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MAGNETIC BEAM PLUCKING IN A PIEZOELECTRIC ENERGY HARVESTER WITH ROTATING PROOF MASS

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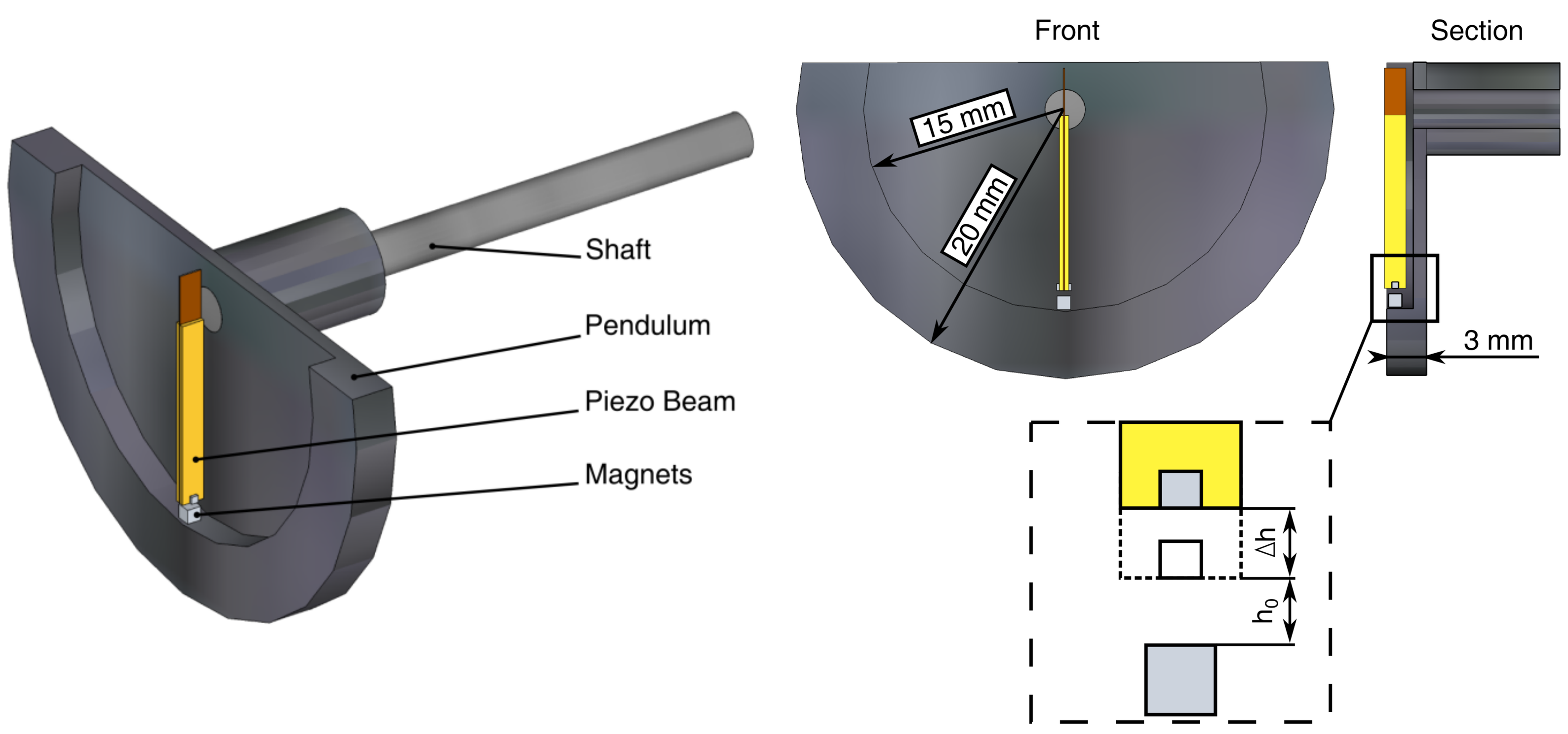
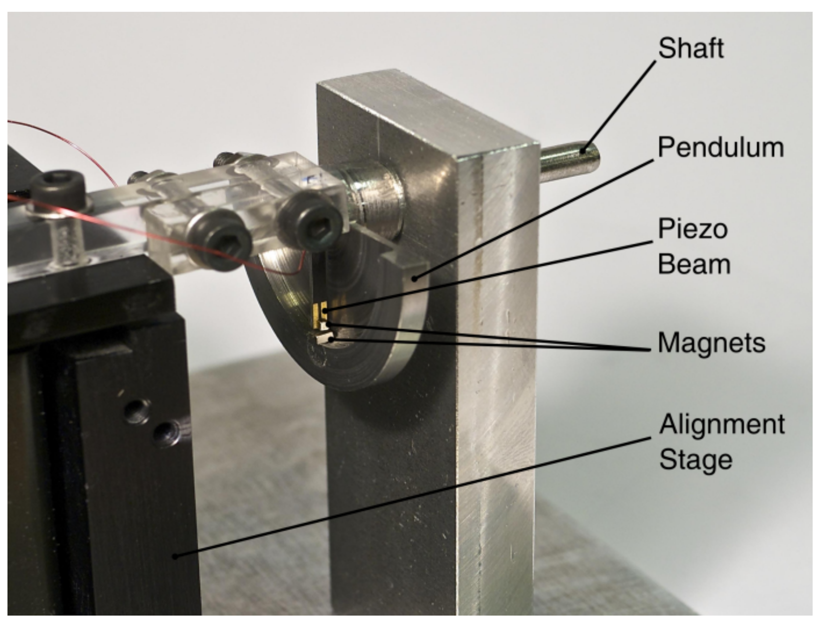
INTRODUCTION

