DEVELOPMENT OF INCHWORM TYPE MOBILE ROBOT MOVABLE IN PIPES WITH T-JUNCTION

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1. Introduction

We have many small diameter pipes, which are gas and water pipelines for individual or corporate houses. They must be inspected in order to protect the accident previously. Since these pipes are buried in the underground or buildings, it is very difficult to inspect the pipes from the outside. Moreover, the pipes have T-junction at the point where the main pipe and the branch pipe connect. Therefore, the inspection robot must move in the pipes and turn the T-junction of rectangular.

Authors have been researched in-pipe robots which are driven by the air pressure and can pass the Y-junction which is about 60 degrees [1], [2]. But they could not pass the T-junction of rectangular. Now, authors fabricate a robot which can pass the T-junction. The fabricated robot is structured by a moving mechanism to move in the pipe and a steering mechanism to pass the T-junction of the pipe. For the moving mechanism, we used three rubber bellows actuators which are 33 mm in outer diameter and 60 mm long. Two outer rubber bellows actuators are provided four bulging rubber sheets. These are called as friction braking mechanism. The friction brake mechanism works as a brake of the moving mechanism. The center rubber bellows actuators is called as a moving element, because the rubber bellows actuators drives the moving mechanism by its stretching and shrinking motion. For the steering mechanism, we use four rubber bellows actuators, which are arranged in the shape of a matrix, and 16 mm in outer diameter and 60 mm long. Seven electromagnetic valves, which switch the pneumatic pressure and the vacuum pressure, are connected to the seven rubber bellows actuators. The sequence of operation is programmed by a computer and carried out through the valve controller. The matrix shaped rubber bellows steering actuators are controlled by a joystick connected to the computer.

The steering actuators can steer the head of the robot for the eight directions in 45 degrees. The seven rubber bellows actuators are stretched by the pneumatic pressure of 0.05 MPa and shrunk by the vacuum pressure of -0.08 MPa. The fabricated robot was confirmed to pass the T-junction of rectangular with speed of 21 mm/s.

2. Structure of the fabricated robot

An in-pipe mobile robot which is able to move in T-junction pipes is shown in Fig. 1.

The fabricated robot is structured by a moving mechanism to move in the pipe and a steering mechanism to pass the T-junction of the pipe. For the moving mechanism, we used three rubber bellows actuators which are 33 mm in outer diameter, 22 mm in inner diameter and 60 mm long. Two outer rubber bellows actuators are provided six bulging rubber sheets. These are called as friction braking mechanism. The friction braking mechanism works as a brake of the moving mechanism. The bulging rubber sheets are 60 mm long, 20 mm wide and 2.5 mm thick. The center rubber bellows actuators is called as a moving element, because the rubber bellows actuators drives the moving mechanism by its stretching and shrinking motion. For the steering mechanism, we use four rubber bellows actuators, which are arranged in the shape of a matrix, and 16 mm in outer diameter, 10 mm in inner diameter and 60 mm long. Seven electromagnetic valves, which switch the pneumatic pressure and the vacuum pressure, are connected to the seven rubber bellows actuators.

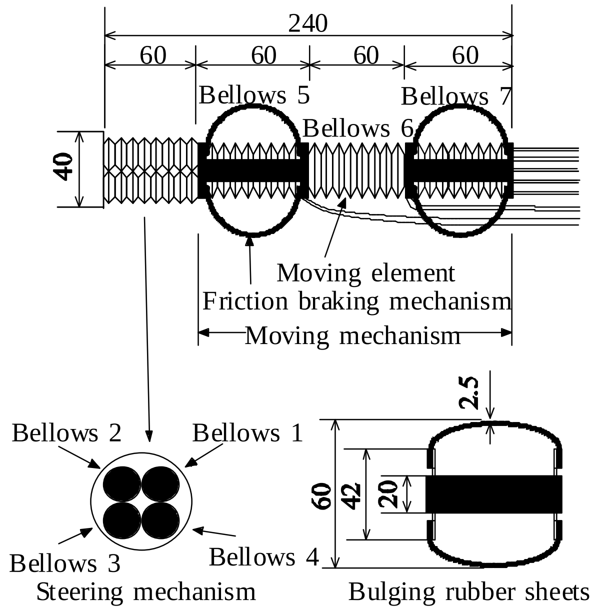

Fig. 1 Structure of in-pipe robot

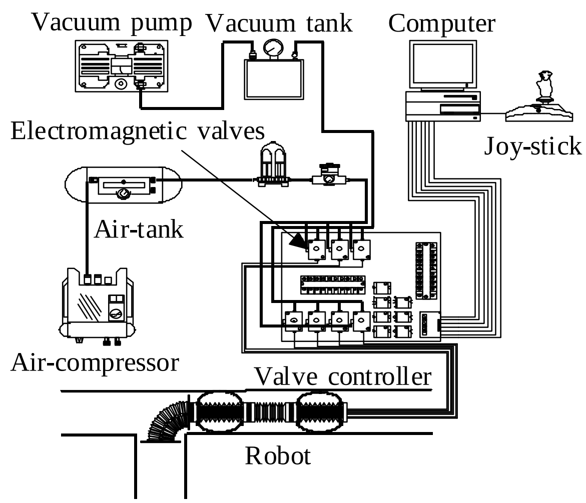

Fig. 2 The control system of the robot

3. The control system of the robot

The control system for measuring the characteristics of the mobile moving mechanism is show in Fig. 2. The sequence of operation is programmed by a computer and carried out through the valve controller. The matrix shaped rubber bellows steering actuators are controlled by a joystick connected to the computer. The other ends of air-feeding tubes are attached to the air-compressor and the vacuum pump.

