Variable Speed Optimization of a Vibro-Impact Capsule System in Both the Forward and Backward Directions

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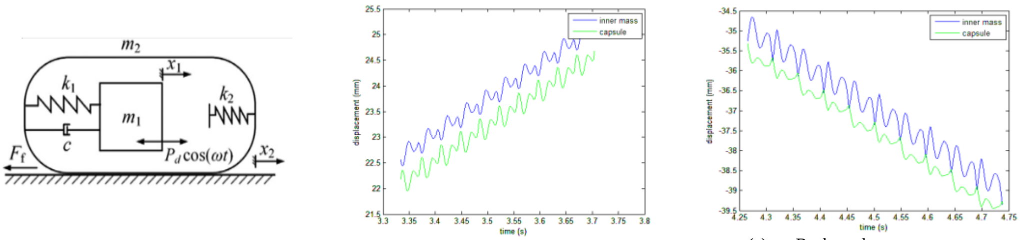
Abstract. A vibro-impact self-propulsion capsule system is studied, whose purpose is to optimize its moving speed according to the practical requirements of diagnosis in small-bowel circumstance. Seven variable speed steps for the steady movement of the capsule are proposed, and the uncertainty of the friction coefficient due to the varied structure and lubrication of the practical small-bowel is considered. Specifically, the seven variable speed steps include fast backward and forward movements, medium backward and forward movements, slow backward and forward movements, and hover movement under gastrointestinal motility. In order to obtain the corresponding excitation parameters for such seven variable speed steps, Six-Sigma algorithm, Multi-Island Genetic algorithm, Monte Carlo algorithm, are combined for optimization. Finally, except the slow and fast forward movements which can't achieve steady speeds, the excitation parameters for other five variable speed steps are explored, and their stabilities under the uncertain friction coefficient are verified as 100%.

Introduction

Developing small-size capsule robots for endoscopy in small-bowel is a challenging task, particularly for the control of both the speed and direction for the capsule moving in uncertain small-bowel circumstance [1]. In order to solve such a problem, an optimization algorithm combination is proposed, and the corresponding optimization parameters consist of the frequency (f), amplitude (P_d), and duty circle ratio (D) of the excitation square signal. Specifically, based on the developed dynamic model of the capsule system, Six-Sigma algorithm is applied to drive Multi-Island Genetic algorithm to run the optimization design, and simultaneously to drive Monte Carlo algorithm to evaluate the stability of the obtained optimal solution [2], and finally the steady optimization designs can thus be extracted from massive combinations of excitation parameters.



(a) Physical model of capsule (b) Forward movement (c) Backward movement

Figure 1: Physical model and movement types of a vibro-impact capsule

Table 1: Optimization results of variable speed steps for the capsule movement

type of speed step	optimization settings						optimization results				stability analysis		
	uncertain friction coefficient μ	ranges for optimization parameters f (Hz)	P_d (mN)	D (%)	optimization target (mm/s)	allowed range (mm/s)	optimized parameters f (Hz)	P_d (mN)	D (%)	obtained speed (mm/s)	fluctuation around optimized parameters	distribution type	degree of reliability (%)
fast backward					-10	[-15, -5]	33.77	22.28	66.86	-9.01			100%
medium backward					-5	[-10, -0.1]	44.14	24.17	14.66	-5.05			100%
slow backward					-1	[-3, -0.1]	44.14	4.45	25.70	-0.91			100%
hover	[0.2, 0.5]	[1,50]	[1,30]	[10,90]	0	[-0.1, 0.1]	21.84	4.31	86.75	0	± 3%	uniform	100%
slow forward					1	[0.5, 1.5]	failed						failed
medium forward					5	[0.1, 10]	40.95	25.17	34.23	4.58			100%
fast forward					10	[5, 15]	failed						failed

Results and discussion

Fig.1 shows the physical model and the two cases of movement of the capsule, and Table.1 listed the optimization settings and the corresponding results of the optimization and stability analysis. According to the optimization of excitation parameters for the vibro-impact capsule, five variable speed steps of the capsule with steady moving speeds are explored. However, given the current excitation parameter ranges, the steady slow and fast forward movements of the studied capsule can't be confirmed.

References

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