- Human body motion is characterized by random, slow movements
- Piezoelectric beam plucking is a popular technique to improve electromechanical coupling for these excitations
- Plucking with plectra can damage the brittle piezo material
- A simplified model for the magnetic coupling used in a rotational harvester is presented

ROTATIONAL GENERATOR



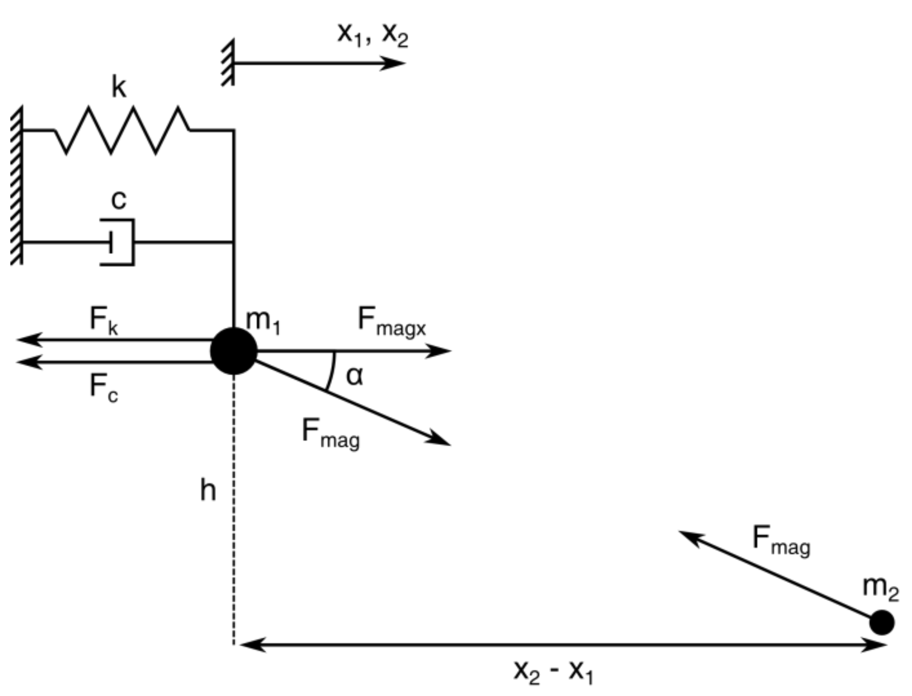
- A steel rotor is free to oscillate around its axis of rotation
- The rotor provides an eccentric proof mass and can accept linear and rotational external excitations
- Permanent magnets are attached to the rotor and to the tip of a piezoelectric beam each
- When the rotor magnet swings past the beam magnet, the beam gets actuated without physical contact



- The release and the following free vibration of the beam are strongly influenced by the magnetic coupling
- Novelties compared to other devices are the rotational set-up [1], the inertial design [2] and the magnetic plucking [3]
- 1.4 μW at 2 Hz, 2.7 m/s^2 and 3.7 cm^3 functional volume

MODEL OF THE MAGNETIC COUPLING

- Piezoelectric effect is not considered
- The mechanical properties of the beam are reduced to a spring-mass-damper system
- m_1, lumped mass for magnet and beam
- m_2, represents second magnet passing with velocity v_0
- h, initial gap at zero position in x-direction



