Kinematic simulation of rock cutting performance of a 130t Roadheader in Korea

Mun-Gyu Kim, Hyun-Jun Park, Joo-Young Oh, Chang-Heon Song, Jung-Woo Cho
Kitech (Korea Institute of Industrial Technology), Gyeongsan-si, Republic of Korea

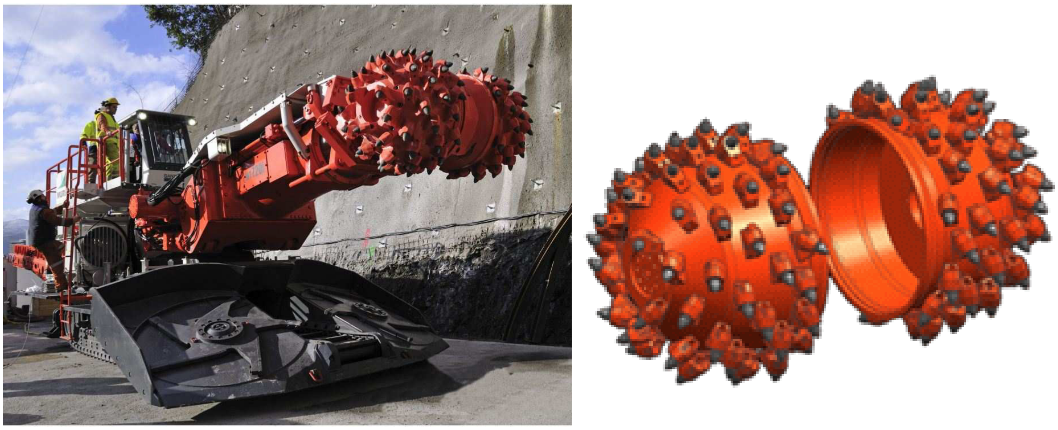
Ho-Young Jeong
Pukyong National University, Busan-si, Republic of Korea

ABSTRACT: Roadheaders are being adopted to tunneling site in the South Korea because of the vibration issues of the conventional blasting method. Their tunnelling data for the Korean rocks has not been reported, Korean constructors are curious about the cutting performance of the machines. The study modelled the cutting head of 130 ton Roadheader and rock surfaces cut by it. The contacts between pick cutters and rock were defined by a kinematic software. A series of cutting operations (i.e., sumping and shearing processes) was simulated. Four classes of rock strength were considered as rock models. The cutting forces and torque was obtained from the simulation. The results showed that the torque level of current machine can penetrate up to the medium strength rock in the sumping process. In the shearing process, the cutting head can cut through up to hard rock.

Keywords: Roadheader, cutting head model, Kinematic simulation, cutting force, torque.

1. INTRODUCTION

Roadheaders are being adopted to tunneling site in the South Korea because of the civilians' complaints about noise and vibration of the conventional blasting method. Their tunneling data for the Korean rocks has not been reported, many engineers are curious about the maximum cutting performance of the machines. The study modeled the cutting head of 130 ton Roadheader (Figure 1(a)) and rock surfaces cut by it. The shearing height was simulated by varying the shearing height and sumping depth. Figure 1(b) shows the features of a cutting head modeled in the study. The cutting motors power is 300 kW, 72 picks are welded on each side of the head (Figure 1(b)). The optimum range of operation for rock strength is 40-100 MPa (Sandvik, 2016).

