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An experimental study on the effect of rock properties on the production of fine materials by a conical pick

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This study examines how rock properties affect the production of fines and chips during rock cutting, a crucial aspect of mechanized excavation science that dictates cutting efficiency and excavator performance. Small-scale linear cutting tests using a conical tool were conducted on thirteen rock specimens made up of sedimentary and metamorphic rocks. Unrelieved mode cutting depths ranged from 0.5 to 6 mm, with fines production quantified through sieve analysis. Mechanical properties, including uniaxial compressive strength (UCS), significantly affected fines: the greater the UCS, the lower the fines due to microcrack extension. At greater strengths and cutting depths, however, the force to break rock resistance enlarged the crushed zone, sometimes contributing to an enhancement in fines production. Also, among the physical properties of rocks, an increase in density and a decrease in porosity lead to a reduction in fine grains, greater rock compaction, and an increase in the amount of chips. Microscopic properties indicated texture coefficient to be the most influential factor, with greater texture coefficient making the rock stronger and favoring crack propagation to the free surface to minimize fines. Shape factor was the least contributing factor. The study shows how rock properties control cutting behavior, giving insight into the optimization of excavation performance through a better understanding of fines, chips, and crack growth mechanisms.

Keywords Linear rock cutting, Mechanical excavation, Fines and chips formation, Rock properties

The efficiency of the rock cutting process plays a crucial role in shaping the economic aspects of mechanized excavation. The size distribution of the particles (fine material and chip) generated during excavation in competent rock formations exhibits a direct correlation with cutting efficiency. This distribution can also provide valuable insights into the excavation process and the mechanisms involved in rock breaking[1]. In the field of mechanized excavation research, numerous comprehensive studies have been undertaken to investigate the production of fine material (FM) and chip material (CH) resulting from rock cutting. These studies investigate the characteristics of FM and CH and analyze their influence on excavation performance[1–24]. Jeong and Jeon (2018) found that, in linear cutting tests of sandstone, the chip size distribution (analyzed using sieving and image processing) peaks at the optimal cut spacing and shows a strong correlation with cutter forces and specific energy[19]. Mohammadi et al. (2019) revealed that chip geometry, characterized by very platy and bladed shapes and an inverse exponential correlation between specific energy and particle size indicators (e.g., median size, coarseness index), significantly influences rock cutting efficiency[2]. Hou et al. (2021) demonstrated that mechanical specific energy in PDC bit rock cutting decreases exponentially with increased cuttings size, with the coarseness index significantly influenced by depth of cut and rake angle[17]. Bejari and Khademi Hamidi (2023) demonstrated that water saturation reduces chisel pick production capacity, decreases chip size, and increases fine material production in rock cutting, highlighting the need for further investigation into environmental effects on excavation performance in the present study[13]. Kadkhodaei et al. (2024) investigated the ductile-to-brittle transition in rock cutting using a conical tool on sedimentary and metamorphic rocks, demonstrating that cutting depths below the critical value produce high fines under ductile failure mode and developing a support vector machine model to accurately evaluate the fines-to-chip transition zone[25]. Kadkhodaei et al. (2024) found

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