UNIVERSITY OF Southampton

Electronics and Computer Science

A HIP IMPLANT ENERGY HARVESTER

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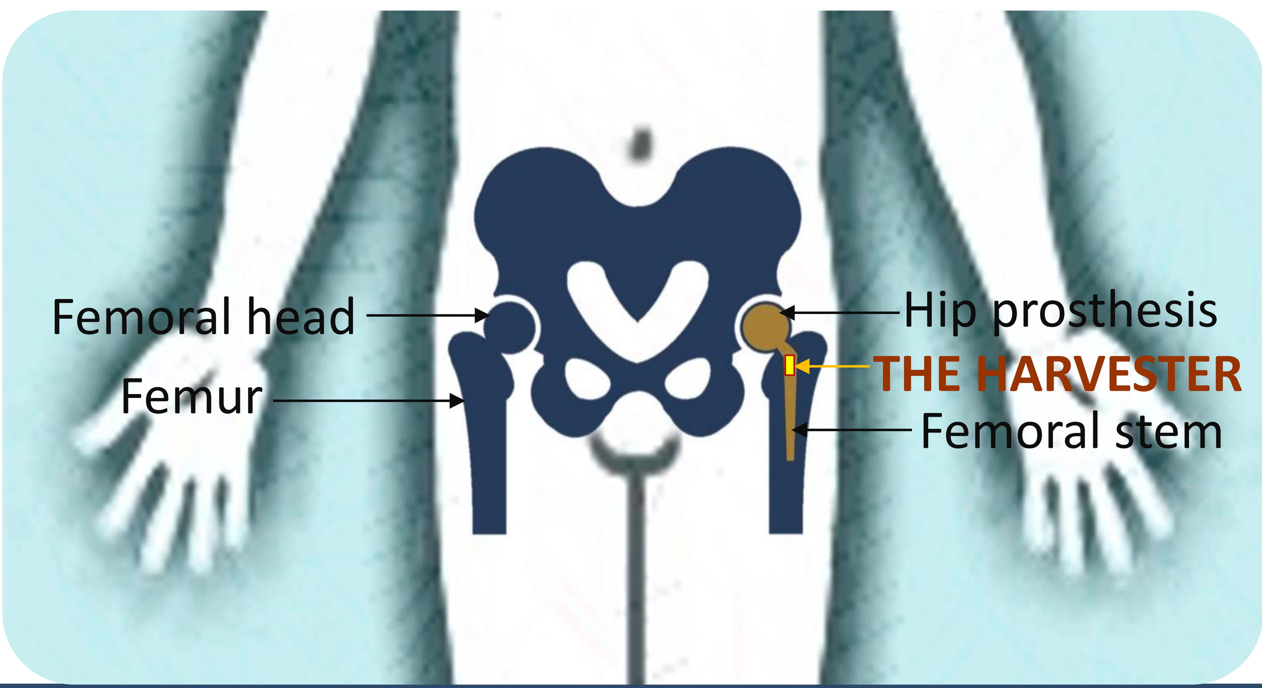
Introduction

In-vivo monitoring of hip-joint replacement has been proposed to address the problem of joint replacement failure leading to difficult surgery and rising costs of healthcare. To power instrumented hip implants, a magnetically levitated electromagnetic vibration energy harvester based on coupled levitated magnets is presented in this poster. The harvester is designed to be embedded in a hip prosthesis and harvest energy from low frequency movements (< 5 Hz) associated with human motion. The concept of magnetic-force-driven energy harvesting is applied to the harvester with a two-degree-of-freedom configuration. This results in a nonlinear response that extends the operating bandwidth and enhances the power output of the harvesting device.

