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# Developing a New Model for Predicting Specific Energy (SE) for Economic and Environmental Optimization of the Diamond Wire Cutting Operation

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*Abstract*

Diamond wire cutting is a common method to extract dimension stones, which depends on various factors, including the mechanical and physical properties of the stone, cutting specifications, and operational characteristics. Specific energy, production rate, efficiency, and wear of diamond beads are some of the criteria that influence economic and environmental optimization of diamond wire cutting operations. In this study, the specific energy of the diamond wire cutting process was measured for 11 samples of Granite stones. By analyzing the impact of parameters such as stone density, porosity, and cutting rate on energy consumption, a linear regression model was developed with a correlation coefficient (R2) of 0.944 to predict specific energy for different types of stones. Statistical analyses, including ANOVA, have confirmed that the model accurately predicts specific energy values. Data from three new stone samples were used to validate the model, and their predicted energy values were compared with actual values. The model presented achieved an R2 value of 0.827, demonstrating its high accuracy. The results indicate that energy consumption in dimension stone cutting operation can be accurately predicted and characterized indirectly using high precision stone properties and operational parameters. This method can accurately and indirectly monitor energy consumption and cutting machine performance during the dimension stone cutting operation and can be used to optimize economic and environmental aspects of this process.

## 1. Introduction

There is a significant demand for dimension stones due to urbanization and increased construction activities. The production cycle of dimension stones involves three main phases: exploration, extraction, and processing. Extraction and block cutting are the most critical processes. Different methods have been developed for extracting dimension stones, such as block cutting using steel wire, diamond wire cutting, electric saws, disc cutters, flame jets, water jets, and explosive methods. Diamond wire cutting is one of the most commonly used techniques [1, 2]. The process involves drilling horizontal and vertical holes using a drilling machine. The diamond wire is then threaded through these holes and placed around the wheel of a stone cutting machine. The machine's wheel and wire are set in motion by an electric motor to cut through the stone gradually. As the cutting progresses, the wire saw machine is pulled back along a rail. Depending on the diamond beads' type and quality, the cutting can be either dry or wet. Diamond wire cutting is advantageous due to its high cutting speed, high flexibility, cost-effectiveness, acceptable cutting precision, and ease of operation compared to other methods [3-6]. Figure 1 illustrates a schematic of the dimension stone cutting operation using a diamond wire saw machine.

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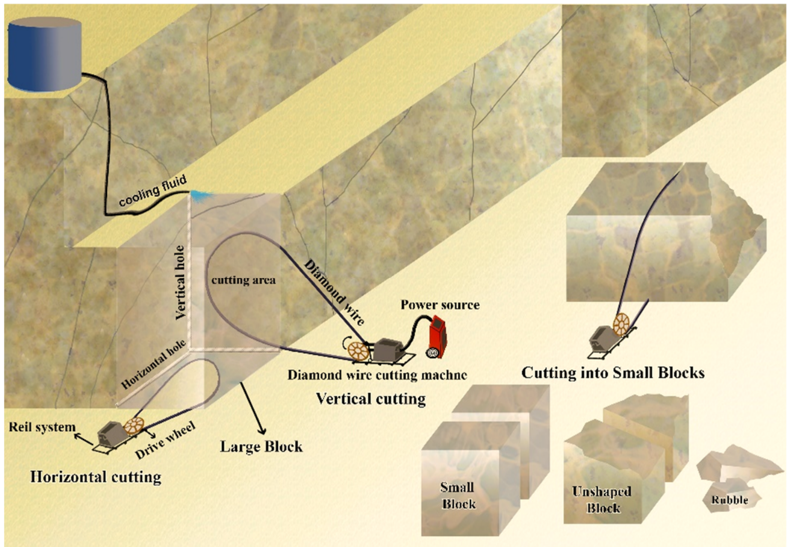


**Figure 1. Schematic of diamond wire cutting operation [7]**

Cutting blocks is a crucial step in the production of dimension stones. To optimize this phase, it is essential to evaluate its performance by considering factors such as production rate, energy, and tool consumption. The factors that affect wire cutting performance can be grouped into three categories: those associated with stone characteristics, cutting specifications, and operational parameters. The optimization of dimension stone cutting operations is evaluated based on several criteria, including energy efficiency, maximum productivity, best production rate, and optimal tool consumption [5, 8, 9]. Figure 2 provides a schematic of the significant elements and optimization criteria for the dimension stone cutting operation [10].

