

# FABRICATION OF A SNAKE TYPE IN-PIPE MOBILE ROBOT CORRESPONDING TO THE DIFFERENT DIAMETERS

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## 1. INTRODUCTION

We have many small diameter pipes that are cooling pipes for atomic power stations, boiler pipes, and gas or water pipe lines. They must be periodically inspected in order to protect the accident previously. Diameters of these pipes are different at the place where pipes change from the main to the branch. The inspection microrobot for these pipes must move different diameter.

A step comes where the pipe changes its diameter. The in-pipe microrobot driven by wheels is very difficult to cross the step [1]. We have used cone-shape friction rings for the driving legs of the in-pipe microrobot. However, the microrobot driven by friction rings is also difficult to move in the pipe where diameter changes more than 3 mm [2].

Now, we propose a mobile microrobot that can surely move in a pipe whose diameter changes. The microrobot is constructed by the six rubber bellows as pneumatic actuator, six electromagnetic valves and six air feeding tubes. Outer diameter and natural length of the bellows are 8 mm and 53 mm, respectively. The bellows composes three somite by being arranged in two rows and three columns. The somite can make the arc like the bimetal by

giving different pressure to each bellows. The arc somite can hold the pipe. The movement of the microrobot with three somite is imitating as for the accordion movement that is the movement of the snake operation.

The fabricated mobile microrobot was confirmed to move in different diameter pipes whose diameters are between 20 mm and 30 mm. Its speed was 50 mm/s.

## 2. STRUCTURE OF IN-PIPE MOBILE ROBOT

A structure of the fabricated microrobot is shown in Fig. 1. The microrobot is constructed by the six rubber bellows as pneumatic actuator, six electromagnetic valves and six air feeding tubes. Outer diameter and natural length of the microrobot is 15 mm and 170 mm, respectively. The bellows composes three somite by being arranged in two rows and three columns. Outer diameter and natural length of the bellows are 8 mm and 53 mm, respectively. The somite is defined forward of the microrobot as first somite, second somite and third somite. Each somite can make the arc like the bimetal by giving different pressure to each bellows. The first somite and third somite are mechanisms that hold the pipe and the second somite is mechanisms that obtain displacement.

An experimental apparatus for measuring the

characteristics of the microrobot is shown in Fig. 2. A computer controls six electromagnetic valves through a valve controller. Three air feeding tubes are connected from the electromagnetic valves to each bellows of the microrobot. An air compressor is connected to the entrance ports of the electromagnetic valves and feeds pneumatic pressure to stretch the bellows. A vacuum pump is connected to the exit ports of the electromagnetic valves and feeds vacuum pressure to shrink the bellows.

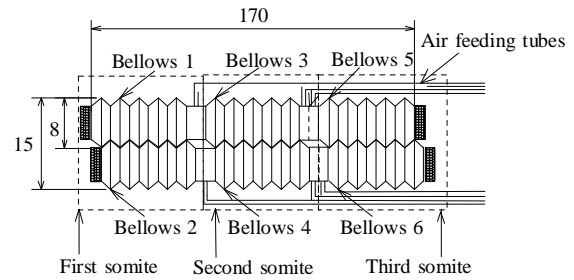


Figure 1. Structure of in-pipe mobile microrobot

### 3. MOVEMENT OF SNAKE IN A PIPE

We observed snake's accordion movement in pipe. Fig. 3 shows the brief movement of an snake. When the snake moves a vertical pipe,

- (1) The snake bends the body like the accordion and holds the pipe by the whole body.
- (2) The snake stretches oneself to the moving direction. At this time, snake's lower part of the body continues the holding of the pipe.
- (3) The snake bends the upper part of the body and holds the pipe.
- (4) The snake extends the lower part of the body, and releases the holding of the pipe.
- (5) The snake hauled in the lower part of the body. Afterwards, the snake bends the lower part of the body and holds the pipe.