4. Moving principle of the robot

The seven rubber bellows actuators are stretched by the pneumatic pressure of 0.05 MPa and shrunk by the vacuum pressure of -0.08 MPa.

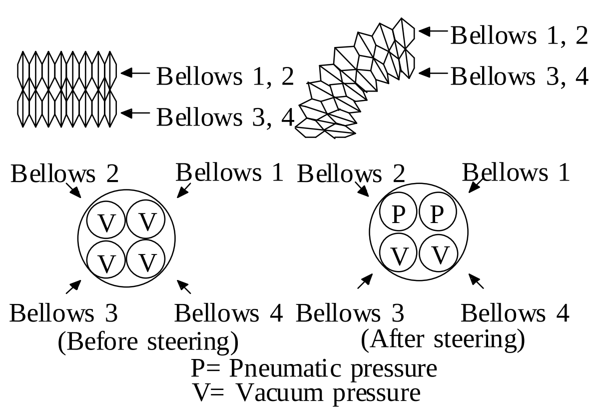

Fig. 3 Steering motion of the rubber bellows at the junction (Downward direction)

4.1 Moving of steering mechanism

First, to the four rubber bellows the vacuum pressure in given before steering motion. If the pneumatic pressure is given to two or three bellows and the vacuum pressure is still given to another bellows, the four bellows bend their head to the vacuum bellows. The steering mechanism is able to displace its head eight directions of each 45 degrees.

For example, if the bellows 1 and bellows 2 are stretched and the bellows 3 and the bellows 4 are shrunk, the four bellows bend their heads to the side of the bellows 3 and the bellows 4. Bending motion of the four rubber bellows at T-junction is shown in Fig. 3. In this case, the robot is steered to the downward direction.

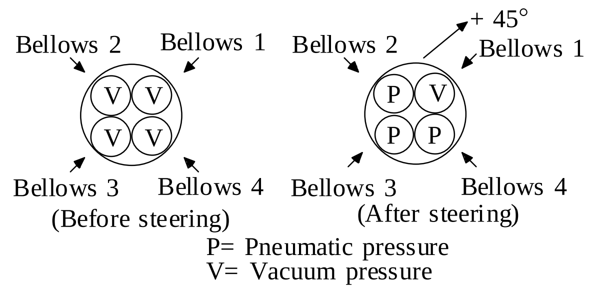

Fig. 4 Steering motion of the rubber bellows at the junction (+ 45 degree direction)

When three bellows within the three bellows are stretched and one bellows is shrunk as shown in Fig. 4, the robot is steered to the direction of 45 degree from horizontal and vertical direction.

4.2 Moving principle

The air-feeding time schedule and moving principle of the robot are shown in Fig. 5.

Step 0: At initial, all the bellows are in the shrinking by the vacuum pressure. The front and rear friction braking mechanisms are at the condition of the braking and hold the pipe.

Step 1: The pneumatic pressure is supplied to the front friction braking mechanism and the braking is free. The friction braking mechanism is pushed out in the length direction of a pipe.

Step 2: The pneumatic pressure is supplied to the central moving element and the mobile moving mechanism is stretching. Then the front part of the mobile moving mechanism can move to the forward direction, because the rear friction braking mechanism is still at the condition of the braking and holds the pipe.

Step 3: The pneumatic pressure is supplied to the rear friction braking mechanism and the braking is free. At the same time, the vacuum pressure is supplied to the front friction braking mechanism and it is at the condition of the braking. The friction braking mechanism is swelled out in the diameter direction of a pipe.