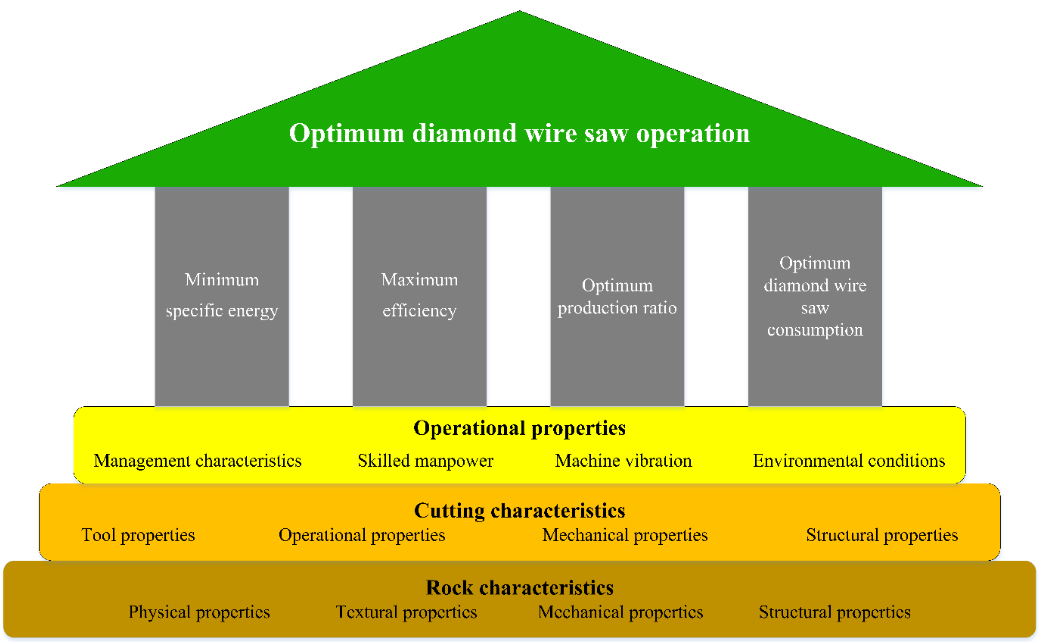


**Figure 2. Influential factors and optimization criteria for the diamond wire cutting operation**

Researchers have shown considerable interest in optimizing stone cutting operations. Numerous studies have been conducted to explore the cutting process of dimension stones and achieve different objectives, such as predicting wear rates, optimizing operations, evaluating the performance of diamond wire cutting, and determining its energy consumption. Table 1 presents several examples of such studies conducted in this field.

**Table 1. Several examples of such studies that have considerable interest in optimizing stone cutting operations.**

| Authors | year | method | Results |
|---|---|---|---|
| Ozcelik et al. [11] | 2004 | Investigation of the effect of textural properties on marble cutting with diamond wire | Observation of an Inverse relationship between grain size and wear rate and a significant relation between the texture coefficients and wear on diamond beads and cutting rate |
| Ersoy and Atici [12] | 2005 | Investigation of the performance of the circular diamond saw | Observation of the relationship between the specific cutting energy and the saw blade operating parameters and rock properties |
| Mikaeil et al. [13] | 2008 | Investigating the production rate of diamond wire saws using a developed model | Predicting the production rate of diamond wire saws in carbonate rock cutting |
| Ozcelik and Yilmazkaya [14] | 2011 | Investigation of the effect of rock anisotropy on the efficiency of diamond wire cutting machines and also on the vibration of the cutting machine | The direct relation of UCS of the rock, cutting efficiency, and vibration of the machine during the cutting operation to rock anisotropy |
| Yurdakul and Akdas [15] | 2012 | Investigation of specific cutting energy values ($SE_{cut}$) based on the operational variables of block cutters and rock properties | Prediction of the $SE_{cut}$ values for carbonate rocks in the stone cutting process by using the developed model |
| Ataei et al. [16] | 2012 | Investigation of the production rate of diamond wire saw diamond wire saw using statistical analysis | Estimation of the production rate of carbonate rock using a diamond wire saw using the developed model |
| Ghaysary et al. [17] | 2012 | Investigation of the performance of diamond wire saw concerning texture characteristics of rock | It was concluded that area, perimeter, diameter equivalent, and index of grain size homogeneity are very effective in reducing the production rate of diamond wire saws. |
| Huang and Xu [18] | 2013 | Evaluation of the sawing performances of brazed diamond wire from the aspect of process parameters | Providing a basis for popularizing the brazed diamond wire |
| Sadegheslam et al. [19] | 2013 | Investigation of the production rate of diamond wire saws using multiple nonlinear regression analysis | It was concluded that the sawing speed of carbonate rocks using diamond wire saws can reliably be estimated. |
| Yarahmadi et al. [20] | 2014 | Recognition of dangerous incidents in quarries and investigation of safety risks of them | The high importance of cutting wire performance after transportation in Safety risks of quarries |
| Karakurt [21] | 2014 | Selecting optimal operating variables to obtain the minimum specific energy (SE) in sawing of rocks | Providing a prediction model that is highly useful for practical applications |
| Yurdakul [22] | 2015 | Investigation of the effect of the cutting mode, cutting depth, and feed rate on the level of consumed power during granite cutting using circular saw blades | Determining the effects of the cutting mode, cutting depth, and feed rate on the cutting efficiency and power consumption |
| Yilmazkaya and Ozcelik [23} | 2016 | Investigation of the effects of the wire rotational speed (peripheral speed) and wire descending speed (cutting speed) on unit wear and unit energy | Establishing the most appropriate usage of a mono-wire cutting system for all kinds of marble by determining optimum working parameters |
| Turchetta et al. [24] | 2017 | Analysis of cutting forces and the optimization of diamond bead wear | Evaluation of the torque that the wire as a function of applied tension and determining that the axial rotation of the wire made the entire bead surface work correctly |
| Almasi et al. [25] | 2017 | Analysis of bead wear in diamond wire sawing considering the rock properties | Predicting the wear rate of diamond beads as one of the principal performance criteria in dimension stone quarrying |
| Mikaeil et al. [26] | 2017 | Investigating the performance of diamond wire saw using the application of multivariate regression analysis | The results showed that the performance of diamond wire saws can reliably be predicted using the proposed models in carbonate rock sawing based on only physical and mechanical properties testing. |
| Yilmazkaya et al. [27] | 2018 | Investigating artificial neural networks (ANN) and regression models for predicting UW and UE as mono-wire cutting machine parameters | Concluding that the ANN-based models can be used for the prediction of reliable UE and UW parameters of mono-wire cutting operations |
| Mikaeil et al. [28] | 2019 | Evaluation and prediction of the performance of diamond wire saw | Classification of the performance of diamond wire saw according to its wear rate by some famous physical and mechanical properties of dimension stones |
| Akhyani et al. [29] | 2019 | Predicting wear performance of circular diamond saw in hard rock cutting process using combining fuzzy RES with GA | Predicting the circular diamond saw wear |
| Yarahmadi et al.[3] | 2019 | Optimizing the cutting direction parameter in cutting processes | Observation of different cutting directions with very diverse cutting rates and a direct relationship between the quartz content and the cutting rate |
| Rajpurohit et al. [30] | 2020 | Investigation of the statistical relationship between the Cerchar Hardness Index and diamond tool wear of diamond wire saw beads | Observation of a significant positive correlation between rock hardness and tool wear |
| Ziaei et al. [31] | 2020 | Evaluating abrasiveness of andesite rocks in the rock sawing process using A modified Schimazek's F-abrasiveness factor | Predicting the wear rate and cutting rate of andesite rocks using the Modified Schimazek's F-abrasiveness Factor |
| Gupta and Pratap [32] | 2021 | Investigation of the wear rate of the diamond tool segment by measuring the tip speed and spindle speed | The wear rate increases with the increase of tip speed and spindle speed |
| Amirsharafi et al. [33] | 2023 | Investigation of Cutting Rate of Diamond Wire Saw Machine Using Numerical Modeling | Predicting and improving the performance of diamond wire saw in granite stones' cutting |
| Rezaei and Nyazyan [34] | 2024 | Investigation of the cutting rate of diamond wire saw machine using numerical modeling | It was concluded that the horizontal drilling rate was more correlated to the rock's physical properties than its mechanical characteristics. This study's outputs were reliable and should be used to determine the horizontal drilling rate in practice. |