Thus, the snake can move in the vertical pipe.

### 4. Moving principle of the microrobot

The moving principle of the microrobot shown in Fig. 4. The moving principle of the microrobot referred to the accordion movement of the snake.

As for step 0, negative pressure is given to all bellows.

Step 1: The third somite is bent and it holds of pipe.

Step 2: Positive pressure is given to the first

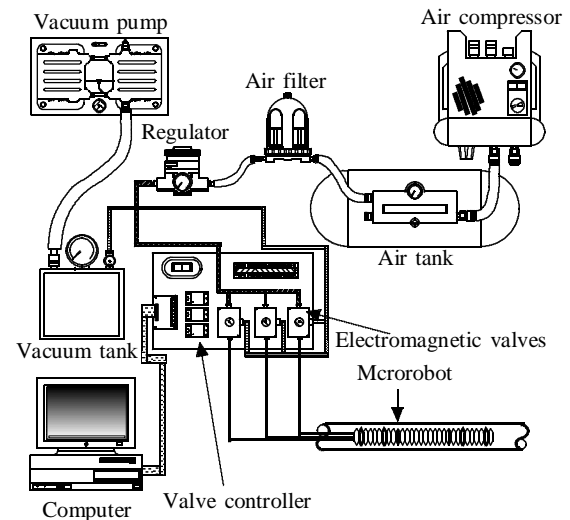


FIGURE 2. Experimental apparatus

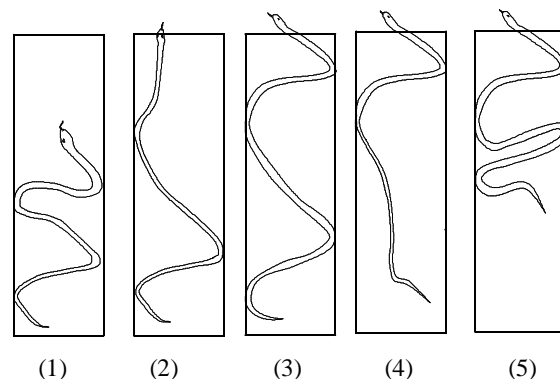


Figure 3. Accordion movement of a snake

and second somite and somite are stretched.

- Step 3: The first somite is bent and it holds of pipe.
- Step 4: Negative pressure is given to the third somite and the holding of the pipe is released.
- Step 5: Negative pressure is given to the second somite. The latter half of the robot advances in this step.
- Step 6: The third somite is bent and it holds of pipe.

The microrobot can move by repeating these steps.

