Improvement of Writing Experience for Pen-input Devices by means of Textured Glass Surfaces

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ABSTRACT

Textured glass surfaces have two types of roughness, and they have been developed for pen-input devices. The surfaces that can control the friction coefficient are anticipated as a novel method to improve the writing experience on glass surfaces.

1 Introduction

In recent years, the handwriting input of tablet computers has become more widespread because it reduces paper consumption, is convenient, and improves work efficiency. Furthermore, the introduction of these devices into the education field is progressing to realize personalized education and improve the quality of education [1]. In handwriting input, the frictional behaviors of pen tips are crucial, and they influence the user's feeling of writing with a pen. Generally, a pen tip on a flat glass surface is slippery, and the user experiences a "poor" writing feeling. This can be improved by adjusting the elastic modulus or changing the material of the pen tip. However, it is difficult to achieve "good" writing by only improving the pen tip. In addition to the pen tip, textured films are commonly used to improve the feeling of writing. However, since the film is composed of resin components, there are problems such as low scratch resistance and loss of the feeling of glass.

Thus, to solve these problems, an improvement in the feeling of writing was attempted by inducing a unique surface texture (sub-millimeter-millimeter-sized texture and nanometer-sized fine roughness) on the glass surface. In this study, the friction behaviors of commercially available pen tips on textured glass that represents the surface of tablet computers were investigated to achieve better friction control to improve the feeling of writing. We evaluated the friction behavior via reciprocating friction tests on textured glass surfaces with two types of roughness: One is the fine roughness of nanometer-sized asperities, which can influence adhesive and abrasive friction. The other is the surface texture of sub-millimeter-millimeter-sized pitches, which can influence the deformation friction generated by the pen tip entering concave parts with elastic deformation. Thus, the frictional mechanisms based on adhesive, abrasive, and deformation frictions were analyzed, considering these two types of surface roughness.

Moreover, an organoleptic evaluation of the feeling of writing on textured glass surfaces was performed using the semantic differential (SD) method.

In this study, the superior performance of textured glass surfaces for pen-input devices was demonstrated based on the results of the friction behavior and organoleptic evaluation.

2 Experiment

The writing-tip specimens included an elastomer tip (ACK-20004, Pen Nibs, Wacom Co. Ltd.). Textured glass surfaces with dimensions of 70 mm × 70 mm × 0.55 mm were prepared via micro-slurry-jet processing [2]. Fig. 1 shows the geometrical parameters of the textured glass surface, which exhibits convex and concave parts. The friction behaviors between the writing tip and textured glass surfaces were measured via a reciprocation friction test. During the test, the writing tip was fixed at an orientation angle of 60° and pressed onto the glass surface with a load of 1.96 N. Reciprocating motions with a stroke of 50 mm and a feeding speed of 5 mm/s were applied for 100 cycles. The friction coefficient was calculated from the frictional force measured using a load cell. An organoleptic evaluation of the textured glass surfaces was performed by seven research subjects using the SD method [3]. The evaluation was made using seven steps of indexes for each evaluation points such as "writing feeling," "smoothness," and "slipperiness."

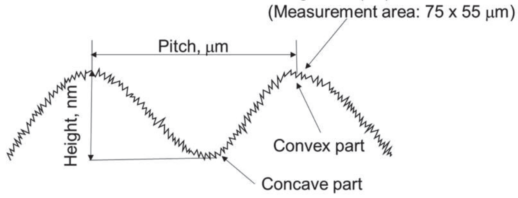

Fig. 1 Geometrical parameters of the textured glass surfaces.

3 Results and discussion

Fig. 2 shows an example of a glass surface processed using the micro-slurry-jet method. The figure shows the formation of continuous and smooth concave-convex parts on the textured surfaces. Moreover, nanometer-sized asperities were simultaneously formed on the textured surfaces. The transparency of the processed glass was maintained [4]. Table 1 lists the surface parameters of the glass surfaces used as writing surface specimens.

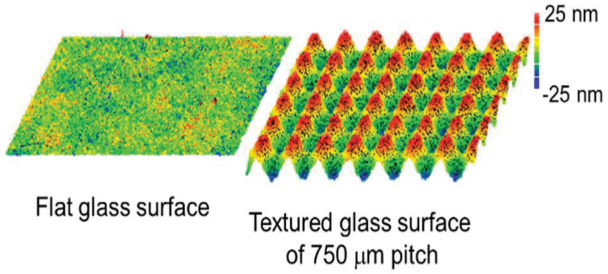

Fig. 2 Examples of glass surfaces.

Table. 1 Surface parameters of glass surfaces.

