

# **Development of an In-pipe Inspection Robot Movable for a Long Distance**

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## **1. Introduction**

Many accidents have happened owing to the crack and the corrosion of pipelines. We will have serious damages if gas leaks from the gas pipeline and explodes. It is very difficult to inspect the gas pipelines because they are buried under the ground. Therefore, we are hoping a new inspection method from the inside of the pipelines without digging the ground. Some excellent in-pipe mobile robots have been proposed. Miyagawa has presented a microrobot which is 23 mm in diameter and driven by an electric motor. Its traction force was 1 N and speed was 6 mm/s [1]. Kubota also has presented an inching microrobot which is 20 mm in diameter and driven by pneumatic pressure. Its speed was 13 mm/s with no load [2]. These robots are not presented to be able to move for a long distance.

We developed an in-pipe inspection robot driven by pneumatic and vacuum pressure movable for a long distance. It is very difficult to move for a long distance, because the robot must pull the air feeding tubes and the electric cables. The robot is desired to have the large traction force to move for a long distance. We solved the problem by generating large traction force by equipping with lots of friction rings.

The in-pipe inspection robot moves freely in the pipe, and can find the crack the corrosion. It was confirmed that the in-pipe inspection robot moved the distance of 20 m (pipe's inner diameter of 44 mm) with the speed of 33 mm/s and the traction force of 7.8 N. The maximum speed was 44 mm/s with no load.

## **2. Structure of the in-pipe inspection robot**

The fabricated new in-pipe inspection robot is shown in Fig. 1. The in-pipe inspection robot consists of a driving mechanism, the CCD camera and four light emitting diodes. A driving mechanism is structured by a rubber bellows actuator, an electromagnetic valve and lot of

friction rings. A rubber bellows actuator is 33 mm in outer diameter, 23 mm in inner diameter and 150 mm long. A rubber bellows actuator is connected with a plastic tube which is 2.5 mm inner diameter, 150 mm long and connected with the out port of an electromagnetic valve. An electromagnetic valve weights 20 g and is connected with two plastic tubes which are 4 mm inner diameter, 6 mm outer diameter and 40 m long. These feed pneumatic pressure and vacuum pressure to the electromagnetic valve. Friction rings are connected with the rubber bellows actuator at the front and the rear sides of the actuator. A friction ring is the outer diameter is 46 mm and the inner diameter 20 mm, made of nitrile butyl rubber.

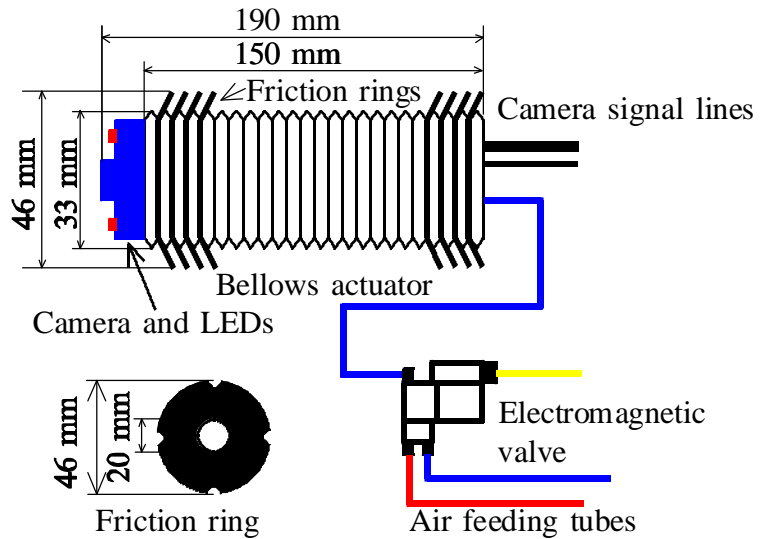


Fig. 1 An in-pipe inspection robot

### 3. Experimental apparatus of the in-pipe inspection robot

An experimental apparatus for measuring the speed and the traction force of the in-pipe inspection robot is shown in Fig. 2. The computer controls an electromagnetic valve through a valve controller. The air feeding tube is connected from the electromagnetic valves to bellows. The air-compressor is connected to the entrance port of the electromagnetic valve and the vacuum pump is connected to the exit ports of the electromagnetic valve.