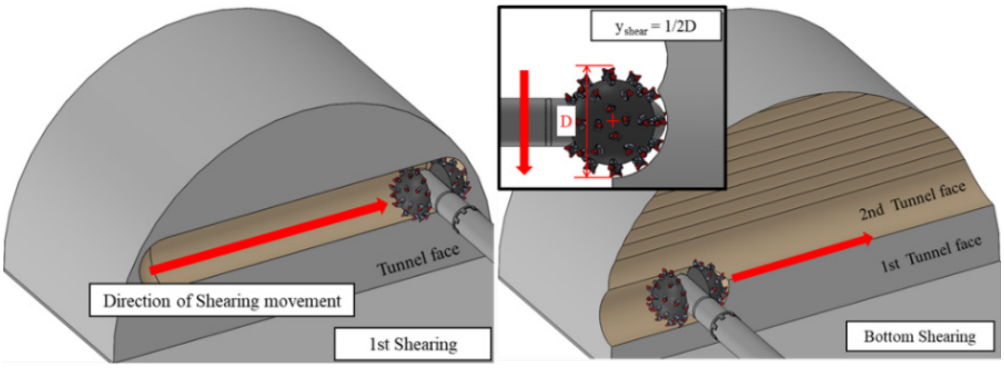


(a) Photograph of 130 ton Roadheader (b) Cutting head

Figure 1. Roadheader model for tunneling in Korea (Sandvik, 2016).

2. ROCK CUTTING PROCESS

The cutting processes for tunneling of roadheader are illustrated in Figure 2. The sumping process is combination of and slewing motion. After indenting into rock surface until the half diameter of cuttinghead are inserted, slewing is done right after indenting. The shearing process is the common process that consumes most of working time, the vertical shearing height (y_{shear}) has to set the optimum value to enhance the net cutting rate.

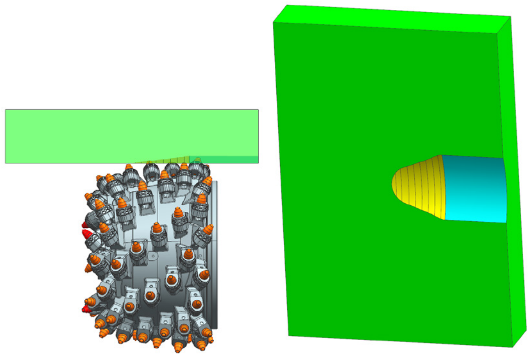


(a) Sumping (b) shearing

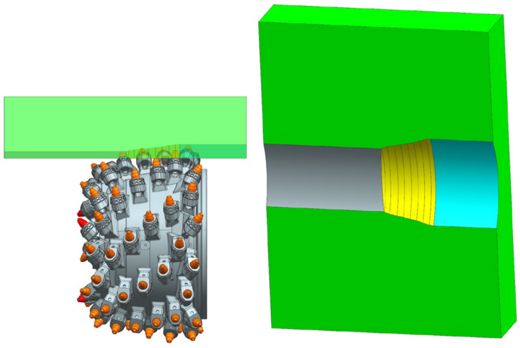
Figure 2. The cutting processes for tunneling of the roadheaders.

3. SIMULATED CONDITIONS

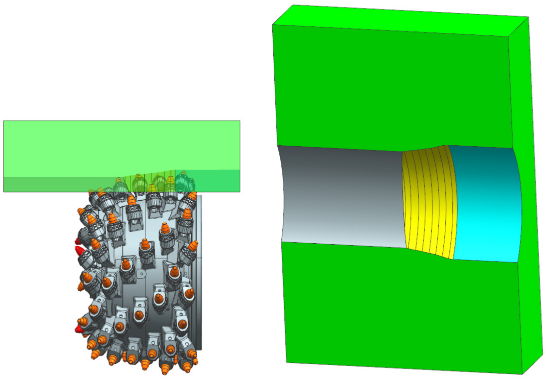
The shearing height for the modeled cutting head was simulated at predesigned shearing and sumping depths. Four rock classes of uniaxial strength (UCS) were simulated. In the simulation, the sumping and shearing trajectories were constant regardless of the UCS. Figure 3 shows the sumping depth at each cuts, and the contact surfaces during the sumping process. The sumping depth was increased with 50 mm step by step. For example, the first sumping cut has cutting depth of 50 mm (Figure 3(a)), second one has 100 mm (Figure 3(b)), respectively. In the model, gray color represents the cut surface by previous sumping region, blue represents sumping surface at current process, and yellow represents currently contacted surface. The mean cutting depth of each pick was set to 2.0 mm.