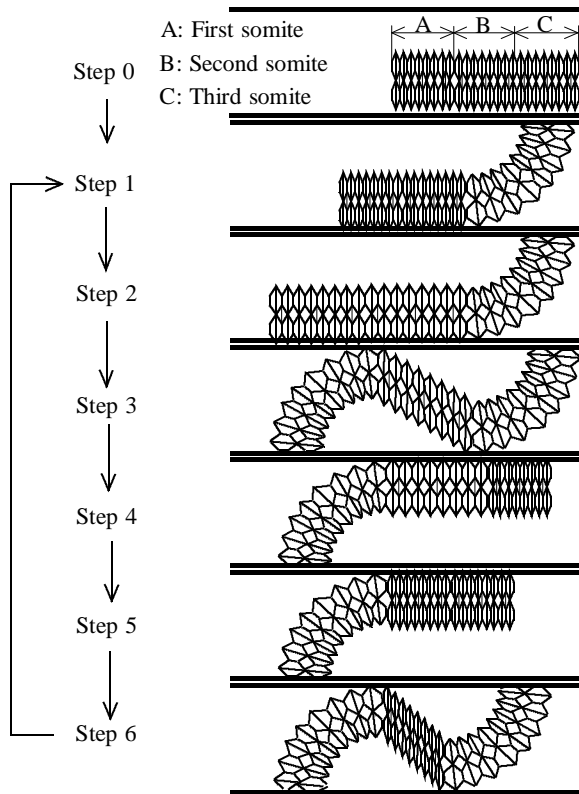


Figure 4. The moving principle of the microrobot

## 5. MOVING EXPERIMENT

### 5.1 Width of bending of a somite

One somite is prepared and the width of

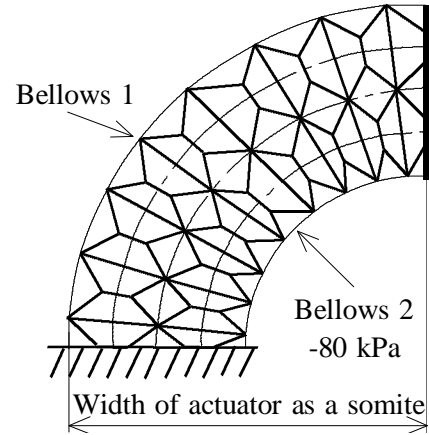


FIGURE 5. The measurement method of width of a somite

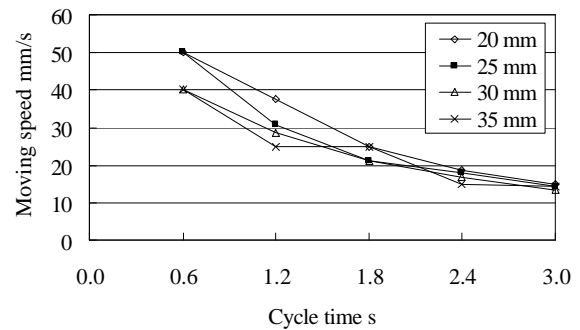


FIGURE 6. Relationship between supply pressure of bellows 1 and width of a somite

bending is measured. The measurement method is shown in Fig. 5 and the experiment result is shown in Fig. 6. The supply pressure of bellows 2 is -80 kPa and supply pressure of bellows 2 is changed from -80 kPa to +50 kPa. We confirmed to width of the somite is proportional to supply pressures and the maximum width of the somite is 37 mm at supply pressure of 30 kPa.

### 5.2 Moving speed of the microrobot

The moving speed of the microrobot is measured. Fig. 7 shows the experiment result.

The using pipes to experiment are 20 mm, 25 mm, 30 mm and 35 mm in the inner diameter. The microrobot is able to move in these pipes and a combined pipe of a different diameter. The air pressures used to experiment are 50 kPa and -80 kPa. We prepare five cycle times in which these air pressures were supplied. It is confirmed that the moving speed of the microrobot influenced the cycle time from Fig. 7. and maximum moving speed is 50 mm/s.

## 6. CONCLUSIONS

We propose the microrobot which is imitate the snake of accordion movement. The fabricated mobile microrobot is confirmed to move in different diameter pipes whose diameters are between 20 mm and 30 mm. Its speed is 50 mm/s.

## REFERENCES

[1] K. Kawaguchi, O. Yoshida, K. Iwao and T. Kikuta: Control of an In-pipe Inspection Robot for Iron Pipes, Journal of the Robotics Society

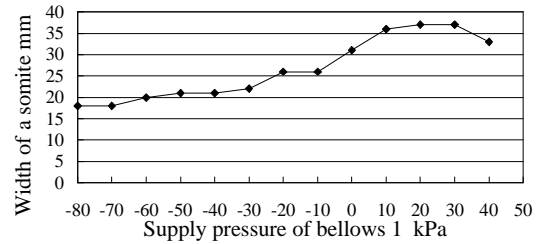


Figure 7. Relationship between moving speed and cycle time

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[2] M. ONO, T. HAMANO and S. KATO: A Basic Study of Mobile Inspection Robot Movable the Long Distance in Small Diameter Pipes, Journal of the Japan Society for Precession Engineering, Vol. 69, No. 4 (2003), 564. (in Japanese)