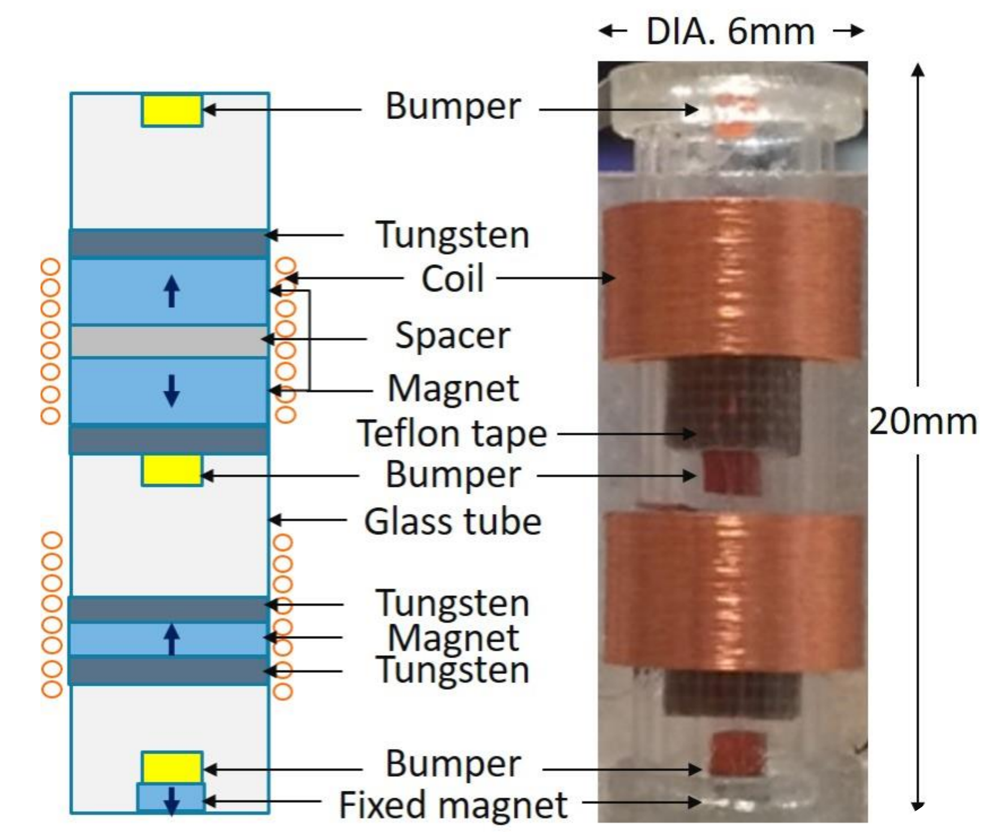
Overview

The energy harvester is presented as an alternative power supply to power instrumented hip implants for in-vivo monitoring of joint replacement failure. The harvester has dimensions of 6mm-diameter × 20mm long. It will be embeded in a hip prosthesis at top of the femoral stem. The constraints on the size of the harvester due to the volume of the hip prosthesis makes designing an effective energy harvester operating at a frequency below 5 Hz a significant challenge.