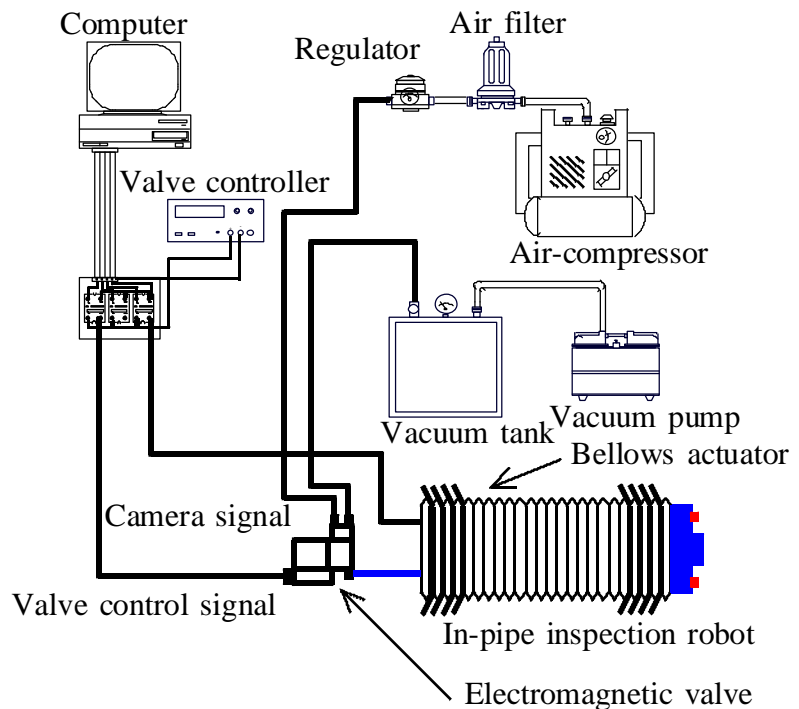


Fig. 2 Experimental apparatus

#### 4. Moving principle of the in-pipe inspection robot

The rubber bellows actuator is driven by pneumatic pressure of 0.3 MPa and vacuum pressure of -0.08 MPa. The pneumatic pressure was used to stretching motion and the vacuum pressure was used to shrinking motion of the rubber bellows actuator. These two pressures are switched by the electromagnetic valve. The pneumatic and the vacuum pressure are independently fed to a rubber bellows actuator. The time-chart of the pneumatic pressure for the in-pipe inspection robot is shown in Fig. 3.

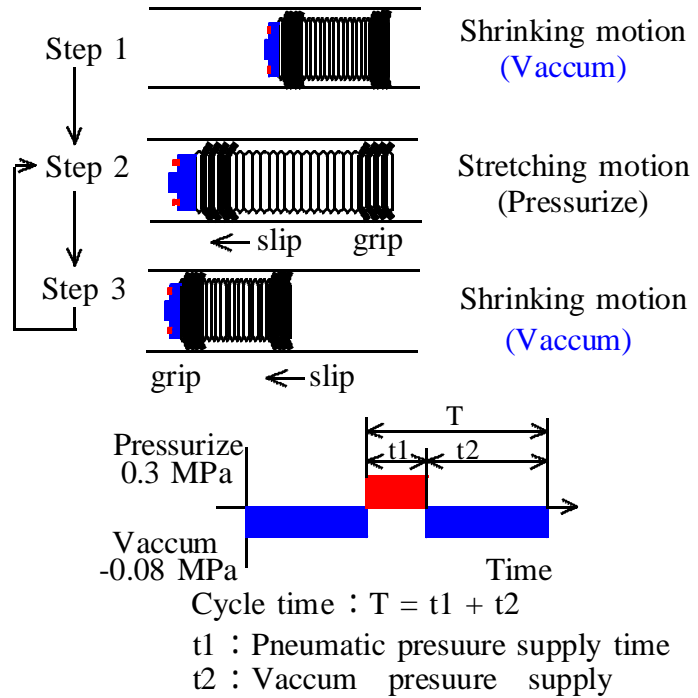


Fig. 3 Time-chart of the pneumatic pressure

The rubber bellows actuator repeats stretching motion and shrinking motion. The friction rings convert the stretching motion and shrinking motion into the forward or backward movement.

