# Investigation of The Relationships Between Cerchar Hardness Index and Some Index Properties of Coal

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ABSTRACT: Within the scope of this paper, firstly index tests used for defining cuttability of rock are applied to specimens which are prepared from block samples taken underground. Secondly, Cerchar hardness index tests are performed by means of bits which have peak angles of 99° and 125°. Then, the relationships between index tests and Cerchar hardness test are investigated. Finally, interpretations of these relationships are discussed and the results are given

## 1 INTRODUCTION

Coal, which has high potential of reserve among in all other fuel resources, is mostly used in both iron-steel industries and other industrial fields. As it is an inevitable raw material used in our country, it should be produced efficiently, fast and economically. Therefore, the mechanized excavation, which is more advantageous in comparison to drilling and blasting methods, should be investigated in all details. In this respect; many successful applications of mechanized systems are present in Turkey. For instance, in the last decade, some of them such as Ansch, high pressure air blasting technology (HPABT) and Cardox (blasting by using liquid $C0_2$) have been tried in Turkey Hardcoal Enterprises (TTK). Among these systems Cardox and HPABT are still being used for coal production at high efficiency rates.

Since cutting machines used in underground mines for mechanized excavation are the systems which require high investments, it is necessary to predict the machine performance before selecting a suitable machine to buy. That's why some rock properties such as pétrographie, physical and mechanical have great significance in predicting the performance and advance rate of mechanized excavation systems. In addition, rock quality designation (RQD) properties and in-situ strength tests should also be performed.

All these tests have been used to predict the cuttability of coal. In order to determine cuttability with high accuracy, some parameters like dry sampling, stronger parts of rock, high loading rates, cubic specimens (H/Dsl) and small specimens should be considered (Natau et al. 1991). What makes this proves so important is that not only the pick consumption, but also the energy consumed by cutting machine should be considered during the cuttability studies. Thus, the properties which depend on rock should be determined accurately and the results should be interpreted carefully. An error made in experimental studies causes an increase in the costs and a loss in time.

The aim of this study is to investigate the relationships between some index properties of coal seams in Zonguldak Hardcoal Basin. For this purpose; block and channel samples are taken. Block samples are prepared for uniaxial compressive strength (UCS), Shore hardness index (SH), cone indenter value (CI), and Cerchar hardness index (CHI) tests. Moreover, impact strength index (ISI) tests are applied to channel samples. Then, all these tests are carried out and finally the relationships between these parameters are determined.

## 2 MATERIALS

To determine index properties of coal, laboratory and in-situ tests are carried out. For this reason, block and channel coal samples were taken from 10 unoxidated distinct seams located in the basin where production works were in progress. The seams had different thickness varying between 1 5 to 4 m and had inclination between 20° to 40°

Because of the difficulties in preparing block specimens, the hardest coal seams are selected In addition, channel samples are taken from the seams that are dirt band free

## 3 LABORATORY STUDIES

During laboratory studies, the tests given below are carried out Dıffeıent kinds of samples are prepared for each test At the time of sample preparation or performing the tests, many problems like breakage or dispersing of coal samples are encountered due to elasticity of coal

### 3.1 Strength and index tests

Strength and index tests are very essential m selecting a cutting machine To define strength properties of coal, uniaxial compressive, uniaxial tensile (or Brazilian) strength tests are carried out Besides, some index tests are applied to estimate the strength values indirectly

#### *3 11 Uniaxial compressive strength test*

Uniaxial compressive strength test is defined as the maximum compressive stress which a rock sample can resist in one direction (Gerçek 1999) It is the most common and widely in use one because of its reliable results

In this study, cubic specimens are trimmed in 70 x 70 x 70 mm dimensions The discontinuity planes which are parallel to the loading direction are covered with plaster Then, tests are applied at 0 1 kN/sec loading rate Finally, the load values (F) are recorded and uniaxial values are calculated

#### *312 Cone indenter test*

This test is used for measuring the resistance of a rock sample against penetration with a comcally shaped indenter (Stimpson & Acott 1983) It is usually used to determine cuttabılıty, dnllability and for the estimation of uniaxial compressive strength of intact rock