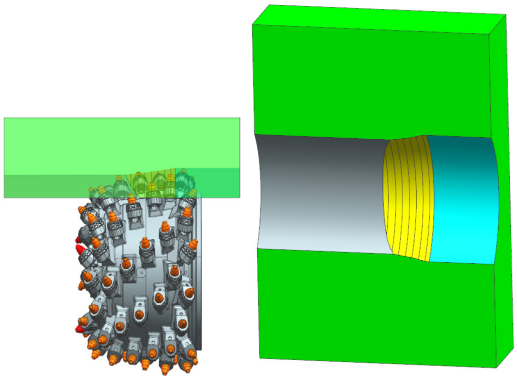
(a) 0 to 50 mm



(b) 50 mm to 100 mm



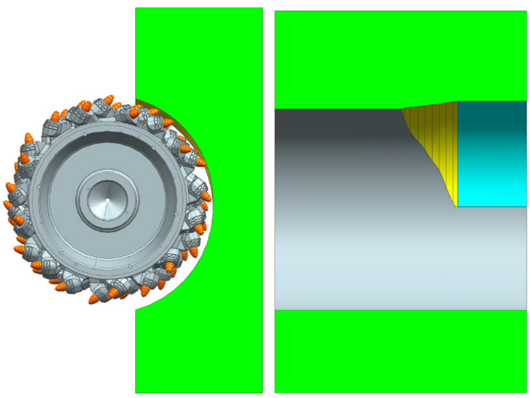
(c) 100 mm to 150 mm



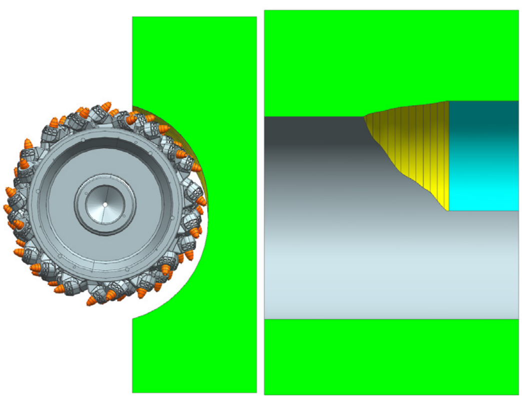
(d) 150 m to 200 mm

Figure 3. The cutting depth in each sumping simulation.

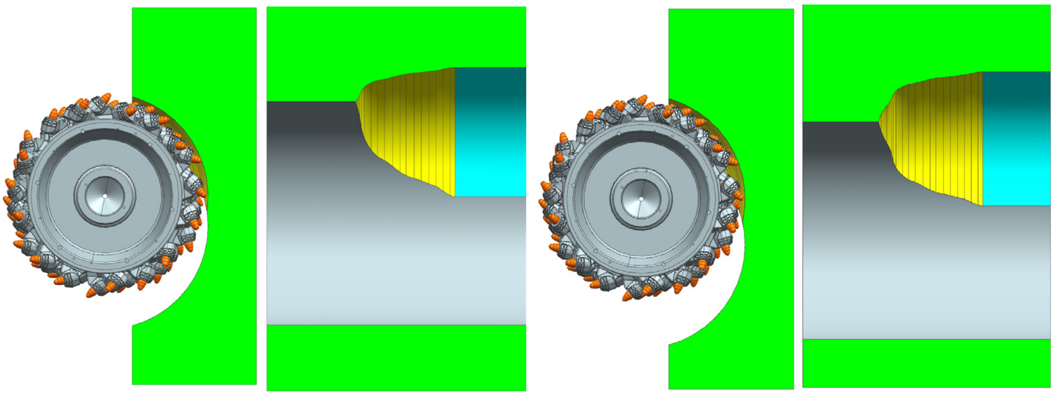
The shearing process conducted after sumping process was also modeled and simulated (Figure 4). The vertical shearing height is considered as the main variable in the simulation. The mean cutting depth of each pick is determined by shearing height. For example, for the values of shearing heights of 50 mm, 100 mm, 200 mm, and 300 mm were the cutting depth of each pick was determined as 2.02 mm, 3.51 mm, 4.7 mm, and 5.8 mm, respectively.



