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Configuration of an Ultrasonic Linear Motor for Use in a Medical Bed

医療ベッド用超音波リニアモータの構成

Atsuyuki Suzuki[1‡], Masaki Tsunoji[2], and Jiromaru Tsujino[3] ([1,2]Tokuyama College of Technology; [3]Fucult. Eng., Kanagawa Univ.)
鈴木 厚行 [1‡], 津野地 政規 [2], 辻野 次郎丸 [3] ([1,2]徳山高専, [3]神奈川大 工)

1. Introduction

Ultrasonic motors have unique characteristics such as high torque at low speed, high holding torque, silent motion, and absence of magnetic noise. At the place like a hospital, these characteristics are required. Therefore, our study focuses on the actuators for use in a medical bed.

We devised a bedsore prevention bed using multiple ultrasonic linear motors **(Fig. 1)**. Bedsores are lesions which are caused by prolonged pressure on the skin. In order to distribute the pressure applied to a body, the motors are installed in a grid arrangement and controlled in response to impressed pressure. Independent motor cells provide even weight distribution and pressure relief. This bed system can be applied to a surgical bed which is chaged into various shapes.

In this study, we developed a prototype an ultrasonic linear motor for use in a medical bed. The vibration and load characteristics of the ultrasonic linear motor were measured.

2. Configuration

Fig. 2 shows the prototype of the ultrasonic linear motor for use in a medical bed. The motor consists mainly of a complex vibration source, a slider, a pressure source. The complex vibration source incorporates a connector, spacers with a flange, and two bolt-clamped Langevin type longitudinal vibration transducers (BLT). The transducer (a) is installed at right angle to the slider. On the other hand, the transducer (b) is installed at an angle of 10 degrees to the slider in order to prevent contact of the electrodes with the slider. Therefore, the shape of the connector is a connected horn. We define the aspect of the contact area with the slider as the anterior aspect.

The resonant frequency of the BLTs is 60 kHz. The diameter of the BLTs is 15 mm. A slider is installed under pressure by using a coil spring. The stroke of the slider is approximately 60 mm. Driving directions can be changed by adjusting phase difference.

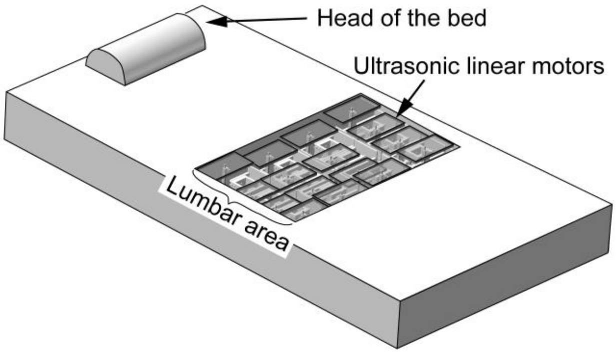

Fig. 1 Schematic diagram of a bedsore prevention bed using multiple ultrasonic linear motors.

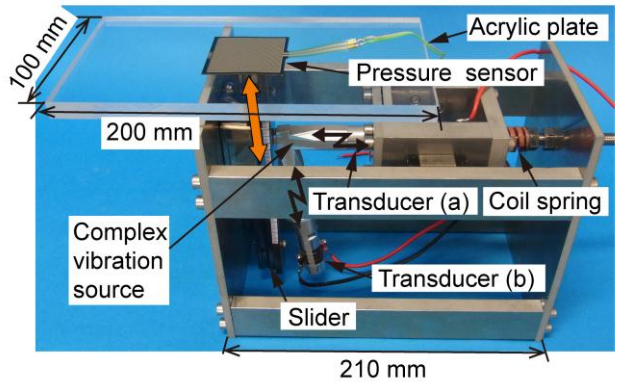

Fig. 2 Configuration of the ultrasonic linear motor for use in a medical bed.

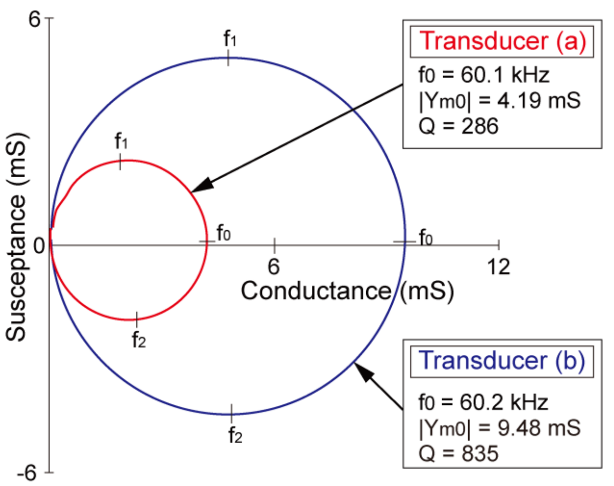

Fig. 3 Admittance loops of the ultrasonic transducers (a) and (b).

