Preliminary demonstration of friction perception generated by Laterally symmetric vibrotactile stimuli

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Abstract. Laterally asymmetric vibrotactile stimuli produce anisotropic or direction-dependent friction force that function as a friction display system [1]. In this study, we showed that laterally symmetric vibrotactile stimuli increase friction perception by a similar principle. We measured the frictional forces between a sliding finger pad and a contactor laterally vibrating at 3 or 5 H. We found that lateral vibrations led to zero relative velocity between the finger pad and contactor, which resulted in frequent sticking between the two bodies. Consequently, humans perceived stronger friction when scanning the vibrating contactor than when scanning a stationary contactor.

Keywords: Texture display, Skin stretch, Friction, Vibrotactile

1 Introduction

Recently, we observed that perceived friction increased when human subjects scanned a contactor that asymmetrically vibrated along the lateral direction of finger pad [1]. We measured the impulse of the frictional force applied to the finger pad sliding on the contactor, and found that it was larger for sliding in one direction than for the other owing to the anisotropic frictional condition produced by asymmetric vibration. This anisotropy was also verified in a perceptual experiment. A possible explanation of this phenomenon is that the finger pad sticks more frequently to the contactor when sliding in one direction, and that the sticking phase produces a frictional force larger than the sliding phase.

In principle, even symmetric vibration (e.g., a sinusoidal wave) could cause more frequent sticking than a non-vibrating condition. In this study, we experimentally tested this possibility. We measured the frictional forces between the sliding finger pad and the contactor, when the latter vibrated at 0 (no vibration), 3 and 5 Hz. By comparing the frictional forces among these conditions, we concluded that laterally symmetric vibrotactile stimuli could cause stick-and-slip phenomena that led to increased friction and its perception. Although, some earlier studies [2–6] on the relationship between percepts for vibration and friction have been conducted, no study appears to have increased friction perception by laterally symmetric vibration.

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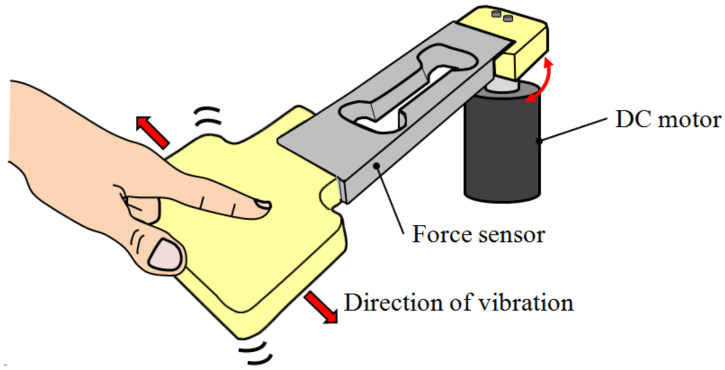

Fig. 1. Lateral vibrotactile display based on a DC motor and equipped with a load cell. The finger scans the contactor along the direction of vibration.

2 Experimental setup and Procedure

2.1 Lateral vibrotactile display

We constructed a vibrotactile display based on a DC motor (RE-40, Maxon) with an encoder (Type L, Maxon), as shown in Fig. 1. The contactor, which was made of finely polished ABS plastic, was fastened to the motor through a load cell (Model 1004, Tedea Huntleigh). We estimated the frictional force between the finger pad and contactor by subtracting the inertial force of the contactor from the force measured by the load cell.

2.2 Measuring frictional force

We measured the frictional forces while a voluntary participant slid his or her finger along the contactor. Three contactor conditions were tested : vibrating at 3 Hz, vibrating at 5 Hz, and stationary. Each participant repeatedly scanned the contactor under these conditions in one direction for a sustained amount of time. Fig. 2 shows two samples of measured frictional forces. For comparison purposes, the frictional forces for the still contactor (solid curve) and those for the vibrating contactor (dotted curves) are plotted on the same figure. Note that the figures also show forces while the finger was not in contact with the contactor. These non-contact phases are indicated by the periods with negligible friction forces.

The frictional forces of the still contactor (solid curves) indicate that stick-and-slip phenomena hardly occurred when the contactor was slid by the finger because the fluctuations in friction were minuscule. Although some exceptions were observed at the beginning of sliding motions, the measurements corroborated the notion that kinetic friction was dominant for the still plastic contactor.

