FABRICATION OF A MICROROBOT MOVABLE IN THE SMALL INTESTINE OF A PIG

Shigeo KATO, Mizuyuki SHIRAKAWA, Manabu OHNO and Masako TABATA

Nippon Institute of Technology
Miyashiro, Saitama 345-8501, JAPAN
E-mail: kato@nit.ac.jp

Abstract

This paper describes the fabrication of an in-pipe mobile microrobot which is able to move in the small intestine of a pig. The microrobot is inchworm type and is structured by a flexible plastic bellows which is 17.3 mm in outer diameter and 50 mm long. The microrobot is driven by the pneumatic pressure and the vacuum pressure. It is confirmed that the microrobot is able to move with the maximum speed of 65 mm/s in the small intestine of a pig.

***Keywords*:** In-pipe, Inchworm, Microrobot, Pig's small intestine

1. Introduction

New in-pipe mobile microrobots to inspect or to repair the intestine or blood vessel in the the human body have been investigated. Kato et al. have presented in-pipe mobile robots which are driven by only pneumatic pressure [1], [2]. However, these in-pipe mobile microrobots were not yet able to move in the the large intestine or the blood vessel.

We fabricated a prototype of a new mobile inchworm type microrobot which is able to move in the small intestine of a pig. The microrobot is driven by pneumatic and vacuum pressure. The pneumatic pressure is used to stretch and the vacuum pressure is used to shrink the microrobot. The microrobot is made by a flexible plastic bellows which is 17.3 mm in diameter and 50 mm long. The microrobot is equipped two thin friction-rings which are located at the front and the rear of the microrobot. The rings are 25 mm in outer diameter and 0.3 mm thin made of vinyl chloride with the cutting lines. The friction for inching motion of the microrobot comes from these friction rings.

The pneumatic pressure of +0.02 MPa and the vacuum pressure of -0.095 MPa are used to drive the microrobot. These two pressures are switched by an electromagnetic valve. The maximum speed in a pig's small intestine was confirmed to be 65 mm/s. The length of the large intestine of the man is less than 1000 mm. If this microrobot can move in the large intestine of the man, the microrobot is able to move in the large intestine in the time of 16 seconds.

2. Structure of the fabricated microrobot

The section of the fabricated microrobot is shown in Fig. 1. The microrobot is able to move in pipes by imitating the motion of an inchworm. The microrobot is structured by a flexible plastic bellows. The bellows is 17.3 mm in outer diameter and 50 mm long. A plastic air feeding tube which feeds pneumatic and vacuum pressure to the microrobot is 2 mm in inner diameter, 3 mm in outer diameter and 1000 mm long. Two friction rings 25 mm in outer diameter, 10 mm in inner diameter are fixed at the double ends of the bellows. Materials of the friction rings are vinyl chloride and rubber. The friction rings of vinyl chloride are 0.4 mm thick and the friction rings of rubber are 0.5 mm thick. These friction rings make friction force between the pipe and the microrobot. The friction rings make cones, because the inner diameter of the friction rings is smaller than the diameter of the bellows. The friction rings are slitted for the direction of radius. The friction forces made by the friction rings are shown in Table 1. The friction force of the vinyl chloride is smaller than that of the rubber. The friction forces between the vinyl chloride pipe and the vinyl chloride rings are 0.09 N for the forward direction and 0.48 N for the backward direction. However, the friction forces between the small intestine of a pig and the vinyl chloride rings are as large as 0.9 N for the forward direction and 1.21 N for the backward direction. The large forces come from the transforming of the small intestine by the friction rings, because the small intestine is very flexible. This matter is shown by the small difference between the friction force for the forward direction and the friction force for the backward direction.

An experimental apparatus for measuring the speed of the microrobot is shown in Fig. 2. A computer controls a electromagnetic valve through a valve controller. The feeding air-tube is connected from the electromagnetic valve to the bellows. A air-compressor is connected to the entrance port of the electromagnetic valve and a vacuum pump is connected to the exit port of the electromagnetic valve. When the pneumatic pressure is supplied to the bellows in the time of τ seconds, the bellows is stretched. The front friction ring slips, because its friction force is smaller than that of the rear friction ring. The other hand, the rear friction ring holds the pipe, because its friction force is larger than that of the front friction ring. Consequently in this period, the front

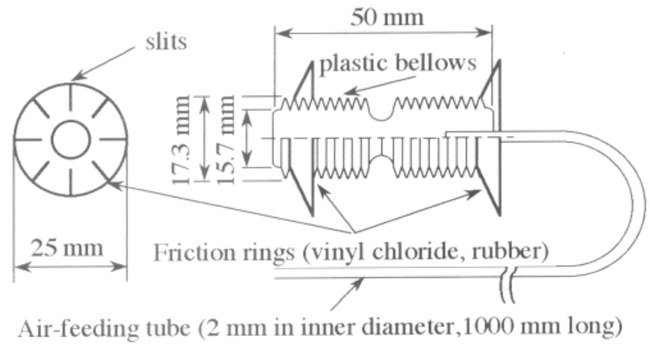

Fig. 1 The section of the inchworm type microrobot

Table 1 The friction forces made by the friction rings

	Friction ring	Forward direction (N)	Backward direction (N)	Difference (N)
Vinyl chloride hard pipe	Vinyl chloride	0.09	0.48	0.39
	Rubber	0.55	1.47	0.92
Pig's small intestine	Vinyl chloride	0.90	1.21	0.31
	Rubber	1.71	2.48	0.77

