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Predicting the noise level in rock sawing from the physico-mechanical and mineralogical properties of rocks

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ABSTRACT

Millions of employees in the World are exposed to noise at work. Block cutting machine is one of the most important noise sources in the stone processing plants. In this study, the predictability of the noise from the block cutting machines in the stone processing plants was investigated by using the physico-mechanical and mineralogical properties of rocks. The noise levels of some block cutting machines were firstly measured during the cutting of the three different rocks. Then, the core samples of the same rocks were cut by an automatic cutting machine in the laboratory and the noise levels were measured. A conversion factor was obtained by dividing the site noise levels by the laboratory noise levels. Then, nineteen different rocks were cut by the automatic cutting machine in the laboratory and the noise levels were measured. Strong correlations were found between the laboratory noise level and the rock properties. The noise level increases with increasing rock strength, abrasive mineral content, and density. However, increasing porosity decreases the noise level. It was concluded that the laboratory noise level for a new rock type to be cut can be estimated using the derived relations. Then, the laboratory noise level can be converted to the site noise level using the derived conversion factor.

1. Introduction

About 20% of European labors are exposed to noise so loud that they would have to raise their voice to talk to other people. Exposure to noise is especially common in the construction and manufacturing sectors [1]. Noise affects humans both physically and psychologically, whose impacts vary from person to person. Exposure to excessive noise for a short time can cause temporary hearing loss, while long-term exposure to loud noise, or short exposures to very loud noises, can cause permanent hearing loss. In addition to hearing loss, exposure to noise in the workplace can cause a variety of other problems, including chronic health problems [2].

The level of noise allowed by most countries' noise standards is generally 85–90 dB over an eight-hour workday [2]. Block cutting machine is one of the most important noise sources in the stone processing factories. The noise levels of these machines during cutting the rock are generally higher than the allowable level of noise.

As per the long research experience of the authors, the noise level produced during rock drilling or cutting depends on the physico-mechanical properties of rock, mineral content and rock texture. Increasing the values of some rock properties such as strength and density generally increases the noise level. However, the increase in the values of some rock properties such as porosity generally decreases noise level. The abrasivity and the hardness of minerals may also have strong effect on the noise level. High noise level is produced during cutting the hard rock or the rock having hard and abrasive minerals such as quartz and feldspar. The texture of rock also effects noise level. The noise level produced during cutting the rock with strongly interlocked grains will be higher than that of the rocks with weakly interlocked grains. Another issue is that some rocks consist of matrix and mineral grains that affect the noise level during cutting. When cutting these rocks, in addition to mineral grains, the strength and hardness of matrix material also influence noise level. The harder the matrix, the higher the noise level produced during rock cutting.

In the literature, there are some studies on the formation characterization by analyzing the noise or acoustic waves during drilling in oil and gas industries [3–7]. These studies have suggested the use of noise produced by the bit during drilling as a seismic source for surveying the area around a well and also for formation

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characterization while drilling. On the other hand, some researchers [8–12] indicated that there are correlations between the rock properties and the noise level produced by drilling machine. Roy and Adhikari [8] stated that drilling in hard rock produced higher noise levels than drilling in soft rock. In their study, the sound level varied from 76 to 79 dB in soft sandstone, 80–82 dB in medium sandstone and 85–86 dB in hard sandstone. Vardhan and Murthy [9], and Vardhan et al. [10] investigated the influence on sound level due to drilling in rocks of varying physical properties i.e. compressive strength and abrasivity using jackhammer drill. They found that both the thrust and air pressure had a significant effect on the sound level produced by pneumatic drill at all the measurement locations i.e., at operator's position, exhaust, drill rod and the drill bit. They explained that the increased compressive strength and lower abrasivity of rocks would require higher air pressure and thrusts to be applied to achieve an optimum penetration rate and therefore would result in higher sound level at the operator's position. They concluded that the estimation of rock properties using sound levels produced during drilling could be a very useful technique for the purpose of selecting suitable explosives and designing blast hole patterns. Kumar et al. [11–13] attempted made to estimate rock properties such as uniaxial compressive strength, Schmidt rebound number and Young's modulus using the sound level produced during rotary drilling in the laboratory. They derived some empirical relations using multiple regression analysis between sound level produced during drilling and rock properties considering the effects of drill bit diameter, drill bit speed and drill bit penetration rate. Kumar et al. [14] also studied the predictability of the rock properties using the sound levels produced during drilling in the field. Their findings indicated that sound level produced during drilling could be a promising tool for estimating rock properties. Kivade et al. [15] investigated the predictability of penetration rate and the sound level produced during percussive drilling. In the study, the effect of uniaxial compressive strength, air pressure, and thrust on sound level and penetration rate was examined. They derived multiple regression models for the estimation of penetration rate and sound level and stated that uniaxial compressive strength and air pressure were the major parameters influencing the sound level and penetration rate. Kumar et al. [16,17] investigated the predictability rock properties from the sound level produced during rotary drilling in the laboratory by using artificial neural networks and compared the results to regression models. They concluded that neural network approach was efficient when compared to statistical analysis in predicting rock properties from the sound level produced during drilling. Li et al. [18] reviewed the measurement-while-drilling (MWD) technology for small-diameter drilling machines. They stated that the sound level is a promising parameter for MWD systems and a standardized drilling system in terms of hardware and drilling method is more reliable and precise for inferring rock properties. Kivade et al. [19] developed ANN models to predict the properties of sedimentary rocks by using penetration rate and sound level produced during percussive drilling. The ANN models were developed for predicting rock properties such as uniaxial compressive strength, abrasivity, tensile strength, and Schmidt rebound number using air pressure, thrust, bit diameter, penetration rate and sound level. They also developed ANN models for predicting penetration rate and sound level using air pressure, thrust, bit diameter and rock properties as input parameters.