(a) 50 mm



(b) 100 mm



(c) 150 mm (d) 200 mm

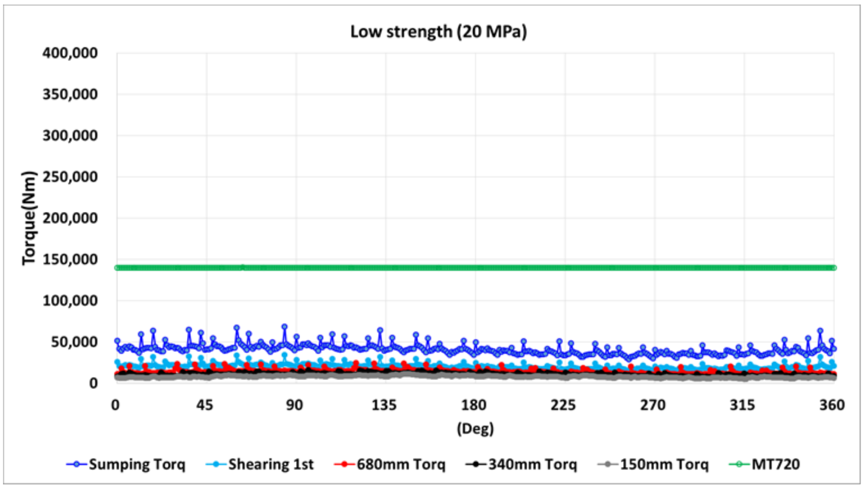
Figure 4. The cutting head contact areas at different shearing height.

4. RESULTS AND CONCLUSIONS

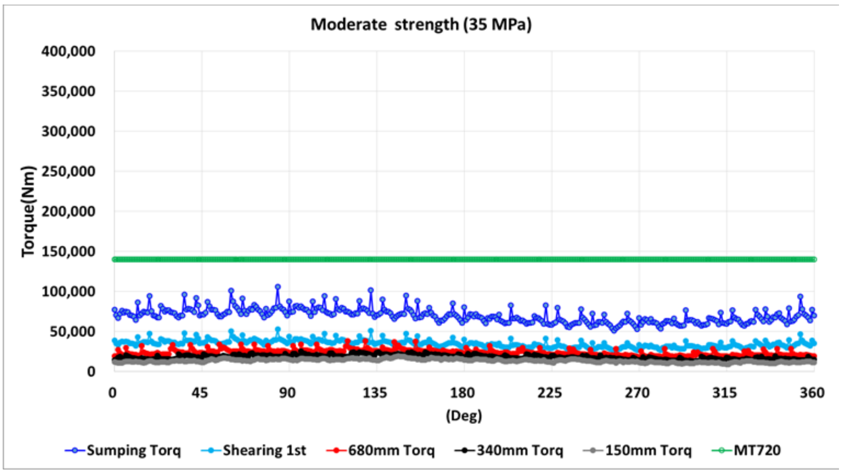
Four rock classes of uniaxial compressive strength (UCS) were input in the rock model's properties. The cutting forces according to the UCS was determined by previous testing results (Bilgin et al., 2006). The kinematics software (i.e., RecurDyn) was used for calculating the cutting forces of pick cutters and torques of the cutting head (FunctionBay, 2021). The forces and torque was recorded during 360 degree rotating simulation. The mean cutting depth was set for calculating the normal and cutting force during picks' indenting and cutting motions.

The simulation results of four rock models were shown in Figure 5. The green line means the maximum power of 130 ton roadheader, the blue line is the necessary torque of sumping process at maximum sumping depth. Other colors are the data of shearing processes. The cutting head are sufficient for cutting low and moderate strength rock up to UCS of 35 MPa. For the medium strength rock (UCS: 75 MPa), the necessary torque partially exceed the maximum power of the machine. In the case of hard rock cutting, the simulation torque output recorded two times higher values than the maximum power level, and the first shearing torque was nearly equal to the maximum power.