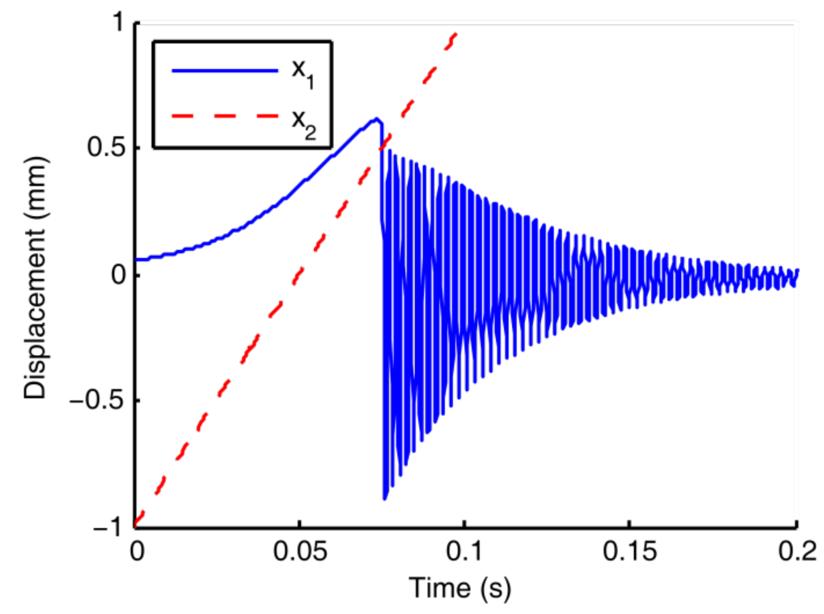
$$F_{mag} = \frac{F_0 h^2}{r^2} \qquad F_{magx} = F_0 h^2 \frac{(x_2 - x_1)}{(h^2 + (x_2 - x_1)^2)^{3/2}}$$

$$\ddot{x}_1 = -\frac{k}{m_1} x_1 - \frac{c}{m_1}\dot{x}_1 + \frac{F_0 h^2}{m_1} \cdot \frac{(x_2 - x_1)}{(h^2 + (x_2 - x_1)^2)^{3/2}}$$

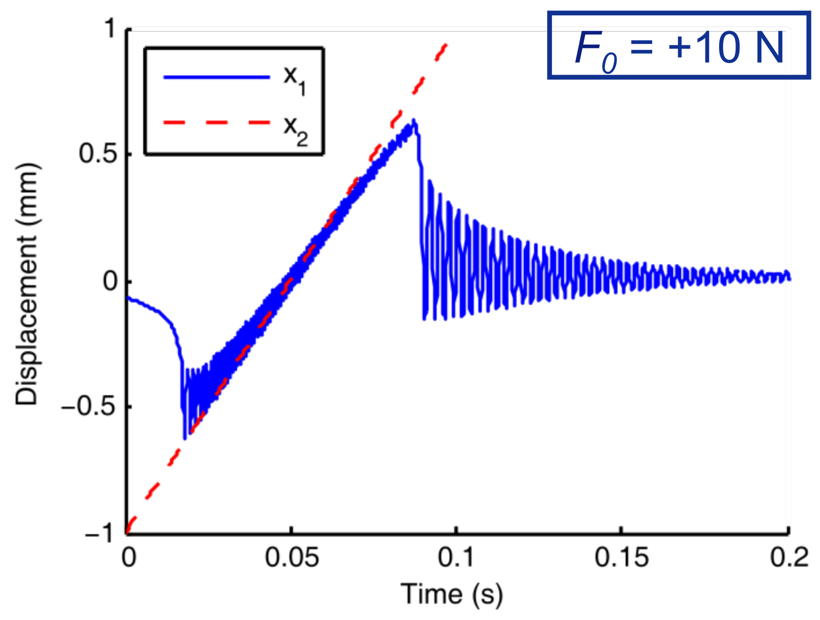
RESULTS

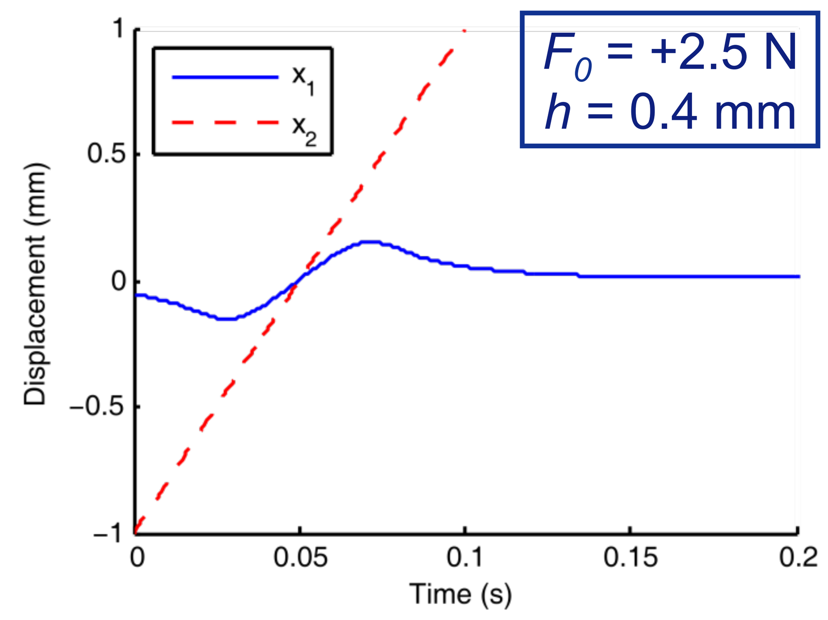
Initial parameters for repulsive magnets

