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Micro Tattooing Mechanism for the Capsule Endoscope

Seonggun Joe[1], Dongkyu Lee[1], Byungjeon Kang[2] and Jong-Oh Park[2], Byungkyu Kim[1]
[1] School of Aerospace and Mechanical Engineering, Korea Aerospace University, Goyang-si, Republic of Korea.
(Tel : +82-2-300-0101; E-mail: bkim@kau.ac.kr)
[2] School of Mechanical Engineering, Chonnam National University, Gwangju, Republic of Korea

Abstract – With advent of the capsule endoscope, tattooing to mark the position of the intestinal polyps becomes critical technique for successful removal of polyps. Therefore, we develop a micro tattooing mechanism activated by multiple conical springs which can be installed in a capsule endoscope. In order to insert the needle and inject ink, a conical spring is released by cutting a post with Ni-Cr wire. Then, the needle is withdrawn by another conical spring activated by SMA wire. As a result, we could inject and withdraw the needle with electrical power consumption of 36.52 mWh.

Keywords – Capsule endoscope, Tattooing mechanism, Conical spring, Triggering method, Colonoscopy.

1. Introduction

The commercial endoscopy has been developed to diagnose and treat the disease in digestive organ. As a diagnosis tool, endoscopic tattooing is utilized to mark position of lesions in the digestive organ for effective treatment (e.g. laparoscopic or robot surgery) since the operator relies on only visual recognition of the location [1].

With advent of the capsule endoscope [2, 3], nowadays, a micro tattooing mechanism is necessary to upgrade the function of the capsule endoscope which is currently limited to diagnosis of lesions. Therefore, we develop a simplified micro tattooing mechanism which can be installed in capsule endoscope using multiple conical springs. By designing a needle to move longitudinally, a mechanism enables the operator to observe polyps through the camera and activate the needle. The proposed tattooing mechanism consists of two procedures as follows: ink and needle injection, and withdrawal of inserted needle. Firstly, the 1st conical spring is designed to generate the elastic force for ink injection. The 2nd conical spring is designed to withdraw the inserted needle and compress the 1st conical spring. Based on the concept design, the tattooing module is fabricated and implemented experimental validation of the mechanism.

2. Design of the tattooing mechanism

2.1 Tattooing mechanism configuration

As shown in Fig. 1, the proposed tattooing mechanism consists of two activation mechanism. The first one comprises 1st conical spring, acrylic post, and Ni-Cr wire for ink injection and needle insertion at the same time. The other one comprises the 2nd conical spring, the plate, nylon cable, and SMA wire for withdrawal of the 23G size needle [4]. The housing volume of the proposed tattooing module occupies 493.564 mm^3 and the tattooing ink is loaded 288.806 µl. Conclusively, the proposed tattooing apparatus has high space efficiency of 58.51% due to employment of multiple conical springs.

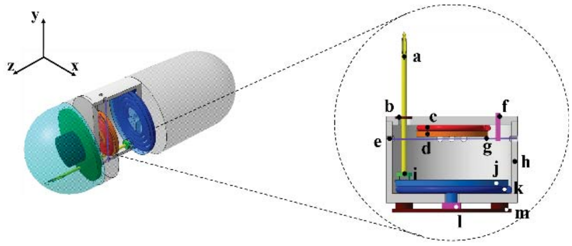

Fig. 1. Configuration of tattooing module: a. Needle, b. Rubber stopper, c. 2nd conical spring, d. Plate, e. Nylon cable hole, f. SMA wire, g. Nylon cable, h. Housing, i. Needle holder, j. Acrylic post, k. 1st conical spring, l. Ni-Cr wire, m. Heat shield

2.2 Working principle

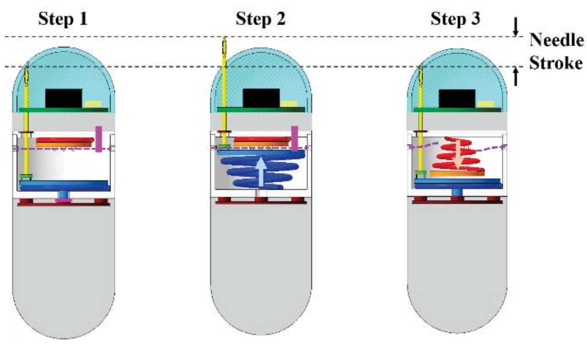

Fig. 2. Working principle of tattooing module.