In one of the Ghose & Chakraborti's (1986) studies, they got very excellent correlation coefficient with uniaxial compressive strength versus cone indenter value (Fig 1)

For cone indenter test, prismatic samples which are 12 x 12 x 6 mm in dimensions are prepared In order to minimize the roughness, the sample surfaces are grinded with abrasive (in number 0) Then, the test is carried out and results are recorded

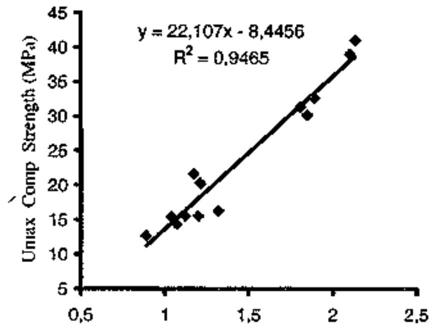


Figure 1 The relationship between cone indenter value and uniaxial compressive strength (Ghose & Chakraborti 1986)

#### *313 Impact strength test*

Impact strength index test is first discovered by Protodyakonov to put forward an idea about the rock's strength properties, cuttabihty and bnttleness, then is improved by Evans & Pomeroy (1966)

This test is performed by a vertical cylinder apparatus which is 30 48 cm in height and has a steel plunger 1816 gr in weight Channel samples are screened within -9 5/ +3 17 mm fractions and are weighted in 100 gr Then, sample is poured down into the apparatus and steel plunger is dropped on it for 20 times Finally, the samples which are taken out the cylinder are screened from 3 17 mm sieve and the oversize is accepted as impact strength index of coal

The test procedure is repeated 6 times and means are accepted

### 3.2 Hardness tests

Hardness is one of the properties of rock that is a measure of resistance to indentation or scratch

While hardness is affected by moisture in soft rocks and quartz content m hard rocks To determine hardness values, three kinds of methods which are scratch hardness tests (Mohs), rebound hardness tests (Shore, Schmidt) and indentation hardness tests (Vickers, Knoop, Cerchar) are used

#### *3 2 1 Cerchar hardness index tat*

The test is generally used for defining the strength and cuttabihty characteristics of coal or rock samples (Bilgin 1992, Coder 1973, Valantin 1973). According to this test, indentation time of bits (in seconds) into the prepared sample (for 1 cm) is measured.

In Turkey, there are not many studies about Cerchar hardness index test. However, there is one that was carried out by Bilgin et al. (1992) by using 5 x 5 x 5 cm coal samples. In their study, they figured out a linear relationship between uniaxial compressive strength and Cerchar hardness index as given in Figure 2.

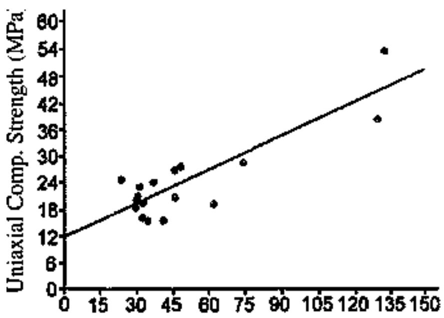


Figure 2. The relationship between uniaxial compressive strength and Cerchar hardness index (Bilgin et al. 1992).

In addition, for coal samples, they formed a cuttability classification by using CHI values that is given in Table 1 (Bilgin et al. 1992).

Table 1. A cuttability classification for Cerchar hardness index (Bilgin et al. 1992).

| CHI (sec) | Cuttability |
|---|---|
| <15 | Easy |
| 15-21 | Normal |
| 21-54 | Difficult |
| >54 | Very difficult |

In this study, modified Cerchar hardness test machine is used so as to determine the Cerchar hardness index values. Test machine is made up of four basic parts (Fig. 3). These are a bit, a chronometer, a vertical weight (to provide compressive force) of 20 kg and a horizontal belt which can be changed for three different positions such as 190, 500, 700 rev/min to adjust the drilling rates.

The test is performed at 190 rev/min drilling rate, by using cubic samples in 70 x 70 x 70 mm dimensions. In addition, two bits with different peak angles (99° and 125°), which are produced particularly in 8 mm length based on DIN 8039 standards, are used.

