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Performance prediction of roadheaders in metallic ore excavation

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ABSTRACT

Using mechanical miners such as roadheaders may be a solution to increase the production rate and to decrease the costs in metallic mines. In this study, the performance prediction and cutter consumption of roadheaders were investigated for the eight different ore types. Small-scale linear cutting tests, Cerchar abrasivity tests and physico-mechanical tests were carried out on the ore samples collected from the site. The instantaneous cutting rates of a selected roadheader were calculated using specific energy (*SE*) values and compared to the previous models. The amount of cutter consumption was also calculated for each ore type and it was seen that the estimated cutter consumption values for the tested ores are generally lower than the proposed economical upper limit. Since only the performance prediction and cutter consumption of roadheaders were investigated for the excavation of ores in the current study, analyzing all mining operations is necessary for the adaptation of roadheader excavation to a mine. Simple and multiple regression models were also derived for the estimation of *SE* from the ore properties. A significant practical model including the Schmidt hammer value and density of ores was produced from the multiple regression analysis. This regression model can be reliably used for the estimation of *SE* especially for the preliminary studies.

1. Introduction

The small-scale mines are easily affected by changing market conditions and fluctuations in the global demand for metallic ores. Therefore, the small-scale mine operations need to be more efficient to increase their competitiveness. Using mechanical miners such as roadheaders will increase the production rate and decrease the costs in the metal mines. A successful application of roadheaders in underground gold mining was reported by Breitrick (1998). The mining system at the Billie Borate Mine was revised using a combination of roadheader development and drill/blast stopes. It was stated that the revised mining system was working very satisfactorily (Garret, 1985). Bilgin et al. (2005) and Tuncdemir et al. (2003) investigated the possibility of using mechanical excavators such as roadheaders and impact hammers in two different underground chromite mines. They concluded that a mechanical miner could produce nearly three times more chromite ore than could the existing drilling and blasting methods.

Numerous underground metal mines are present in Turkey. Most of these mines are small-scale, and the excavation methods applied in these mines are drilling and blasting. Operations for these small-scale mines need to be more efficient to increase their competitiveness. In this study, the excavation capacity of roadheaders was estimated for eight different metallic ores, and some prediction equations were derived for the assessment of specific energy.

2. Performance prediction methods for roadheaders

The specific energy (*SE*) method is a simple procedure for the quick performance prediction of roadheaders (Rostami et al., 1994):

$$ICR = k\frac{P}{SE} \tag{1}$$

where *ICR* is instantaneous cutting rate ($\mathrm{m^3/h}$), *P* is cutting head power (kW or HP), *k* is the energy transfer ratio usually assumed as 0.8 for roadheaders (Balci et al., 2004), *SE* is specific energy ($\mathrm{kW\,h/m^3}$).

Gehring (1989) presented a performance prediction model based on the performance of a roadheader with a 250 kW transverse type cutterhead:

$$ICR = \frac{719}{\sigma_c^{0.78}} \tag{2}$$

Gehring (1989) also presented a performance prediction model based on the performance of a roadheader with a 230 kW axial type cutterhead:

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$$ICR = \frac{1739}{\sigma_c^{1.13}} \tag{3}$$

where ICR is the instantaneous cutting rate of roadheaders (m^3/h) and σ_c is the uniaxial compressive strength (MPa).

Based on the in situ observation of many tunnelling and mining projects, Bilgin et al. (1990) suggested a performance prediction model for axial type roadheaders:

$$ICR = 0.28P(0.974)^{RMCI} \tag{4}$$

$$RMCI = \sigma_c \left(\frac{RQD}{100}\right)^{2/3} \tag{5}$$

where ICR is the instantaneous cutting rate of roadheaders (m^3/h), P is the power of cutting head (HP), $RMCI$ is rock mass cuttability index, σ_c is the uniaxial compressive strength (MPa) and RQD is rock quality designation (%).

Thuro and Plinninger (1999) derived a prediction model based on the performance of a 132 kW transverse type roadheader:

$$ICR = 75.7 - 14.3 \ln \sigma_c \tag{6}$$

where ICR is the instantaneous cutting rate of roadheaders (m^3/h) and σ_c is the uniaxial compressive strength (MPa).

3. Sampling

Ore mineral deposits are common in the Taurus Mountain Belt, which runs from west to east in the south of Turkey. This mountain belt is subdivided into three parts: the western, the middle and the eastern Taurus Mountains. The boundary between the middle and the eastern part is called Aladaglar. The block samples of chromite, hematite, galena and smithsonite were collected from the mines or outcrops in the vicinity of Aladaglar (Fig. 1). 70 mm-diameter samples for cutting and Schmidt hammer tests, and 38 mm-diameter samples for the physico-mechanical tests were cored from these blocks.