There are limited studies on the relation between the rock properties and the sound level during cutting rock by diamond saw in the literature. Karakurt et al. [20] carried out a study on the noise level generated during the sawing of granites using circular diamond sawblades. They showed that increasing of peripheral speed, traverse speed and cutting depth increased noise levels. They derived relations having moderate correlation coefficients between the noise level and both compressive strength and density. They also developed multiple regression models for the prediction of noise level by including the operating variables and rock properties. We [21] studied the assessability of the noise from sawing rock by diamond saw using the P-wave velocity. The noise level measurement and P-wave velocity tests were performed on 36 different rock types. The evaluation of the results showed that there was a strong power relation between the noise level and the P-wave velocity. It was concluded that the noise level from the diamond sawing could be assessed using the P-wave velocity. We [22] also investigated the predictability of the Los Angeles abrasion loss from the noise level in cutting rocks by diamond saw and developed a prediction equation. In the study, the Los Angeles abrasion, noise level measurement, density, and porosity tests were carried out on 27 different rock types such as igneous, metamorphic, and sedimentary. A good relation between the Los Angeles abrasion loss and noise level was found. The multiple regression analysis was also performed by also including density and porosity values in order to check the possibility of obtaining the more significant relations. However, it was seen that the correlation coefficients of the multiple regression equations were slightly higher than that of the simple regression equation. In our recent study [23], we evaluated the predictability of the physico-mechanical rock properties from the noise level in cutting rock by diamond saw in the laboratory and derived some correlations. The noise measurement, uniaxial compressive strength, Brazilian tensile strength, point load strength, density, and porosity test were carried out on 54 different rock types in the study. Significant correlations were found between the noise level and the rock properties except the uniaxial compressive strength. It was concluded that the physico-mechanical rock properties could be estimated from the noise level measured during cutting the rock with diamond saw. Another conclusion was that further research was necessary to check the significance of the relation between the uniaxial compressive strength and the noise level.

Estimating the noise level of the block cutting machine during the cutting a new rock type is useful for the noise management in the stone processing plants. In this study, the predictability of the noise level from the block cutting machines was investigated by using the physico-mechanical and mineralogical properties of rocks. Since in this work, only limited types of rocks are considered, to assess the site noise level from cutting a large number of rock types is very difficult. For this reason, a conversion factor for estimating the site noise level from laboratory noise level is proposed in this paper.

The remaining sections of this paper are organized as follows: Section 2 explains the noise measurements in the field and the sampling process; Sections 3 and 4 respectively present the mineralogical analysis and laboratory studies; Section 5 explains the noise level conversion factor estimation; Section 6 presents the details of correlating the noise level with various rock properties; Section 7 presents the statistical significance of correlation coefficient through F-test; and the conclusions are presented in Section 8.

2. Field studies

2.1. Noise measurement in the field

The two stone processing plants located in Kayseri City of Turkey were visited for the site studies. The site noise levels of block cutting machines (Fig. 1) were recorded during cutting the three different limestone blocks. The measurements were carried out at a distance of two meters from the machine.