#### 5. Moving characteristics

The in-pipe inspection robot can move in the pipe which is 44 mm inner diameters. The straight moving speed was measured. The number of connecting friction rings are changed. The moving speed characteristics is shown in Fig. 4. The maximum speed of 44 mm/s was obtained at the cycle time of 4.9 seconds when the number of connecting friction rings was four pieces. On the whole, the moving speed is quick

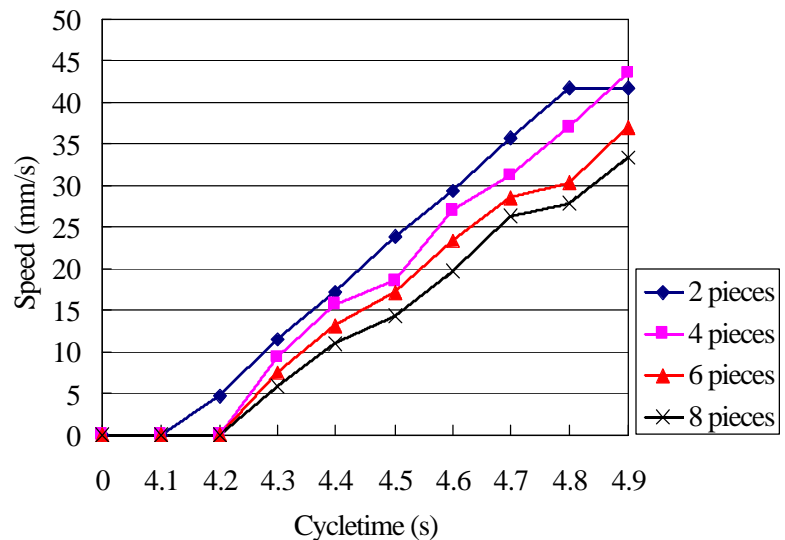


Fig. 4 Moving speed characteristics

when there are small number of the friction rings.

## 6. Traction force characteristics

The traction force characteristics of in-pipe inspection robot is shown in Fig. 5. The maximum traction force is 7.8 N when eight friction rings are connected. It turns out that the traction force is proportional to the number of the friction ring.

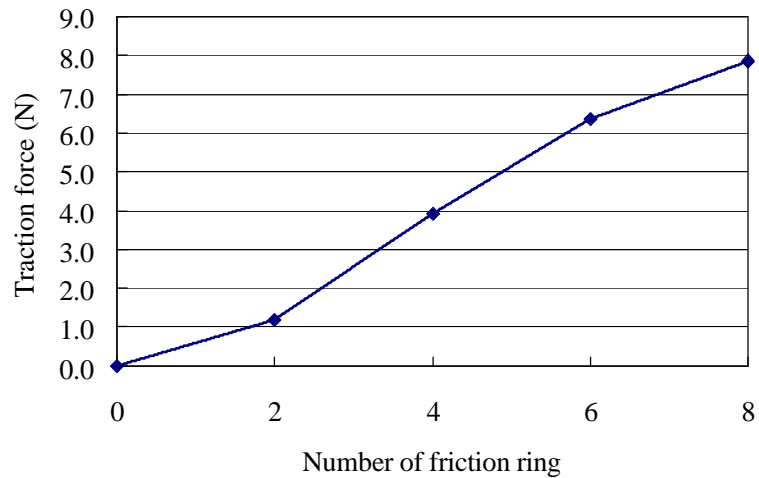


Fig. 5 Traction force characteristics

## 7. Conclusions

- (1) We developed a new in-pipe inspection robot which moves freely in the pipe. It was confirmed that the in-pipe inspection robot moved the distance of 20 m (pipe's inner diameter of 44 mm) with the speed of 33 mm/s and the traction force of 7.8 N.
- (2) The maximum speed of 44 mm/s was obtained at the cycle time of 4.9 seconds and the number of connecting friction rings was four pieces. The maximum traction force is 7.8 N when the eight friction rings are connected.
- (3) The inspection robot is equipped with a CCD camera and light emitting diodes to find out crack and corrosion in the pipe.

## References:

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