## 2. Specific energy in the cutting of dimension stones

Specific energy refers to the amount of energy required to extract, cut, or produce a unit volume of dimension stone. This value is affected by several factors, including the physical, mechanical, and microscopic properties of the dimension stone being cut, the specifications of the diamond wire components, and parameters related to the wire cutting machine. The general relationship for specific energy can be calculated using Equation 1[35].

$$SE_{cut} = E_t/Q \tag{1}$$

Where $SE_{cut}$ is the specific cutting energy in joules per cubic millimeter (J/mm3), Et is the total energy consumed during the cutting process in watt-seconds (W.s), and Q signifies the volume of the cut portion of the stone in cubic millimeters ($mm^3$). Additionally, the specific energy for each cut can be calculated using Equation 2.

$$SE_{cut} = Pt/V_f tdw \tag{2}$$

This paper calculates the specific cutting energy by measuring and recording the electrical power consumption (P) in watts, time duration (t) in seconds, depth of the cut (d) in millimeters, and average width of the cut area (w) in millimeters for each stone cut using Equation 2.

## 3. Laboratory Experiments

### 3.1. Stone cutting tests

The cutting experiments on stones were carried out using a laboratory-scale diamond wire cutting machine available at the Dimension Stones Laboratory of the Faculty of Mining at Isfahan University of Technology. The energy consumption was calculated by conducting experiments on stone samples. An illustration of the diamond wire cutting machine used, along with its various components, is provided in Figure 3.

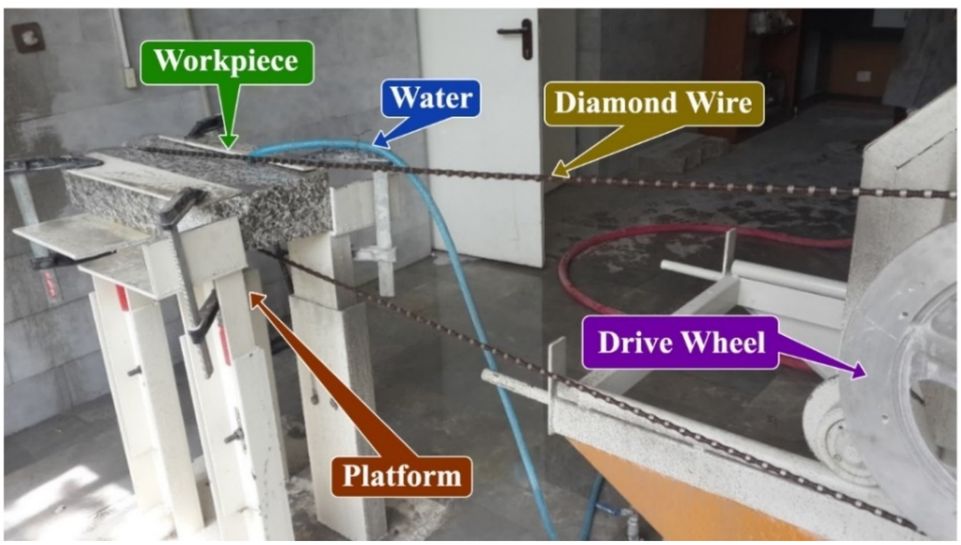


**Figure 3. A view of the laboratory diamond wire cutting machine in the process of cutting stone.**

The technical specifications of the machine used are provided in Table 2.

