı parametresi ile aralarındaki ilişkiler saptanmıştır.

Anahtar Kelimeler: *Aşınma yüzeyi genişliği, tek eksenli basma dayanımı, kesici uçlar*

1.INTRODUCTION

Roadheaders have been applied in a wide range of rock types and structures in addition to coal measures strata since the early 1960's. The major improvements achieved in the last 50 years consist of steadily increased machine weight, size and cutterhead power, improved design of boom, muck pick-up and loading system, more efficient cutterhead design and metallurgical developments of cutting picks.

The performance of mine excavation machinery depends upon a variety of factors, including strength properties of rocks, shape, size and geometry of cutting tools, type and configuration of cutting picks on the excavating heads, the cutting specific energies (MJ/m³) and the mean cutting forces (kN) available in the excavation machinery, rock mechanics parameters, abrasiveness and wearness of the rocks and the cutting materials. The abrasive wear of cutting tools due to rock pick interaction is important as the cost and delays incurred for the replacement of the worn out parts reflects upon overall machine performance.

Studies have been mainly carried out to establish the relationships between the cutting performance and the rock properties [1-6]. McFeat Smith and Fowell developed standard cutting tests and established a good relationship

between the laboratory cutting specific energy and the in-situ cutting performance of rocks by roadheaders [7-9]. Similar relationships have also been found by other researchers for different size roadheaders [10].

In case where laboratory facilities for rock cutting tests are not available, some empirical models regarding some intact rock properties are used to predict the specific energy. McFeat Smith studied the relationships and established a correlation between the laboratory cutting specific energy (SE) and some rock properties [11].

Boom type roadheaders are mechanical excavation machines that break rock by utilizing tungsten carbide tipped cutting tools faced in a specific geometry on a rotating cutting head. The cutter head is driven by an electric motor through a heavy duty gearbox for either milling or ripping cutting actions. Boom movement is controlled by hydraulic cylinders sized to provide sufficient force to maintain the cutting head in contact with the face, and the machine is track mounted to allow tramming from one work face to another. Roadheaders have traditionally operated in sedimentary rock with an unconfined compressive strength of less than 100 MPa [12]. Occasionally harder rocks can be excavated where joints, bedding planes, fractures or other planes of weakness are present. The roadheaders can be classified according to their times of production, their rock-cutting abilities and their weights [13].

1.1. Classification According to Times of Production

First generation machines were introduced in Western Europe in the 1960's. The lighter models of these early boom miners weighed about 9 tons and could cut soft rocks having compressive strength up to about 40 MPa. Second generation machines were developed around 1970. These machines generally weigh between 22-37 tons. Some of these machines can cut competent rock with compressive strength as high as 85 MPa if the silica content of the rock is low. The third generation, heavy-weight machines became available in 1976. These machines weigh between 45-70 tons and can cut competent rock with compressive strength of 100 MPa. Machine weights have reached up to 120 tons about 2000 which can be considered as fourth generation machines. Such machines can cut economically most rock formations up to 100 MPa uniaxial compressive strength (UCS) and rocks up to 160 MPa UCS if favorable jointing or bedding is present with low RQD numbers [3,4,12].

1.2. Classification According to Weight

Roadheaders have been classified by Tucker according to weight as [14]:
- Light Duty; weight up to 30 t, cutting capabilities up to 70 MPa
- Medium Duty; weight between 34-45 t, cutting capabilities up to 100 MPa
- Heavy Duty; weight over 45 t, cutting capabilities up to 120 MPa

Table 1. Classification According to Weight by Atlas Copco – Eickhoff [15].

Class	Weight (t)
0	<20
I	20-30
II	30-50
III	50-75
IV	>75

1.3.Classification According to Rock-Cutting Abilities

Boom type roadheaders consist mainly of boom, cutting head and cutting picks. Roadheaders can have either fixed or telescopic booms. Telescopic boom is advantageous especially on soft floors since sumping can be achieved without moving the machine forward. All boom miners utilize cutter bits fixed on a rotary cutterhead that is powered by an electric motor. Sumping of the boom-miner cutterhead into the face usually utilizes a forward thrust on its crawlers. This initial cut is then enlarged using vertical, horizontal, or spiral cuts. The two significantly different cutting actions are milling and ripping. There are three styles of pick in general use: radial, forward attack and point attack (Figure 1). Radial picks have their shanks positioned normal to their cutting direction. The shanks of forward attack picks, on the other hand, are angled backwards from the cutting direction, usually at about 45º. Both of these picks use wedge tips. These picks are used for cutting coal and soft-medium hard rock. Point attack picks are essentially forward attack picks with conical tips. They usually have circular cross-section shanks and are free to rotate within their holders. They are generally used for cutting hard coal, medium, hard and abrasive rocks [16].