Initially, the test is applied by means of the bit with peak angle of 99°. The specimen is placed in the clamp, the vertical scale is adjusted for 1 cm and the penetration time is recorded. Second, the bit with peak angle of 125° is affixed and the test is repeated on the cross surface of the cubic specimen. Finally, the penetration times are accepted as CHI values.

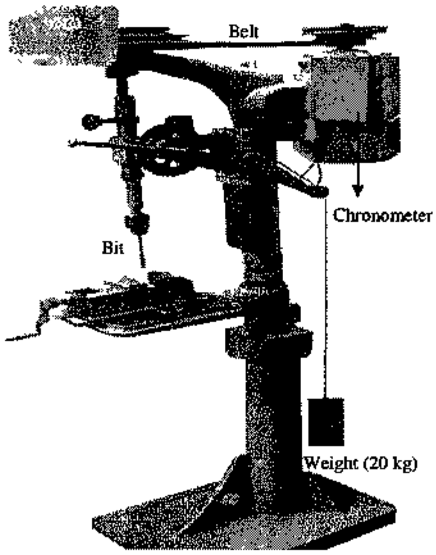


Figure 3. Modified Cerchar hardness test machine.

*3.2.2 Shore hardness test*

The Shore hardness index test is used in empirical equations concerning drillability and wearing of drill tools, which is also influenced by rock mineralogy, elasticity and cementation (Altindag 2002, Rabia & Brook 1978).

The Shore scleroscope measures hardness in terms of the elasticity of the material. A diamond-tipped hammer is allowed to fall from a known height on the surface of specimen to be tested and the hardness number depends on the height to which the hammer rebounds is determined (Material hardness 2001).

In order to perform the tests, samples are prepared to have 15 $cm^2$ surfaces and 1 cm thickness. Then, surfaces are polished with abrasive. D model scleroscope which exists in Zonguldak Industrial Support Centre's Laboratory is used to perform the tests. Shore hardness values are recorded for 20 times in 3 mm spacing on the surface and mean value is accepted SH value

## 4. RESULTS AND DISCUSSIONS

The mam objective of this paper is to investigate the relationships between Cerchar hardness index test (for two different peak angles of 99° and 125°) and some index tests which are applied after sample preparation and laboratory studies In this frame, test results are mentioned m Table 2 and it has been found that even the hardest coal seam having 17 MPa compressive strength m the basm has approximately 37 sec/cm CHI value The relationships obtained from these results are given in Figure 4-7

Table 2 The results of the laboratory studies (Su, 2003)

| Coal Seam Name | UCS (MPa) | SH | ISI | CI | CHI (sec) | |
|---|---|---|---|---|---|---|
| | | | | | 99° | 125° |
| Batı Acılık | 2 82 | 3135 | - | - | - | |
| Doğu Acılık | 4 23 | 34 40 | 412 | - | 12 40 | 601 |
| Domuzcu | - | 39 70 | 437 | 106 | 8 24 | 1160 |
| Acenta | - | 34 20 | 52 7 | 0 65 | 12 27 | 24 31 |
| Unudulmuş | 4 09 | 3190 | 56 0 | - | - | - |
| Nasıfoğlu | 5 08 | 37 70 | 42 1 | 103 | - | - |
| Sulu | 3 41 | 34 05 | 42 6 | 0 82 | 411 | 3 73 |
| Çay | 4 39 | 28 80 | 401 | 0 46 | 6 12 | 8 80 |
| Kalın | 12 19 | 56 35 | 68 8 | 146 | 28 77 | 25 11 |
| Taşlı | 17 34 | 60 40 | 714 | 130 | 31 13 | 36 90 |

According to Figure 4, there are excellent linear relationships between uniaxial compressive strength and Cerchar hardness index Two graphs conflict at 9 5 MPa The author thinks that because of the cracks and discontinuity planes in coal structure, the relations obtained for the values above 9 5 MPa may be more realistic