**Table 2. Technical specifications of the laboratory diamond wire cutting machine used**

| Tool properties | Description |
|---|---|
| Main motor power (KW) | 30 |
| Machine required voltage (V) | 380 |
| Linear speed (m/s) | 20–24 |
| Length of wire (m) | 5 |
| Pulley diameter (m) | 0.6 |
| Beads per meter | 36 |
| Bead type | Special for hard rocks |

To calculate the specific cutting energy, you need to follow a two-step process. Firstly, determine the cutting energy in joules by using two parameters - the average motor power (in watts) and the average cutting time for three work pieces (in seconds). Secondly, calculate the volume of material removed or cut from the stone by multiplying three parameters - the cutting height, cutting length, and thickness of the beads. Finally, divide the cutting energy and drilling volume to find the specific cutting energy for each stone. The values for motor power, cutting time, drilling volume, and calculated specific energy can be found in Table 3.

**Table 3. Calculation of specific cutting energy based on relevant parameters**

| Rock sample | Average power of motor (W) | Time (sec) | Cutting energy (J) | Cutting volume ($mm^3$) | Cutting specific energy ($J/mm^3$) |
|---|---|---|---|---|---|
| S1 | 24000 | 58.91 | 1365840 | 69283.9 | 19.71 |
| S2 | 24000 | 21.67 | 520104 | 30416.1 | 17.1 |
| S3 | 24000 | 26.48 | 635627 | 76052.5 | 8.36 |
| S4 | 24000 | 33.49 | 803653 | 43095.4 | 18.65 |
| S5 | 24000 | 89.61 | 2150533 | 113770.1 | 18.9 |
| S6 | 24000 | 24.89 | 597413 | 63193.7 | 9.45 |
| S7 | 24000 | 75.48 | 1811467 | 68485 | 26.45 |
| S8 | 24000 | 32.57 | 781787 | 52620.4 | 14.86 |
| S9 | 24000 | 22.24 | 533707 | 39924.5 | 13.37 |
| S10 | 24000 | 27.71 | 665147 | 72692.5 | 9.15 |
| S11 | 24000 | 18.44 | 442507 | 72916.4 | 6.07 |

### 3.2. Determination of cutting rates for stone samples

Apart from the specifications of the stone, the cutting rate also played a crucial role in predicting the specific cutting energy. The process of calculating the cutting rate is as follows: the cutting speed or cutting rate (CR) in square centimeters per second for each stage of the cut was calculated based on the recorded time, height of the sample (H), and the cutting length (L) in each stage. Tensile variations in each of these conditions were repeatedly read and recorded from a digital display (Figure 4).

**Figure 4. Recording the length and time of cutting for calculating cutting rate**

In Figure 5, the values of the cutting rates for each of the tested stones are presented.

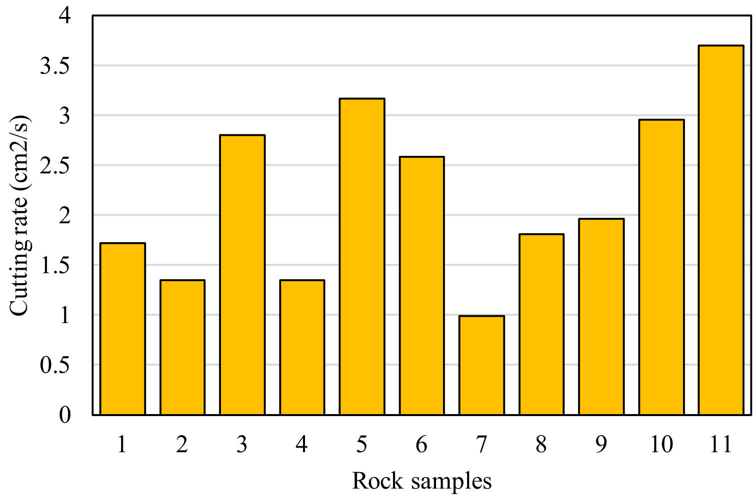


**Figure 5. Cutting rate values from cutting experiments.**

## 4. Determination of physical, mechanical, and microscopic properties of stone samples

This article uses 11 hard granite samples to evaluate and predict the specific energy required for diamond wire cutting. A view of the rock samples is shown in Figure 6.

The stones were first subjected to mechanical rock tests and cutting experiments, and their physical and mechanical properties were examined. Various criteria and parameters were used to determine the stones' properties, including Brazilian tensile strength, equivalent quartz content, average grain size, and density [36]. Some of the most influential experiments were conducted. Table 4 presents the results of these experiments along with the corresponding standards used.

