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An intelligent approach to predict the drilling penetration rate using acoustic emission technique (AET)

Mehrbod Khoshouei, Raheb Bagherpour✉, Mohammad Hossein Jalalian & Ehsan Purhamadani

Optimization has become a central concern in geotechnical engineering with increasing constraints on energy resources and the rising demand for cost-effective operations. Drilling, as a critical and energy-intensive component of mining and tunneling (particularly in transportation infrastructure), requires efficient and intelligent performance strategies. Monitoring While Drilling (MWD) provides a promising approach for real-time acquisition of drilling conditions. Recent advancements, including the integration of Acoustic Emission Technique (AET) with artificial intelligence (AI), enhance data-driven modeling and predictive analysis of drilling performance. In this study, vibroacoustic signals and drilling parameters were analyzed to predict penetration rate (PR) using three machine learning models: Artificial Neural Network (ANN), Random Forest (RF), and Support Vector Regression (SVR). Comparative evaluation showed that all three models achieved reliable predictive accuracy, with ANN reaching $R^2 = 0.744$, MAPE = 36.98%, RMSE = 0.161; RF yielding $R^2 = 0.816$, MAPE = 31.54%, RMSE = 0.142; and SVR attaining $R^2 = 0.808$, MAPE = 29.52%, RMSE = 0.141. The results demonstrate the feasibility of integrating vibroacoustic monitoring with AI-driven models for accurate PR prediction. This approach supports real-time decision-making, enhances drilling efficiency, and promotes sustainable practices in both underground and surface excavation projects.

Keywords Artificial intelligence (AI), Penetration rate, Acoustic emission technique (AET), Monitoring while drilling (MWD)

Drilling is recognized as one of the most complex and cost-intensive operations in geotechnical engineering, particularly in the fields of mining, tunneling, and construction1. This operation significantly impacts both capital and operational expenses. In mining, drilling influences production costs and overall operating expenses[2]. More than 25–35% of mining operation costs are related to drilling[3,4]. Drilling plays a crucial role in tunneling and mining, particularly in hard rocks, where it is used for creating blast holes, bolting for rock reinforcement, coring, water drainage, and monitoring deformations or fractures in the rock mass[5]. The effectiveness of drilling directly impacts achieving the desired rock fragmentation in mining[6].

Rock drilling is conducted using various techniques depending on the hardness of the rock. In extremely hard rocks, rotary-percussive drilling is employed, while in medium-hard rocks, rotary-crushing drilling is used, and in soft rocks, cutting methods are applied[2]. In rotary drilling, drill bits penetrate rocks ranging from soft to extremely hard. The borehole diameters in this method can range from 150 to 455 millimeters[7]. Today, this drilling equipment is widely used in large open-pit mines for creating blast holes with large diameters, and different types of this equipment are designed to accommodate a wide range of drilling parameters suited to specific drilling conditions[8,9].

Given the significant costs associated with drilling, optimizing this process is essential. The primary goals of drilling optimization, especially in the early stages, include reducing drilling time, lowering drilling costs, and enhancing efficiency[10,11]. The drilling process is inherently complex, with factors influencing its performance categorized into three main groups: parameters related to the drilling machine and cutting tool, rock properties, and operational parameters[12,13]. A thorough understanding and optimization of these parameters are crucial for improving drilling efficiency and effectiveness. Figure 1 shows some of the parameters affecting drilling performance.

Department of Mining Engineering, Isfahan University of Technology, Isfahan 8415683111, Iran. ✉email: bagherpour@iut.ac.ir