PROTOTYPE OF CUTTING MACHINE BY WIRE-SAWING IN VACUUM FOR IN-SITU INVESTIGATION OF ROCKS. Katsushi Furutani[1], Eiji Ikeda[1], Tatsuaki Okada[2], Kazuto Saiki[3], Hiroyuki Ohue[4], [1]Toyota Technological Institute, Nagoya 468-8511 Japan (furutani@toyota-ti.ac.jp), [2]Institute of Space and Astronautical Science, JAXA, Sagamihara, Kanagawa 229-8510 Japan, [3]Osaka University, Toyonaka 560-0043 Osaka Japan, [4]Tokusen Kogyo, Ono, Hyogo 675-1361 Japan

Introduction: A bullet type sampler is sometimes used to obtain a sample from an asteroid on sample-return missions [1]. On the other hand, in-situ analysis is demanded for the investigation of more amount of rock samples. Many drilling or coring devices have been developed [2-5]. Slicing the rock sample is preferable to observe its interior rather than shaving [6]. Because coolant cannot use in vacuum environment, tool life will be shorten. It is expected for a wire saw to maintain cutting performance due to successive supply of cutting edges. This abstract describes a prototype of a cutting machine by wire-sawing and some demonstrations.

Preliminary Experiments: Fig. 1 and Table 1 show a setup and conditions for a preliminary experiments, respectively. A terrestrial basalt block, which has a similar structure and strength to a lunar mare basalt rock, with a width of 10 mm was cut with 0.2-mm wire saws with a tungsten carbide coating deposited by electrical discharge machining [7] or diamond abrasive electroplated with nickel. Cutting loads of 2.5 N in air and 3.8 N in vacuum were applied with a dead weight. The saw was reciprocated with a motor-driven xy stage from the outside of a vacuum chamber. After 2000 stroke-cutting, abrasive layers were completely removed and the core was exposed. The short stroke caused heavy wear. The cutting depth was 0.2 mm in both environments. The requirements for the cutting machine were clarified as follows. (1) Use a long wire saw to decrease the reciprocation. (2) Increase the feeding velocity of the wire saw to decrease the machining time.

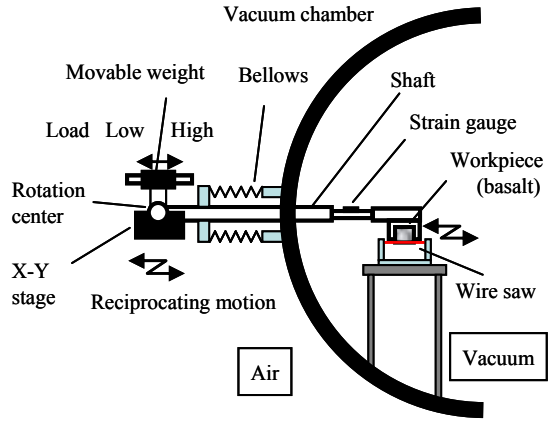


Fig. 1 Setup for preliminary experiment

Design of Cutting Machine: Fig. 2 and Table 2 show an appearance and specifications of a prototype with two motors, respectively. It was placed in the chamber and the motors were mounted on the side wall with rotational feedthroughs. While the wire saw was reciprocated, one motor wound at a constant velocity and another applied the tension by a PID control. The maximum speed of the wire saw was 2 m/s by the limitation of the motor torque. A workpiece was mounted on an end of a lever and a cutting load was applied with a constant force spring.

Cutting Experiments: The cutting performance in vacuum was compared with that in air. Table 3 shows cutting conditions. A wire saw with 30-40-μm diamond grits was used. The length of the wire saw was set to 7 m (5 m at a constant speed of 1 m/s) for the acceleration test of the wear. The machining time was 20 min. The pressure during cutting was 5.1-

Table 1 Conditions for preliminary experiments

Environment	Vacuum (3.5×10^{-3} Pa)
Workpiece	Basalt
Cutting speed	8 mm/s (0.48 m/min)
Stroke	7 mm
Number of reciprocation	2000
Cutting load	2.8 N in air, 3.8 N in vacuum
Abrasive grits	Diamond, Tungsten carbide