Flat glass		Height, nm	—					
		Roughness (Sa), nm	0.09					
Pitch	500 mm	Height, nm	1.7	5.5	8.8	21.6	45.1	
		Roughness (Sa), nm	2.33	4.10	5.22	6.23	6.81	
	750 mm	Height, nm	0.9	4.5	6.9	14.2	21.6	35.3
		Roughness (Sa), nm	1.99	3.47	4.02	5.09	5.77	6.27
	1000 mm	Height, nm	4.3	9.1	13.6	23.8		
		Roughness (Sa), nm	1.66	1.97	2.69	3.15		

Fig. 3 shows the relationship between the friction coefficient and the height of the concave-convex shapes on the glass surfaces for the elastomer tip. The highest friction coefficient was observed with the elastomer sliding on the flat glass surface (height of approximately 0 nm) owing to the high adhesion of the elastomer. The textured glass surfaces afforded reduced friction coefficients of the elastomer, compared with the flat glass surface, because of the reduced apparent contact area and adhesion at the asperity level. The friction coefficient decreased with increasing heights of the concave and convex sides. However, above a height of approximately 22 nm, the friction coefficient increases owing to the deformation friction caused by the writing tip entering the concave parts [5]. The friction coefficients of the 750-μm pitches dramatically decreased with an increase in the height of the concave-convex shapes. The reduction in the friction coefficients of the 1,000 μm pitches was the slowest. The friction coefficients of friction of the 500-μm pitches showed an intermediate behavior. These results can be interpreted based on the relationship between the diameter of the contact area of the elastomer tip (approximately 850 μm) and the glass surfaces [5]. The 750-μm pitches were smaller than and closer to the diameter of the contact area (850 μm), thereby reducing the apparent contact area. In contrast, in the 1,000-μm pitches, the elastomer could easily reach the concave part of the texture because the pitch size was larger than the diameter of the contact area. In the case of the 500-μm pitches, although the effect of the apparent contact area was smaller than that in the 750-μm pitches, a similar friction coefficient was obtained as the height of the convex and concave increased (~20 nm) [6].

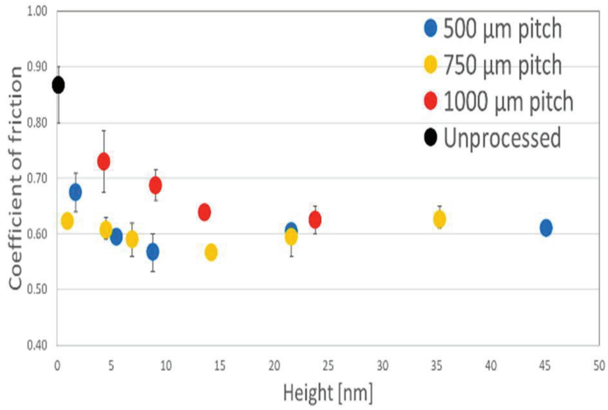

Fig. 3 Relation between the friction coefficient and the height of the concave-convex shapes on glass surfaces for the elastomer tip.

Fig. 4 shows the results of the organoleptic evaluation using the SD method. Based on the results in Fig. 3, samples were prepared with three types of concave-convex height differences for the SD test. The comfort level at each height was higher than that of the flat glass surface, which had the highest friction coefficient. This suggests that the slipperiness of the elastomer on the glass surface improves the comfort level for writing. Furthermore, the feelings of writing on the textured glass surfaces were close to the evaluation results of a pair of paper and pen (notebook paper and ballpoint pen (JETSTREAM, Mitsubishi Pencil Co., Ltd.)). These results indicate the possibility that the experience obtained writing on a paper can also be obtained writing on glass by controlling the friction coefficient of the glass surfaces.

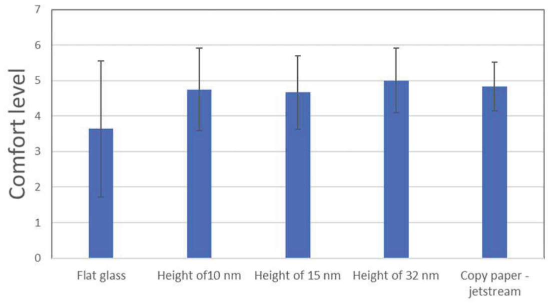

Fig. 4 Experimental results of the organoleptic evaluation for the textured glass surfaces with 750 μm pitch. Number of subjects: 12.

4 Conclusions

Reciprocating friction tests were conducted with an elastomer sliding on textured glass surfaces. It was found that the friction coefficients varied with the textured glass surfaces. The textured glass surfaces of submillimeter-sized concave-convex surfaces with nanometer-sized asperities caused frictional behavior differences arising from adhesive and deformation friction. The experience of writing on glass surfaces can be improved by inducing the surface texture with two types of surface roughness based on the results of the organoleptic evaluation test. These results can facilitate the development of writing surfaces for pen-input devices.

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