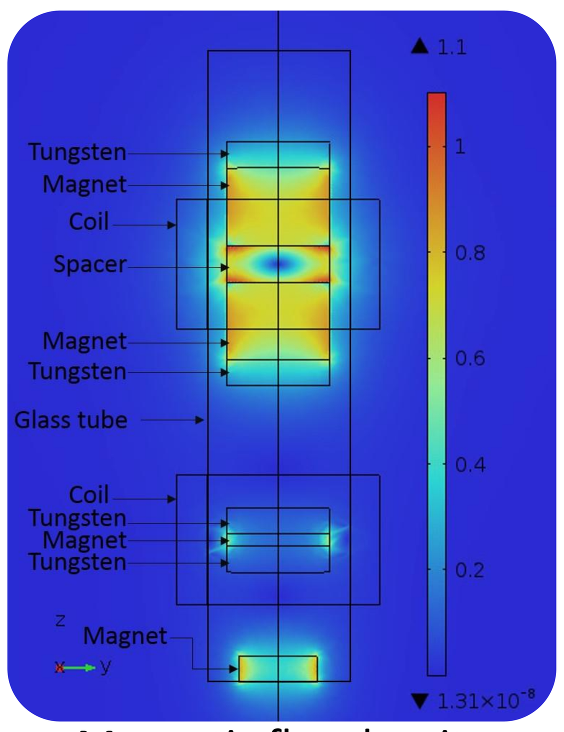
Structure of the energy harvester

The two movable magnets are arranged in the tube with like-pole facing each other, and levitated by the bottom fixed magnet. The 30μm-diameter Copper wire wrapped around the tube with the coil lengths of 5 mm. The thickness of the 4 mm-diameter NdFeB cylindrical magnets is 4 mm for the top movable mass and 0.5 mm for the bottom movable mass. The weight of movable masses are 1.52 grams and 0.59 grams for the top mass and the bottom mass, respectively. The coil fill factor is 0.54. Crepe rubber bumpers are added to conserve kinetic energy.

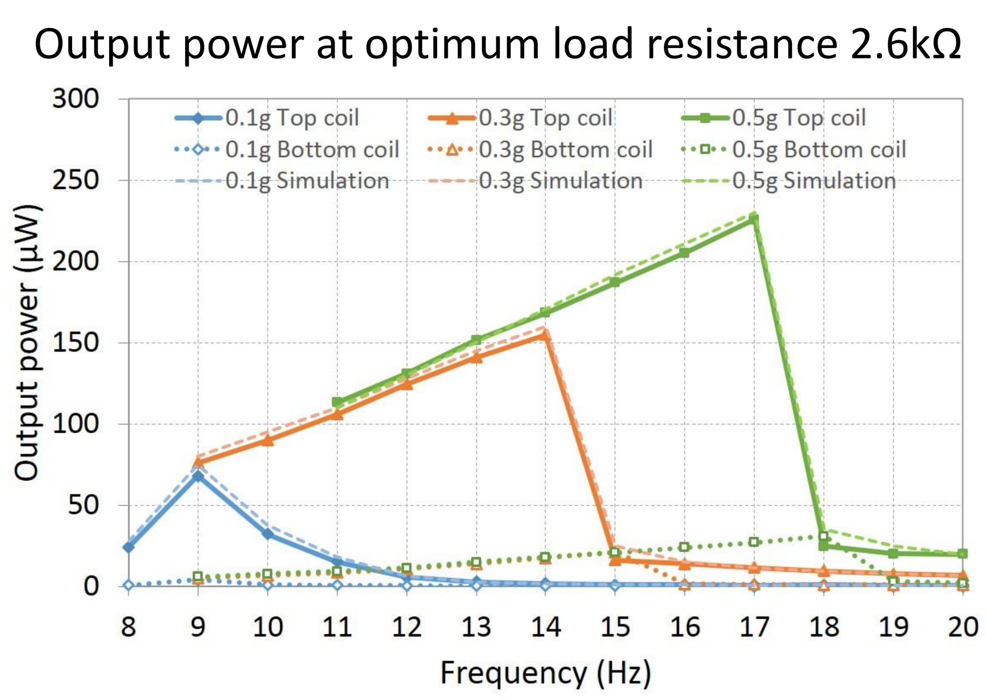


Simulation and Experimental results

The magnetic flux density along the tube was simulated in COMSOL. Experimental results on an electrodynamic shaker show that the resonant frequencies of the harvester change with increasing acceleration amplitudes (0.1*g*, 0.3*g*, and 0.5*g*) going from 9 Hz to 17 Hz, which are consistent with the simulation result. The shape of the plot of output power versus exciting frequency at different levels of acceleration indicates a hard nonlinearity that will influence the bandwidth and output power of the harvester.