**Figure 6. A view of 11 hard granite samples**

**Table 4. Conducted experiments with corresponding standards**

| Symbol | Concept | Type of properties | Summarized description of the test |
|---|---|---|---|
| BTS | Brazilian tensile strength | Mechanical properties | As stated by ASTM-C496-71 |
| EQC | Equivalent quarts content | Microscopic properties | $EQC = \sum_{i=1}^{n} A_i \times R_i$ (%) |
| Gs | Grain size | | determined from thin sections using a polarizing microscope and TS view software |
| D | Density | Physical properties | Density is the measure of a material's mass per unit volume (ISRM 1981) |

Below is a summary of the processes used during the laboratory tests described.

### 4.1. BTS test

The BTS tests were conducted on the core samples, which have a diameter of 54 mm and a height-to-diameter ratio of 0.5, according to ASTM D3967 in the laboratory (Figure 7).

### 4.2. Equivalent quartz content (EQC)

EQC was determined by studying thin sections (see Figure 8) to explain the effect of all rock minerals on tool wear. The EQC value is determined from Equation 2 [37]:

$$EQC = \sum_{i=1}^{n} A_i \times R_i \ (\%) \quad (3)$$

where Ai is the percentage of a mineral in the sample and Ri is the Rosiwal's hardness of the mineral [38].

Figure 7. Laboratory experiment to determine BTS.

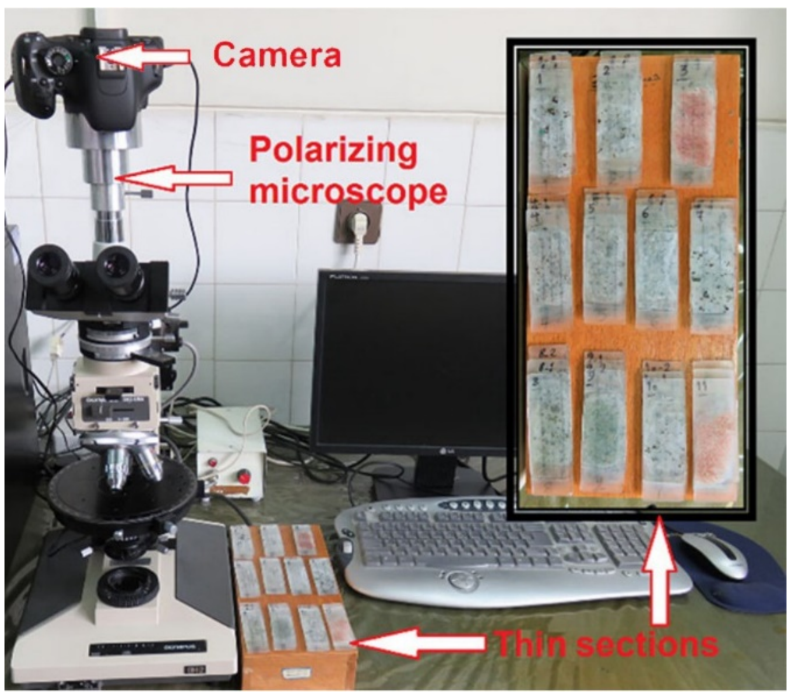


Figure 8: Microscopic and Thin sections studies.

### 4.3. Grain size.

The samples' mineralogical composition and average grain size were analyzed using a polarizing microscope, and TS view software (Figure 8). Equation 4 determines each particle's diameter equivalent or grain size (Gs) [17]. According to Equation 5, the average grain size for any given sample is calculated by taking the average of the grains' sizes in the thin sections.

$$Gs = \frac{\sum_{i=1}^{N} \sum_{k=1}^{n} D_k}{N \times n} \quad (4)$$

$$D_{eq} = \sqrt{\frac{4A_i}{\pi}} \quad (5)$$

Deq is the diameter equivalent in millimeters, Ai is the area of a grain (mm2), N is the number of thin sections, n is the number of grains in any thin section, and D is the diameter equivalent.

### 4.4. Density (D).

The density of rock samples was determined using the immersion method based on the ISRM standard. In this process, ten pieces of 50-55 grams were separated from each rock sample (it is important to note that the selected samples should not have any microcracks or defects). The samples were then saturated in water for an hour, and their weight was measured. Next, the samples were placed inside a floating basket in water to obtain their immersion weight. Finally, to measure the dry weight of the samples, they were placed inside an oven with a temperature of 105°C for 24 hours, and then their dry weight was measured. Having the saturated, immersion, and dry weights, we can calculate and evaluate the total volume of the sample and the volume of empty spaces in the sample [39].

