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

Mohammad Hossein Jalalian¹, Raheb Bagherpour^{1*}, Mehrbod Khoshouei¹, and S. Najmedin Almasi²

1. Department of Mining Engineering, Isfahan University of Technology, Isfahan, Iran

2. Department of Mining Engineering, Lorestan University, Lorestan, Iran

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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 (R^2) 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 R^2 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.

✉ Corresponding author: bagherpour@iut.ac.ir (R. Bagherpour)