[TS1401_7020] Optimization of HJC material parameters of rock splitting mechanism by dynamics simulation

Changheon Song, Sang-Min Lee, Joo-Young Oh, Mun-Gyu Kim, Jung-Woo Cho#, Sang-hwa Yu and Hoyoung Jeong
Corresponding Author: chojw1665@kitech.re.kr

ABSTRACT

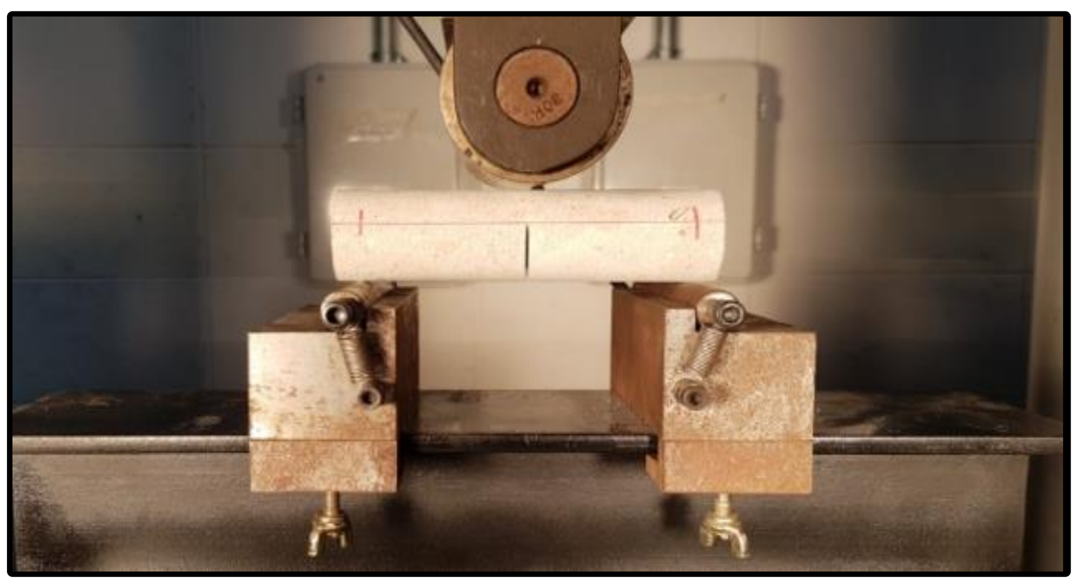
To understand the tensile fracturing mechanism of rock cutting-splitting method, the fracture toughness of rock should be defined. We performed 3-point bending tests for 2 types of rocks. Then, the LS-Dyna code was adopted to simulate the 3-point bending tests and the tensile fracturing procedures of rock. The sample rock was modeled using the HJC (Holmquist-Johnson-Cook) rock material model, and the key parameters were selected by sensitivity analysis and then optimized to precisely describe the mechanism. Finally, the suggested material model and the simulation results were validated with the 3-point bending experiment results.

Introduction

•The study is developing a new cutting-splitting method which is for rapid excavation rate for hard rocks. The procedure is that cutting rock at a certain depth by a rock saw, and then splitting the rock into two blocks by inserting a chisel into the crevice.

• The key mechanism of the method is tensile fracture propagation on the basement of rock blocks. To understand the fracture mechanism of rock, the fracture toughness (mode I) of each rock should be determined.

•3-point bending tests were performed for two strength rock classes (i.e., medium and hard strength). From the results, fracture toughness (mode I) values of the samples were obtained. Then, the LS-Dyna code was used to simulate the tensile fracturing procedures during 3-point bending tests. HJC (Holmquist-Johnson-Cook) material model (Holmquist et al., 1993) was adopted