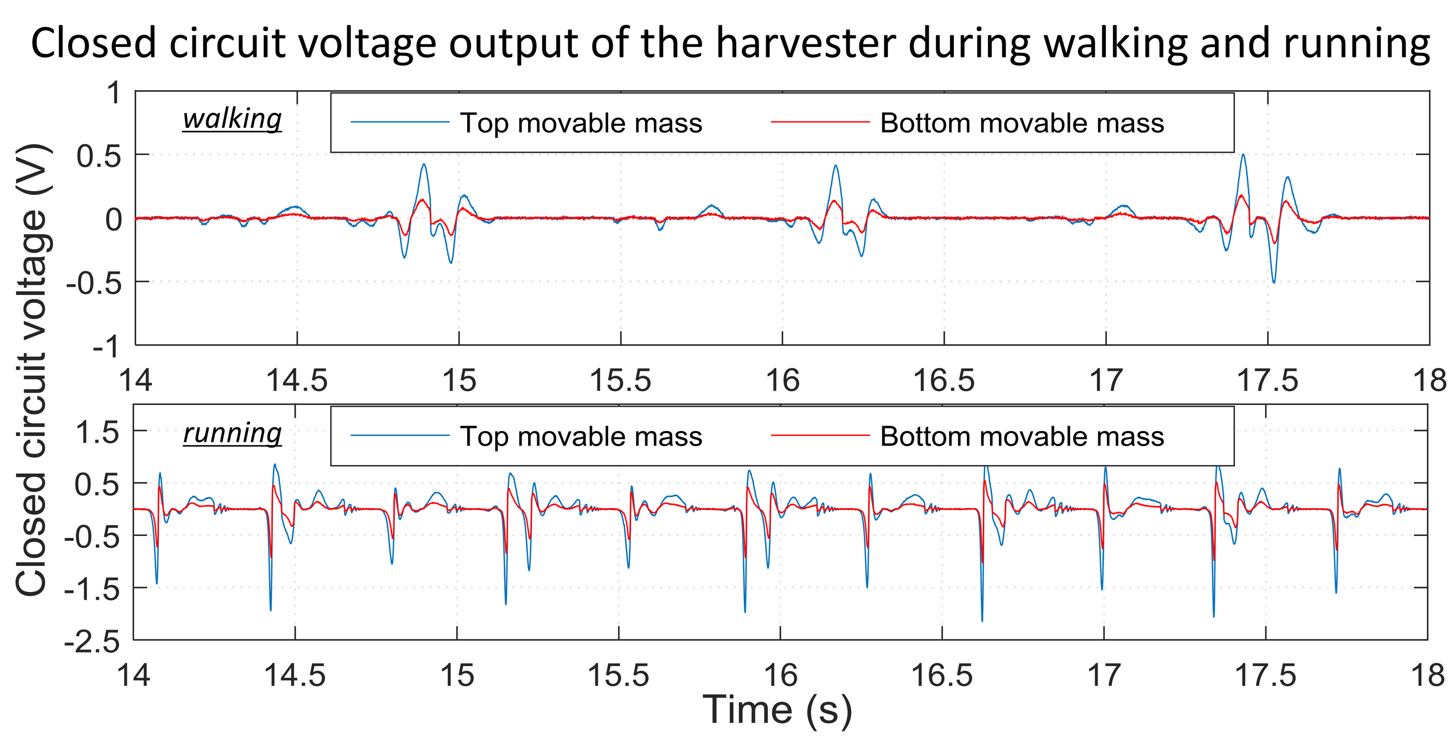
Magnetic flux density



The harvester was mounted at the hip to record the output voltage during walking (2.6 km/h) and slow jogging (7 km/h) on a treadmill. The output voltage and power are presented in Table 1.

Table 1: Closed circuit voltage and output power harvested during walking and running

	Closed circuit voltage (V)		Output power (μW)	
	Walking	Running	Walking	Running
Top movable mass	0.12	0.314	5.61	37.07
Bottom movable mass	0.04	0.14	0.52	7.58



Conclusions

- A good agreement is found in the comparison between simulation and experimental results.
- The nonlinear coupling between the movable magnets has reduced the operating frequency of the harvester, which is more suitable for harvesting energy from human movement.
- The harvester promises sufficient voltage and power output for powering an instrumented hip implant according to the experimental results.

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