4. Physico-mechanical tests

4.1. Uniaxial compressive strength (UCS) test

Uniaxial compressive strength tests were conducted on trimmed core samples, which had a diameter of 38 mm and a length-to-diameter ratio of 2–2.5. The stress rate was applied within the limits of 0.5–1.0 MPa/s. The tests were repeated at least five times for each ore type and the average value was recorded as the uniaxial compressive strength.

4.2. Brazilian tensile strength (BTS) test

Brazilian tensile strength tests were conducted on core samples having a diameter of 38 mm and a height to diameter ratio of 0.5–1.0. A tensile loading rate of 200 N/s was applied until failure occurred. At least six samples were tested for each ore type and the results were averaged.

4.3. Point load test

The samples cored perpendicular to any visible weakness plane and the samples having weakness plane were discarded. The diametral point load test was carried out on the cores having a diameter of 38 mm and a length-to-diameter ratio of 1.2. The results were corrected to a specimen diameter of 50 mm. The tests were repeated at least seven times for each rock type, and the average value was recorded as the point load strength (I_s).

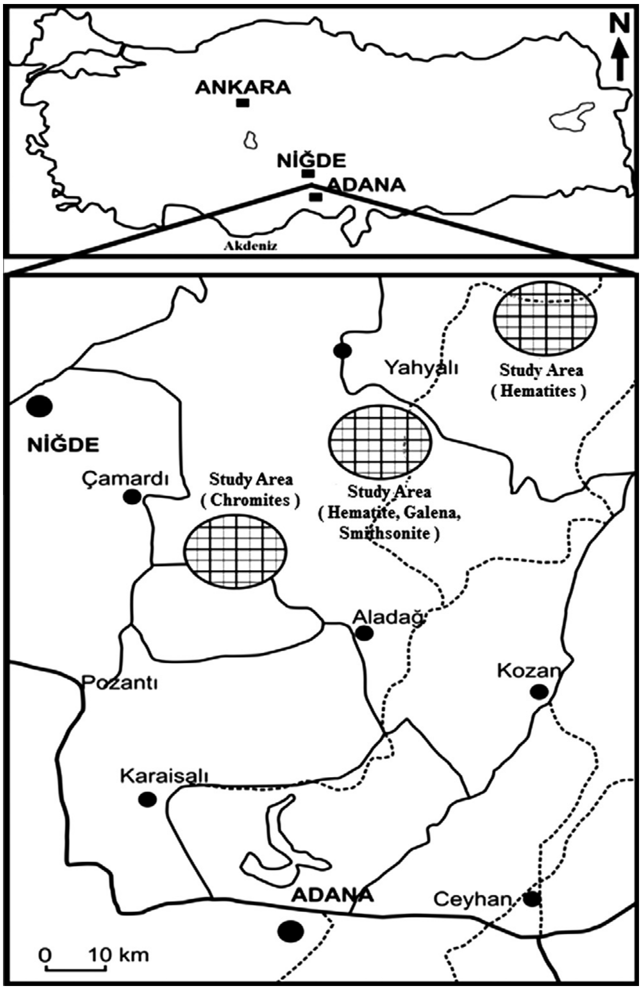

Fig. 1. Location map of sampling area.

4.4. Schmidt hammer test

70 mm-diameter-specimens were tested in a steel V-block having a weight of approx 23 kg. Rock cores were clamped to adequately secure the specimen against vibration and movement during the test. The base was placed on a flat concrete surface and the tests were made with the N-type hammer held vertically downwards. In the tests, ISRM (2007) method was applied for each ore type. ISRM suggested that twenty rebound values from single impacts separated by at least a plunger diameter should be recorded and the upper ten values should be averaged. The test was repeated at least three times on any ore type and the average value was recorded as Schmidt hammer value (R_N).

4.5. Ultrasonic test

P-wave velocities (V_P) were measured on the samples having a diameter of 38 mm and a length of 76 mm. End surfaces of the core samples were polished sufficiently smooth to provide good coupling. In the tests, the PUNDIT 6 instrument and two transducers (a transmitter and a receiver) having a frequency of 1 MHz were used. A good acoustic coupling between transducer faces and sample surface is necessary for the accuracy of transit time measurement. Stiffer grease was used as a coupling agent in this study. Transducers were pressed to either end of the sample and the pulse transit time was recorded. The tests were repeated three times for