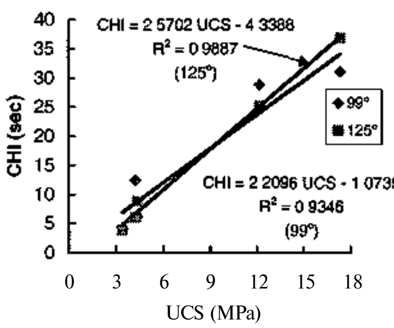


Figure 4 The relationship between Cerchar hardness index and uniaxial compressive strength

As given m Figure 5, linear relationships are found out between Shore hardness index and CHI values The correlation coefficient obtained from the test during which the bit with peak angle of 99° is higher than that of the one with 125° due to the elasticity of coal In this case, block samples should be selected as hard as possible

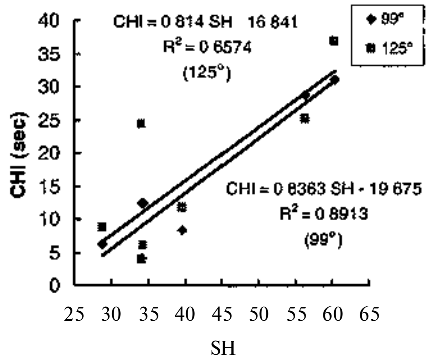


Figure 5 The relationship between Cerchar hardness index and Shore hardness index

Moreover, there are linear relationships and higher correlations between impact strength index and Cerchar hardness index values (Fig 6) The coefficient with the peak angle of 99° is also higher than the other

Although the specimens are taken m two different ways, the obtained high correlation coefficients indicate that both the channel and block samples reflect the same characteristic

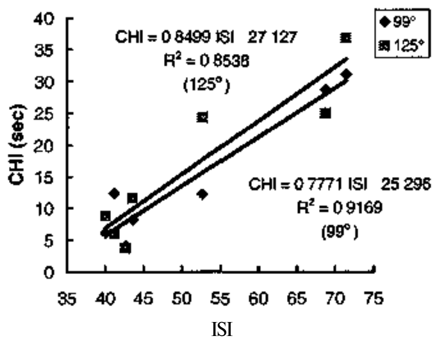


Figure 6 The relationship between Cerchar hardness index and impact strength index

There is no meaningful relationship between cone mdenter value and Cerchar hardness index test carried out by means of the bit with the peak angle of 125° However, a hnear relationship is figured out the one applied with a peak angle of 99° Either cone indenter value or indentation time of bit increases as seen in Figure 7 It is difficult to prepare specimen due to low strength properties of coal, cone indenter tests should be carried on with more specimens

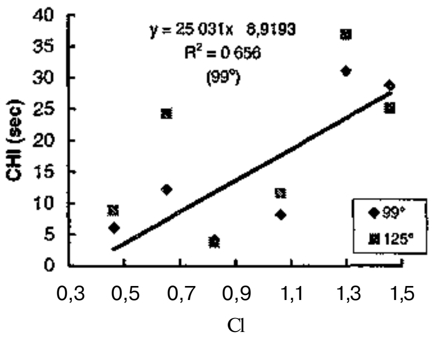


Figure 7 The relationship between Cerchar hardness index and cone indenter value

## 5 CONCLUSIONS

This paper concerns with some index tests affecting the Cerchar hardness of coal samples

For this purpose two kinds of samples are taken from Zonguldak Hardcoal Basın and samples are prepared in different dimensions Then, index tests are canned out and the relationships related to CHI are investigated

During Cerchar hardness index tests, two kinds of peak angles (of 99° and 125°) are used The best fit for CHI values is figured out with UCS values that are limited at 9 5 MPa Values higher than 9 5 MPa provide more accurate results due to elasticity and bnttleness of coal

Besides strength tests, index tests have linear relations versus CHI values In the light of the higher correlations obtained from test results, it is highly recommended that the Cerchar index test for coal samples should be carried on by using a bit with a peak angle of 99°

Moreover, probably because of the deficiencies in performing the test or the insufficient number of the specimens, no relation between cone indenter value and CHI test applied by means of a bit with the peak angle of 125°, is found

The results and relations can be considered while the dnllability and cuttabihty studies

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