DEVELOPMENT OF A TWEEZERS ROBOT EQUIPPED WITH BIMORPH PIEZOELECTRIC ACTUATORS

Toru Fujishita and Satoshi Honda
Tokyo Metropolitan Institute of Technology, Japan

1. Introduction

When we pick up a small soft capsule of unknown weight and unknown surface condition by using a tweezers, we must estimate the appropriate grasping force. If estimated value of grasping force is too weak or too strong, the capsule slips down or is distorted. If the picking robot picks up the soft capsule of unknown weight and unknown surface condition, the robot has to have an intelligent method to estimate the most suitable grasping force or has to have a huge date base for referring the value of the most suitable grasping force against all of capsules. However, to have the huge data base is not possible in fact because the value of the most suitable grasping force for individual capsule is different and there are many capsules that the picking robot might be required to grasp. Some tweezers robots have been developed with an intelligent method.[1)2)] This tweezers robot can automatically grasp the small soft capsule of unknown weight and unknown surface condition with its most suitable grasping force. The tweezers robot can estimate the most suitable grasping force by using active vibrating. This paper describes the structure of the tweezers robot, the grasping algorithm and theoretical analysis.

2. Structure of the tweezers robot

The tweezers robot has two parallel fingers. Each finger consists of the front slender beam attached

