Shape Forming of a Soft Magnetic Microrobot Using Non-Homogeneous Magnetic Fields

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Abstract. Microrobotics is an actively growing field with applications in the medical domain. However, miniaturization of robotics presents a challenge in their manipulation and control. Several actuation techniques have offered solutions to this problem, however magnetic actuation has been preferred, due to its remote maneuverability, precise microrobot response and biocompatibility. Soft continuum magnetic microrobots have typically been controlled using homogeneous magnetic fields. In this study, we present the characterization of soft continuum microrobots in a non-homogeneous fields using permanent magnets. Cylindrical permanent magnets were used to apply focused fields across the length of the robot's body, with three different combinations of actuating fields being explored to achieve full body shape control of 600 µm diameter soft continuum magnetic robots. In this approach, one actuating field gives the device a general direction, while a second localized actuation is provided based on the scenario. Using this approach, it is possible to add versatility to the shape forming of microrobots, which we demonstrate using a static 3-point manipulation.

Introduction

Magnetic continuum microrobots have been developed as endovascular interventional tools, where their soft cylindrical structures can be controlled to navigate inside vascular networks [1]. More recently, fully soft continuum robots capable of achieving shape formation have been introduced (Fig. 1 (a)) [2, 3]. The soft continuum microrobots used in the presented work were made of a magnetic responsive elastomer (MRE) material, fabricated by embedding magnetic microparticles in an elastomer matrix. This type of material combines magnetic and elastic properties to allow controlled deformation and manipulation of the devices.

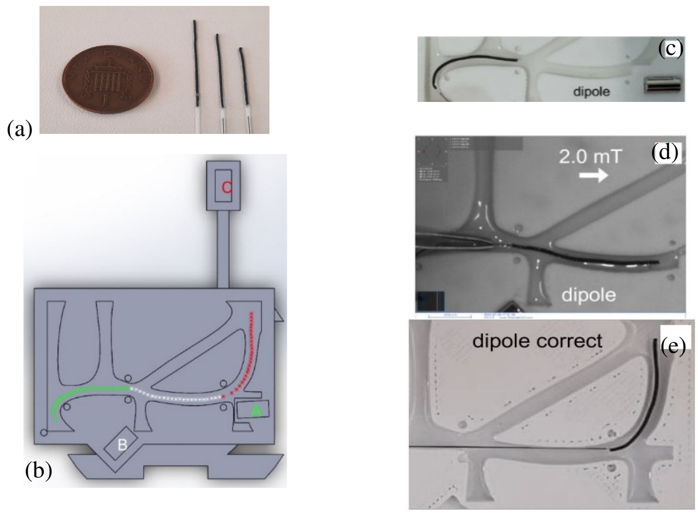

Figure 1. Soft magnetic microrobot shape forming(a) microrobot of with 20mm 25mm 30mm length and (diameter <600 µm), (b) complex path with three shape conditions (c) shape condition with one permanent magnet (d) shape condition with permanent magnet and electromagnet (e) shape condition with two permanent magnets (all conditions are statics)

Results and discussion

The study was divided into three main experiments, all conducted with the microrobot submerged in fluid. This configuration was chosen to reduce friction of between the devices. We first studied the microrobot's behaviour under inhomogeneous fields to identify possible shape-forming primitives. Subsequently, the possibility to achieve more complex, sequential shape forming was simulated (Fig. 1 (b)). Finally, the approach of shape-forming under inhomogeneous fields was tested (Fig. 1 (c), (d) and (e)) which shows the successful proof-of-concept result and five different modes for shape forming was identified.

References

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