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A Study on an Object Transport System Using Ultrasonic Wave Excitation

Sang-Hwa Jeong[a,*], Gwang-Ho Kim[b], Suk-Bong Choi[b], Jun-Ho Park[b],
Kyoung-Rae Cha[c]

[a] *Dept. Of Mechanical Engineering, College of Engineering, Chosun University, 375 Seosuk-dong, Dong-gu, Gwang-ju, 501-759, Korea*
[b] *Department of Mechanical Engineering, Graduate School, Chosun Univ., Gwang-ju, Korea*
[c] *Department of Mechanical Aerospace Engineering, North Carolina State Univ., Raleigh, U. S. A.*

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Abstract

The development of information and telecommunication industries leads to the development of semiconductor and optical industries. In recent years, the demand of optical components is growing due to the demand of faster network. On the other hand, conventional transport systems are not adequate for transporting precision optical components and semiconductors. Because the conveyor belt can damage precision optical components with contact force and a magnetic system would destroy the inner structure of semiconductor with magnetic field, a new system for transporting optical components and semiconductors is required. One of the alternatives to the existing systems is a transport system using ultrasonic wave excitation since it can transport precision components such as semiconductors and optical components without damage. In this paper, a transport system using 2-mode ultrasonic wave excitation was developed for transporting optical components and semiconductor, and its performance was evaluated. The relationship between transporting characteristics and flexural beam shapes were evaluated.

Keywords: Transport system; Ultrasonic wave excitation

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1. Introduction

A transport system is one of the essential equipment required in various fields of industry and important for higher productivity and production automation. In recent years, faster and more accurate transport systems are required compared with conventional transport system. They also required to be condition-specific in which each has to suit product property or work environment. The semiconductor, optical communication and optical industries are thriving due to the development of the information and communication industry in the early to mid 1990' s. With the recent demand of faster communication net, the demand of optical elements required for optical communication is also on the rise. Furthermore, the demand of semiconductor is multiplying with the progression in mobile communication and computer. Thus, a new system is required to transport semiconductors and optical elements because existing systems may damage precision materials in which magnetism affects semiconductors and contact force damages the surface of optical elements. A new transport system using ultrasonic wave excitation would be an answer to these problems by being able to safely transport optical elements by preventing contact force resulting in lens scratch and semiconductors by avoiding damage from electronic array. Compared with the conventional conveyor transport

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[*] Corresponding author. Tel.: +82 62 230 7178, Fax.: +82 62 230 7178
E-mail address: shjeong@chosun.ac.kr

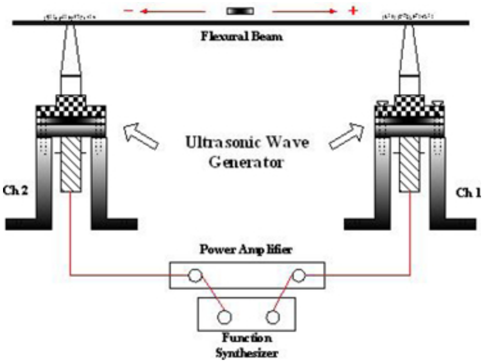


Fig. 1. Layout of an object transport system.

system, an object transport system using ultrasonic wave would be appropriate for transporting precision items prone to damage. Actuators using ultrasonic wave have been examined in the late 1980' s mainly in the US and Japan.

In this paper, an object transport system using ultrasonic wave was developed, and the characteristics of this system was examined. Relationship between progressive frequency transporting objects and phase-difference, phase-difference and transportting direction, and progressive frequency and transporting direction were examined. An experiment was done to evaluate changes in the shape and length of flexural beam, which transmits traveling wave directly to the object.

2. Experiment apparatus

The object transport system using ultrasonic wave excitation is shown in Fig. 1 and composed of function synthesizer, power amplifier, flexural beam and ultrasonic wave generator. The ultrasonic wave generator is composed of the piezoelectric actuator, booster, and conical horn. The piezoelectric actuator generates ultrasonic wave, and booster protects the piezoelectric actuator from damage and amplifies ultrasonic wave generated. Ultrasonic wave amplified in the booster is amplified the second time in the horn. The flexural beam converts ultrasonic wave generated in the ultrasonic wave generator into traveling wave and levitation wave. It is connected with a bolt avoiding the ultrasonic wave generator and node and composed of a material having high acoustic characteristics.