Figure 1. Radial, Forward-Attack and Point-Attack Picks

2. MATERIAL AND METHODS

The compressive strength of the rock to be excavated is often quoted as a measure of cuttability but compressive strength alone has been found to be a poor predictor of machine performance [17]. Factors that need to be considered when assessing roadheader performance and tool consumption rates are given in Table 2.

Table 2. Factors Influencing Roadheader Performance and Tool Consumption rates [17].

Properties	Characteristics
Rock Degradation Properties	Hard Mineral Content, Grain size, Angularity, Cementation
Rock Mass Properties	Discontinuity frequency, Thickness and Position of Beds
Machine Characteristics	Slewing Forces, Cutting Torque, Stability, Cutting Speed, Head Geometry
Cutting Tool Properties	Type, Tip Geometry, Tungsten Carbide, Composition
Operational Characteristics	Made of Cutting Slewing Speed Advance/rev.
Tunnel Characteristics	Gradient, Size and Shape Presence of Water
Rock Material Properties	Strength, Toughness

2.1. Uniaxial Compressive Strength

Unconfined compressive strength is often used as the main predictor of cutting machine performance for rocks associated with coal seams or the weaker sedimentary rocks such as sandstone, siltstone and mudstone. On the other hand, when the range of application has to be extended into other rock materials, compressive strength alone is not always a good predictor of performance. Evaporate rocks, breccias and chalk containing flints are materials that do not follow the established relationships for compressive strength and excavation rate [18].

Bilgin et. al (1996) studied the correlation between ICR, UCS and RQD. Figure 2 shows the relationship between ICR and UCS for rocks having RQD greater than 50 and less than 50, respectively. No correlation exists for rocks with RQD less than 50.
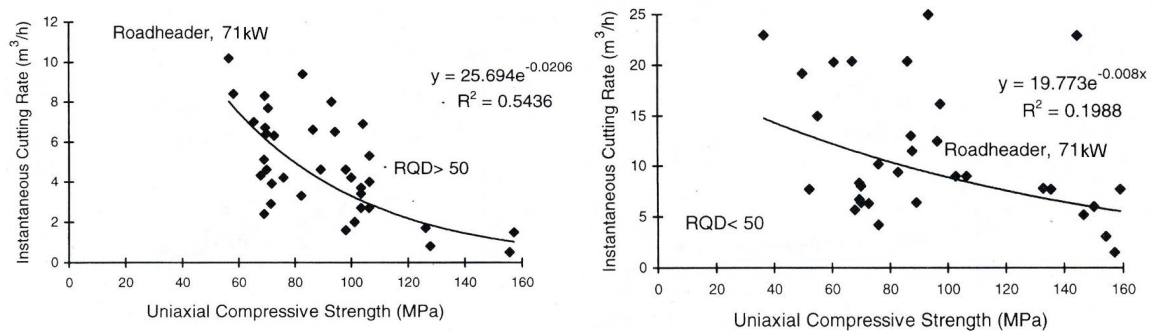

Figure 2. The Variation of Instantaneous Cutting Rate with Uniaxial Compressive Strength of Rock, RQD > 50 and RQD < 50 [19].

Thuro and Plinninger determined the relationship between the cutting rate and the uniaxial compressive strength for 132 kW roadheader as shown in Figure 3. They have found that the correlation between UCS and cutting performance is not sufficient (Thuro and Plinninger, 1999).
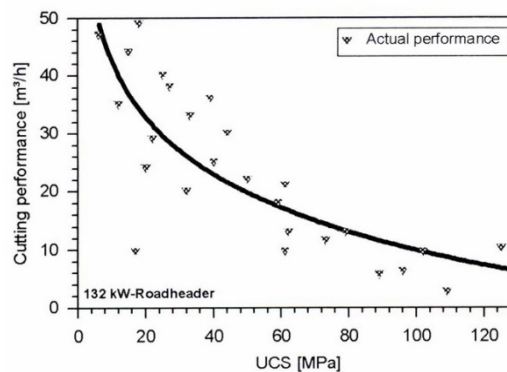

Figure 3. Cutting Performance Correlated with Compressive Strength of 26 Rock Samples [4].