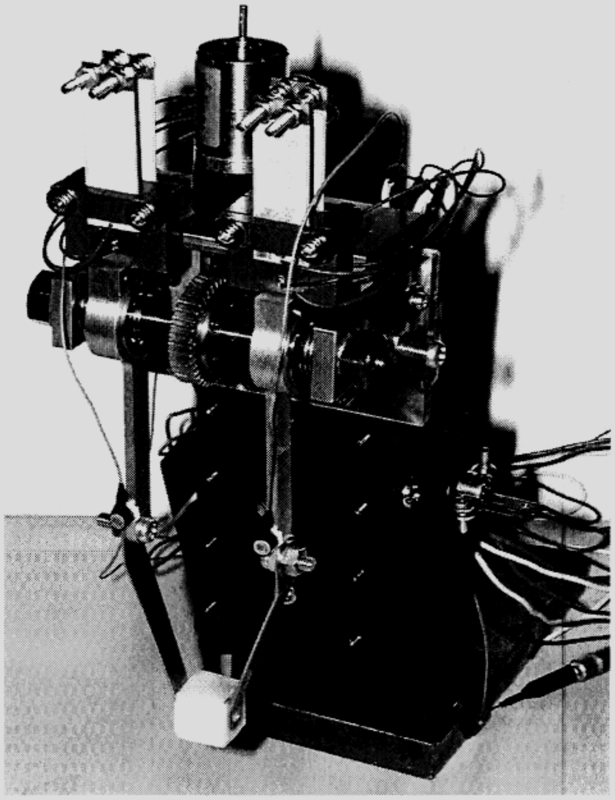


Figure 1. The tweezers robots equipped with bimorph piezoelectric actuators

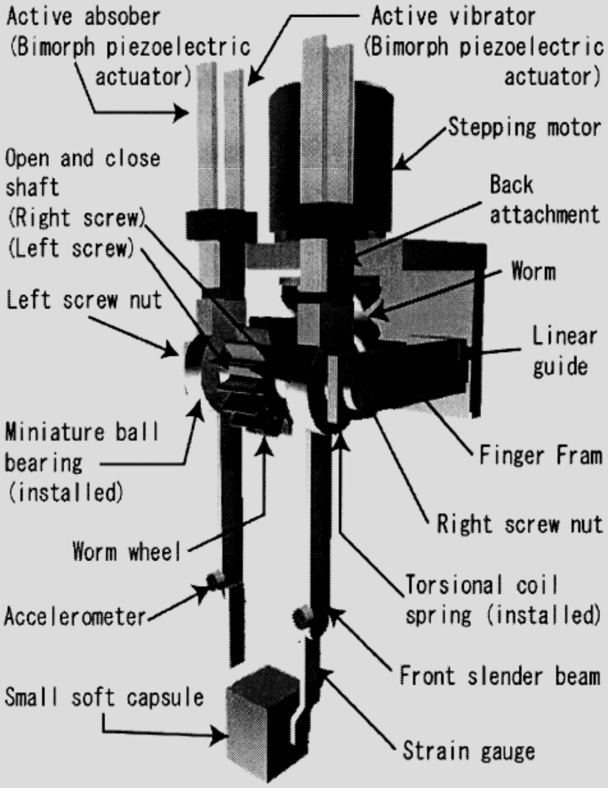


Figure 2. Structure of the tweezers robot

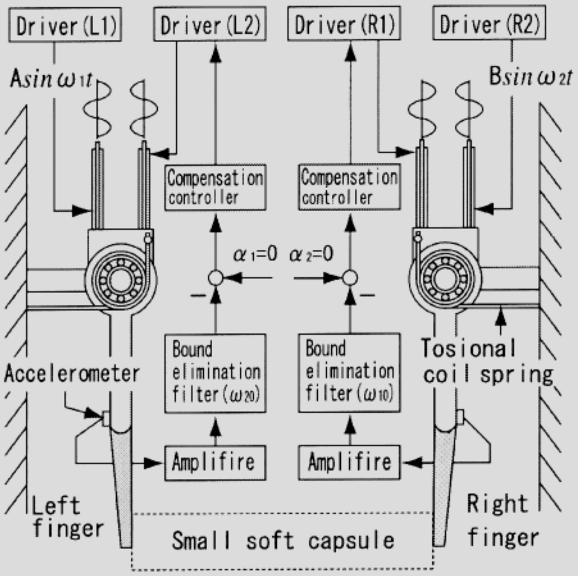


Figure 3. Control circuit for the active absorber and the active absorbers

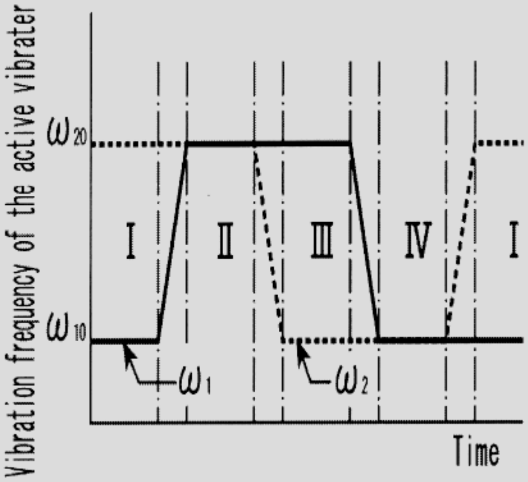


Figure 4. Control sequence of the vibrators

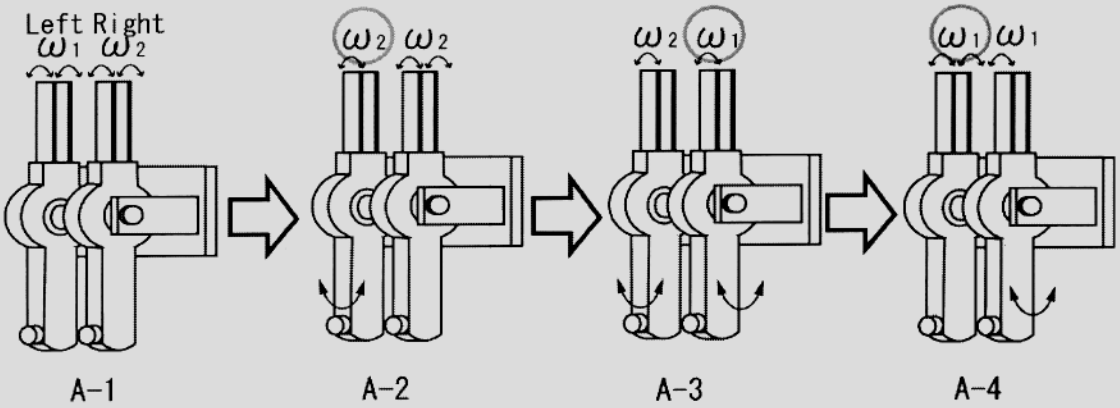
an accelerometer and a vibration unit composed of the active vibrator and the active absorber. The miniature ball bearing is installed between the front slender beam and the vibration unit. Each finger is supported on an open and close shaft as like a balancing toy. The torsional coil spring couples on the finger to a finger frame supporting the bearing shaft, so the finger composes a rotational vibration system. The active vibrator and the active absorber are composed of bimorph piezoelectric actuators. When the active vibrator shakes with a certain amplitude and a certain frequency, the tip of the front slender beam vibrates with relative amplitude and the same frequency. In the tweezers robot, the active absorbers are driven, so the rotational acceleration of the front slender beam reduces to zero and the tips of the front slender beams keep in a stationary condition. The small soft capsule is grasped between both tips of the front slender beams.

