Development of the Earthworm Robot using a Shape Memory Alloy

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Abstract

This paper describes the earthworm robot composed of commercial shape memory alloy, called BioMetal. Our mechanism has the unique stracture with SF tubing for extention force. This robot aims at not only moving by changing length, but also changing thickness like real earthworm. The mechanism makes difference of a friction coefficient to the ground is produced, and the robot can move more smoothly. Finally, our robot realized a motion like earthworm by connecting units and controlling timing by the microcomputer. The robot has four units. The total length is 475[mm], and promosion speed is 3.4[mm/s].

1 The Background of Research

Human beings are extending a world of activity from the seabed to the universe today. However, the action range in which we can work actually is narrow. Therefore, it is very important to develop robots that becomes instead of man at place, which cannot be touched directly by human's hand, like a inside of a pipe, a dangerous place, or a small space. Many researchers are developing the earthworm robot, but the practical robot is not yet developed. Almost all of their robots are the type, which needs a big drive and cables, such as an air actuator. Therefore, the range that can move is restricted. Then, this research aims to develop an independent type robot which carries all of actuators and batteries.

2 About the movement of an earthworm

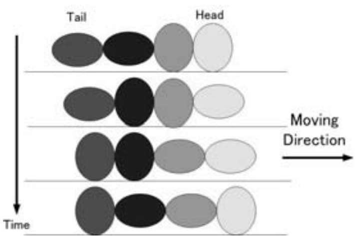

Fig.1. The model of an earthworm robot

We modeled earthworm movement as depicted in Figure.1. First, Section 1 and Section 2 become short and thick, and they come to contact with the ground. Next, Section 1 becomes long and thin, and Section 3 becomes short and thick at the same time. Since Section 2 does not change at this time, a robot continues support in the position of Section 2. The whole robot move forward by the expansion of Section 1. By repeating this cycle, robot can move .

3 Actuator

In this research, We used the "BioMetal (a trademark of TOKI CORPORATION), which is a kind of a shape memory alloy. BioMetal is a fiber-like actuator which is anisotropically structured by special fabrication method from a Ti-Ni shape-memory alloy so as to deliver its superb performance characteristics in a specific direction. Since it is made of a metal and looks like a living thing because of its smooth movement, it is designated as BioMetal. Although soft and pliable like a nylon thread under normal conditions, it becomes stiff like a piano wire and sharply contracts, when a current is fed through it. If the passage of a current is stopped, it will soften and extend to its original length. TOKI CORPORATION provides two types of BioMetal. One product is called BioMetal Fiber(BMF), another is called BioMetal Helix(BMX)[(1)].

Our first prototype used BMF, but we chose BMX as the second prototype. Although BMF makes strong shrinkage force(180gf), BMF's contraction length is 4.5%. BMX is small force(30gf), but, its stroke is 100%-200%.

Fundamentally, BMX is used, as shown in Figure.2. When a current fed through in BMX, it contracts. If the passage of current is stopped, it will move by spring's force.

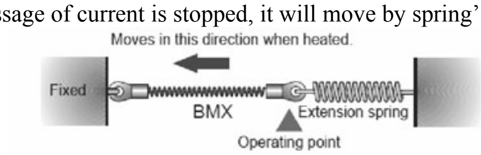

Fig.2. Basic use of the BMX[(1)]

But we use other material instead of extension spring. It is called SF tubing(SHINAGAWA SHOKO CO.,LTD) , that is A polyester braided tube for protecting wiring. The woven construction of the tube gives excellent elasticity and flexibility. It spreads to between 1.5 and 4 times its width under pressure.

4 Making of the robot

We designed earthworm mechanism as shown in Figure.3. When a current fed through in 4 BMX, the unit will contract and rubber will touch on the ground. At the time, the unit is fixed to the ground. If the passage of current is stopped, the unit will move by SF Tubing's force. At the time, 4 ball caster will touch to the ground instead of rubber. So unit can move freely. The unit we made is shown in Figure.4.

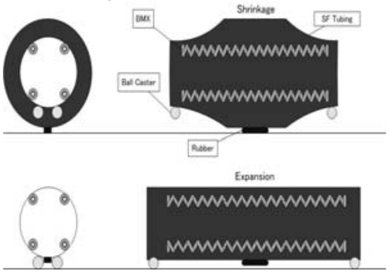

Fig.3. Design of one unit

Fig.4. Figure of one unit

4.1 Results

We measured locomotion pattern of earthworm robot at each points(shown in Figure.5). The results are shown in Figure.6.

According to research of Ueda, the details of movement of an earthworm can be known by measuring propulsion time (Tp), stopping time (Ts), and promotion distance (L)[(2)].

As in Figure.7, the value of point5 are, Tp=4.6s, Ts=4.0s, L=29mm. So we can calculate, Speed, Duty factor, Protrusion rate, Stride frequency.

$$speed = \frac{L}{Tp + Ts} = 3.4[mm/s] \quad (1)$$

$$duty \quad factor = \frac{Ts}{Tp + Ts} \times 100 = 47[\%] \quad (2)$$

$$protrusion \quad rate = \frac{L}{Tp} = 6.3[mm/s] \quad (3)$$

$$stride \quad frequancy = \frac{1}{Tp + Ts} = 0.12[Hz] \quad (4)$$

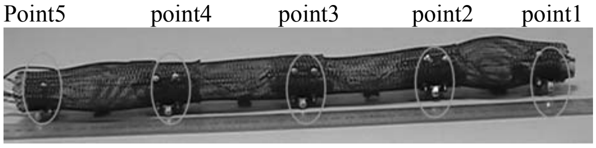

Fig.5. Measured points

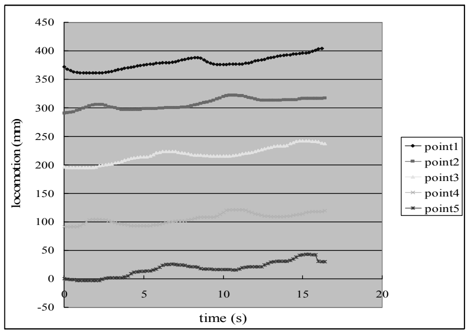

Fig.6. Locomotion patterns of the earthworm robot

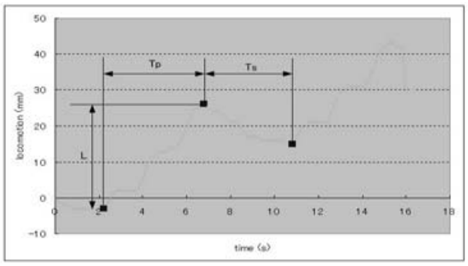

Fig.7. Locomotion pattern of point5

4.2. Consideration

The unit is slipping back about 10mm. This affects the whole promotion distance. As the cause, the unit shrinkage timing doesn't suit enough. And friction force isn't enough too.

5 Conclusion

We developed the earthworm robot using BMX and made run experiment. It was showed that the robot can move like real earthworm.

7 Referrences

[1] http://www.toki.co.jp/BioMetal/

[2] S, Ueda, N, Saga, & T, Nakamura, (2003.7) Study on Peristaltic Crawling Robot Using Artificial Muscle Actuator. SICE Tohoku Chapter the 210th research meeting data pp.1-7.