3-point bending test

Numerical Simulation Results of the HJC Model Parameters

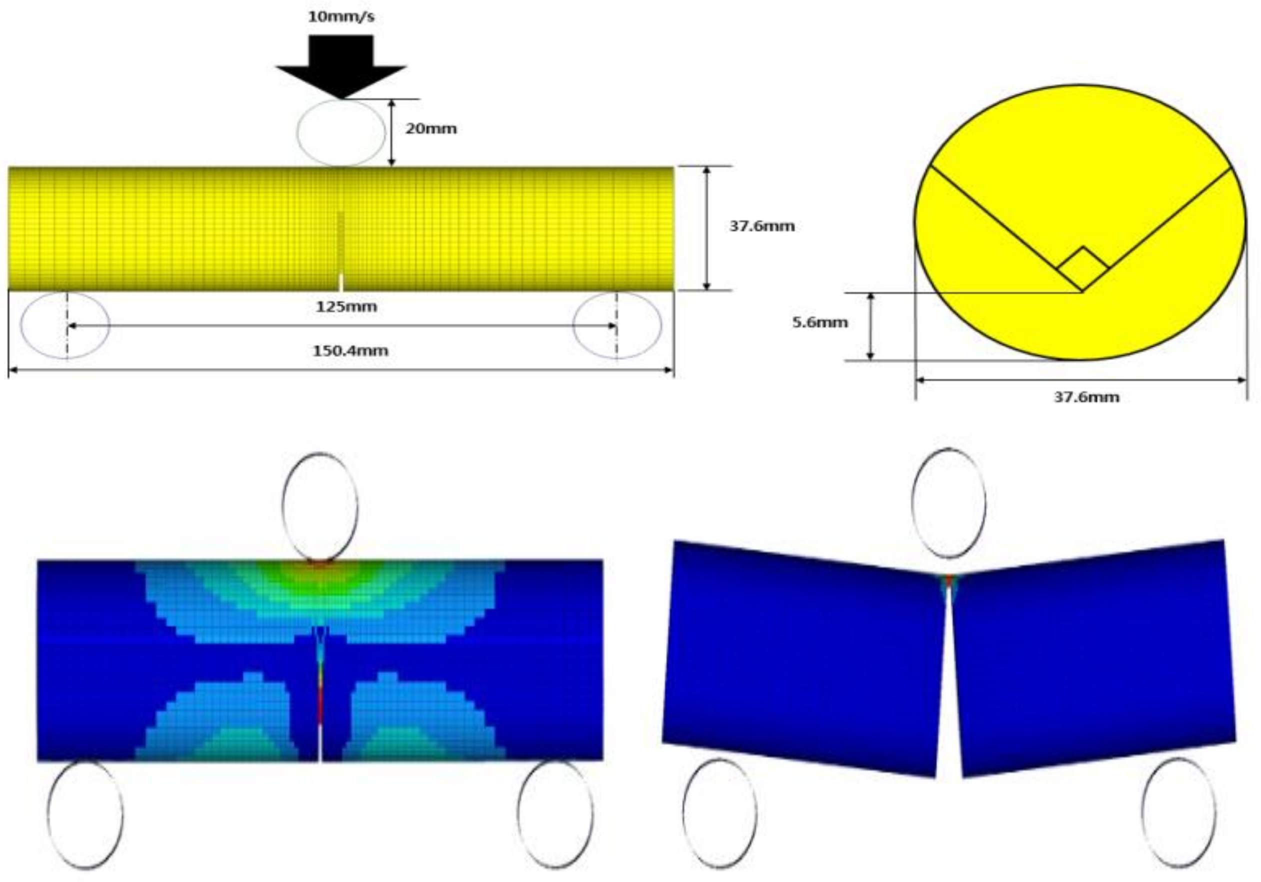
Opt. No.	PL	k1	evol	G1	O1
1	2.4884	83.39	0.0097	5.1%	234.2%
2	2.4978	3.47	0.0005	6.2%	60.9%
3	2.4903	3.74	0.0006	6.2%	59.2%
4	1.9726	4.10	0.0007	3.4%	52.4%
5	1.47719	4.14	0.0007	1.4%	48.9%
6	0.8318	4.14	0.0008	5.4%	43.9%
7	0.8314	5.40	0.0008	6.2%	42.7%
8	0.8309	7.82	0.0008	17.7%	40.2%
9	0.8453	4.64	0.0009	8.2%	35.4%
10	0.8765	5.07	0.0010	5.4%	32.0%
11	0.9803	5.09	0.0011	11.0%	22.9%
12	1.4796	8.00	0.0012	6.2%	19.9%
13	1.7118	8.02	0.0012	3.4%	15.3%
14	1.7881	8.20	0.0013	3.4%	13.9%
15	1.7994	8.04	0.0013	3.4%	14.6%
16	1.7890	8.17	0.0014	0.6%	11.8%
17	1.7534	8.32	0.00151	1.4%	7.3%
18	1.7245	8.40	0.00165	1.4%	6.3%
19	1.7181	8.50	0.00167	0.6%	0.4%

(high strength rock)

