The 2021 International Conference on Tunnels and Underground Spaces (ICTUS2021), August 25-26, 2021, Seoul, Korea

Characteristics of cutting behavior of a pick cutter in hard rock

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Introduction

Recently, roadheader is considered as an excavation method in various tunnel and underground space development projects planned in Korea. In the applications, major potential problems are the decrease in cutting performance in hard rocks and the excessive wear of a pick in abrasive rocks. In order to assess the applicability of pick cutters in abrasive hard rocks, this paper performed the linear cutting machine (LCM) test using a pick cutter for hard rock specimen. The results indicated that excessive cutter forces and specific energy will be required to break the hard rock. Also, additional problems related to the wear of a cutting tool and the mechanical stability of a pick holder were observed in the LCM test. Based on the results, this paper discusses the possible problems when the pick cutters are applied to hard rock formation and the major issues to be addressed in the future.

LCM test condition

The LCM system used in this study has a 20-ton loading capacity and can provide sufficient stiffness for a pick cutter during the linear cutting test. The gneiss specimen which can be considered as an extremely hard rock, was cut to the dimension of 300 mm × 300 mm × 200 mm for the test. The cut spacing was fixed as 12 mm, and the depth of cut was considered as 4 levels (1.5, 2.0, 4.0 and 6.0 mm). The two cutting angles of a pick, i.e., attack and skew angles were set as 45˚ and 5˚, respectively.

Fig. 1. Experimental set-up of the LCM test

Table 1. Mechanical properties rock used in LCM test

Density (g/cm^3)	Uniaxial compressive Strength (MPa)	Brazilian tensile strength (MPa)	Young`s Modulus (GPa)	Poisson`s ratio
2.62	245.01	11.19	33.65	0.22

Results

- **Cutter forces**

The three force components (normal, cutting and side) linearly increased with depth of cuts. This trend is consistent with the results of previous studies. In particular, both mean and peak cutter forces drastically increased at the 4 mm of depth of cut.

Table 2. Result of cutter forces obtained from the LCM

Depth of cut (mm)	Cutter forces (kN)					
	Mean			Peak		
	Side	Cutting	Normal	Side	Cutting	Normal
1.5	3.33	15.79	17.06	9.02	36.78	46.98
2.0	1.76	17.16	20.11	5.19	37.27	48.85
4.0	13.83	28.84	47.67	24.62	52.18	83.77
6.0	15.69	29.13	55.52	30.70	54.73	110.16

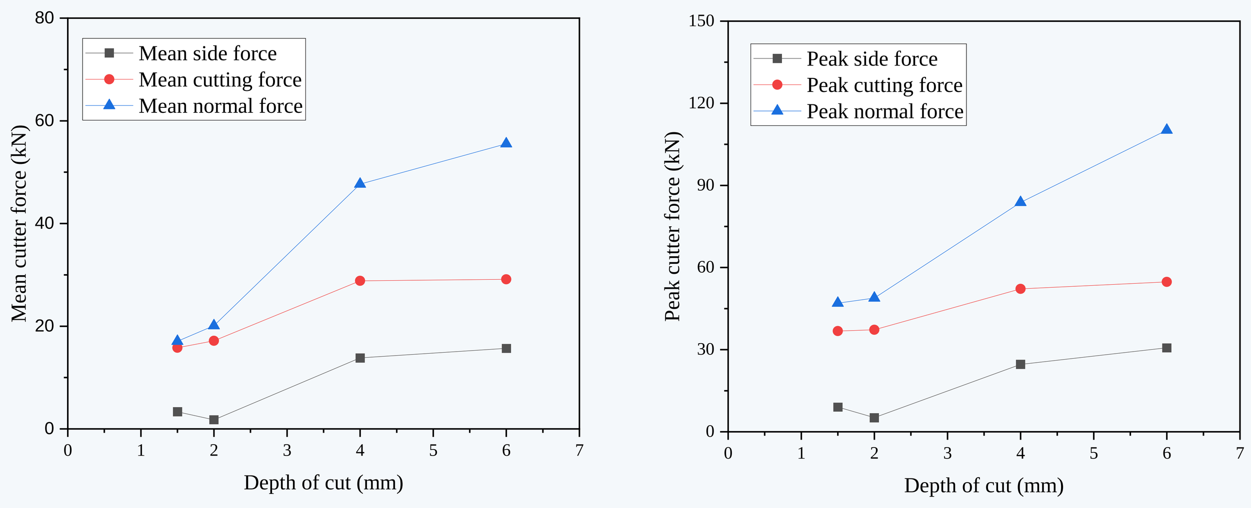

Fig. 2. Mean and peak cutter forces in LCM test

Results

Also, the cutting and side coefficients are calculated as 0.59 and 0.26, respectively. The result of cutting coefficient indicated that cutting an extremely hard rock requires higher attack angle than 45˚. On the other hand, the ratio of peak force to mean force in hard rock falls within the range reported in the previous studies.

