Investigation of Force Magnification for the Vibro-Impact Capsule System using FEA

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Abstract. This work aims to study the performance of force magnification of the vibro-impact mechanism in the capsule system through finite element analysis and experimental investigation. Two configurations of the vibro-impact mechanism, one with a one-sided constraint and the other with a two-sided constraint, are considered. It was found that for a proper selection of the control parameters, i.e. the frequency, magnitude and duty cycle of the external excitation, the driving force can be magnified up to 40 times through the vibro-impact mechanism.

Introduction

The introduction of capsule endoscopy two decades ago came as a natural consequence of the advances in the minimisation and efficiency of the semiconductor technology and provided an innovative, non-invasive means to examine the surface lining of the small intestine, an area that clinicians previously considered inaccessible. However, despite the approval it has gained, capsule endoscopy remains an immature technique, due to some flaws that are yet to be overcome. These are as follows: (a) Precise screening requires real-time positioning and control. (b) Clinical treatment, in many cases, demands biopsy and therapy. (c) The interaction between the capsule and the intestine has no unified and realistic mathematical model. (d) The propulsion of the capsule endoscope relies on gastrointestinal peristalsis [1]. Nevertheless, all these obstacles can be addressed by the so-called vibro-impact capsule system [2], which is a self-propelled device that utilises an external harmonic excitation and moves rectilinearly in the small intestine. The present work aims to investigate the performance of force magnification of the vibro-impact mechanism in the capsule by using finite element (FE) analysis and numerical simulations. Two configurations of the vibro-impact mechanism, one with a one-sided constraint and the other with a two-sided constraint [3], will be considered to examine the magnification efficiency of the system.

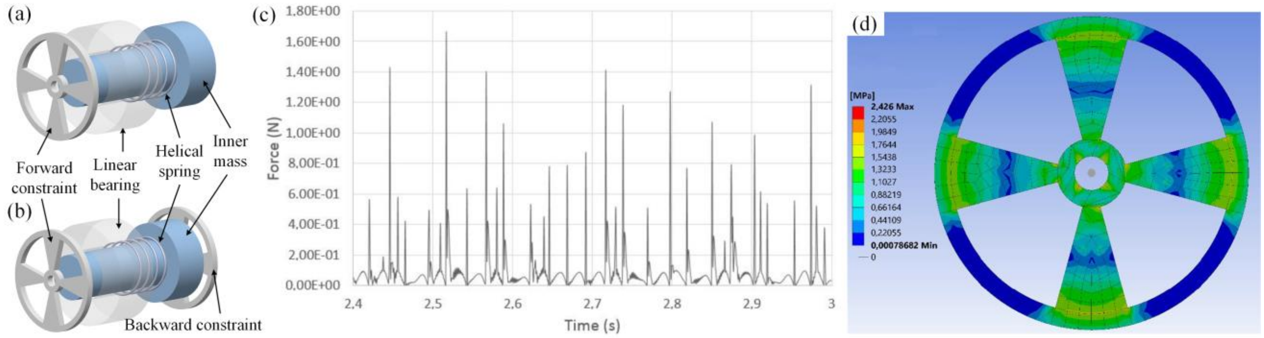

Figure 1: The vibro-impact mechanism of the capsule systems with (a) a one-sided constraint and (b) a two-sided constraint. (c) Interactive force acting on the capsule at the excitation frequency 40 Hz, forcing magnitude 50 mN and duty cycle ratio 0.5. (d) Pressure distribution on the forward constraint.

Results and discussion

The FE analysis was carried out by using the Transient Structural solver in ANSYS Mechanical. Two configurations of the vibro-impact mechanism are presented in Figure 1(a) and (b), where the capsule was stationary and the inner mass was excited by a square wave signal impacting with the constraints. Control parameters to be studied include the frequency, magnitude and duty cycle of the external excitation. The considered excitation frequency ranged between 1 and 50 Hz, while the amplitudes of the excitation force were 5 mN and 50 mN. Furthermore, the effect of various duty cycle ratios of the excitation force was examined for both configurations. Figure 1(c) shows an example of the interactive force acting on the capsule, where both forward and backward impacts were observed. The pressure distribution on the forward constraint can be seen in Figure 1(d). It reveals that higher pressure was concentrated around the areas where the spokes of the constraint connected to its outer ring.

References

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