Opt. No.	PL	k1	evol	G1	O1
1	1.6118	4.51	0.00065	62.3%	40.8%
2	1.5557	4.63	0.00069	60.6%	35.0%
3	1.6213	0.66	0.00104	47.3%	3.1%
4	1.0958	1.73	0.00140	10.6%	18.4%
5	0.9745	1.70	0.00128	8.9%	21.6%
6	1.0425	3.64	0.00139	35.6%	21.3%
7	1.5552	0.66	0.00106	47.3%	2.9%
8	1.5555	0.50	0.00105	43.9%	2.9%
9	1.9498	1.17	0.00734	92.9%	253.7%
10	1.5557	0.65	0.00104	47.3%	3.3%
11	1.1995	1.17	0.00107	3.6%	0.9%
12	1.1904	1.25	0.00122	1.4%	13.4%
13	1.1995	1.15	0.00100	55.6%	10.5%
14	1.1025	1.17	0.00120	3.0%	10.1%
15	1.1025	1.17	0.00116	1.4%	9.1%
16	0.907	1.17	0.00117	1.4%	9.2%
17	0.819	1.16	0.00118	0.3%	0.8%
18	0.8320	1.16	0.00118	0.3%	0.7%

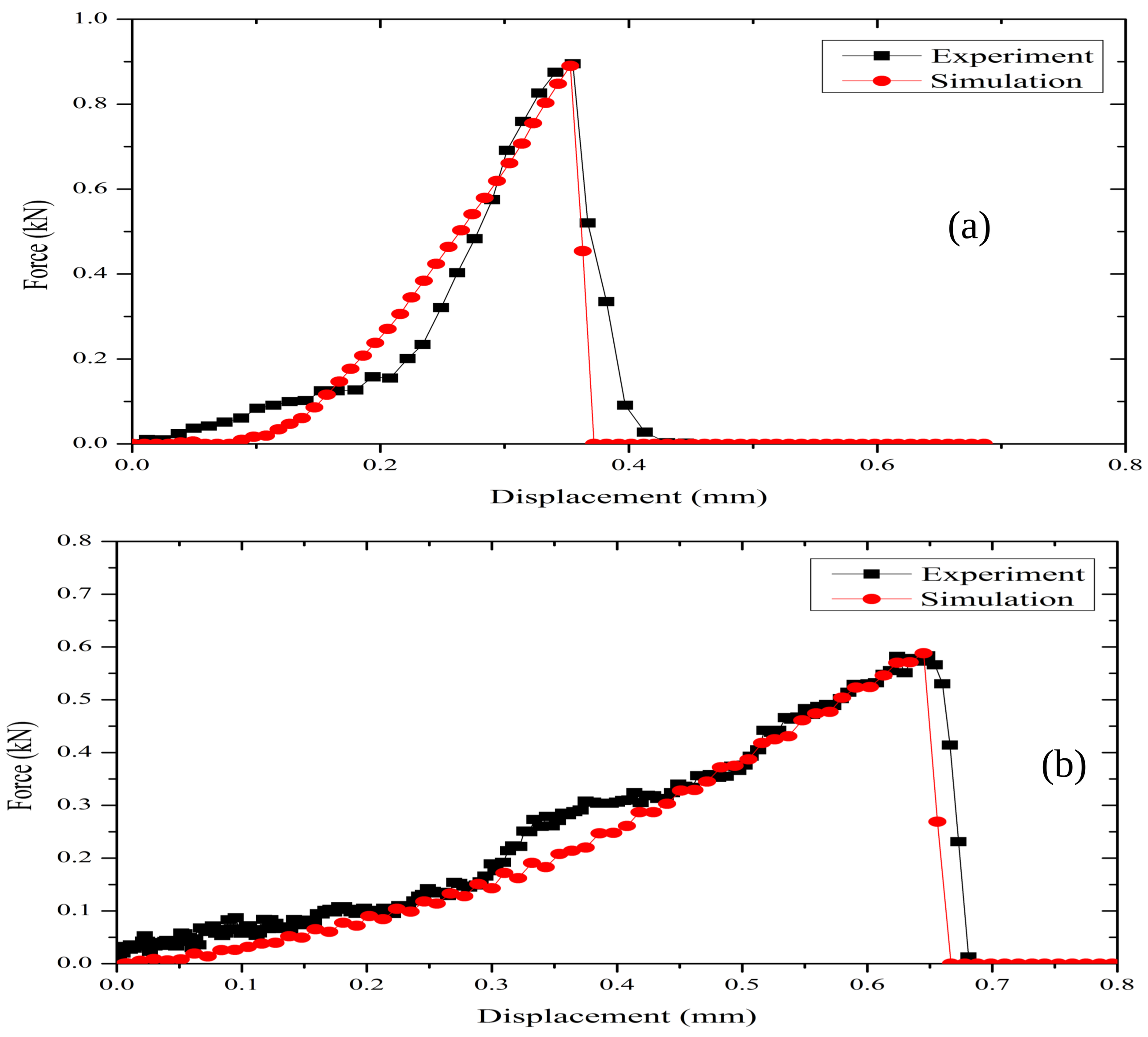
(medium strength rock)