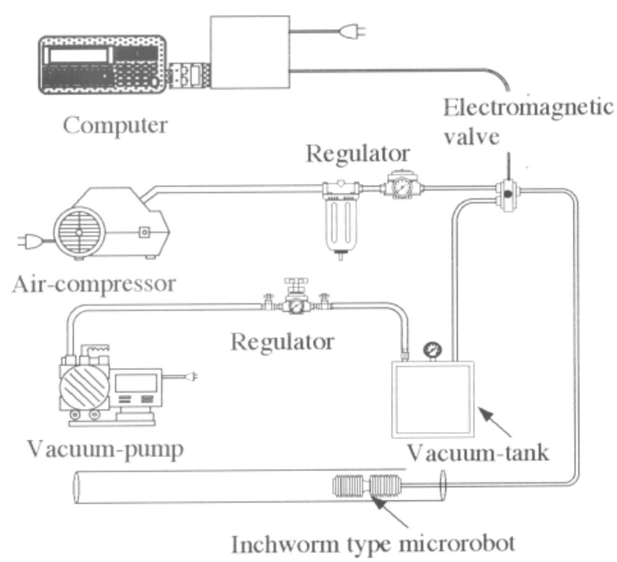

Fig. 2 The experimental apparatus for measuring the speed of the inchworm type microrobot

part of the microrobot goes forward. When the vacuum pressure is supplied to the bellows in the time of τ seconds, the bellows is shrunk. At this time, the front friction ring holds the pipe, because its friction force is larger than that of the rear friction ring. The other hand, the rear friction ring slips, because its friction force is smaller than that of the front friction ring. Consequently in this period, the rear part of the microrobot goes forward. Consequently the microrobot goes forward about the displacement of the bellows in the cycle time of 2τ.

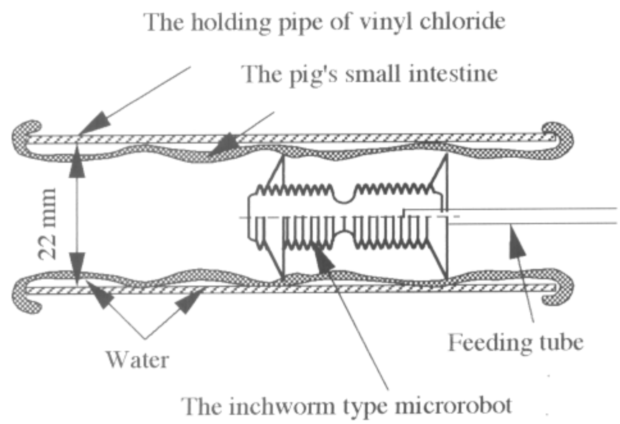

Fig. 3 The inchworm type microrobot in the pig's small intestine

3. Moving characteristics of the fabricated microrobot

The moving speed of the microrobot is measured. The fabricated microrobot in the pig's small intestine is shown in Fig. 3. The small intestine is that used to make the sausage. The small intestine is held in the vinyl chloride hard pipe which is 22 mm in the inner diameter. The outer diameter of the small intestine is a little smaller than 22 mm, because small quantity of water exists between the intestine an the pipe. The vacuum pressure for the shrinking of the bellows is -0.095 MPa and the pneumatic pressure for the stretching is +0.02 MPa. The cycle time 2τ is changed from 0.04 seconds to 0.6 seconds.