3. RESULTS AND DISCUSSION

In this study, chisel type cutting picks have been blunted artifically using diamond grinding disc in varying degrees of 1 mm, 2 mm, 3 mm and 4 mm widths. Figure 4 shows a standard sharp and blunted to 4 mm pick used in the experiments. Since the standard pick has negative rake, standard picks were blunted by grinding with 40º wear angle to obtain wear flats of width 1 mm, 2 mm, 3 mm and 4 mm. Standard cutting tests were carried

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out on twenty different rock types, with picks having varying degrees of blunting. The uniaxial compressive strengths were applied on same rock types and the correlations were found out.
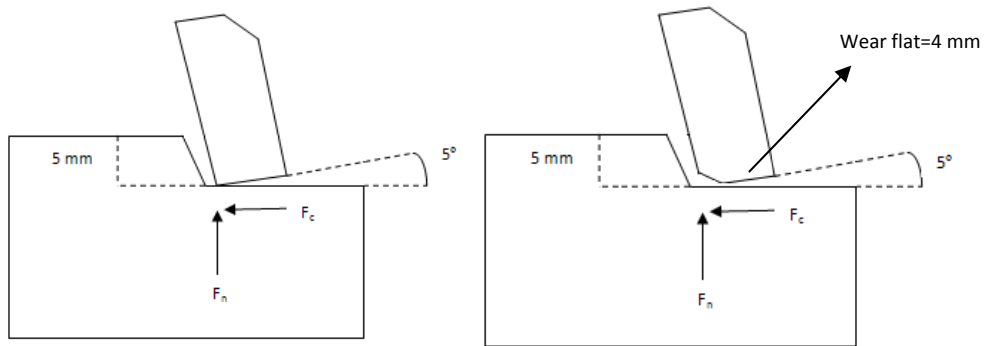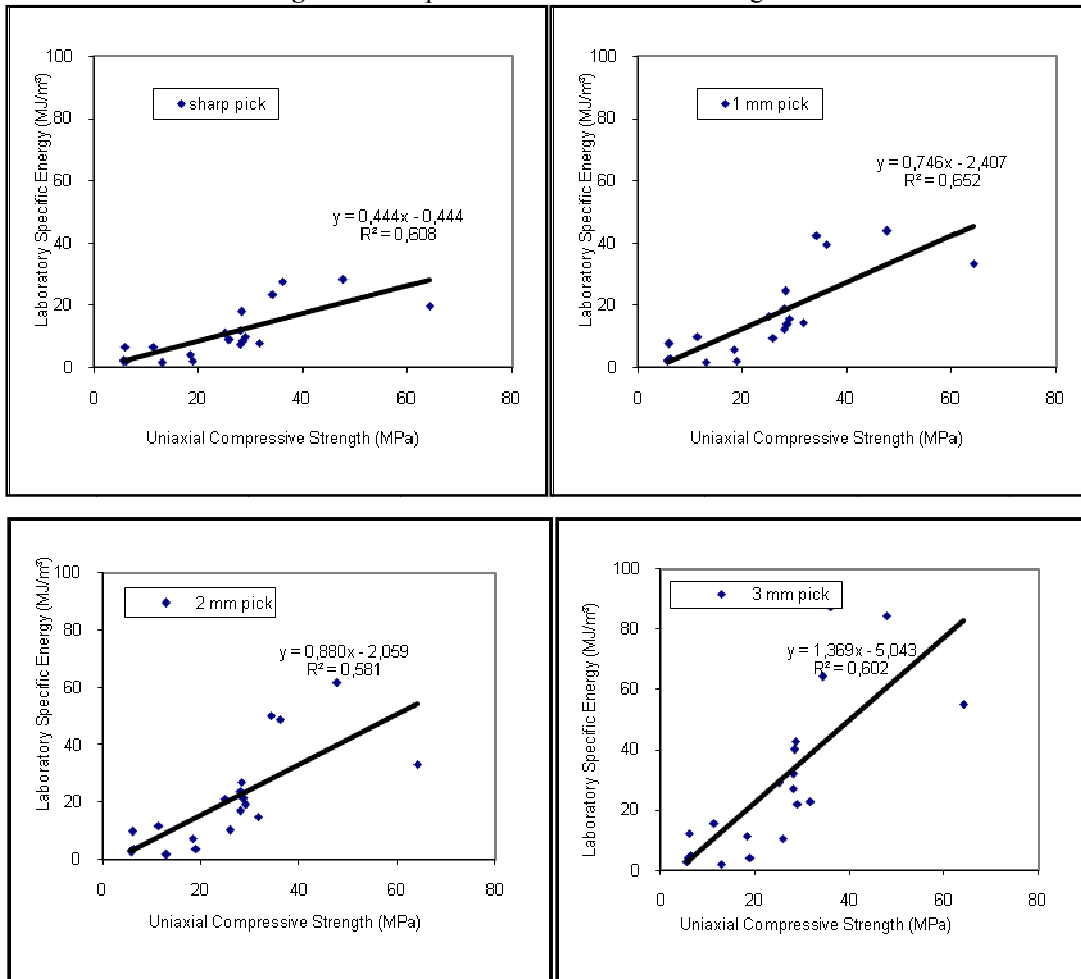

