The Effects of Specimen Surface Conditions and Type of Test Apparatus on Cerchar Abrasivity Index

Örnek Yüzey Koşulları ve Deney Aletinin Cerchar Aşınma İndeksinin Etkisi

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Abstract

Cerchar abrasivity index (CAI) test is widely used for determining the abrasivity of rocks. This test is applied to estimate bit life and determine the wear in various mining and tunneling machines. The results of tests in different laboratories have been showing some variations depending on type of test apparatus (classic or West) and tested specimen surface conditions. In this study, the effects of these factors on CAI tests were investigated. In this context, CAI tests were performed using two separate testing apparatus both on rough and on saw cut specimen surfaces of 13 different rock samples. The results indicated that there are some differences between rough and saw cut specimen surfaces. It was also found that rough surface CAI values were generally higher than the saw cut surface values. In addition, the statistical analysis in these experiments revealed that there exist linear relationships between CAI values on rough and saw cut surface. Additionally, CAI values on rough surface is about 15% higher than CAI values on saw cut surface. However, it was seen that the type of testing apparatus has insignificant effects on CAI measurements. Because, CAI measured by Classical test device was found higher than CAI measured by West apparatus and the difference was about 1%.

Keywords: Abrasivity, Bit life, Bit wear, Cerchar, West apparatus

Öz


Anahtar Kelimeler: Aşınma, Keski ömrü, Keski aşınması, Cerchar, West deney aleti

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1. Introduction

Abrasion can be defined as the wearing or tearing away of particles from the rock surface. The abrasiveness of soil and rock is a key factor for tool wear in all processes of rock excavation above and below ground such as drilling, cutting and excavating (Thuro and Kasling 2009).

Excavation of rock is accomplished by drilling and blasting techniques or by use of the mechanized technologies in civil and mining applications (Hood and Roxborough 1992). In mechanized excavation, the cutters including disks or picks, are mounted on the cutting head which are in contact with the rock at the cutting surface. The cutters transfer the forces and energy to the rock for breaking and fragmentation. Wear on the cutting tools wear is an important parameter affecting tool consumption and advance rate as well as cost of excavation project (Maidl et al. 2012). Therefore it is important to know the abrasiveness of formation in the excavation site before tunneling works start.

There are numerous tests to identify the rock abrasivity. CAI is one of the widely used index test. It has been used for cutter life and cost estimation of excavation machines (Plinninger et al. 2003, Yaralı et al. 2008). The test was developed at the Cerchar Institute in France in 1970s and some test results were firstly published by Valantin (1973). This test instrument is passed into literature as a first generation machine. Cerchar Institute suggested a standard numbered of NF P94-430-1 in 1986 for this test due to expansion of the application of this test method and the differences have been seen in the efforts of various researchers. However, as these standards were prepared only for formal purposes, it had not been accepted by a lot of researchers. Therefore, in 2015 ISRM published a suggested method for determining the abrasivity of rock by the Cerchar Abrasivity Test (ISRM 2015).

There are mainly two types of apparatus which are in use these days (Fig. 1). One of them is the original Cerchar test device which was suggested by Laboratoire du Centre d’Etudeset Recherches des Charbonnages (Cerchar) de France (Valantin 1973). The other test device is West apparatus which was designed by West (1989) and it is a widely used system in commercial and laboratory application. This apparatus is named after him but was marketed by a company in the UK (Ergotech).

There are two fundamentally different mechanisms to actuate the relative movement between the stylus and rock surface. In the original CERCHAR design, both the stylus and deadweight are made to move across the stationary on rock surface with the lever actuation in 10 mm/sec. In the case of the West design, the rock samples moved under a stationary stylus with the slow screw feed actuation in 1 mm/sec testing speed. Figure 1 schematically depicts the method of actuation in the two designs (ISRM 2015).