Model & simulation result



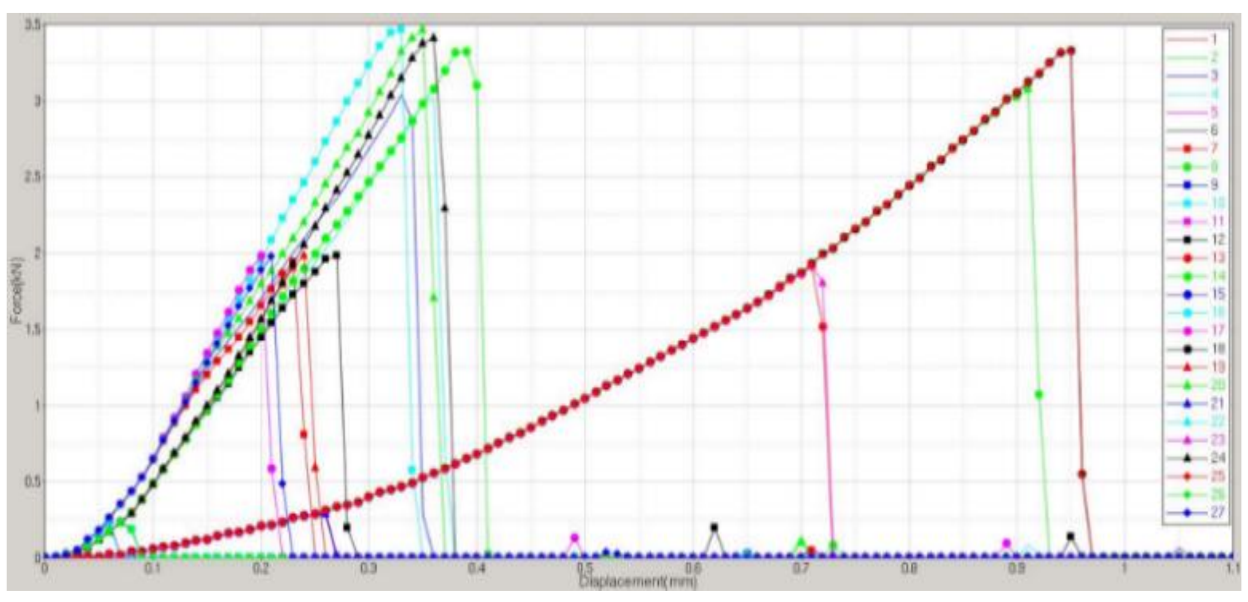
•The 3-point bending simulation was performed. this finite element model used in the 3-point bending simulation. Then a series of simulations were carried out.

Testing results



This picture shows the numerical simulation results of the HJC model parameters derived through the optimization process for two rock classes in comparison with the experimental results. Fig. 6 (a) to (b) show the simulations of tensile fracture toughness for hard rock, medium hard rock, respectively.

force-displacement curves



• The simulations results were obtained. The effect of each parameter on the tensile failure of the rock was evaluated using analysis of variance (ANOVA).

CONCLUSIONS

- In order to analyze the tensile fracture mechanism of rocks, the 3-point bending tests and numerical simulations were performed. The tensile fracture characteristics of rocks were analyzed by the HJC material model and the Kriging meta-model and the evolution algorithm were adopted to fit and optimize the HJC parameters.
- The 3 key parameters of the HJC material model, that significantly influence to the tensile fracture of rocks, were identified by the sensitivity analysis. Then, the levels of each parameter were proposed by processing optimization technique. Based on this result, the proposed three parameters (e.g. PL, k1, and evol) can successfully describe the tensile fracturing process of rock model.
- The results of this study can be used as the fundamental research data for producing rock blocks using rock cutting and splitting methods. Future study will be required to analyze the tensile crack characteristics of various rock classes considering the real-scale rock mass.

Acknowledgement

•This research was supported by a grant (21TBIP-C160989-01) from Technology Business Innovation Program (TBIP) funded by Ministry of Land, Infrastructure and Transport of Korean government.

KITECH
한국생산기술연구원