AN IN-PIPE MOBILE INSPECTION ROBOT PROVIDED AN ARTIFICIAL INTELLIGENCE AND PASSABLE AT SEVERAL T-JUNCTIONS

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1. INTRODUCTION

Many small diameter pipes that are gas or water pipelines 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 recognize the T-junction by itself and turn the T-junction of rectangular. Authors have researched in-pipe robots that are driven by air pressure and can pass Y-junction and T-junction [1], [2], [3]. However, they could not recognize the junctions by themselves, because they have no optical sensors. Now, authors fabricate a robot that has an optical sensor and artificial intelligence and can pass the T-junction by itself. The fabricated robot is confirmed to recognize the T-junction and to move to the desirable direction of the pipe.

2. STRUCTURE OF THE ROBOT SYSTEM

A structure of the fabricated robot system is shown in Fig. 1. The robot system consists of an optical sensor unit, a robot, a comparator which compares signals from the optical sensor unit and the threshold, air feeding tubes and signal line, electromagnetic valves, a computer,

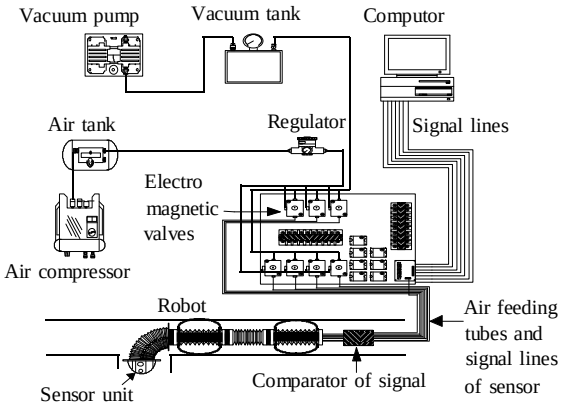

Figure 1. Structure of mobile robot system

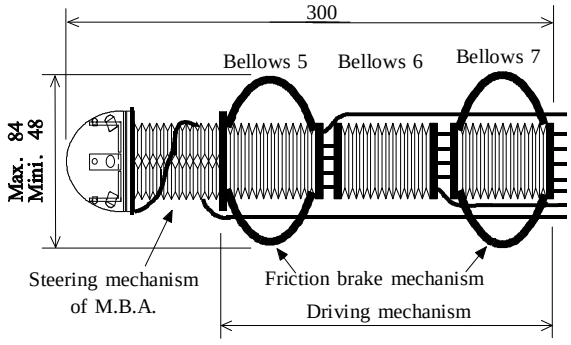

Figure 2. Structure of in-pipe robot

an electromagnetic valve controller, an air compressor which generates positive pressure and a vacuum pump which generates negative pressure.

2.1 Structure of the robot

Structure of the fabricated robot is shown in Fig. 2. The robot consists of a steering mechanism and a driving mechanism. The steering mechanism consists of a matrix bellows actuator (MBA) and is attached the front of the robot. The driving mechanism consists of three bellows that are 33 mm in outer diameter and 60 mm long. Three air-feeding tubes are independently connected to three bellows. Bulging brakes are provided to the Bellows-5 and Bellows-7. Friction brake mechanism consists of these bellows and bulging brakes. The bulging brakes are spread to radius direction and hold the pipe, when bellows of the friction brake mechanism is contracted. The bulging brakes are spread to longitudinal direction and cancel to hold the pipe, when bellows of the friction brake mechanism is stretched.

2.2 Structure of MBA and its movement

A structure of the MBA is shown in Fig. 3. The MBA consists of four bellows that are arrayed in a matrix. Each bellows is supplied positive and negative pressure independently. When the positive pressure is supplied to Bellow-2, -3, -4 and the negative pressure is supplied to Bellow-1, the head of the MBA is inclined to Bellows-1, because the bellows that is given negative pressure contracts and the bellows that is given positive pressure stretches. The MBA can steer the robot by a step of 45 degrees.

2.3 Control system of the robot

The positive pressure that is needed for stretching of the bellows is given by an air-compressor. The negative pressure that is needed for contracting of the bellows is given by a vacuum pump. The positive pressure and the negative pressure for bellows are switched by electromagnetic valves which are controlled by the computer through a valve controller. A control sequence is programmed in the computer. Since the computer can process the signal from the optical sensors, the computer can steer the robot for the direction that is desired by the operator.

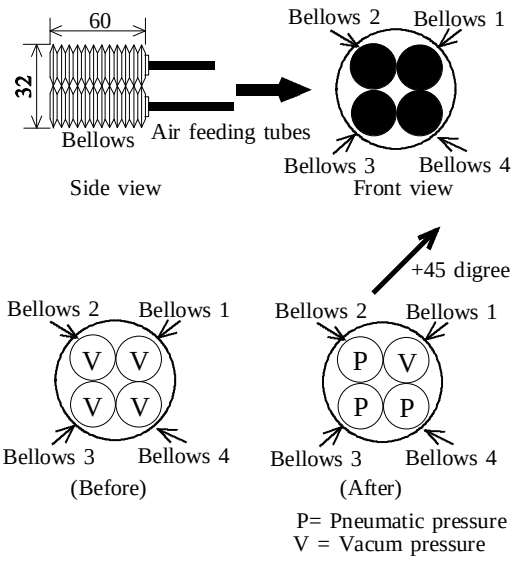

Figure 3. Structure of M.B.A.