Table 1. Conditions of phase-difference.

	Ch 1	Ch 2
Case 1	Set at 0°	10° decrement
Case 2	10° increment	Set at 0°
Case 3	10° decrement	Set at 0°
Case 4	Set at 0°	10° increment

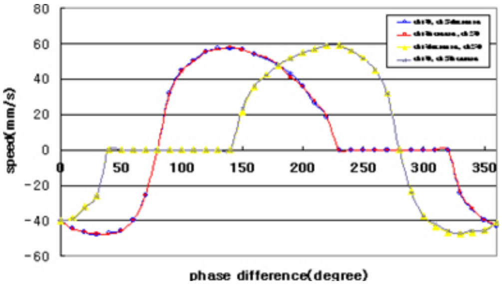


Fig. 2. Transport speed according to phase-difference.

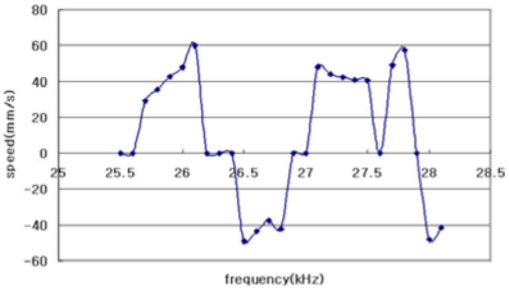
3. Transport characteristics according to changes in phase-difference

Transport characteristics were observed by changing phase-difference and setting frequency and voltage constant. As for experimental condition, the frequency was set at 28.0kHz, input voltage at 500V, and weight of object at 20g. The experiment was carried out by changing phase-difference between the two ultrasonic wave generators from 0° to 360° at a 10° increment or decrement. Table 1 shows phase-difference change in the function synthesizer.

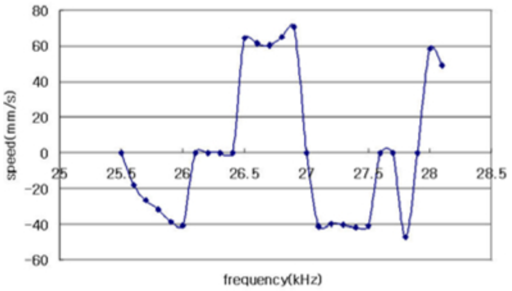
Figure 2 is the graph showing changes in transport speed and direction according to changes in phase-difference. When the experiment was carried out with the conditions cases 1 and 2, the results showed that the fastest transport speed in the negative direction (−) was 48.1mm/s with the phase-difference between the two generators of 30°, whereas it in the positive direction (+) was 58.0mm/s with the phase-difference of 140°. In cases 3 and 4, it in the negative direction(−) was 47.6mm/s with the phase-difference of 330°, and it in the positive direction (+) was 59.2mm/s with the phase difference of 220°. These results showed that the direction and speed of transporting object could be changed by changing the phase-difference between the two ultrasonic wave generators.

4. Changes in object transport according to changes in transport frequency

In order to determine changes in object transport according to changes in frequency, the input voltage was set to be constant at 500V with the phase-difference of 30° and 140° and the frequency was increased from 25.5kHz to 28.1kHz at a 100Hz increment to observe changes in object transport. Figure 3(a) is the graph showing changes in transport according to frequency change when the phase-difference was set to be constant at 30°. Figure 3(b) is the graph showing transport changes according to frequency change when it was set at 140°. The results in Fig. 3(a) showed that when the phase-difference was set to be constant at 30°, the maximum transport speed was occurred in the positive direction (+) at 26.1kHz for 60.0mm/s, whereas it was shown in the negative direction (−) at 26.5kHz for 49.1mm/s. When the phase-difference was set at 140° as in Fig. 3(b), the maximum transport speed of 70.7mm/s was shown at 26.9kHz in the positive direction (+), whereas it was 47.3mm/s at 27.8kHz in the negative direction (−). The results showed that the transport direction and speed could be changed by changing the frequency.



