A Vibro-Impact Capsule Driven by its Inner GMM Exciter

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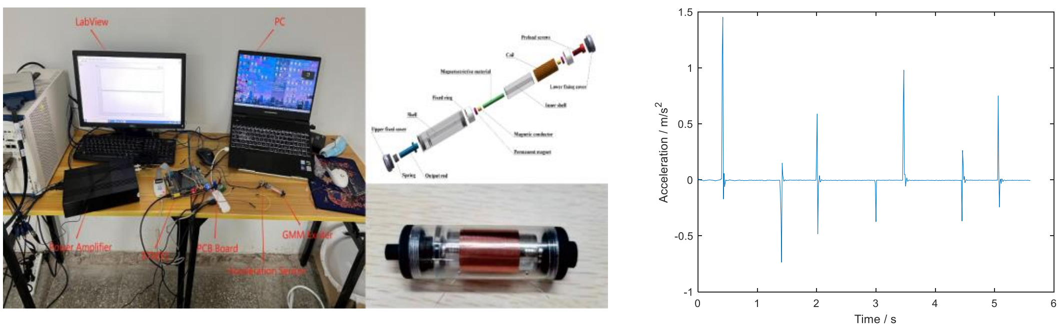
Abstract. In order to offer a vibro-impact capsule with the self-propelled ability meanwhile getting rid of its dependence on external driving equipment, an exciter made of giant magnetostrictive material (GMM) is applied inside the capsule to provide the vibro-impact driving force. Considering the magnetostrictive properties of GMM, the control mechanisms of both the alternating magnetic field and the preloading force of the exciter are designed. Meanwhile, in order to model the dynamic behaviours of the magnetostrictive exciter, the correlation between the input excitation voltage and the output impact force of the exciter is determined. Comparing the obtained experimental results with the numerical simulations, their consistency is observed. The designed GMM exciter with even a small size can provide the required driving force for the vibro-impact capsule moving in the intestinal environment independently.

Introduction

For design of an electromagnetic exciter, the GMM rod is widely used as the deformation part and the output component, which is characterized by the change of its volume under the action of an alternating magnetic field. Compared with piezoelectric ceramics, the GMM has excellent properties with both the high energy conversion efficiency and the strong output force. Based on existing designs of the GMM exciter [1], its magnetostrictive properties should be calculated precisely, which are mainly determined by the designs of the alternating magnetic field device and preloading force device of the exciter. Furthermore, based on the magnetic-machine coupling schematics of the designed exciter, by establishing the voltage input equation, magnetic flux equation, magnetostrictive force equation and force balance equation, the transfer function expression between the input excitation voltage and the output impact force of the magnetostrictive exciter can be obtained. Finally, the corresponding experiments should be carried out to systematically test all the functions of the exciter [2-3], in particular, the driving force and energy consumption intensity.

Result analysis

During the experimental tests, a self-made miniature acceleration sensor is installed at the front end of the GMM rod of the exciter, see Fig.1(a), and thus the output acceleration signal of the exciter controlled by an input square wave signal is measured, see Fig.1(b). Specifically, an acceleration peak can be observed when the square wave signal is turned on, otherwise the acceleration signal will go back to zero. Moreover, the positive peak indicates the extension of the GMM rod, thereby pushing the capsule to move in the intestinal environment; while the negative peak indicates that the extension of the GMM rod disappears; by this way, the periodic movement of the capsule can be completed.



(a) Experimental setup (b) experimental acceleration signal

Figure 1: Experimental test, (a) Experimental setup and (b) the measured experimental acceleration signal

References

[1] Bryant, Michael D., and Ning Wang. "Audio range dynamic models and controllability of linear motion terfenol actuators." Journal of intelligent material systems and structures 5.3 (1994): 431-436.

[2] Guo, Bingyong, et al. "Self-propelled capsule endoscopy for small-bowel examination: proof-of-concept and model verification." International Journal of Mechanical Sciences 174 (2020): 105506.

[3] Zhang, Jiajia, et al. "Simulation and experimental studies of a vibro-impact capsule system driven by an external magnetic field." Nonlinear Dynamics (2022): 1-16.