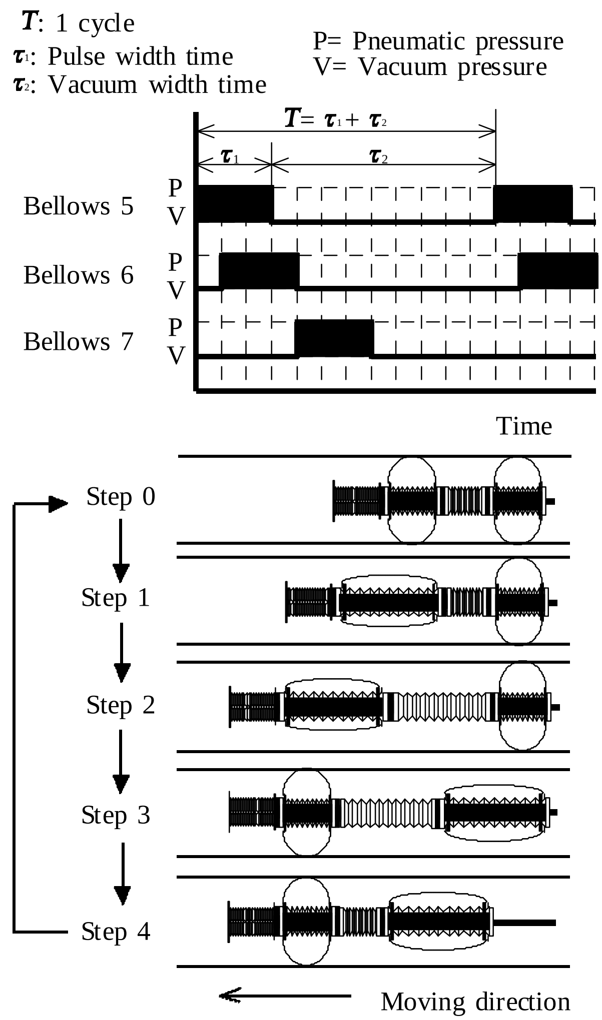

Fig. 5 Moving principle of the in-pipe robot

Step 4: The vacuum pressure is supplied to the central moving element and the mobile moving mechanism is shrinking. Then the rear part of the mobile moving mechanism can move to the forward direction, because the braking of the rear friction braking mechanism is free. After that, all the bellows are shrunk by the vacuum pressure. The braking mechanism of the front and rear holding element are in the condition of braking and hold the pipe. It is same as the initial condition and one cycle is over. The moving mechanism moves the stretching displacement of the moving element.

5. Moving experiment

5.1 Moving speed of the robot

The moving speed of each direction of a robot is shown in Fig. 6. The rubber bellows actuators are stretched by the pneumatic pressure of 0.05 MPa and shrunk by the vacuum pressure of -0.08 MPa. The cycle time is 2.4 s. The robot could move forward and backward with the speed of 26 mm/s. The robot was confirmed to pass the T-junction of rectangular with the speed of 21 mm/s in the right-turn and the left-turn. Right-turn and left-turn is slower than straight pipe. But, it is enough speed to moving a T-junction.

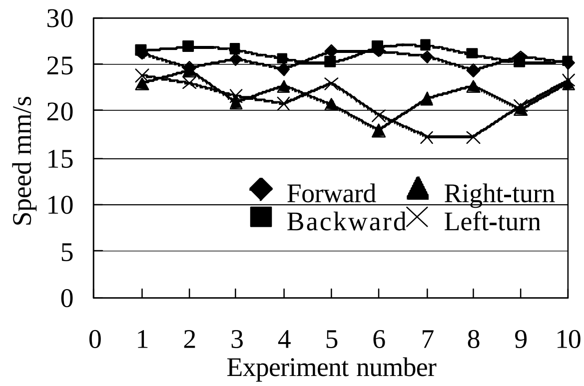

Fig. 6 Moving speed

5.2 Steering characteristics

The steering mechanism is steered to any direction from 45 till 315 degrees. The photograph of the bending four bellows to +45 degrees direction is shown in Fig. 7.

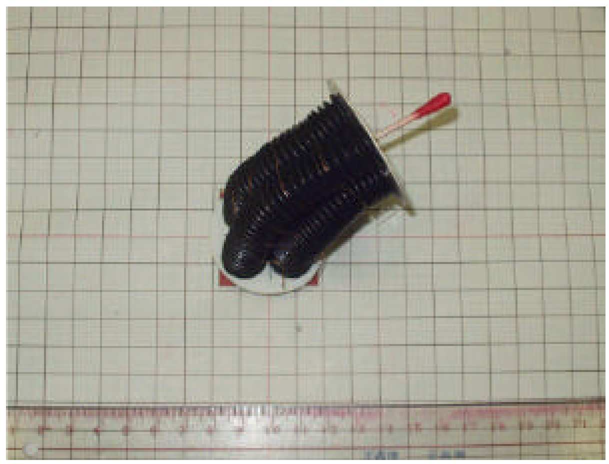

Fig. 7 The photograph of the bending steering mechanism (+45 degree direction)

6. Conclusions

(1) We fabricated a robot which is structured by a moving mechanism to move in pipes and a steering mechanism to pass the T-junction of pipes.

(2) We used four rubber bellows actuators which are arranged in the shape of a matrix for the steering mechanism.

(3) The fabricated robot was confirmed to pass the T-junction of rectangular with speed of 21 mm/s.

References

[1] S. Kato, M.Shirakawa, M. Ono and S. Fukumoto: Fabrication of In-pipe Mobile Micromachines Driven by Pneumatic and Vacuum Pressure, Proceedings of ASPE 1999 (Fourteenth) Annual Meeting , pp. 37-40.

[2] S. Kato, H. Sugiyama, T. Saito, M. Ono and N. Kato: 3D Mechanical Steering Control of an In-pipe Mobile Microrobot, Proceedings of IASTED International Conference Control and Applications, pp. 450-454.