Bulletin of Engineering Geology and the Environment (2024) 83:276
https://doi.org/10.1007/s10064-024-03771-1

ORIGINAL PAPER

Evaluation of fine material and chip formation in rock cutting with a conical tool

Mohammad Hossein Kadkhodaei[1] · **Ebrahim Ghasemi**[1] · **Jafar Khademi Hamidi**[2] · **Jamal Rostami**[3]

Received: 16 December 2023 / Accepted: 3 June 2024

Abstract

The production of fines and chips during rock cutting plays an essential role in the efficiency of rock cutting, which in turn impacts productivity and performance of mechanical excavators. In this study, small scale linear rock cutting experiments were conducted using a conical tool on thirteen sedimentary and metamorphic rock samples to evaluate the transition between ductile to brittle cutting mode by examining the volume of fines versus chips produced in the process of cutting. Cuts with depths of 0.5, 0.8, 1, 2, 3, 4, 5, and 6 mm were made to investigate the production of fines and chips in unrelieved cutting mode. The forces acting on the conical tool, cutting rate, and volume of fines were measured. Initially, the critical cutting depth was determined by analyzing the cutting force signals, aiming to identify both ductile and brittle cutting failure zones. Subsequently, the percentage of fines were classified into three classes using the hierarchical clustering algorithm. Finally, the support vector machine algorithm was employed to create a two-dimensional space utilizing cutting parameters, enabling the identification of the fines to chip transition zone. The effective cutting depth was determined based on specific energy variations, and subsequently, the effective limit was determined in the fines transition zone. The results showed that cutting depths lower than the critical value lead to the production of high fines under ductile failure mode. Also, the results obtained from assessing the performance of the two-dimensional fines space, predicated on cutting parameters, demonstrated that the developed model effectively evaluates the fines transition zone with a high level of accuracy. The results of this study can help in managing the fines production.

Keywords Linear rock cutting · Mechanical excavation · Fines volume · Chip formation · Cutting rate · Support vector machine

Abbreviations

FM	Fine material
CH	Chip
UCS	Uniaxial compressive strength
BTS	Brazilian tensile strength
D	Density
P	Porosity
F_{Tmax}	Maximum resultant force
F_{Tavg}	Average resultant force
d	Cutting depth
ΔF	Cutting force difference
ΔT	Cutting time difference
Ra	Ratio of cutting force difference to cutting time difference
SLR	Slope of the linear fit
HC	Hierarchical clustering
CR	Cutting rate
SVM	Support vector machine
SVC	Support vector classification
OAO	One-against-one algorithm
OAA	One-against-all algorithm
SE	Sensitivity
AC	Accuracy
SP	Specificity
MCC	Matthew's correlation coefficient

✉ Ebrahim Ghasemi
e_ghasemi@iut.ac.ir

1 Department of Mining Engineering, Isfahan University of Technology, Isfahan 8415683111, Iran

2 Mining Engineering Department, Faculty of Engineering, Tarbiat Modares University, Jalal Ale Ahmad Highway, P.O. Box 14115-111, Tehran, Iran

3 Department of Mining Engineering, Earth Mechanics Institute (EMI), Colorado School of Mines, Golden, CO, USA

Published online: 13 June 2024