The detail working principle is shown in Fig. 2.

1) Each conical spring is fully compressed and constrained. The needle is installed within the housing to prevent damage and perforation of internal wall of organs.
2) If the acrylic post is broken by Ni-Cr wire, the constrained 1st conical spring initiated the deployment. The needle comes out of tattooing module and is inserted up to a 3.5 mm depth. At the same time, the flow is loaded to the needle by enough pressure and the fluid is injected through the needle.
3) After the injection of the ink, the constrained 2nd conical spring initiated deployment when the nylon

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cable is cut off by the SMA wire. Consequently, the needle returns to the original position.

2.3 Design of the conical springs

A. Conical springs for high space efficiency

Two activation modules are required to control position of the needle for injection of the ink and withdrawal of the needle. However, the dimension for each activation module must be minimized to maximize the space efficiency of tattooing module. In addition, it must have sufficient force to insert the needle and the injection of the ink at submucosa layer of colon. Reflecting these requirements, the conical spring is employed to supply greater space efficiency and acting force than the same sized coil spring with uniform diameter.

B. Theoretical analysis for conical spring

Analysis on the elastic behavior of conical spring is carried out to apply the tattooing module. Above all, conical spring, which deploys under the maximum compression condition, shows the nonlinear elastic behavior until reaching transition point [4].

For normal operation, the elastic force of the 2nd spring (F_2) must be larger than the elastic force of the 1st spring (F_1). In detail, deployed condition (displacement=3.5 mm) of F_2 should be larger than compressed condition of F_1. Based on this theory, the 1st and 2nd conical springs are designed as shown in Fig. 3.

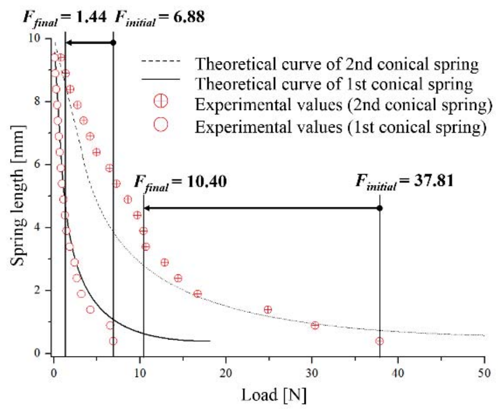

Fig. 3. Experimental data of conical springs.

3. Experimental results

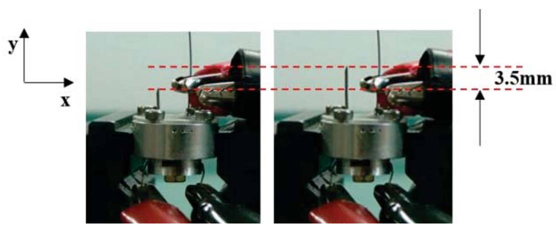

Fig. 4. Tattooing mechanism experiment.

To verify the tattooing mechanism, we conducted experiment as shown in Fig. 4. First, Ni-Cr wire (5 cm) is wrapped around acrylic post and 3 V is applied. After 8 sec, the acrylic post was broken, and the displacement was caused by the deployment of 1st conical spring. As a result, the displacement of needle satisfies the designed stroke (+3.5 mm) which is not to perforate the mucous membrane. In the withdraw mechanism of the needle, SMA wire (5 cm) is connected with nylon cable and 3 V is applied on SMA wire. After 1 sec, 2nd conical spring is deployed and the needle returned to the original position (-3.5 mm). The electrical power consumption of Ni-Cr wire was 33 mWh which takes 6.95% of total battery capacity (475 mWh). In the case of SMA wire, it spent 3.525 mWh which takes 0.742% of total battery capacity. Conclusively, the tattooing module can operate with only using 7.692% of the total battery capacity.

4. Conclusion

In this paper, we proposed a micro tattooing module for a capsule endoscope. At first, two conical springs are employed to secure enough space for ink loading. Two conical springs are triggered by independent signal. Also, to minimize electrical power consumption of battery, the minimum length of Ni-Cr and SMA wire were used. Consequently, we confirmed operation of the tattooing mechanism that can inject the needle up to 3.5mm. In the near future, the proposed tattooing mechanism will be integrated in the capsule endoscope through optimization of the proposed tattooing mechanism.

Acknowledgement

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