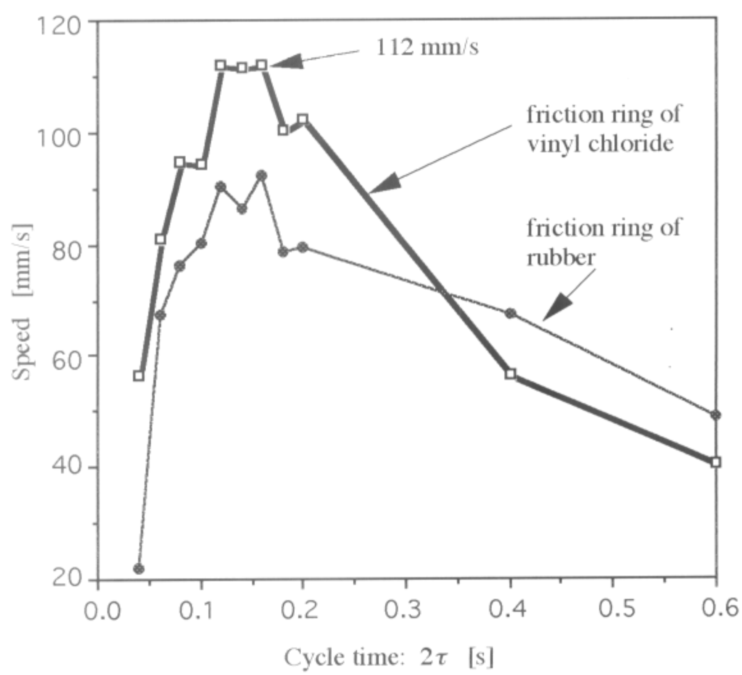

Fig. 4 The speed of the inchworm type microrobot in the hard straight pipe

3.1 Moving characteristics in the hard straight pipe

First, the moving speed of the microrobot in the hard straight pipe made of vinyl chloride is measured. The speed of the microrobot in the hard straight pipe is shown in Fig. 4. The speed of the microrobot using the friction rings of vinyl chloride is higher than that of the microrobot using the friction rings of rubber. The one side of friction rings must slip. The speed of the microrobot may be small when the rubber, which is large in the friction force, is used. The maximum speed of 112 mm/s was obtained at the cycle time of 0.16 seconds, when the friction rings of vinyl chloride was used. This speed is 1.5 times of the former maximum speed of our microrobot.

3.2 Moving characteristics in the pig's small intestine

The speed of the microrobot in the pig's small intestine is shown in Fig. 5. The speed of the microrobot in the pig's intestine using the friction rings of vinyl chloride is also higher than that of the microrobot using the friction rings of rubber. The maximum speed of 65 mm/s in the pig's small intestine was obtained at the cycle time of 0.18 seconds, when the friction rings of vinyl chloride was used. This speed is about 1/2 times of the speed in the hard straight pipe. The reasons of small maximum speed in the small intestine are that the friction force is large and the intestine is movable against the microrobot.

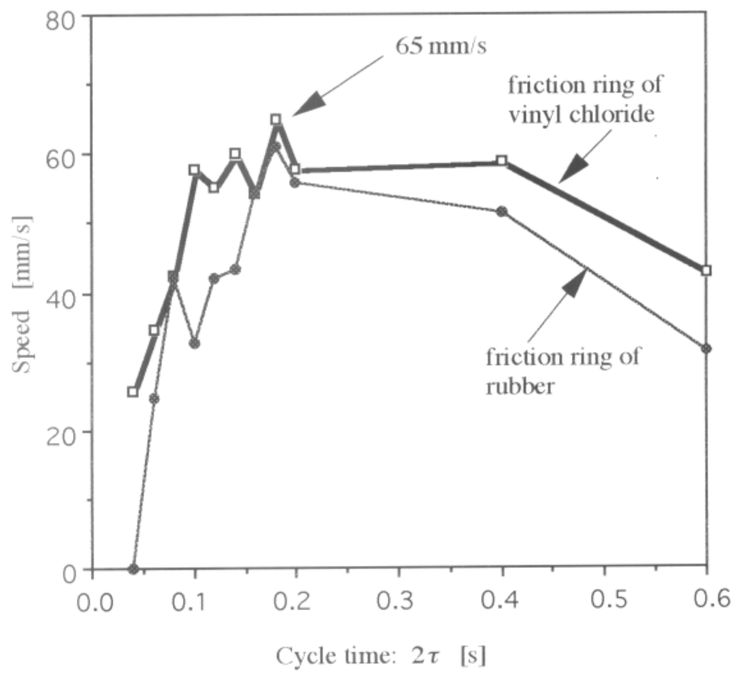

Fig. 5 The speed of the inchworm type microrobot in the pig's small intestine

4. Conclusions

Fabrication of a prototype of a new microrobot to inspect or to repair thin pipes in the the human body or pipelines was performed. The followings are the conclusions of the fabrication.

(1) We fabricated a new inchworm type microrobot which is constructed by a plastic bellows which is 17.3 mm in outer diameter and 50 mm long. A plastic air feeding tube which feeds pneumatic and vacuum pressure to the microrobot is 2 mm in inner diameter and 1000 mm long.

(2) Two friction rings of vinyl chloride 25 mm in outer diameter are fixed at the double ends of the bellows. These friction rings make friction force between the pipe and the microrobot. The friction forces between the vinyl chloride pipe and the vinyl chloride rings are 0.09 N for the forward direction and 0.48 N for the backward direction.

(3) The microrobot is able to move in a vinyl chloride hard pipe of 22 mm in diameter. The maximum speed of 112 mm/s was obtained at the cycle time of 0.16 seconds, the vacuum pressure is -0.095 MPa and the pneumatic pressure is +0.02 MPa.

(4) The microrobot can move in pig's small intestine. The maximum speed of 65 mm/s was obtained at the cycle time of 0.18 seconds, the vacuum pressure is -0.095 MPa and the pneumatic pressure is +0.02 MPa. This speed is about 1/2 times of the speed in the vinyl chloride hard pipe.

References:

[1] S. Kato and K. Ohtsuki, *Proceedings of the ASPE 1998 Annual Meeting*, Vol. 18 (1998), pp. 248-251.

[2] S. Kato and T. Hirayama, *Proceedings of the 4th Japan-France Congress & 2nd Asia-Europe Congress on Mechatronics*, Vol. 2 (1998), pp. 429 - 432