CAI test has been examined by several researchers in the past. They investigated the effects of petrographic properties from thin section analyses (such as grain size, mineralogical composition, degree of cementation, quartz content, the equivalent quartz content, matrix properties) and geomechanical properties (such as strength, young modulus, etc.) on Cerchar abrasivity index (CAI) (Suana and Peters 1982, West 1986, AL-Ameen and Waller 1994, Deketh 1995, Plinninger et al. 2003, Yaralı, 2005, Yaralı et al. 2008, Mathier and Gisiger 2003, Plinninger et al. 2004, Lassnig et al. 2008, Thuro and Kasling 2009, Kahraman et al. 2010, Deliormanlı 2012). Other researchers have made experiments with different hardness and different metallurgical properties of pins using CAI values. These researchers have also emphasized that hardness of pin effects results of CAI values (Plinninger et al. 2003, Yaralı et al. 2008, West 1986, Suana and Peters 1982, AL-Ameen and Waller 1994, Rostami et al. 2005, Michalakopoulos et al. 2006, Stanford and Hagan 2009, Cardu et al. 2012, Duru 2014). CAI tests were performed by Kasling and Thuro (2010) found that the CAI derived on saw cut surface is a bit lower than the CAI derived on rough surface. In ASTM D(7625), it is recommended to use a stylus of hardness 55 HRC. In some cases (e.g. when testing low abrasive rocks), other steel qualities might be preferred (ASTM 2012).

2. Material and Methods

In this study, CAI tests were carried out on thirteen rock samples (Table 1) and the tests were performed according to ISRM (2015) suggested methods in order to find out the effects of specimens’ surfaces conditions and type of test devices on CAI values. The tests were performed both on rough (freshly broken rock surface) and saw cut specimens’ surfaces using classical (Type 1) and West apparatus (Type 2).

Before each test, the tip of the stylus (Rockwell Hardness of HRC 54-56, tensile strength of 2000 MPa) was sharpened to achieve a conical tip angle of 90°. Experiments were repeated on three samples with five scratches for each rock types (54 mm core sample with 30 mm height, rough surface was obtained by Brazilian testing on rock disks Fig. 2). Wear on the pin was examined with a digital microscope (magnification 35x) and the surface of the worn pin was captured with a digital imaging software. Stylus tip wear examination were carried both vertically and horizontally and averaged for the final Cerchar index.
Table 1. CAI values on saw cut and rough surfaces.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Sample Name</th>
<th>Location</th>
<th>CAI Values</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Saw Cut</td>
<td>Rough</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>1</td>
<td>Fine Grain Sandstone</td>
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<td>Medium Grain Sandstone</td>
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<td>1.47</td>
<td>2.43</td>
</tr>
<tr>
<td>3</td>
<td>Coarse Grain Sandstone</td>
<td>Zonguldak</td>
<td>1.06</td>
<td>2.92</td>
</tr>
<tr>
<td>4</td>
<td>Limestone</td>
<td>Adana</td>
<td>0.62</td>
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<tr>
<td>5</td>
<td>Quartz Sandstone</td>
<td>Eregli</td>
<td>2.88</td>
<td>3.70</td>
</tr>
<tr>
<td>6</td>
<td>Granite</td>
<td>Bergama</td>
<td>3.05</td>
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</tr>
<tr>
<td>7</td>
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<td>Yenice</td>
<td>2.72</td>
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<td>Andesite</td>
<td>Nigde</td>
<td>2.44</td>
<td>3.54</td>
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<tr>
<td>9</td>
<td>Diabase</td>
<td>Nigde</td>
<td>1.76</td>
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<td>13</td>
<td>Marble</td>
<td>Marmara</td>
<td>0.41</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Figure 1. Basic mechanisms of the two main forms of test apparatus in use. Left Type 1, original design CERCHAR - type testing apparatus. Right Type 2, the modified CERCHAR apparatus as reported by West (1989). 1 mass, 2 pin chuck / guide, 3 stylus, 4 specimen, 5 vice, 6 lever/ hand crank (ISRM 2015).
3. Results

In this study, statistical analysis was performed with R (statistical computing and graphics) (R Core 2013) to investigate the effects of various factors on CAI test results. The statistical analysis indicates that CAI mean values on saw cut surface were generally lower than CAI mean values on rough surface (Table 1 and fig. 3-4). Overall results for all rocks showed that for CAI values saw cut surface changed between 0.36 to 5.65 with a coefficient of variation (CV) of 49.8, while for rough surface it changed between 0.36 to 6.96 with a CV of 54.5.

Statistical analysis also indicated a significant linear relation between CAI values of saw cut surface and rough surface.
4. Conclusions

The result of this study shows about 15% difference between CAI values on rough surface and saw cut surface. There is no significant difference between CAI values of apparatus used.

In conclusion, regarding the use of apparatus, as long as they are used according to ISRM (2015) suggested methods both apparatus gives similar results. Therefore, researchers freely choose type of apparatus in their use. Regarding the preference of specimen surface type, saw cut surface should be chosen because of lower variation in the test results and ease of specimen preparation.

5. Acknowledgements

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