In contrast, the frictional forces (dotted curves) between the vibrating contactor and finger pad significantly fluctuated. This suggests that the sticking and

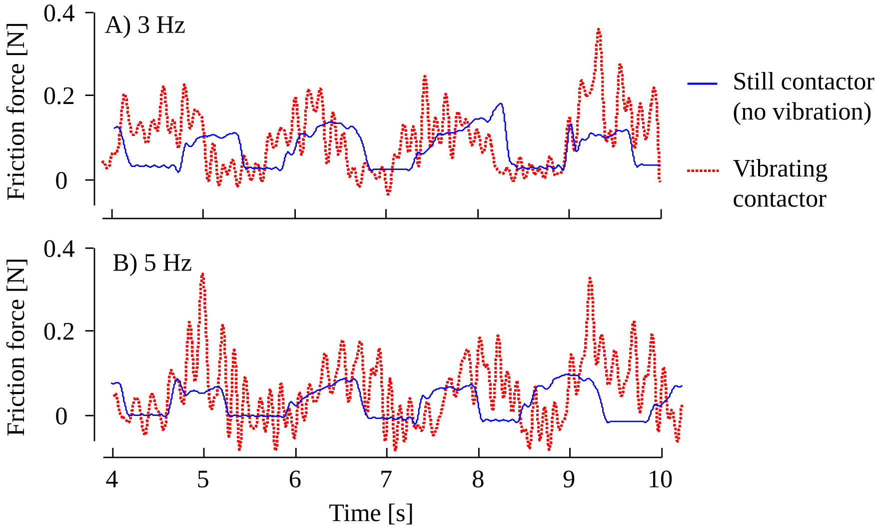

Fig. 2. Frictional forces when the finger scanned the contactor with and without vibration (A : 3 Hz, B : 5 Hz). During periods in which the frictional force was nearly zero, the finger was not in contact with the contactor. Sticking was more frequently observed between the vibrating contactor and finger than between the still contactor and finger. For visual clarity, components larger than 10 Hz have been filtered out.

slipping modes alternatively appeared. Given that the maximum static friction is greater than the kinetic friction, the frictional forces observed with the vibrating contactor were largely greater than those observed with the still contactor. Furthermore, such sticking between the finger pad and vibrating contactor were perceived clearly by all those who experienced the laterally vibrating stimuli.

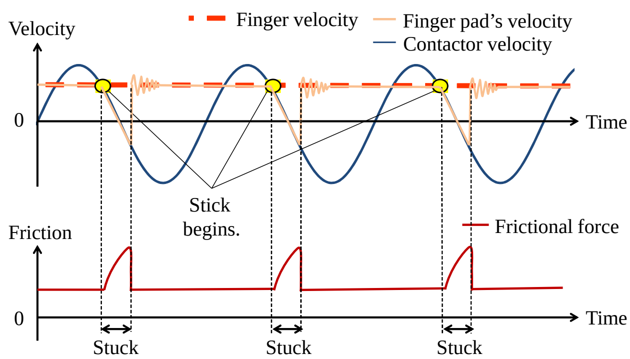

Fig. 3. Velocity of the finger and vibrating contactor and the frictional force between them

3 Discussion and Conclusion

Larger frictional forces were observed when scanning the vibratory contactor than when scanning the still contactor. Fig. 3 shows a conjectural interpretation of this observation. In general, when the relative velocity between the two bodies is non-zero, they are sliding. As described before, slippage was predominant when the finger slid on the still contactor. On the other hand, when the finger slid on the vibrating contactor, the sign of the relative velocities periodically switched. This switch would have led to sticking of the two bodies and caused greater friction. The friction increased, synchronizing with the occurrence of sticking or vibration because the maximum static friction is greater than the kinetic friction. Our interpretation is supported by the fact that the frictional forces observed in Fig. 2 showed frictional fluctuations whose frequencies were consistent with the vibratory frequencies of the contactor.

In summary, we speculate that when a finger slides on a laterally vibrating contactor, sticking occurs between the two bodies and perception of this friction is amplified. We will pursue the principles underlying this phenomenon in future studies.

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