## 5. Results and discussion

### 5.1. Rock properties determination

The schistosity of stones is determined by analyzing parameters such as the tensile strength, quartz content, and average grain size of the constituent minerals in each sample. In this study, Schimazek's abrasivity factor was used to measure abrasiveness. This factor was chosen because it measures abrasiveness directly and is based on the characteristics of the rock. Schimazek and Knatz developed the test, which involves creating a disk-shaped rock sample, polishing its surface with SiC240 powder, and placing it on a rotating plate. A St50 steel pin with a diameter of 10mm and strength of 700MPa is used to scratch the sample while rotating. The pin has a cone-shaped tip with an apex angle of 90 and a tip width of 0.3mm. The pin is fixed in a holder and is pressed on the sample with a weight of 4.5kg. The sample is rotated 100 times at a speed of 25 revolutions per minute, causing the pin to travel a distance of 16 meters on the sample. Finally, the pin's weight loss is measured. This procedure is repeated ten times, and the average of the results is reported as the abrasivity of the rock. This test is performed on concrete specimens with equivalent quartz content, tensile strength, and various grain sizes, and the relationship between these parameters and the weight of the steel pin is determined. The abrasivity factor (F) is calculated using Equation 5 [40-42].

$$F = \frac{EQC \times BTS \times \varphi}{100} \tag{5}$$

The equation uses EQC to represent equivalent quartz content in percentage, φ to represent the average grain diameter in millimeters, and BTS to represent the Brazilian tensile strength in MPa. F is a common measure to evaluate the abrasivity of rocks. Microscopic studies were conducted to obtain the schistosity values for the stone samples to determine the equivalent quartz content and average grain size of the constituent minerals in the stones. Additionally, the tensile strength of the rocks was determined using Equation 1, and the results were recorded in Table 5.

**Table 5. Results of microscopic and physical-mechanical property determination tests on stone samples.**

| Rock Samples | Properties | | | | |
|---|---|---|---|---|---|
| | BTS (MPa) | D (g/cm3) | GS (mm) | EQC (%) | Sfa (N/mm) |
| S1 | 12.8 | 2.59 | 2.719952 | 63.7815 | 22.2 |
| S2 | 10.67 | 2.63 | 3.697811 | 61.36184 | 24.22 |
| S3 | 6.36 | 2.33 | 1.731259 | 47.94129 | 0.81 |
| S4 | 10.22 | 3.04 | 3.593559 | 59.95476 | 22.03 |
| S5 | 6.27 | 2.82 | 3.751265 | 44.49274 | 10.47 |
| S6 | 7.89 | 2.59 | 3.191456 | 38.73543 | 9.75 |
| S7 | 14.98 | 3.06 | 2.655692 | 65.04349 | 25.88 |
| S8 | 15.12 | 2.63 | 2.808719 | 66.30254 | 28.16 |
| S9 | 10.18 | 2.63 | 3.635009 | 57.918 | 21.43 |
| S10 | 8.43 | 2.63 | 3.190241 | 50.079 | 13.47 |
| S11 | 8.83 | 2.58 | 3.712564 | 54.55145 | 3.51 |

After analyzing the characteristics of the rock samples, the researchers investigated and evaluated the relationship between each characteristic and the amount of energy required for cutting operations. The results showed that the amount of energy required decreased as the rocks' density increased and their porosity decreased. However, increasing the samples' tensile strength and abrasivity led to cutting with more resistance, resulting in higher energy consumption. As expected, the cutting rate is inversely proportional to the specific energy, meaning that the energy required decreases linearly in rocks where the cutting speed is higher since the amount of specific energy is directly proportional to the amount of cutting done.

### 5.2. Energy evaluation and development of specific energy prediction model

An assessment was conducted to determine the relationship between the physical, mechanical, and microscopic properties of the stone samples and the specific energy values obtained during the cutting operations. Initially, the input parameters, including stone properties such as density and schistosity, as well as the operational parameter of cutting rate, were examined for correlation. Figure 9 illustrates the correlation and relationship between these input parameters.

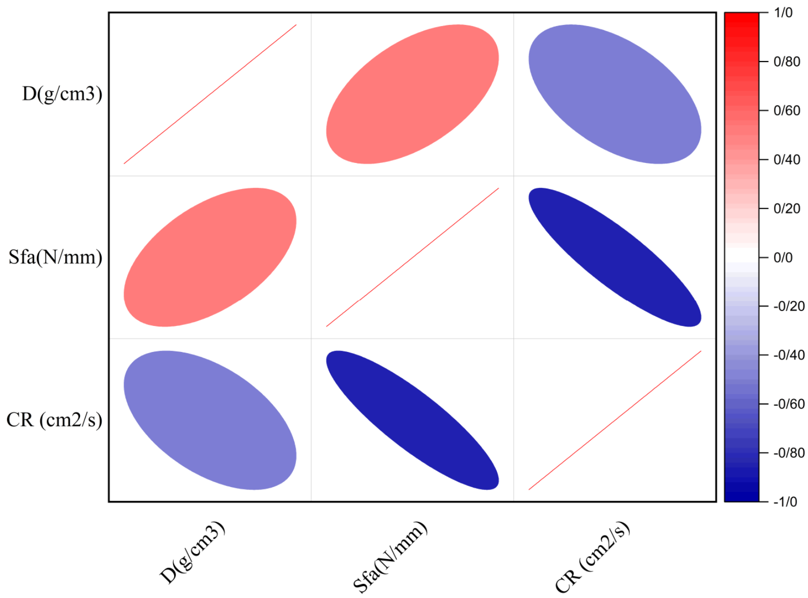


**Figure 9. Correlation matrix of input parameters**

Figure 6 shows that by examining the relationship between density, porosity, and cutting rate, it can be concluded that as the density of the rock samples increases, their porosity increases and the cutting rate decreases. Furthermore, increasing the porosity of granite rock samples decreases the diamond wire saw's cutting rate or cutting speed. A multiple linear regression method was used to investigate the relationship between rock properties and operational parameters with specific cutting energy consumption. As part of the evaluation of the proposed regression model, three rock samples, equivalent to 30% of the data, were selected as test data. Statistical analyses were performed to create a regression model on eight rock samples. The relationship between input parameters and cutting energy is shown in Table 6 using simple and multiple linear regression.