(a) Phase difference : 30°

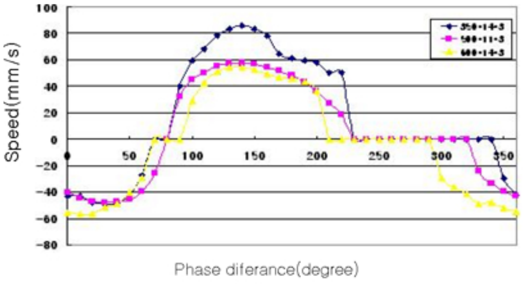


(b) Phase difference : 140°

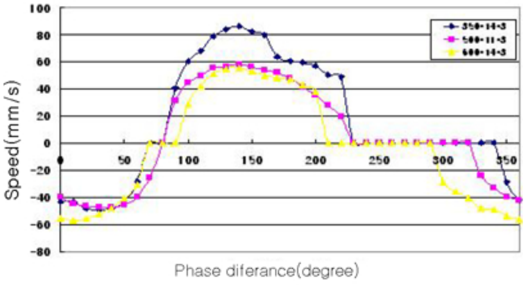
Fig. 3. Transport speed according to frequency.

Table 2. Good-working frequency according to length of the flexural beam.

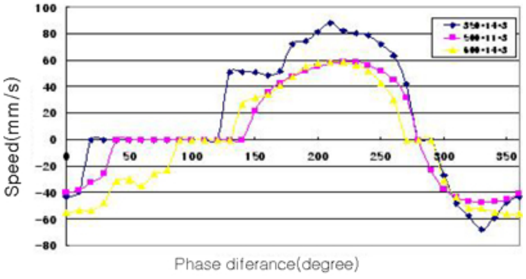
Flexural beam	350 14 3	500 11 3	600 14 3
Good-working frequency	25.5kHz	28.0 kHz	25.9 kHz
Maximum speed	82.94mm/s	32.2 mm/s	50.99 mm/s



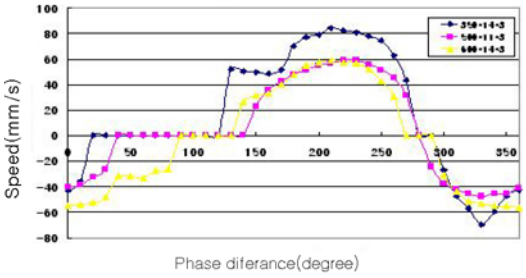
(a) Case 1



(b) Case 2



(c) Case 3



(d) Case 4

Fig. 4. Transport speed according to phase differences at case 1, 2, 3 and 4.

5. Changes in transport characteristics according to changes in flexural beam length

Transport characteristics were observed by changing the flexural beam length 600mm, 500mm, and 350mm. In order to determine the progressive frequency for different length flexural beam, an experiment was performed on transporting a 20g object using an output voltage of 500V and phase-difference of 90°. The frequency was changed from 24.5kHz to 28.1kHz at a 100Hz increment. Table 2 shows the results.

Based on the progressive frequency according to flexural beam length, changes in length according to changes in phase-difference were observed. The direction was defined by positive (+) when the object moved from the left to the right side, and by negative (−) when it moved from the right to the left side. As shown in the graph in Fig. 4, although the maximum transport speed changed slightly according to beam length, the maximum transport speed was shown in the positive direction (+) with phase-difference at 140° and 220° and in the negative direction (−) at 30° and 330°.

6. Transport characteristics according to flexural beam shape

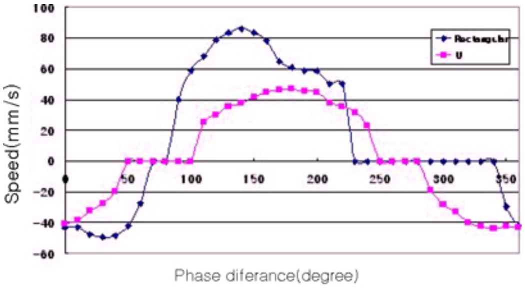
Transport characteristics were observed by changing the flexural beam shape from rectangle to with the flexural beam length set at 350mm. In order to determine the optimal progressive frequency depending on flexural beam shape, an experiment was carried out transporting a 20g object using an out-put voltage of 500V and phase-difference between the two generators of 140°. The frequency was changed from 24.5kHz to 28.1kHz at an increment of 100Hz. Table 3 shows the results.