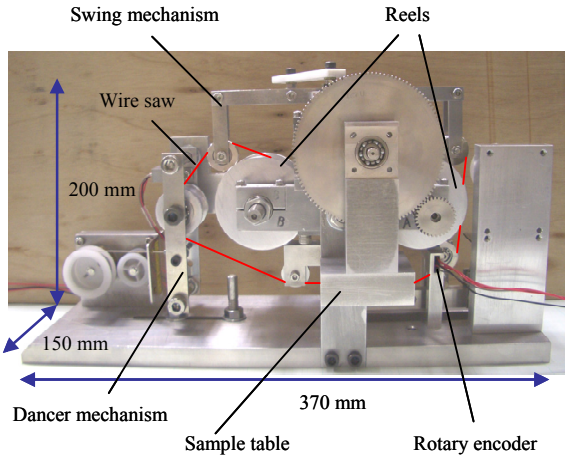


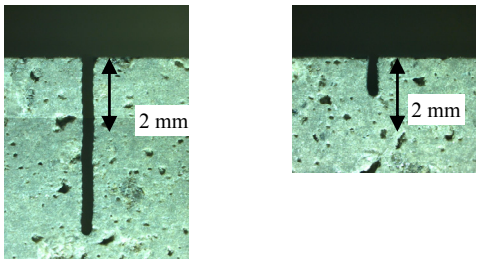
Fig. 2 Prototype of cutting machine with wire saw

Table 2 Specifications of prototype

Dimensions	370×150×200 mm
Weight	5.3 kg
Maximum wire length	800 m
Maximum wire speed	2 m/s
Materials of structure	A2052, SUS304

Table 3 Cutting conditions with prototype machine

Environment	Air, vacuum
Workpiece	Basalt, 10 mm in width
Wire saw	ϕ0.2 mm-core, 30-40 μm diamond
Wire speed	1 m/s
Reciprocating length	7 m
Number of reciprocation	5, 10, 20
Cutting load	2 N
Tension of wire saw	2 N



(a) In air (b) In vacuum

Fig. 3 Results of cutting after 20 reciprocation

7.0×10^{-3} Pa, which was not increased because of the gas from the rock. Fig. 3 shows side views of machined groove after 20 reciprocations. The kerf loss was 0.3 mm. Fig. 4 shows the progress of cutting. The cutting depth in air was proportional to the number of reciprocation. However, that in vacuum was saturated and shallower than in air at 5th reciprocations. Fig 5 shows expanded views of the wire saw and debris. A grit in vacuum wore more than one in air as shown in Fig. 5 (a). Adhesive was observed near the edge of the grits as shown in Fig. 5 (b). The surface force such as electrification due to the fracture of the rock may

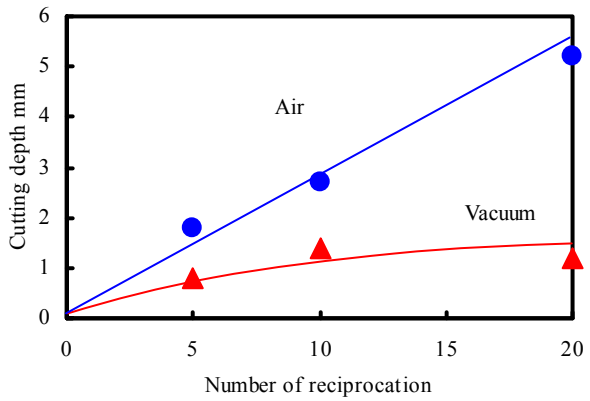


Fig. 4 Progress of cutting

caused the loading. The grits did not shed from the core wire in both cases. The debris collected around the workpiece measured sub-μm to tens of μm order.

Conclusions: The prototype of the cutting machine was built and cutting was demonstrated. The cutting depth was saturated in vacuum because of loading. The components of adhesive on the wire saw will be analyzed and its removal method will be investigated.

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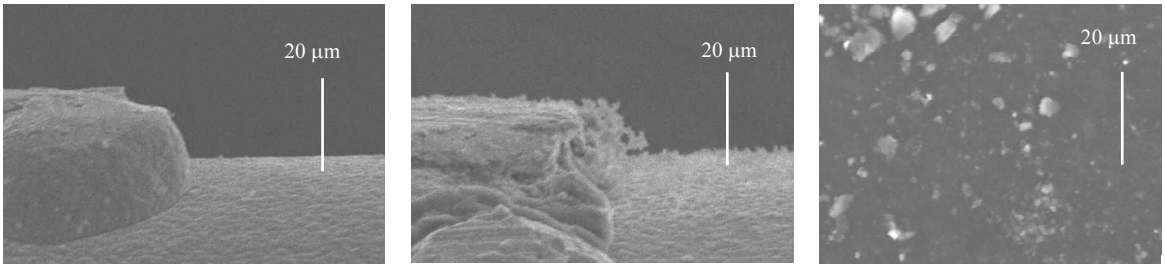

(a) After cutting in air (b) After cutting in vacuum (c) Debris

Fig. 5 Expanded view around grains and debris