**Table 6. Results of Best Subsets Regression on Input Data**

| Variables | $R^2$ | $R^2$(adj) | $c_p$ | D(g/cm$^3$) | Sfa(N/mm) | CR(cm$^2$/s) |
|---|---|---|---|---|---|---|
| 1 | 85.8 | 83.4 | 6.1 | | | × |
| 1 | 67.7 | 62.4 | 18.9 | × | | |
| 1 | 47.3 | 38.5 | 33.5 | | × | |
| 2 | 93.3 | 90.6 | 2.8 | × | | × |
| 2 | 86.4 | 80.9 | 7.7 | | × | × |
| 2 | 82.7 | 75.8 | 10.3 | × | × | |
| 3 | 94.4 | 90.2 | 4 | × | × | × |

Table 6 displays that the specific cutting energy for stone can be accurately predicted using operational parameters and rock characteristics, resulting in a correlation coefficient 0.944. The relationship between input parameters and cutting energy is presented in Equation 6 using multiple linear regression.

$$SE(\text{J/mm3}) = 0.146 \times Sfa(\text{N/mm}) - 4.02 \times CR(\text{cm2/s}) + 12.21 \times D(\text{g/cm3}) - 13.5 \quad (6)$$

$R^2$=94.4%

Equation 6 demonstrates that the cutting specific energy decreases with an increased cutting rate. In contrast, an increase in the density and slenderness of the stones leads to an increase in specific energy. Figure 10 compares the actual specific energy values to the energy obtained from the model.

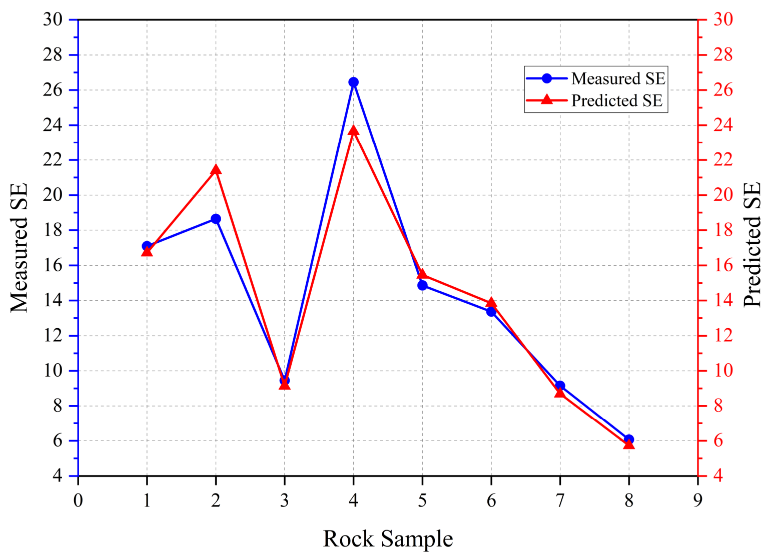


**Figure 10. Comparison of actual and predicted specific cutting energy values for rock samples.**

To verify the accuracy of the statistical model that was developed, we performed a prediction of specific energy consumed in cutting for three additional stone samples. We then compared the specific energy values obtained from the tested samples with the actual specific energy values using the developed model. Table 7 displays the specifications of each of the stones, along with the measured and predicted specific energy values.

To verify the accuracy of the developed statistical model, the specific energy consumed in cutting for three additional stone samples was predicted. Then, using the developed model, the specific energy values obtained from the tested samples were compared with the actual specific energy values. Table 7 displays the specifications of each stone, along with the measured and predicted specific energy values.

**Table 7. Measured and predicted SE for train rock samples using linear regression.**

| Rock samples | Parameters | | | | | | Measured SE | Predicted SE | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | D | BTS | GS | EQS | Sfa | CR | | | |
| 1 | 2.59 | 12.8 | 2.72 | 63.78 | 22.2 | 1.72 | 19.71 | 14.45 | 0.8269 |
| 2 | 2.33 | 6.36 | 1.73 | 47.94 | 5.3 | 2.79 | 8.36 | 4.46 | |
| 3 | 2.82 | 6.27 | 3.75 | 44.49 | 10.5 | 3.17 | 18.9 | 9.72 | |

After conducting thorough investigations, it has been established that various parameters directly influence specific energy values for stone cutting. This article examines the relationship between several parameters related to the cutting machine and the physical, mechanical, and microscopic characteristics of the stones associated with specific cutting energy. Statistical results indicate a strong correlation between specific energy and three parameters: stone density, cutting rate, and soundness. The developed model has been validated on other stone samples, demonstrating that it can predict energy values with an R2 of 0.83. The statistical analyses suggest that, with knowledge of stone characteristics, it is possible to accurately estimate the specific energy of cutting operations.

