A Study of Mounting Methods for Tactors Using an Elastic Polymer

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ABSTRACT

Vibrotactile displays are expected to be useful and effective tools for presenting personal information. However, various external factors, such as the orientation of the tactor or pressure applied to it, affect the consistency of the vibration. Here, we propose a new robust mounting method for a traditional tactor using an elastic polymer. Results from simulated experiments using FEM and a user study indicate that our proposed method provides more consistent vibrotactile sensation than conventional methods, independent of outside forces.

CR Categories: H.5.2 [Information Interfaces and Presentation]: User Interfaces - Haptic I/O

Keywords: vibrotactile, mounting method, elastic polymer.

1 INTRODUCTION

Current research focusing on displaying near-field haptic cues in immersive virtual environments often use DC motors to function as vibrotactile units (we call "tactors"). These tactors create a vibration with a spinning eccentric mass where an increase in voltage produces an increase in vibration intensity.

One problem with using this type of tactor is that the actual frequency depends on various factors beyond the control of just the applied voltage. The changing characteristics of how the tactor is mounted, such as the orientation of the tactor or pressure applied to it, can significantly change the frequency with which the tactor vibrates.

In certain scenarios this is not a significant problem. For instance, in some cases like cell phone, tactors run with only a binary state, ON or OFF [1, 2]. A change in the frequency does not matter, as long as the subject can feel the vibration. However, in situations where the intensity of vibration is important, such in [3], external effects, such as pressure, can alter the intended result of their stimulus.

To solve this problem, we have proposed a method utilizing a piezoelectric film sensor that monitors mechanical conditions of vibration and using a feedback loop to dynamically adjust the motor power to maintain the target frequency [4]. The method has produced the desired result, however, it increases the complexity of the system. The goal in this paper is to realize a robust mounting method for a traditional tactor using an elastic polymer, which is less susceptible to outside forces without the additional complexity of a feedback system.

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2 PROPOASED METHOD

Conventionally, tactors are mounted directly on the skin using sticky tape, or held tight using an elastic belt. In such cases, the mechanical condition around the tactor and the skin changes over time. We believe the vibration of the tactor deeply depends on this inconstant mechanical condition of mounting. We, therefore, insert the tactor into elastic material and mount it on the skin using tape or a belt. Using this method, pressure applied on the tactor from the tape or the belt is evenly dissipated, then mechanical deformation and stress on the skin attached the tactor are reduced. Finally, we expect that the user will feel constant vibration independent of changing conditions.

Figure 1 shows a prototype of the proposed method. We use a cylindrical acrylic ring with a bottom as an outer case, and fill it with elastic silicone polymer (Human Skin Gel, hardness 0, by Exseal Corp.). Then we mount a conventional DC-motor-based tactor (FMIU-004 made by Fujikura) into the silicone. The gel we use has human-skin-like properties. The tactor is 8mm in diameter and 5mm in height, and weights 1.2g. After the tactor is encased it is 19mm in diameter and 19mm in height. Total weight of the prototype is 4.0g.

3 FEM SIMULATION

To evaluate the mechanical effectiveness of the proposed method, we performed a simulation of the deformation of the skin using FEM. To ease the FEM, we use a two-dimensional model. As shown in Figure 2, we define a three-layer model consisting of bone, skin material, and the tactor. The thickness of the skin and bone is 20 mm and 10 mm, respectively. The tactor is covered by elastic material. Young's modulus of the bone, the tactor, and the outer case are $2.2x10^2$ Pa ($2.2x10^{-2}$gf/mm^2) and the modulus of the skin and the elastic material is 1.4x10 Pa ($1.4x10^{-3}$gf/mm^2). As the boundary condition, the bone and skin structures are extended infinitely in the X and Y directions. We applied 9.8N(1kgf) on the top of the

