# CUTTABILITY ASSESSMENT OF UPPER RED SANDSTONE USING SMALL SCALE LINEAR ROCK CUTTING TEST

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***Abstract:*** Design, selection and performance prediction of excavators are very delicate for project planning and cost estimation in mechanical mining and mechanized tunneling. Rock cuttability assessment in mechanized excavation includes investigation of rock mechanical behavior and rock-cutting tool interaction. Use of laboratory scale rock cutting tests is the most reliable method for accurate assessment of rock-tool interactive behavior in a situation close to its actual field condition. In this study, small scale linear cutting test was used for evaluating the rock cuttability and its relationship with rock mechanical parameters. To perform this action, rock samples of Upper-red sandstone were prepared for rock physical and mechanical characterization tests. The results obtained from cutting tests revealed that the cutting depth has a direct linear and a non-linear relationship with the cutting force, and the specific energy, respectively. Also, the cutting velocity showed no significant relationship with cutting force and specific energy. Moreover, the cutting forces obtained from the experiments showed a good agreement with those obtained from the theoretical model developed by Evans. However, these results are preliminary and need to be further verified with much larger cutting tests on various rock specimens.

***Keywords:*** Rock cutting test, cutting forces, specific energy.

## INTRODUCTION

In mechanical mining, rock cuttability assessment is crucial for selecting and designing the machine and predicting its performance. Rock cuttability is defined as the ease or difficulty of rock breakage by mechanical tools and is usually expressed by specific energy (SE), as well as cutting forces. The SE is defined as the energy required to cut a unit volume/weight of the rock. The most reliable and cost-effective method for determining the cuttability is laboratory scale rock cutting test. In this case, selected rock specimens taken from the project site are transferred to the laboratory and cut using small scale or full scale cutting tests. The small scale rock cutting test is cheaper and easier to run compared to the full scale rock cutting test. To date, the rock cuttability and its relationship with rock properties, tool and cutting geometry in experimental scheme using linear rock cutting tests have been the research subjects of many researchers. For example, Baraker (1964) used pointed and chisel shaped tools to determine cuttability and coarseness index (CI) of sandstone. Roxborough and Rispin (1973) carried out a series of rock cutting tests on Lower Chalk using V-shaped disc cutters. They found that the specific energy decreases with increasing CI. A simplified energy model was developed by Rånman (1985) to estimate the mean and peak forces from input energy per unit of cut length. Roxborough and Liu (1995) developed a model that considers the effect of friction and radius of the hole for point attack tools. Goktan (1997) proposed a modified equation for point attack pick based on Evans's theory. Tiryaki and Dikmen (2006)

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investigated the effects of rock properties on specific cutting energy in linear cutting of Sandstones. Bilgin et al. (2006) investigated the dominant rock properties affecting the performance of conical picks by running full-scale cutting tests and compared the experimental and theoretical results. More recently, Tumac et al. (2018) investigated the effect of textural properties of natural stones such as texture coefficient, packing weighting, and grain size on the cutting performance of a standard chisel tool.

In present study, a set of experimental small scale cutting tests was carried out on an upper-red sandstone using a simple chisel pick. The main objective of this study is to investigate the factors influencing the rock cuttability and confirm the results with those obtained from theoretical models.

## METHODS

In this study, several rock block samples were taken from the upper-red sandstone formation located southwest of Qom, central Iran, and transferred to the mechanised excavation laboratory (MEL) of Tarbiat Modares University. A small scale linear cutting machine (SSLCM), developed at MEL was used to evaluate the cuttability of rock samples. Also, the main physical and mechanical properties of rock samples were measured from the laboratory tests according to ISRM suggested methods (Ulusay and Hudson, 2007). Rock cutting experiments were carried out on 76 mm diameter core samples. The cutting forces were measured and recorded with dynamometer and datalogger, respectively. All rock chips were collected after cutting tests and weighted to determine the specific energy. The influence of cut depth and cutting velocity on cutting force and SE was investigated. Moreover, the cutting forces obtained from the experiments were compared with the results achieved by Evans's theoretical model.

