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Accuracy validation of pin-on-disk type abrasion testing machine for pick cutters

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ABSTRACT

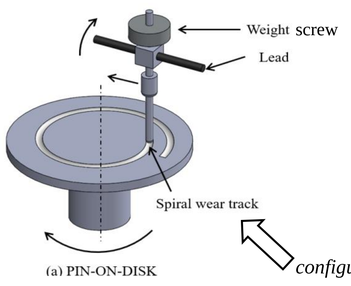
The accurate evaluation of rock abrasion is essential for the estimation of cutter costs in rock cutting and drilling operations. In this study, a novel abrasion testing machine was developed for rock cutting tools such as pick cutters. The developed machine employs the pin-on-disk abrasion method of ASTM (American Society for Testing and Materials). After investigating the operating conditions of the pick cutter under actual cutting conditions, the specifications of the machine were set to simulate field conditions, and the testing apparatus was designed. After the verification of the design through numerical modeling, the test unit was manufactured. This paper, therefore, proposes a pin-on-disk type abrasion testing method which can simulate the actual abrasion phenomenon on the real cutting conditions (i.e., force and velocity) of rock cutting tools

Introduction

• The cutting tools are installed on the cutterheads of various machines for the cutting of rock surfaces. The wear life of cutting tools is critical in the estimation of the operation cost with respect to the cutter cost and down-time (i.e., replacement time of tool) of the machines. The wear life of cutting tools is critical in the estimation of the operation cost with respect to the cutter cost and down-time (i.e., replacement time of tool) of the machines. Numerous cutter types, materials, and shapes have been proposed for improved wear performance and extended cutter life.

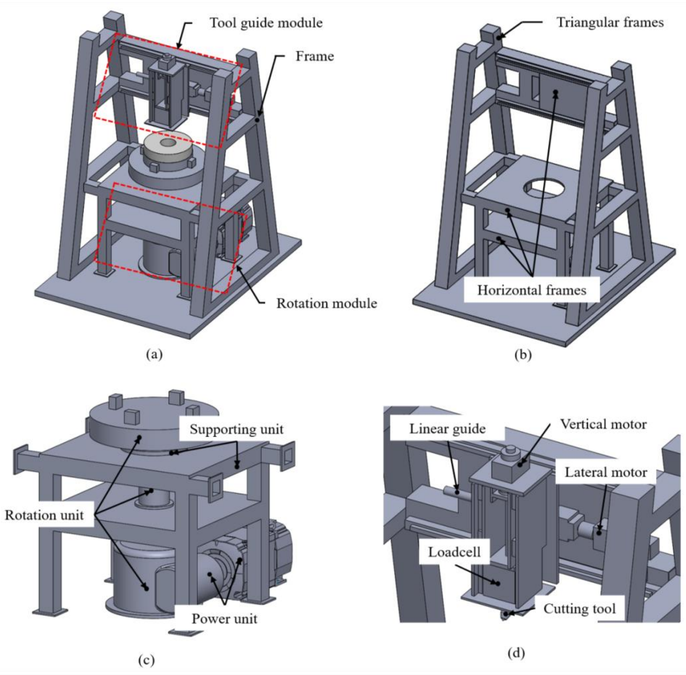
•At present, the most reliable method for the assessment of tool wear is full-scale rock cutting tests in the tunneling or mining fields, given that limited tests under laboratory conditions do not consider critical operational factors.

•This paper proposes a pin-on-disk type abrasion testing machine that applies the same amount of force as in the field to picks, using actual cutting tools to cut the target specimens at the same cutting depths, spacing intervals, and velocities adopted in field applications



configurations of pin abrasion testing machines

Design of testing machine

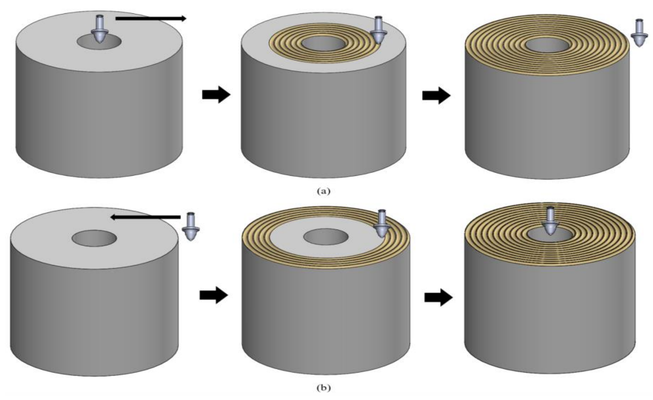


A draft of the proposed abrasion testing machine was developed as shown in this picture. The machine has three modules: frames, a rotation module, and a tool guide module.