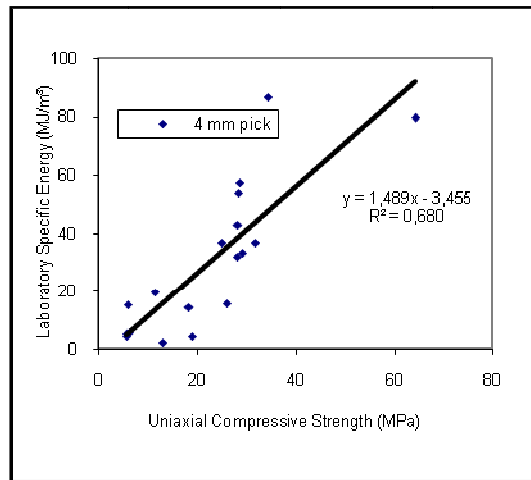**Figure 4.** Sharp and Blunted Standard Cutting Picks

Figure 5. Relationships Between Uniaxial Compressive Strength and Laboratory Cutting Specific Energy
at Different Wear Flats

Figure 5 shows the relationships between uniaxial compressive strength and laboratory cutting specific energy at different wear flats. Graphics show that rather good correlation exists between the laboratory cutting specific energy and the increase in uniaxial compressive strength. Although increase in wear flat causes slight increase in specific energy for low strength rocks, it increases rapidly with increasing wear flat and uniaxial compressive strength, reaching 4-5 times as compared to sharp picks for high strength rocks.
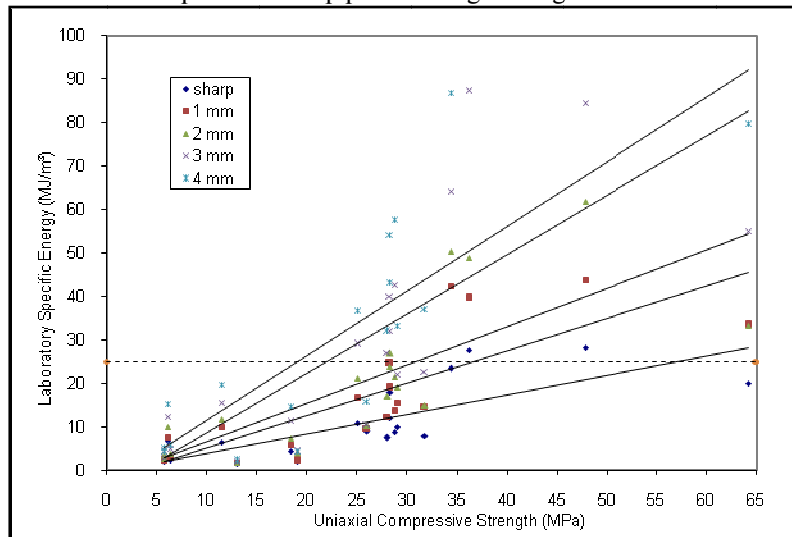

Figure 6. Critical Wear Flats for Varying Uniaxial Compressive Strengths

Figure 6 shows the establishment of the critical wear flats at varying compressive strengths if the limiting cutting specific energy above which poor cutting performance will be obtained is considered to be 25 MJ/m³. As it can be seen from the figure, although the cutting specific energy remains below 25 MJ/m³ even with 4 mm wear flat for rocks having UCS (uniaxial compressive strength) less than about 20 MPa, the critical limit is exceeded even with 1 mm wear flat pick when the uniaxial compressive strength exceeds about 35 MPa.

4. CONCLUSION

A significant correlation exists between the laboratory cutting specific energy and the uniaxial compressive strength. Specific energy and cutting force rise slightly with increasing wear rate for low strength rocks, but the increase is very rapid for higher strength rocks. Specific energy increases 4-5 times with the pick having 4 mm wear flat for higher strength rocks as compared to sharp picks.

Since the critical limit of specific energy is considered to be 25 MJ/m^3 above which poor and difficult cutting condition is expected, this limit is not exceeded even with 4 mm wear flat up to an uniaxial compressive strength of 20 MPa. The limit is exceeded even with 1 mm wear flat when the UCS exceeds 35 MPa. Therefore it can be concluded that, the critical wear flat rate decreases as the UCS of the rock increases.

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