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Technical note

Swimming microrobot actuated by two pairs of Helmholtz coils system

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ABSTRACT

Various electromagnetic based actuation (EMA) methods have been proposed for the actuation of microrobots. The advantage of EMA is that it can generate a wireless driving force for the microrobot, and this is the reason why many researchers have focused on the EMA driven microrobot. This paper proposes a swimming microrobot driven by an external alternating magnet field using two pairs of Helmholtz coils. The microrobot with a fish like shape consists of a buoyant robot body, a permanent magnet, and a fin. Especially, the fin is directly linked to the permanent magnet and is swung by the alternating magnet field. The external alternating magnetic field generates the propulsion and steering force of the microrobot. In this paper, firstly, we design and fabricate the EMA coil system and the tadpole type microrobot. Secondly, we propose the locomotive mechanism of the microrobot using EMA. Thirdly, we set up the control system for the EMA driven microrobot. Finally, through various experiments, we demonstrate and evaluate the performance of the swimming microrobot.

1. Introduction

Worldwide research on medical microrobots has shown much progress and developments in the ongoing efforts to decrease damage to a human body during an operation and to reduce operation time. Especially, microrobots that can move along blood vessels and treat specific parts of body have received much attention. The ultimate objective of the microrobot is to approach its destination accurately and quickly. Generally, small motors and smart materials, such as IPMC and SMA, are known used as actuators for the microrobot. However, they sometimes occupy most of volume of the microrobot, and thus they cannot be practically applied to a microrobot.

To solve this problem, electromagnetic based actuation (EMA) systems for microrobot were used, and the driving mechanisms of biomedical microrobot using EMA systems were studied [1,2]. Kosa et al. suggested a movable microrobot in the body using an external magnetic field of MRI [3,4]. In the microrobot, coil patterns generate current through external electromagnetic induction. The microrobot can move by the interaction between the external magnetic field and the magnetic field generated from the induced current. Because the microrobot drives in MRI, the position of the microrobot and the target destination can be estimated from MRI image. In addition, such a system does not need other external coil systems. However, owing to its complicated structure, it is very difficult to realize a small microrobot whose moving direction can be controlled by using only the MRI system.

Guo et al. suggested a simple swimming microrobot [5–7] which has a magnet and a fin attached the magnet directly. The microrobot moves along a pipe, which is surrounded by a coil. Current flowing through this coil generates a magnetic field along the pipe. In this system, the microrobot has a simple structure and has fast moving speed. However, the microrobot can move only inside the coiled pipe and cannot be applied to the human body. In addition, it is difficult steer the microrobot in a certain direction and to control the swing angle of the fin.

Masahiro et al. suggested a turning fish type microrobot using an NdFeB magnet. Its movement is very similar to the real swimming motion of a fish [8]. An external magnetic field is generated by a coil. When both the basic input offset and frequency of the sinuous function current or modifying wave form are changed, the robot moves either straight or turns. A magnet in the fish type robot is wire-connected with the fin so that the robot can turn naturally. But this type of robot cannot be made small due to the wire connection, and it is also difficult to control precisely because the robot is controlled by a coil.

In this paper, a tadpole shaped swimming microrobot is proposed. The tadpole microrobot has a simple structure and simple parts, but it can be controlled precisely because EMA system with two pairs of Helmholtz coils was used. Therefore, the tadpole microrobot can freely swim with various motions in a water bath in the region of interest (ROI) of the EMA system. The swimming motion of the microrobot can be changed by controlling the swing angle of the fin and the frequency of the swing motion. Through various experiments, the control parameters such as the swing

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