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Force Feedback Device using Electro-Rheological Gel and One-sided Pattern Electrodes

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Abstract

We develop a force feedback device that generates rotational and translational resistive forces using electro-rheological (ER) gel with one-sided pattern electrodes. ER gel is a functional material in which applied electric fields increase the shear stress on the surface. One-sided pattern electrodes allow electrodes to be installed on only one side of the gel, simplifying the structure of the device. We herein describe the device and the software used to test the device. We measure shear stress of the ER gel on one-sided pattern electrodes for rotational and translational movement.

1. Introduction

Virtual reality (VR) technology has improved in recent years, and it is expected to be applied to medical, health, welfare and entertainment equipment. Present VR technology typically only provides audio and visual stimulation; therefore, development of devices which also provide a sense of force are desired.

Passive devices that simulate force consist of passive elements such as brakes. Passive devices are limited in the degrees of freedom of force that they can simulate. However, generating a resistive force is passive and essentially safe. Owing to their simple inexpensive design, such passive devices can be expected to be widely adopted for practical applications [PCM96] [DB97].

In this study, we developed a device that can be placed and operated on a desk, as shown in Figure 1. We would like to avoid the necessity of installing complex mechanisms on desks. The space required to operate our device is larger than existing devices. Therefore, we aimed to simplify the device by using electro-rheological (ER) gel and one-sided pattern electrodes to provide the braking mechanism of the device.

Our device creates a reaction force by resisting rotational and translational movements. It simulates a sense of force as the user interacts with a virtual object. In this paper, we explain the device and the corresponding application software, and we measure the force characteristics of device under rotational and translational inputs

2. Force feedback device (ER-Handle)

The structure of the force feedback device is shown in Figure 2. The name of the feedback device is ER-Handle. The shaft for the

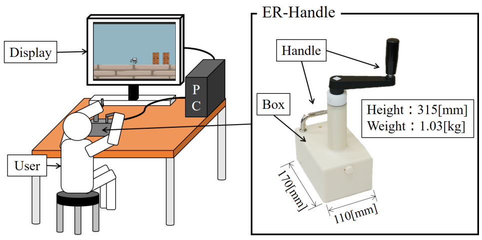

Figure 1: *Device operation*

ER gel and the one-sided pattern electrodes, and the structure that applies electric fields to them, are installed in the box. When the handle of the device is rotated, a resistance force is applied in the opposite direction, giving the user a sense of resistance to being turned or twisted. When the handle of the device is slid horizontally, the resistance force is applied in the direction opposite the motion. Therefore, users can feel senses of force that push objects, giving the user a sense of resistance to being pushed or pulled.

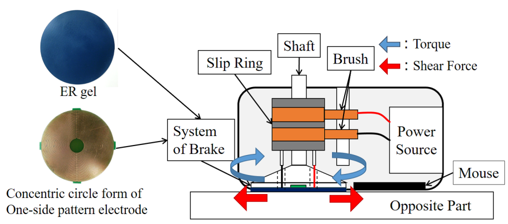

Figure 2: *Device structure*

3. Video game for device testing

An application to test the hardware was developed using the video game development platform, Unity (Unity Technologies, San Fran-

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cisco, CL). Users slide the entire device to move the character of the game. A mouse installed in the base of the device detects this motion, as shown in in Figure 3. The application is a side-scrolling game in which points are scored by making blocks disappear, as shown in Figure.3. Some blocks require user action such as turning the handle of the device to make them disappear. When the character touches a block, electric fields are applied to the ER gel, resulting in the device providing a sense of resistance to twisting or pushing to the user.

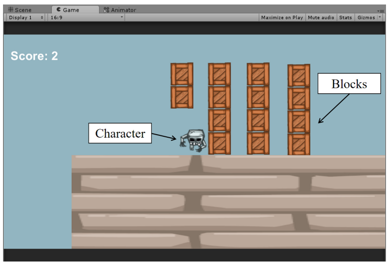


Figure 3: *Video game for device testing*

4. Electro-Rheological gel and electrodes

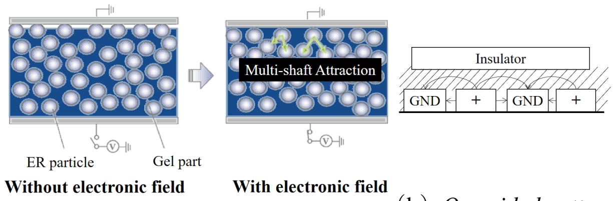
The ER gel is a functional material, and it is shape is constrained by a sheet of light rubber. When an electric field is applied to the gel, the particles become polarized and move to the center of the gel sheet, as shown in Figure 4(a). When an electric field is applied to the ER gel via electrodes sandwiching it, the particles become polarized and viscosity of the ER gel increases [KAA09]

The layout of electrodes on opposite sides of the ER gel is also shown. This structure is called both-sided pattern electrodes. When the electrodes are opposite each other, electricity can flow between them directly. This structure efficiently applies electric fields in the ER gel, creating a strong response from the ER gel. However, two separate electrodes require wiring, making the whole structure complicated [TFI02].

A one-sided pattern electrode is shown in Figure 4(b), with anodes and cathodes alternating along one side of the gel. The electric field arches from cathodes to anodes. The shapes of arches depend on the permittivity of an opposite part. An opposite part is located opposite to the electrode, and the force is generated between the ER gel and that. The response of the ER gel to these arching electric fields is smaller than that for the electrodes on opposite sides of the gel [TFI02] . However, since wiring is only required on one side, the structure is simpler. Moreover, it is possible to use an insulator for both-sided pattern electrodes. .

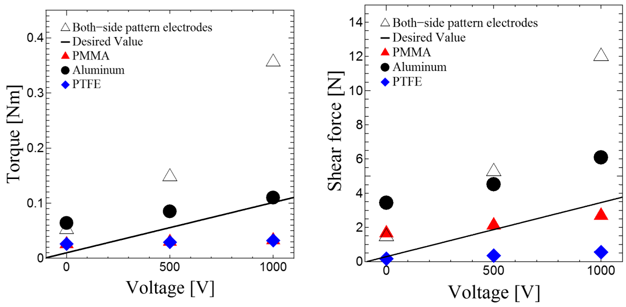
5. Characteristics of ER gel with one-sided pattern electrodes

We measured the shear stress of the ER gel for a single-sided pattern electrode on rotational and translational movement. The results of measurements are shown in Figure 5. In this experiment, we used PMMA and PTFE as insulators, and aluminum as a conductor. Pressure was uniformly applied at 0.5 kPa on the plane of the ER gel. Voltage of 0 V, 500 V and 1000 V were applied to the ER gel. Shear stress was taken as the mean of three measurements of the ER gel.



(a) *Mechanism of the ER gel* (b) *One-sided pattern electrodes*

Figure 4: *ER gel and concept chart of electrodes*



(a) *Rotational movement* (b) *Translational movement*

Figure 5: *Characteristics of ER gel*

Results also show that the material chosen affects the force felt by the user. More conductive materials provide a stronger sense of force, as shown in Figure 5. The force applied by the ER gel changes with the strength of the electric field applied. The proposed device provides simple control of force feedback.

6. Conclusions

In this paper, we proposed a device that uses ER gel and a single-sided pattern electrode as a force-feedback mechanism. We measured the shear stress of the ER gel on rotational and translational movement. The force feedback generated was larger when a more conductive material was used for the side of the ER gel opposite the one-sided pattern electrodes. The difference in the force feedback of the ER gel generated by changes in voltage was smaller than desired. In future work we aim to develop a device that can simulate force and is not limited by the space available for use by the user.

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