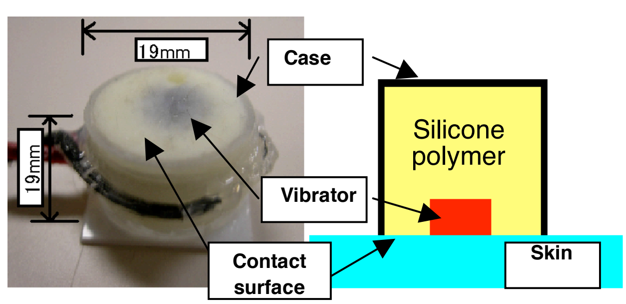

Fig. 1 Proposed mounting method using silicone polymer

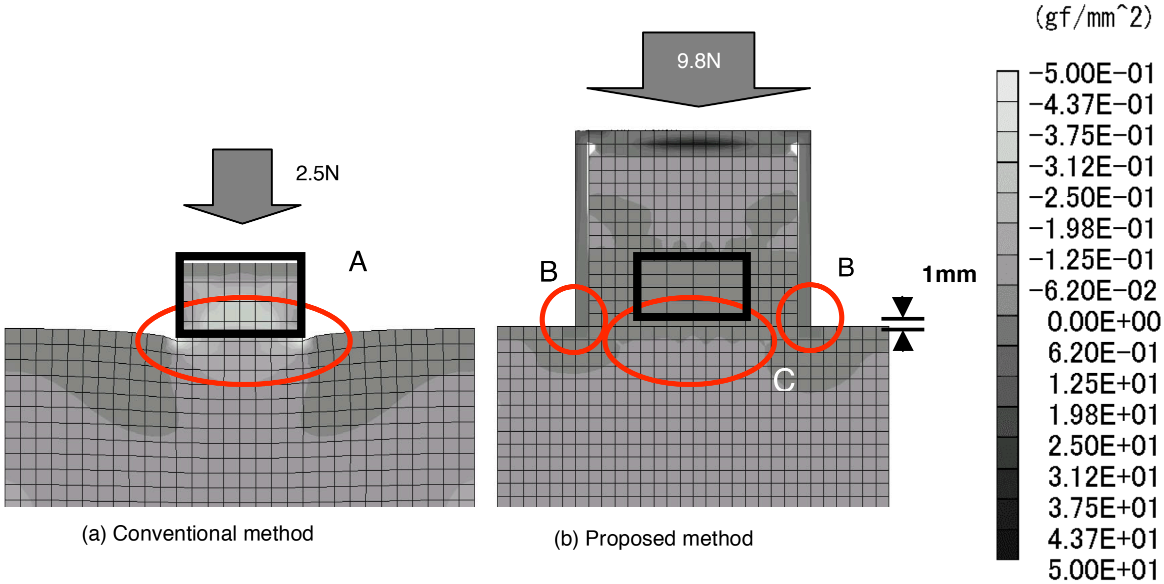

Fig. 2 Stress distribution chart inside a skin in the case of the proposed method

outer case. To compare effectiveness, we modeled a more-conventional mounting method. Here, we directly placed the same tactor on the skin, and applied 2.5N(0.25kgf) on it, where pressure in contact is equal between the two models.

The results show that a concentration of stress and deformation is observed around the edge of the outer case, as indicated in area B in Figure 2. However, compared with the conventional method, just one tenth of the stress is applied near the tactor as indicated area A and B. There are many mechanoreceptors for vibrotactile sensation in subcutaneous tissue. This means that the mechanical stress was reduced in the case of the proposed method. Therefore, applied forces will affect neither the tactor nor our mechanoreceptors for vibrotactile sensation as much.

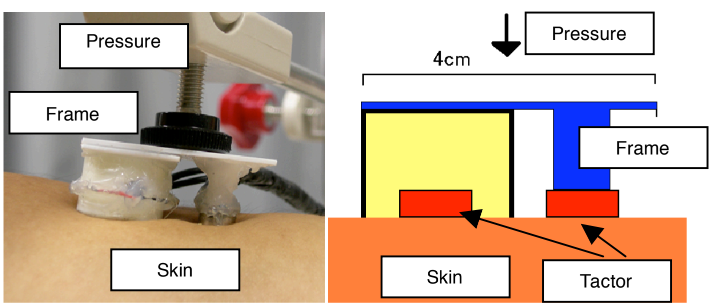

Fig. 3 Experimental setup

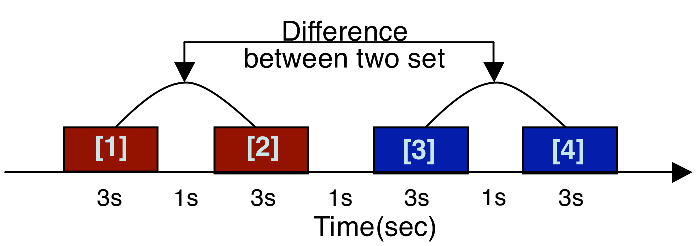

Fig. 4 Process of a trial in the experiment

4 SUBJECTIVE EMPIRICAL STUDY

We performed a user study on 11 subjects by attaching two tactors both using the conventional and the proposed mounting methods. We made a special frame that s mounted two tactors as shown in Figure 3, and placed it on the center of their left upper arm. In each trial, one tactor vibrated for three seconds at first, as shown in Figure 4, then the experimenter applied pressure on tactors, and same tactor was vibrated for three seconds again. The other tactor followed the same sequence. Between the stimulation, we placed 1second interval. After a subject felt the two sets of vibrations, we asked which tactor gave different feeling with and without the weight. We applied the pressure placing metal weights on the frame, so we kept condition consistently. Here, we used a 2.8N(0.28gf) weight.

Figure 5 shows the averaged number of answer, either a subject felt difference in the set of stimulation or not from 9 subjects. The two remaining subjects displayed the opposite

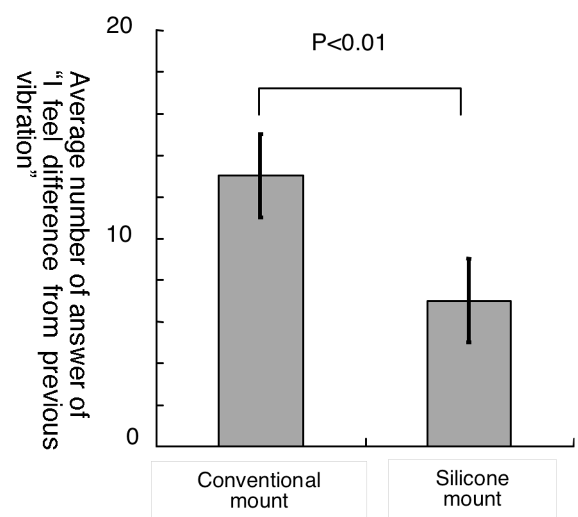

Fig. 5 Subjective answer for difference of vibration with or without pressure

behavior. We checked the condition of experiment, and found that the outer case was attached at an angle, so the silicone face was not touching the skin. Therefore, we have omitted their results. Finally, as shown in Figure 5, the average number of answers shows a statically meaningful difference between the mounting method treatments, and we confirm that the proposed method gave a smaller change of feeling.

5 FUTURE WORK

Results from simulated experiments using FEM and a user study indicate that our proposed method provides more-consistent and robust vibrotactile sensation than the conventional mounting method, independent of outside forces. Through the user study, we noticed that our method may not be very effective near joints. We will try various sizes and structures of elastic materials to achieve a more robust mounting method.

Acknowledgment

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