Machining Performance of Rock Surface Shaver Driven with Piezoelectric Actuator for Space Exploration

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Abstract

For in-situ analysis in future lunar, planetary or asteroid explorations, a rock surface should be smoothed. In this paper, a surface shaver with a piezoelectric actuator is proposed and its machining performance is investigated. Shaving teeth are mounted at the ends of a lever mechanism. The surface roughness of basalt was small with an increase of the pressing force. However, the removal amount was smaller with an increase of the pressing force further.

1 Introduction

In future lunar, planetary or asteroid explorations, in-situ analysis of rock samples is strongly demanded to obtain many data from various aspects. An integrated automatic analyzer for the rock samples, “Science Integrated Package (SIP)” has been proposed [1]. For precise composition analysis, a sample surface should be smoothed. Rotary blades have been used in Mars exploration [2]. In order to avoid heavy wear of the cutting edge caused by lubrication and cooling problems in vacuum, vibration crushers have been proposed [3]. These sometimes compress a rock structure by the machining force perpendicular to a sample surface. A large amplitude of tool vibration is preferable to smooth a rough surface.

In this paper, a surface shaver with a piezoelectric actuator is proposed and its machining performance is investigated.

2 Structure of shaving device

Figure 1 shows a structure of the rock surface shaver. It consists of a shaving device, a sample holder on an octagonal ring dynamometer, and a reciprocating device using

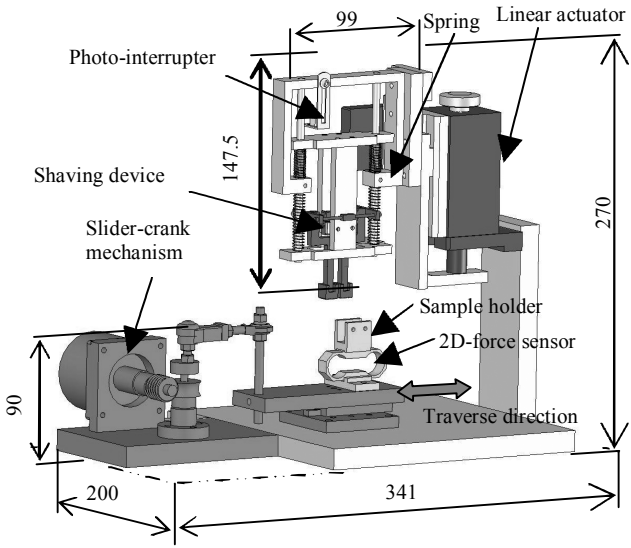


Figure 1: Structure of rock surface shaver

a slider-crank mechanism. The shaver including the feeding mechanisms measures 341 mm × 200 mm × 270 mm. The shaving device consists of a lever mechanism with shaving teeth at its ends and a stacked piezoelectric actuator (NEC-TOKIN AE0505D16F) to vibrate the teeth horizontally.

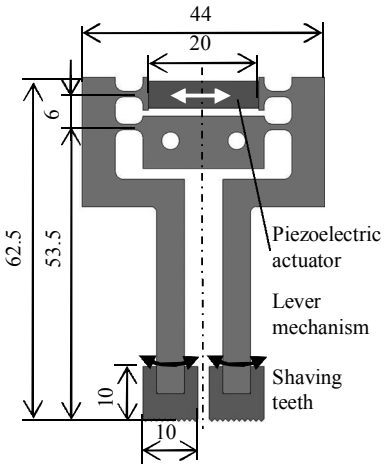


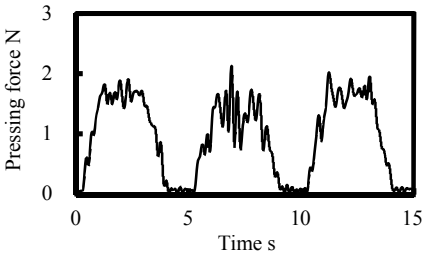
Figure 2: Shaving device

Figure 2 shows the shaving device. It was made of carbon steel. Hinges measure 5mm in length, 5mm in width and 2 mm in thickness. Their end corners were rounded off to a radius of 1.5 mm to decrease the maximum stress. The stress limited to Mises one was checked by the finite element method. The shaving teeth made of tungsten carbide have ridges with a pitch of 1 mm and a height of 0.5 mm on their bottoms. A sinusoidal voltage of 50 Vp-p with an offset voltage of 25 V at the resonance frequency of 565 Hz was