Transport characteristics were observed by changing phase-difference based on the progressive frequency depending on the shape of each flexural beam. The experiment was carried out by setting the output voltage at 500V for each progressive frequency and the object weight at 20g.

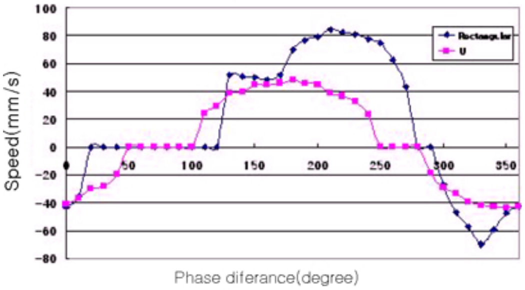
Figure 5 is the graph showing the results of transport characteristics according to changes in phase-difference. The results showed that the maximum transport speed when the flexural beam shape was rectangular was shown in the positive direction (+) at phase-difference around 140° and

Table 3. Good-working frequency according to shape of the flexural beam.

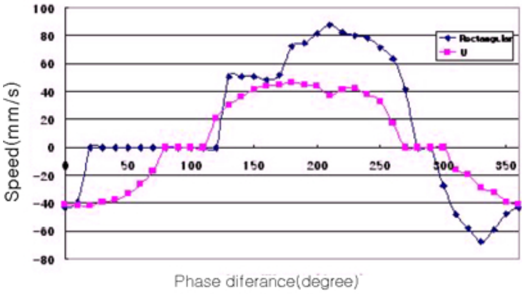
Flexural beam shape	Rectangular	
Good-working frequency	25.5 kHz	26.1 kHz
Maximum speed	82.94 mm/s	37.44 mm/s



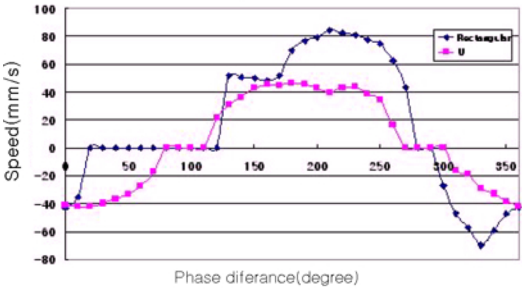
(a) case 1



(b) case 2



(c) case 3



(d) case 4

Fig. 5. Transport speed according to phase differences at case 1, 2, 3 and 4.

220°, and negative direction (-) around 30° and 330°. When the flexural beam shape was , the maximum transport speed occurred in the positive direction around 180°, and the negative direction (-) around 10° and 350°, showing differences. This experiment suggested that the flexural beam shape would significantly affect transport characteristics.

7. Conclusions

An object transport system was developed using ultrasonic wave excitation in this study. To evaluate system performance, experiments were carried out to determine the relationship between progressive frequency and phase-difference, frequency change and transport characteristics, phase-difference change and transport characteristics. In order to apply the developed transport system in other fields, an applicable flexural beam shape was developed and transport characteristics were examined according to changes in the shape and length of flexural beam. The results showed that the changing phase-difference and frequency were detected between the ultrasonic wave generators where the object progressed and transport direction changed. Furthermore, the maximum transport speed was changed in each direction (+ and -) according to changes in phase-difference and frequency. Transport characteristics changed according to changes in flexural beam shape, in which when the flexural beam shape was the same, the maximum transport speed was shown at a same phase-difference regardless of the length or width of flexural beam. However, when the shape was different, the maximum transport speed was showed at different phase-difference according to the shape. When the shape stayed constant and the length changed in the flexural beam, the maximum speed was shown in the positive direction (+) when the phase-difference between the ultrasonic wave generators was 140° and 220° and in the negative direction when it was 30° and 330°. When the flexural beam length was the same and the shape changed, the maximum transport speed was shown in the positive direction (+) when the shape was rectangular at the phase-difference of 140° and 220°, and in the negative direction (−) at 30° and 330°. When the shape was , the maximum transport speed was shown in the positive direction (+) at 180° and in the negative direction (−) at 0° and 360°.

In this paper, the object transport system developed using ultrasonic wave excitation could be applied in actual transport process. It can be especially effective for transporting precision optical and semiconductors affected by magnetic field.

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