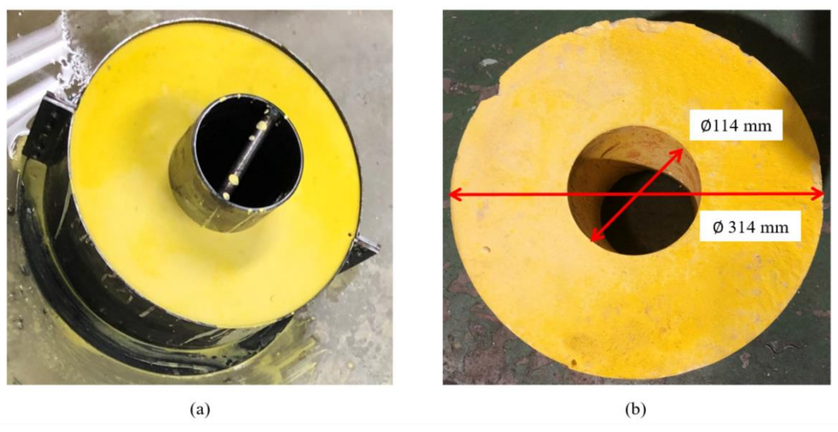
Specifications of testing machine

Type	Requirements of tool	Var.	unit	Value	Specifications of machine	unit	Value
Measurement	Normal force	*Fn*	kN	15.0	3D load cell	kN	30.0
	Cutting force	*Fc*	kN	10.0	Torque meter	kN-m	5.0
Rotation	Radius of specimen	*Rs*	m	0.3	Main motor power	kW	37
	Required Torque	*Tq*	kN-m	3.0	Torque max.	kN-m	4.0
	Moving velocity	*v*	m/s	2.5	Reduction gear ratio	-	1:20
	Required rps	*rps*	-	1.3	Main motor rps	*rps*	2
	Required rpm	*rpm*	-	79.6	Main motor rpm	*rpm*	120
Radial	Max. cut spacing	*s*	mm	10.0	Radial motor power	kW	37
	Required radial velocity	v_{Ro}	mm/s	13.3	Max. velocity	mm/s	20
					Reduction gear ratio	-	1:30
Vertical	Cut depth (/step)	*D*	mm	10.0	Radial motor power	kW	0.5
	Total cut depth	*Dt*	mm	150.0	Max. displacement	mm	180.0
	Constant cut depth condition (Max. normal force)	*Fn*	kN	15.0	Lead screw fixation	kN	25.0

Type & Sample

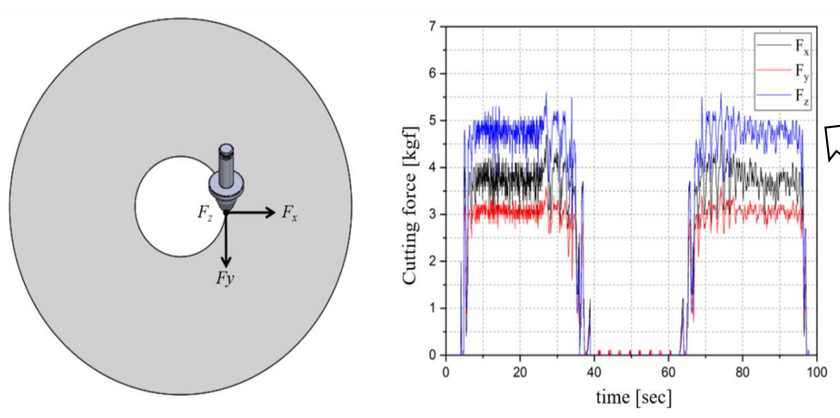


- The power of motor is limited; thus, a targeted cutting depth may not be accurately adjusted.
- A further limitation is the rotational speed. Since the constant moving velocity is a set value, the rotational speed proportionally increases in accordance with a decrease in r (radial position of tool), and is zero at the center point.
- Hence, a hollow-type rock specimen should be used for the continuous abrasion testing of rock cutting tools.

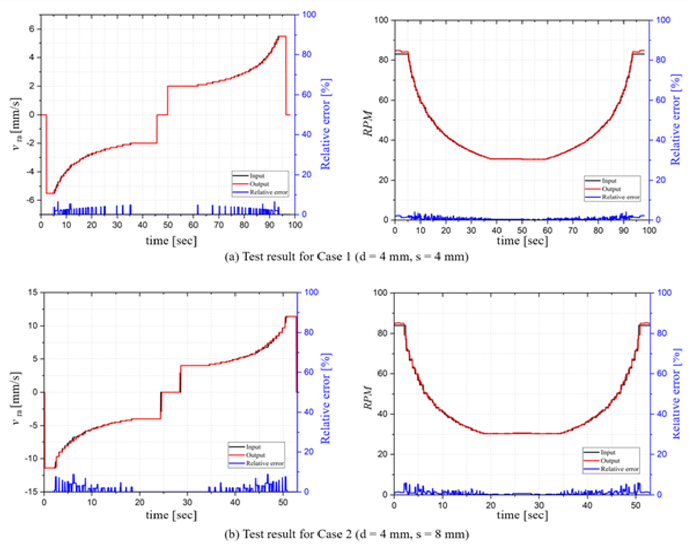


- A rock-like sample was prepared as the reference material for the validation tests.
- The specimen was made of industrial gypsum (Diastone MR-150, Samwoo Chemical Co., Ltd.) with a water to weight ratio of 2.5:1.

Testing results



Real-time cutting force measurement: (a) load measurement direction of 3-axis load cell and (b) cutting force



- For the further validation of the spiral path accuracy, the x- and y-coordinates were measured using a 3D scanning machine (see Fig. (a)).
- 20 points were selected at increments of 90°; the input spiral path, spiral groove, and measurement points are shown in Fig. (b).
- For the validation test, the mean relative errors of the radial velocity were 0.95%, and the average relative errors of the radial velocity were 1.1%. For the spiral path validation, the mean and maximum values of the relative errors were 1.6% and 3.1%, respectively.

CONCLUSION

•This study developed a pin-on disk-type abrasion testing machine following the Archimedean spiral path. The procedure and results were discussed in this paper. To overcome the practical limitations, several solutions were considered.

•Several validation tests were conducted to establish the accuracy of the proposed testing system. The mean relative error value was less than 1.5%, thereby validating the accuracy of the proposed system. Furthermore, the relative error of the spiral accuracy calculated by the 3D scanning machine was less than 5%.

•As such, the proposed abrasion testing machine and method can be employed for the accurate investigation of the wear phenomenon and quantitative evaluation of the amount of tool wear with respect to the rock cutting volume. Future studies will include additional testing in different rock types to verify reliability of proposed testing method.

Acknowledgement

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