Parameter	Value	Units
k	6320	N/m
c	0.05	Ns/m
h	0.2	mm
v_0	20	mm/s
m_1	1	g
F_0	-10	N

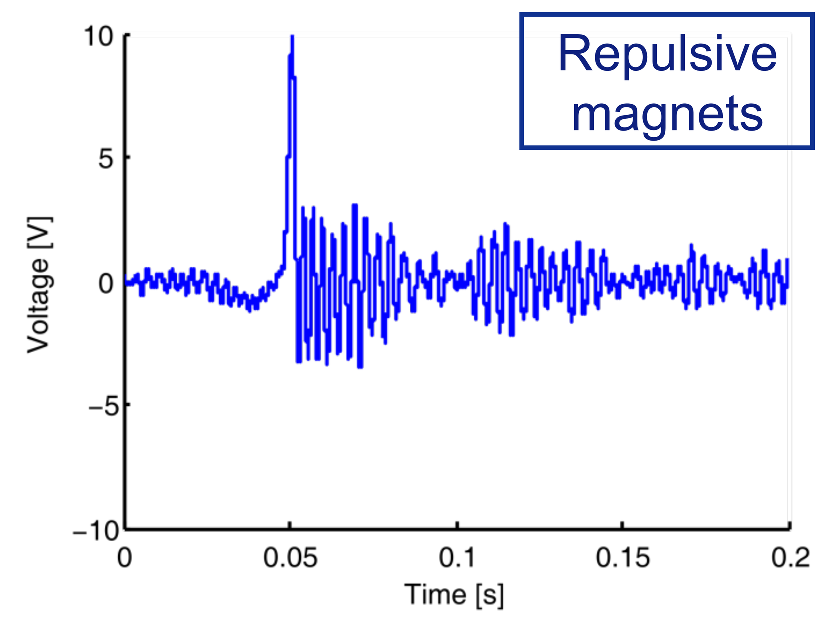


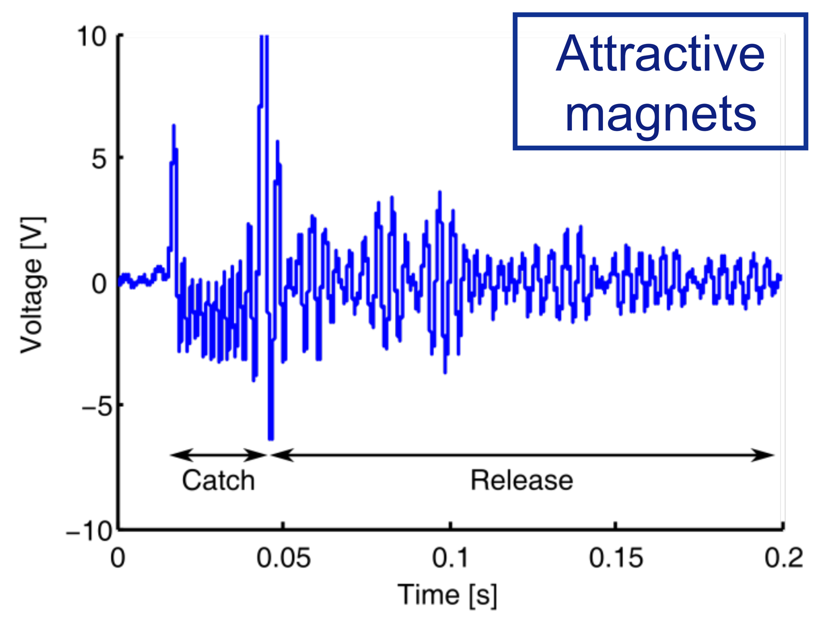
Attractive magnets





Measurements





- Distinct catch and release phases in the attractive set-up
- Frequencies: 785 Hz during catch phase, 370 Hz after release in attractive arrangement, 450 Hz after release in repulsive set-up
- An increased gap causes the beam to deflect gradually, plucking does not occur
- The bevahiour can be shown in the voltage output of the prototype

CONCLUSIONS

- Better release in repulsive arrangement, stronger oscillation
- With given magnets, smaller gaps are better
- Well defined oscillation frequency simplifies impedance match
- Measurements support the model, further research on initial magnetic force and integration of piezoelectrics are in progress

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REFERENCES

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