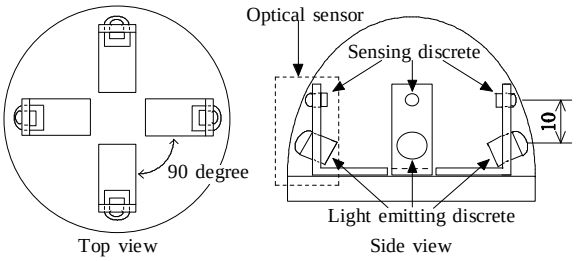

FIGURE 4. Structure of sensor unit

2.4 Structure of the optical sensor unit

A fabricated optical sensor unit is shown in Fig. 4. The optical sensor unit consists of four optical sensors. The optical sensor consists of a light emission diode and a photo transistor.

3. MOVING PRINCIPLE

Moving principle of the robot is shown in Fig. 5. At Step-0, all of bellows are contacted by negative pressure and all of the friction brake mechanisms hold the pipe. At Step-1, the front friction brake mechanism cancels to hold the pipe. At Step-2, the front of the robot is moved to forward direction. At Step-3, the front friction brake mechanism holds the pipe and the rear friction brake mechanism cancels to hold the pipe. At Step-4, the rear end of the robot is moved to forward direction, because bellows-6 is contracted. After Step-4, the rear friction brake mechanism holds the pipe and the step returns to Step-0. During the cycle, the robot can move the displacement of the driving mechanism.

4. SENSING PRINCIPLE OF T-JUNCTION

Sensing principle of T-junction is shown in Fig. 6. The phototransistor produces analog voltage which depends on a received power of the light. At straight pipe, the phototransistor produces high voltage, because the light from the light emission diode is strongly reflected by wall of the straight pipe. At the T-junction, the phototransistor can not receive the light, because the light from the light emission diode is dissipated to the branch pipe at the T-junction and is not returned. The phototransistor produces only low voltage. Then, the T-junction is recognized by change that the phototransistor produces voltage.

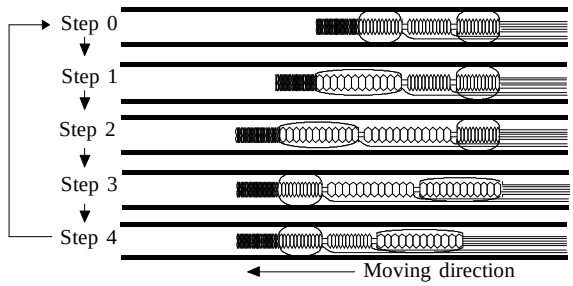

Figure 5. Moving principle of in-pipe robot

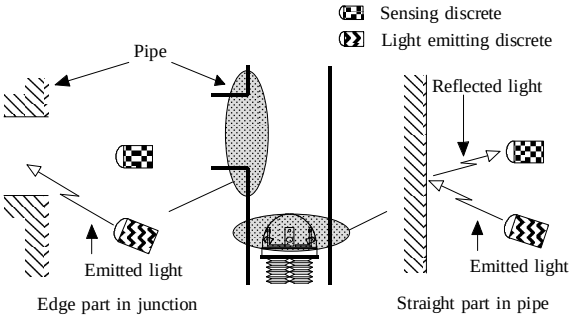

Figure 6. Sensing principle of T-junction

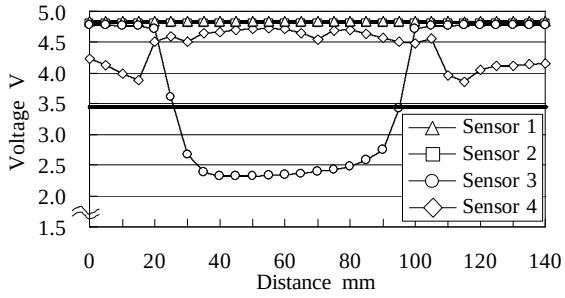

FIGURE 7. Output characteristics of sensor unit

Out put voltage of four phototransistors of the optical sensor unit is shown in Fig. 7. There are two edges of the junction at 20 mm and 100 mm of the distance. Sensor-3 is displayed to the direction of the junction. Therefore, the other sensors are displayed to the direction of the straight pipe. The output voltage which is produced by the sensor-3 is as lower as 2.5 V.

If the threshold is 3.5 V, we confirm that the junction exists to the direction where a sensor produces an output voltage more low than the threshold voltage. The output voltage produced by the phototransistor and the threshold are compared at the comparator arrayed behind the robot. The compared data are transferred to the computer. The computer confirms where the junction is.

5. MOBILE MOVING EXPERIMENT

The robot that has an optical sensor unit, a steering mechanism and an artificial intelligence is experimented to move in the pipe. (1) The robot recognizes the T-junction. (2) Then the driving mechanism stops to move. (3) The steering mechanism turns its head to the desirable direction of the pipe. (4) Then the driving mechanism restarts. The fabricated robot is confirmed to recognize several T-junctions and to move to the desirable direction of the pipe.

6. CONCLUSIONS

(1) We fabricate a robot that has an artificial intelligence and can turn the T-junction by itself. T-junction is recognized by an optical sensor unit and is passed by a steering mechanism that is made by a matrix bellows actuator (MBA).

(2) The robot is moved by a driving mechanism that consists of three bellows and bulging brakes. The robot is confirmed to have a traction force of 22 N.

(3) The fabricated robot is confirmed to recognize automatically several T-junctions and to move to the desirable direction of the pipe.

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