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The use of acoustic emission technique in MWD for mine to mill approach as a smart tool for sustainable mining

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The Mine-to-Mill (MTM) approach is crucial in mining due to the high energy consumption and costs of comminution processes like crushing and grinding, which account for over 50% of total energy use. Optimizing these processes, starting from blasting, enhances efficiency and profitability. Accurate rock mass characterization is key to blasting optimization, and Monitoring While Drilling (MWD) provides real-time geotechnical data foron-the-spot adjustments. Acoustic emission monitoring, a leading MWD technique combined with intelligent models, offers promising results in rock characterization. This study employed a Support Vector Machine (SVM) model to predict rock mass properties from drilling acoustic signals. The model demonstrated high accuracy, achieving R^2 values of 0.976 (training) and 0.808 (testing). The Mean Absolute Percentage Error (MAPE) was 4.36% and 29.52%, while the Root Mean Squared Error (RMSE) reached 0.0486 and 0.141, the Mean Absolute Error (MAE) was 0.021 and 0.103, and the Mean Squared Error (MSE) was 0.0024 and 0.0199 for training and testing, respectively. These results confirm the model's reliability in estimating rock characteristics. Integrating acoustic emission monitoring with advanced modeling can enhance MTM strategies, reducing energy consumption, operational costs, and environmental impact in mining.

Keywords Mine-to-Mill (MTM), Acoustic emission, Monitoring while drilling (MWD), Environmental optimization, Mining automation, Support vector machine (SVM)

The modern economy relies heavily on the production of minerals. However, the mining industry globally consumes a significant amount of energy with very low efficiency, especially during the comminution process, to reduce the size of the mined material. In extracting hard rocks, the initial step involves blasting techniques to break the ore mass into different fragment sizes, commonly known as blast fragmentation. In subsequent operations like crushing and grinding, these fragments undergo further reduction into finer particles[1–3]. These processes, collectively called comminution, are critical in mineral processing, and grinding is generally the stage that consumes the most energy in mineral processing[4].

Overall, the mining operations have very low energy efficiency. For example, rock drilling has about 10% energy efficiency, rock blasting about 6%, rock crushing about 3–5%, and grinding about 1%[5–7]. Furthermore, rock comminution (including crushing and grinding) is associated with substantial energy consumption, representing approximately 4% of the world's total energy usage, 53% of the total energy used in mining, and 67% of total mining expenses. In comparison, the energy consumption related to drilling and blasting is considerably lower, constituting only 2% of the total mining energy and 5% of mining costs[8,9]. This inefficiency in energy usage and high energy consumption leads to significant energy wastage, causing the mining industry to lag behind other industrial sectors in terms of energy efficiency. Figure 1 illustrates energy distribution in different parts of the mining processes.

As shown in Fig. 1, from the point of view of energy consumption, rock crushing and grinding operations include a significant part of the total energy consumption of mining and are among the most consuming industrial operations in the world. These operations not only have a substantial impact on energy usage but also on mine productivity. Today's primary challenge in mining is the abundance of low-grade and widely dispersed mineral reserves. Reducing these low-grade reserves to liberate valuable minerals requires substantial energy input during crushing. Consequently, there is a pressing need to develop solutions that minimize energy consumption in mineral comminution operations. Based on the information presented, it can be inferred that

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