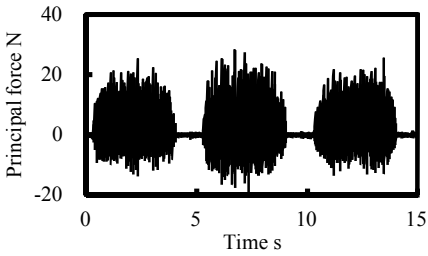
applied to the piezoelectric actuator in order to vibrate the teeth at a large amplitude. The unloaded amplitude of the shaving teeth was 0.77 mmp-p. The input power was 7 W. The shaving device moves up and down by using a linear actuator. Four springs press the shaving device onto the specimen. The frequency components over 700 Hz were eliminated by digital filtering.

Table 1: Machining conditions

Pressing force N		0.3-2.1
Machining time min		10
Feed	Stroke mm	5.4
	Cycle s	10
Specimen	Rock	Basalt
	Dimensions mm	15×7×16-18
	Hardness Hv	700
Initial grooves	Depth mm	0.2-0.3
	Width mm	0.9-1.0



(a) Pressing force



(b) Principal force

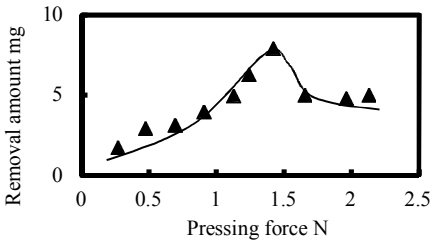
Figure 3: Forces during shaving

3 Machining performance

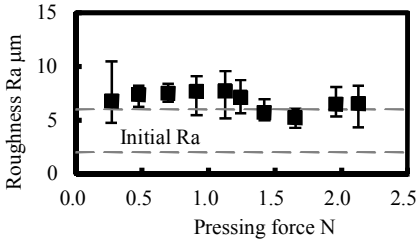
The removal amount and surface roughness against the pressing force were experimentally investigated. Table 1 shows machining conditions. Testing specimens were basalt, which had a similar structure and strength to the rocks in lunar mare. The samples were diced with a rotary diamond cutter. 3×4 gridlike grooves with intervals of 2 mm were made on the top surface of the specimens to adjust the initial condition. The specimen periodically reciprocated by a stroke of 5 mm in 10 s parallel to the vibration direction of the shaving teeth.

Figure 3 shows forces acting on the shaving teeth during machining. Only one of the teeth contacted to measure the principal force. The shaving device was retracted for 2 s every 5 s. The principal force varied up to 20 N by the vibration at a static pressing force of 1.4 N. The teeth vibration amplitude was decreased to 0.22 mmp-p.

Figure 4 (a) shows the removal amount. The removal amount became maximum at a pressing force of 1.4 N because the teeth vibration was decreased over 1.4 N. Figure 4 (b) shows the relationship between the surface roughness after shaving and pressing force. With the increase of the removal amount, the surface roughness was decreased. The minimum was 5 μm in Ra at a pressing force of 1.5 N. Because the swept stroke of the teeth was much larger than the vibration amplitude, ridges caused by the teeth vibration were not observed on the surface. The surface roughness varied widely not only due to removal amount but also due to pores.



(a) Removal amount



(b) Roughness in Ra on bump tops

Figure 4: Machining performance against pressing force

4 Conclusions

The removal amount was the maximum at an appropriate pressing force. Although the average surface roughness was constant, the maximum roughness was fluctuated by pores or cracks on the rock surface. The machining performance will be investigated also in vacuum for the future work.

This study was financially supported by "Sustainable Mechanical Systems Research Center," a matching fund subsidy by MEXT, Japan.

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