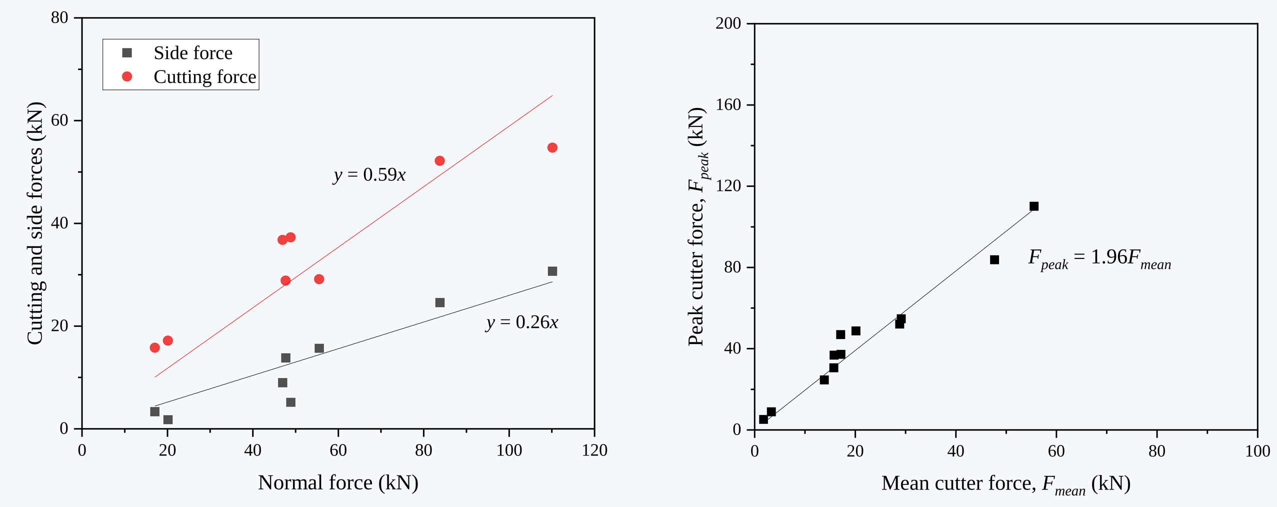

Fig. 3. The relationship between cutter forces obtained from the LCM

- **Specific energy**

In this study, the specific energy decreased with the depth of cut, and optimum value was not found due to the lack of testing data. Based on the literature, the specific energy of pick for soft to medium rock (under 100 MPa) did not exceed tens of MJ/m^3. However, the results showed that the specific energy in this study exceeds hundreds of MJ/m^3. It indicated that the cutting extremely hard rock with conical pick is not efficient significantly.

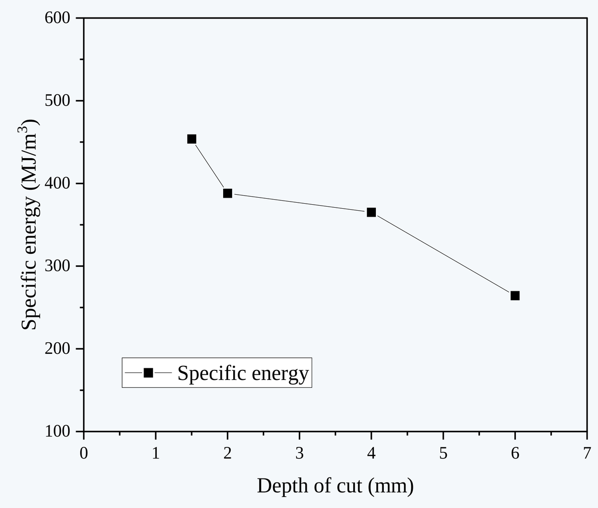

Fig. 4. Effect of s/d ratio on SE

Depth of cut (mm)	Cut spacing (mm)	s/d	Specific energy (MJ/m^3)
1.5	12	8	453.67
2.0	12	6	388.05
4.0	12	3	365.09
6.0	12	2	264.33

Table 3. Result of specific energy obtained from the LCM

- **Potential problems in hard rock cutting of pick**

In hard rock excavation using roadheader, major potential problems might be the decrease of cutting performance in hard rocks and the excessive wear of a pick in abrasive rocks. After the cutting tests, tip and body of pick was severely worn although the pick traveled only 10 m. Also, the tearing in welding part between the pick holder and plate was observed during the test.

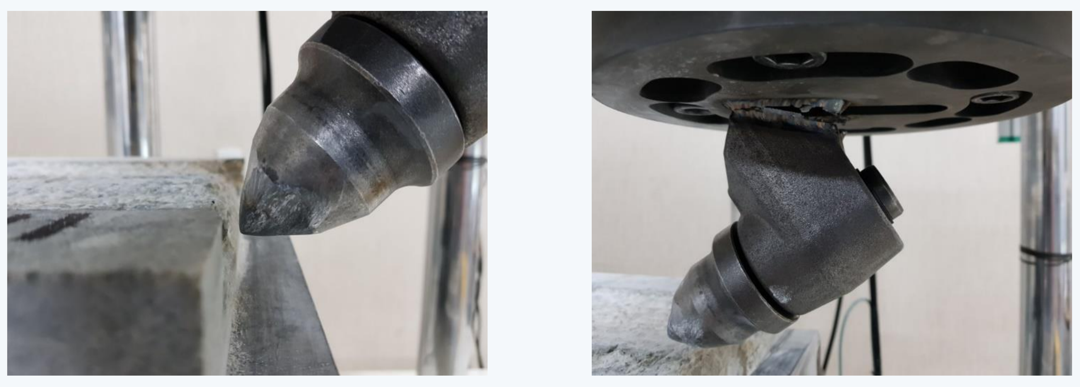

Fig. 5. Wear and stability problems of pick observed in the LCM test

Conclusions

This study tried to evaluate the cutting performance of pick under extremely hard rock, and to investigate the cutting characteristics of pick. In order to assess the applicability of pick cutters in abrasive hard rocks, the linear cutting machine (LCM) test was performed using a pick cutter for hard rock specimen. The results indicated that excessive cutter forces and specific energy will be required to break the hard rock. Also, additional problems related to the wear of a cutting tool and the mechanical stability of a pick holder were observed in the LCM test. It means that The results of this study can be useful information when the pick cutters are applied to hard rock in the future.

ACKNOWLEDGEMENT
This research was supported by a grant (21CTAP-C164190-01) from Technology Advancement Research Program (TARP) funded by Ministry of Land, Infrastructure and Transport of Korean government.

Paper ID: T1403-7028