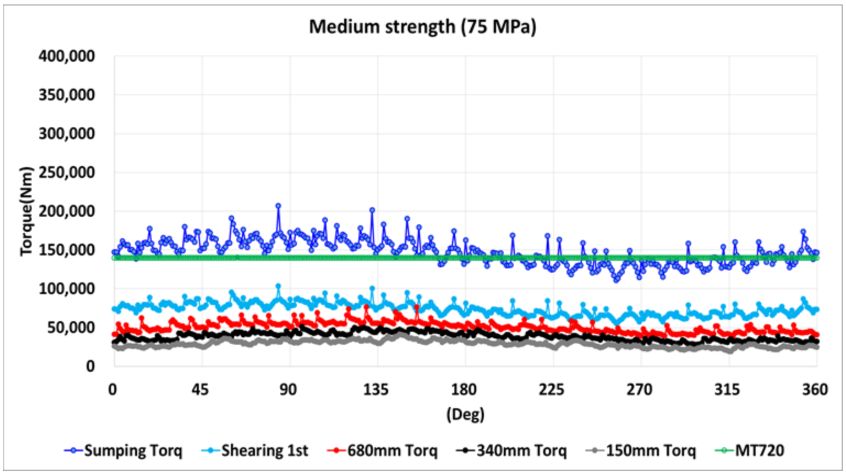
Thus, the 130 ton roadheader can penetrate up to medium class rock (75 MPa). For the hard rock excavation by the roadheader, the total sumping depth and shearing height should be reduced within half value from the pre-designed values for the efficient tunneling procedures.



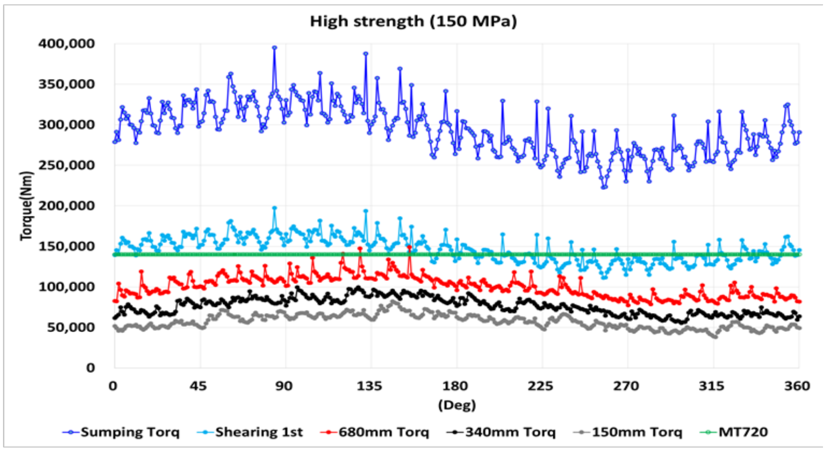
(b) Low strength rock



(c) Moderate strength rock



(d) Medium strength rock



(e) High strength rock

Figure 5. Simulation results of torque for four strength classes of rocks.

ACKNOWLEDGEMENTS

This research was supported by the Consecutive Excavation Technological Development Project of Tunnel Boring Machine funded by Ministry of Land, Infrastructure and Transport of Korean government of Republic of Korea (Grant: RS-2022-00144188).

REFERENCES

Bilgin, N., Demircin, M.A., Copur, H., Balci, C., Tuncdemir, H., Akcin, N., 2006. Dominant rock properties affecting the performance of conical picks and the comparison of some experimental and theoretical results. International Journal of Rock Mechanics and Mining Sciences, 43(1):139–156.

Jin-Young Park, Hoon Kang, Jae-Wook Lee, Jong-Hyoung Kim, Joo-Young Oh, Jung-Woo Cho*, Jamal Rostami, Hyun Deok Kim, 2018, A study on rock cutting efficiency and structural stability of a point attack pick cutter by lab-scale linear cutting machine testing and finite element analysis, International Journal of Rock Mechanics and Mining Sciences, 103 (2018), pp. 215-229.

FunctionBay Inc. 2021. RecurDynTM/Solver Theoretical Manual.

Sandvik, 2016, Operator's Manual, 2016-09-21 (with permission of Sandvik Suhjun)