This study introduces an innovative method for predicting and characterizing energy consumption during diamond wire cutting of dimension stones. While traditional evaluation criteria like specific energy, production rate, and wear of diamond beads are still relevant, this research goes further by measuring specific energy and analyzing the impact of stone properties, such as density, strength, and cutting rate, on energy consumption. The study shows that understanding and using stone properties and operational parameters can indirectly monitor energy consumption and cutting machine performance more accurately. This advancement provides a valuable tool for optimizing diamond wire cutting processes, enhancing efficiency, and potentially reducing costs in dimension stone extraction operations.

## 6. Conclusions

Diamond wire cutting is now widely used in the stone industry for cutting and extracting dimension stone blocks. Therefore, it is crucial to have a method for evaluating the performance of this process. Various criteria are used to assess performance, predict outcomes, and calculate the required resources, including cutting specific energy. In this paper, to evaluate and analyze the relationship between the characteristics of stones under cutting and the specific energy of cutting operations, 11 samples of granite stones with different characteristics were selected and collected from quarries. After preparing the stone samples for tests and stone cutting tests, the stones' physical, mechanical, and microscopic characteristics were calculated according to the rock mechanics standards. Also, after cutting the stone samples and calculating each sample's cutting rate and specific energy, the relationship between the characteristics of the stones and specific energy was evaluated. Each input parameter was examined individually, and one parameter was selected based on its highest correlation with specific energy while being independent of other parameters. The chosen parameters were stone density, abrasivity, and cutting rate. These parameters were evaluated simultaneously using a multiple-variable linear regression model to predict the specific energy required for cutting operations. The developed model achieved an R2 value of 0.944, indicating high accuracy. Statistical evaluations, such as ANOVA analysis, confirmed the model's accuracy in predicting specific energy values. Data from three new stone samples were used to validate the model, and the predicted energy values were compared with the actual values. The presented model achieved an R2 value of 0.827, indicating high accuracy. Since the prediction of the specific energy of the cutting operation using indirect and accurate methods has received much attention in recent years, the results obtained in this study are exactly in line with previous studies in this field. The only difference between these studies is the characteristics of the rocks that are used to predict specific energy or different statistical models. Based on the study's findings, it can be concluded that the properties of dimension stones can be used to predict the specific energy required for cutting construction stones using diamond wire cutting without the need for specialized equipment. Using this method in real-time evaluation and prediction of energy consumption and monitoring the performance of the cutting machine will be very useful and efficient as an accurate and indirect method in the dimension stones cutting operation.

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# توسعه یک مدل جدید برای پیش‌بینی انرژی ویژه (SE) با هدف بهینه‌سازی اقتصادی و زیست‌محیطی عملیات سیم برش الماسه

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**چکیده:**

استفاده از دستگاه سیم برش الماسه روشی رایج برای استخراج سنگ‌های ساختمانی است. استفاده از این روش به عوامل مختلفی همچون مشخصات فیزیکی و مکانیکی سنگ، مشخصات برش و شرایط عملیاتی بستگی دارد. انرژی ویژه، نرخ تولید، بازدهی و سایش مهره‌های الماس ازجمله معیارهایی هستند که بر بهینه‌سازی اقتصادی و زیست‌محیطی این عملیات تأثیر می‌گذارند. در این مطالعه، انرژی ویژه فرآیند برش به‌وسیله سیم الماسه برای ۱۱ نمونه سنگ گرانیت اندازه‌گیری شد. با تجزیه‌وتحلیل تأثیر پارامترهایی مانند چگالی سنگ، تخلخل و نرخ برش بر مصرف انرژی این فرآیند، یک مدل رگرسیون خطی با ضریب همبستگی ۰.۹۴۴ برای پیش‌بینی انرژی ویژه برش سنگ‌ها ایجاد شد. تجزیه‌وتحلیل‌های آماری، ازجمله روش ANOVA، تائید کرده‌اند که مدل به‌طور دقیق مقادیر انرژی ویژه را پیش‌بینی می‌کند. داده‌های سه نمونه سنگ جدید برای اعتبارسنجی مدل مورداستفاده قرار گرفت و مقادیر انرژی پیش‌بینی‌شده آن‌ها با مقادیر واقعی مقایسه شد. مدل ارائه‌شده به مقدار ضریب همبستگی ۰.۸۲۷ دست یافت که دقت بالای آن را نشان می‌دهد. نتایج حاکی از آن است که مصرف انرژی در عملیات برش سنگ‌های ساختمانی را می‌توان به‌طور غیرمستقیم با استفاده از مشخصات سنگ و پارامترهای عملیاتی، با دقت بالا پیش‌بینی و مشخص کرد. این روش می‌تواند به‌طور دقیق و غیرمستقیم مصرف انرژی و عملکرد دستگاه برش را در حین عملیات برش سنگ‌های ساختمانی پایش کرده و برای بهینه‌سازی این فرآیند مورداستفاده قرار گیرد.

**کلمات کلیدی:** انرژی ویژه، سیم برش الماسه، سنگ ساختمانی، بهینه‌سازی اقتصادی و زیست‌محیطی، پیش‌بینی.