## FINDINGS AND ARGUMENT

Analysis results showed that variations in cutting force and specific energy with depth of cut are well fitted with nonlinear curves. Cutting force revealed a direct non-linear relationship with depth of cut, while the specific energy was fitted with a U-shaped curve. The latter is not in agreement with several studies and it could be due to the limited number of datasets. Also, the results revealed that variation in cutting velocity does not significantly change the values of cutting force and specific energy. This is in agreement with the findings reported in several studies.

In addition, in order to check the validity of the experimental results, the cutting forces obtained from experiments were compared with those of theoretical model developed by Evans (1962). The result shows that there is a good consistency between the experimental data and theoretical model results.

In Figs. 1 and 2, variations in cutting force with depth of cut and cutting velocity are shown.

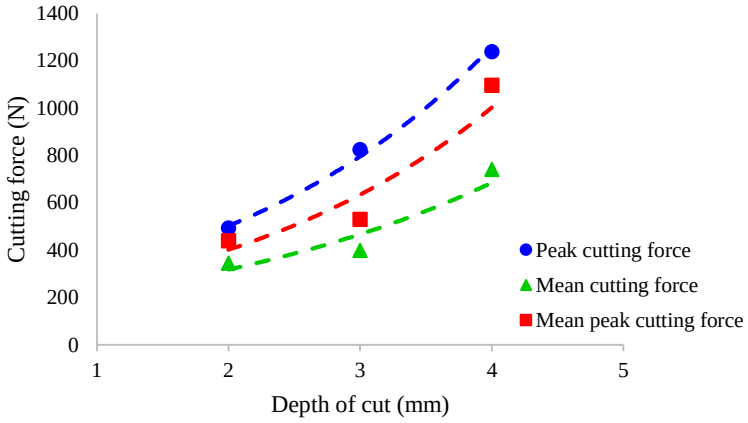


**Fig. 1** Variation in cutting force with depth of cut

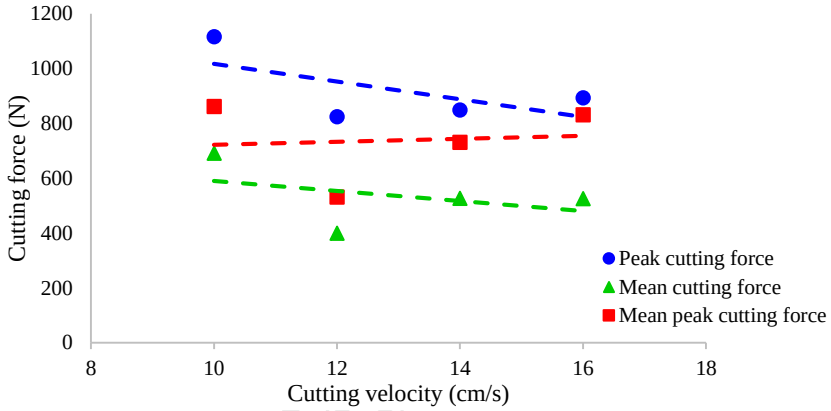


**Fig. 2** Variation in cutting force with cutting velocity

## CONCLUSIONS

Small-scale rock cutting test is one of the simplest practical tests for assessment of rock cuttability that gives good results in order to control the cutting process in the laboratory. This test is to correlate the rock cuttability determined in the lab with the rock machinability required for machine design in the field. In the present study, the influence of two rock cutting parameters, including depth of cut and cutting velocity, on cutting force and specific energy were investigated. The analyses revealed that the cutting force and specific energy respectively show linear and nonlinear relationships with the cutting depth, respectively. Also, the cutting velocity showed no meaningful correlation with either cutting force or specific energy. The cutting force obtained from rock cutting tests was compared with that of Evans's rock cuttability model. The comparison revealed that there is a good consistency between the results of experimental tests and theoretical model. However, further experimental investigations are underway to expand the findings of this study.

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