‡ e-mail address: a-suzuki@tokuyama.ac.jp

3. Vibration characteristics

The admittance loops were measured using an impedance analyzer. **Fig. 3** shows the admittance loops of the ultrasonic transducers. The resonant frequencies of the transducers (a) and (b) were 60.1 kHz and 60.2 kHz, respectively. It was confirmed that the resonant frequencies of the transducers were almost same as those of the BLTs (60 kHz). Characteristics of each transducer are expected to be same. However, the motional admittance |Ym0| and the quality factor of the transducer (a) were less than half of those of the transducer (b).

The vibration amplitude distributions along the side surfaces of the complex vibration source are shown in **Fig. 4**. Only one transducer where the distribution was being measured was driven. Standing waves which were approximately 1.5 times of the wavelength occurred along each of the transducers as designed. However, positions of nodes and antinodes shifted slightly.

The vibration amplitude distributions along the anterior and superior surfaces of the complex vibration source are shown in **Fig. 5**. Only one transducer where the distribution was not being measured was driven. The bending vibrations occurred along the transducers, although the vibration amplitude along the spacers and the BLTs was small as compared to that at the contact areas with the slider (the driving surfaces).

4. Load characteristics

The load characteristics of the ultrasonic linear motor are shown in **Fig. 6**. The maximum thrust, speed, and efficiency of this motor are 40 N, 267 mm/s, and 1.7% (at 12 N), respectively, at the driving frequency of 60 kHz. The maximum thrust and speed were higher than the corresponding values of the motor which we previously devised.

5. Conclusion

In order to develop an actuator for use in a medical bed, we devised the ultrasonic linear motor using two ultrasonic transducers that are installed at an acute angle. The vibration and load characteristics of the motor were measured. The no-load speed of 267 mm/s and the maximum thrust of 40 N were obtained. It is possible to improve the performance of the motor by matching vibration characteristics with those of the transducers. This matching appears achievable by improving machining precision.

Acknowledgment

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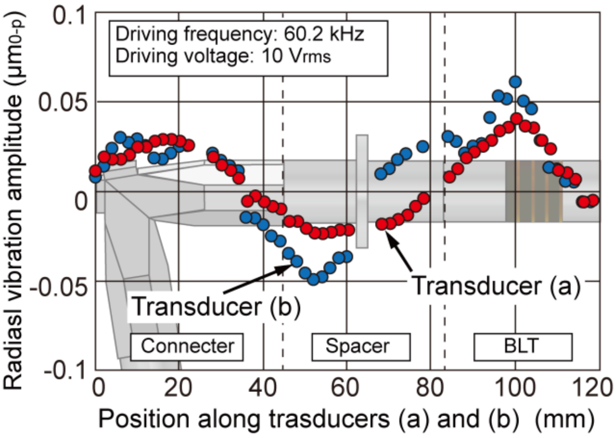

Fig. 4 Vibration amplitude distributions along the side surfaces of the transducers (a) and (b).

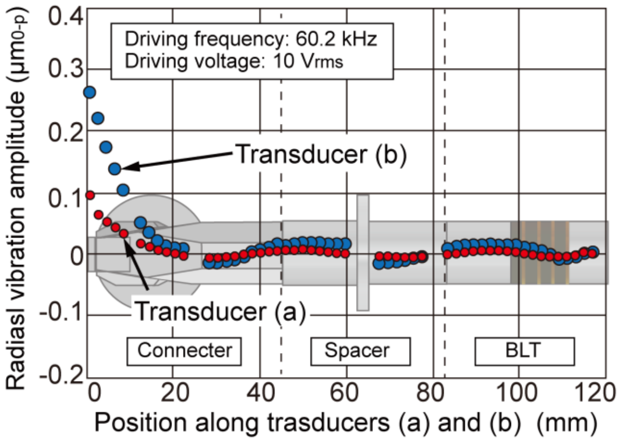

Fig. 5 Vibration amplitude distributions along the anterior and superior surfaces of the transducers (a) and (b).

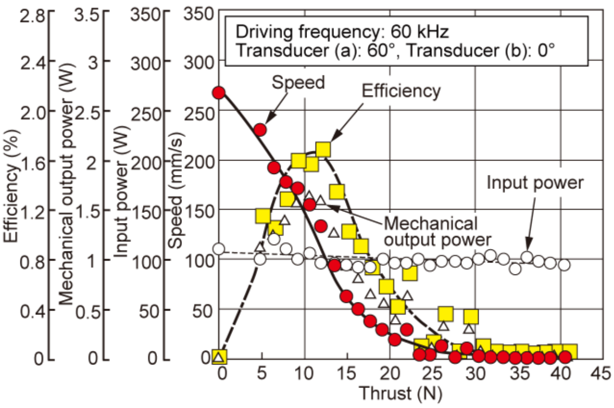

Fig. 6 Load characteristics of the ultrasonic linear motor.