3. Grasping Method

3-1 Initial grasping process

Before the tweezers robot grasps the small soft capsule, vibration frequency of the active vibrators are set to the value of w1 (omega 1) and w2 (omega 2) individually. The tips of both fingers are controlled in the stationary condition by using control circuits as shown in figure 3. In this figure, acceleration of the tip is detected by the accelerometer. Each acceleration signal filters through a bound elimination filter which eliminatory frequency is w20 (omega 20) or w10 (omega 10). Error signal between reference acceleration which value is zero and detected acceleration is inputted to a compensation controller. The active absorbers are driven as the tips of the fingers are in the stationary condition.

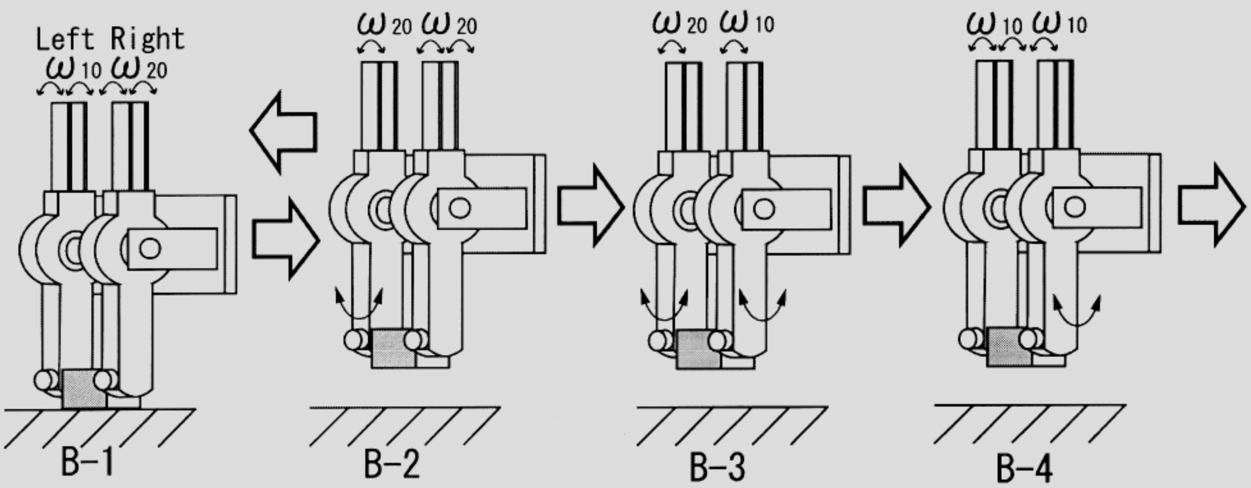
In the tweezers robot, vibration frequency for the active vibrators changes in the sequence shown in figure 4. When the left active vibrator vibrates with frequency of w10 and the right active vibrators vibrates with frequency of w20, both tips of the fingers keep stationary as shown figure 5-A1. When the vibration frequency of the left active vibrator changes to frequency of w20, the tip of the left finger vibrates with frequency of w20 and the tip of the right finger remains stationary (See figure 5-A2). When the vibration frequency of the right active vibrator changes to frequency of w10, the tip of the left finger vibrates with frequency of w20 and the tip of the right finger vibrates with frequency of w10 (See figure 5-A3). When the vibration frequency of the left active vibrator returns to frequency of w10, the tip of the left finger become stationary and the tip of the right finger continues to vibrate (See figure 5-A4). When the vibration frequency of the active vibrators individually return to the initial frequency, both tips of the



Condition of vibration at the tips of the fingers

Left	Stationary	Vibrate with ω_{20}	Vibrate with ω_{20}	Stationary
Right	Stationary	Stationary	Vibrate with ω_{10}	Vibrate with ω_{10}

Figure 5. Initial grasping process



Condition of vibration at the tips of the fingers

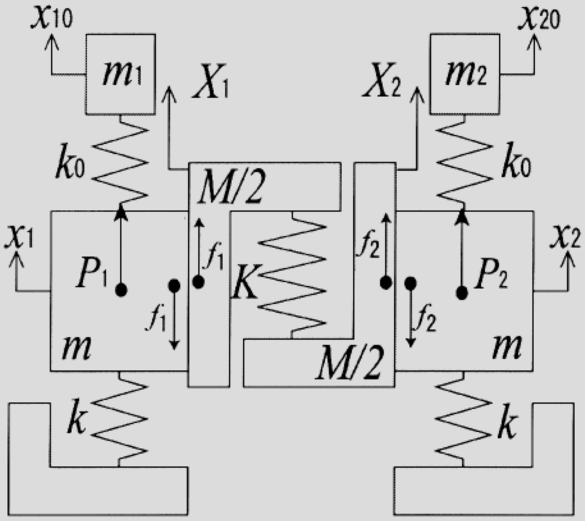
Left	Stationary	Vibrate with ω_{20}	Vibrate with ω_{20}	Stationary
Right	Stationary	Stationary	Vibrate with ω_{10}	Vibrate with ω_{10}
		Grasping force is increased to the value in which the amplitude of left finger becomes smaller than the amplitude in process A-2	Grasping force is decreased to the value in which the amplitude of both finger becomes the same amplitude in process A-3	Grasping force is increased to the value in which the amplitude of right finger becomes smaller than the amplitude in process A-4

Figure 6. Holding process and the most suitable grasping condition

active vibrators become stationary.

3-2 Holding process and the most suitable grasping condition

When the tips of the fingers contact the small soft capsule with weak grasping force, both tips of the fingers remain stationary (See figure 6-B1). When the tweezers robot is slowly raised to lower height and frequency of the active vibrator attached on the left finger changes to the frequency of w20, if the grasping force is smaller than the most suitable grasping force, the capsule slips down and tip of the left finger vibrates with the same amplitude explained process A2. (See figure 5-A2). The tweezers robot increases grasping force step by step, and the grasping trial is repeated. When the grasping force becomes to the most suitable value, amplitude at the tip of the left finger becomes smaller than the amplitude of process A2, for vibration at the tip of the left finger transmits to the right finger through the capsule and transmitted vibration is absorbed by the active absorber of the right finger (See figure 6-B2). In this process, the capsule is grasped with the most suitable grasping force. When frequency of the active vibrator attached on the right finger changes to the frequency of w10, if amplitude at the tips of both fingers remain in small amplitude, the capsule is grasped with excessive force (See figure 6-B3). The tweezers robot decreases grasping force. If amplitude at tips of both fingers become bigger, amplitude at tips of both fingers become bigger, frequency of both active vibrators change to the initial frequency of w10 and w20. The tweezers robot repeats the sequence and grasps the small capsule with the most suitable grasping force.



$P_1 = m_p r \omega_1^2 \sin \omega_1 t \qquad P_2 = m_p r \omega_2^2 \sin \omega_2 t$

$\omega_{10} = \sqrt{\frac{k_0}{m_1}} \qquad \omega_{20} = \sqrt{\frac{k_0}{m_2}}$

Figure 7. Analytical model

4. The most suitable grasping force

Figure 7 showed a theoretical analysis model which represent components of the tweezers robot by mass blocks and springs. Mass of the finger is m. Spring constant of torsional spring is k. The vibration forces generated by both active vibrators composed of bimorph piezoelectric actuators are P_1 and P_2. Passive absorbers composed of mass blocks (m_1, m_2) and spring (k_0) are substituted for the active absorbers composed of the other bimorph piezoelectric actuators. The capsule is consisted of two mass blocks (M/2) and a spring (K). To grasp the capsule with the most suitable grasping force in the process B-2 means to hold the mass block of (M/2) in which the mass block of the left hand is vibrating and the mass block of the right finger is stationary without slipping. The most suitable grasping force F_0 becomes as follows;

$F_0=m_p r(Mm_1k_0^2-Mm_2k_0^2-2mm_1Kk_0+2m_2^2Kk_0)/us(mm_1m_2k_0+Mm_2^2k_0+2mm_2^2k_0+2mm_2^2k_0-2m_1m_2^2k_0-2m_1m_2^2K-4m_2^3K)$, where us is coefficient of friction between the capsule block and finger block.

5.Conclusions

The newly developed tweezers robot can automatically grasp the small soft capsule of unknown weight and unknown surface condition with its most suitable grasping force. The grasping algorithm is designed and the tweezers robot is produced.

References

[1] Satoshi Honda: “Development of an Intelligent Gripper with a Dynamic Vibration Absorber”, International Journal of The Japan Society for Precision Engineering, Vol.31, No.1, March (1997).
[2] Satoshi Honda: “Development of a Tweezers Robot Equipped with Active Vibrations and Active Absorbers”, Proceedings of 1st international conference and general meeting of EuSPEN, Bremen, Germany, Vol.1, pp112-115 (1999).