Institute of Sound and Vibration Research

UNIVERSITY OF Southampton

Energy Harvesting Using Parametric Excitation

B.Zaghari, Dr. M. Ghandchi Tehrani, Dr. E. Rustighi

INTRODUCTION

Energy harvesting is the transformation of ambient energy present in the environment into electrical energy. This energy is derived from different external sources such as solar power, thermal energy, wind energy, salinity gradient and kinetic energy. Harvesting energy from ambient vibration has attracted many researchers and is well-established in literature [1]. Existing energy harvesting research has been based on linear damping and linear stiffness [2]. One of the aims of this project is to improve the performance of the linear harvesters by introducing a periodic time-varying co-efficient to a parameter, such as stiffness, to the dynamic equation in order to generate parametric resonance. When the excitation appears as a time-varying coefficient in the equation of motion, the system is parametrically excited. A small parametric excitation can produce a large response when the system is subjected to a frequency equal to double one of its natural frequencies [3]. It is proposed that the parametric oscillations could be used for energy harvesting. Parametric resonance has been observed in engineering structures such as ships, cable-stayed bridges and aircraft. A further aim is to investigate the energy harvesting potential from parametric structures using a standard harvester.

WHAT IS PARAMETRIC EXCITATION?

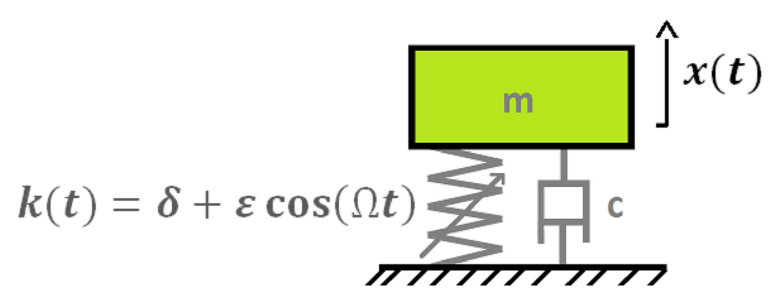
An example of parametric excitation is a child pumping a swing by periodically standing and squatting to increase the height of the swing. Varying the resonance frequency and damping drives the system. It is expected that, when the excitation has a time-varying coefficient in the equation of motion, the system is parametrically excited. The equation is in the form of Mathieu's equation:

$$\ddot{x} + [\delta + \varepsilon\cos(\Omega t)]x = 0$$

Single DOF system with time-varying stiffness

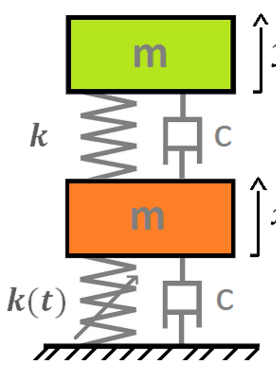
Mathieu type equation of motion:

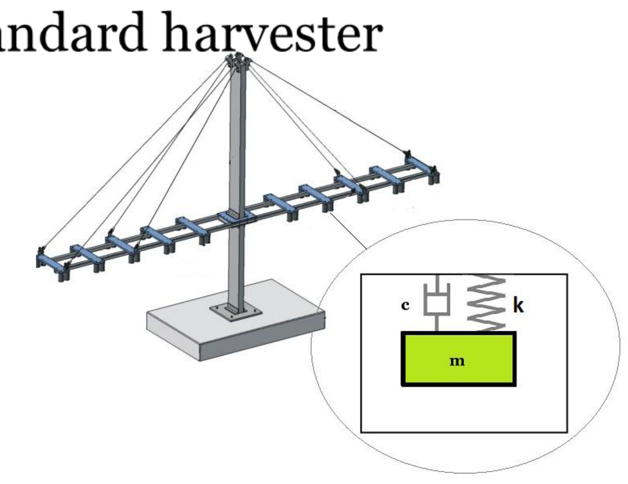
$$m\ddot{x} + c\dot{x} + (\delta + \varepsilon\cos(\Omega t))x = 0$$



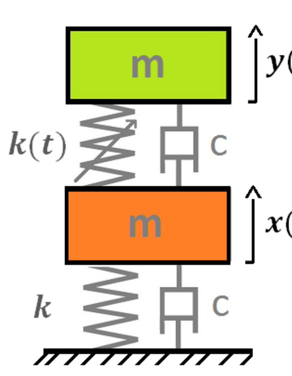
Energy Harvesting based on

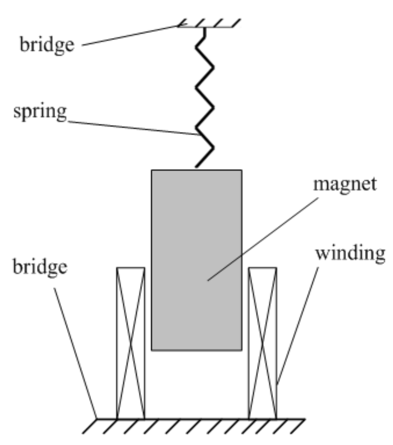
1. Parametrically excited system/ Standard harvester





2. "Parametric" harvester/Standard excited system





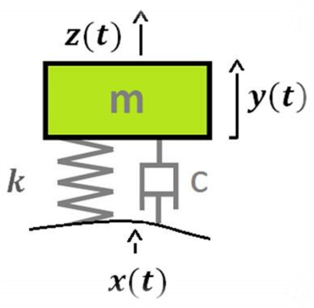
CONCLUSION AND FURTHER WORK

A single DOF vibration energy harvester with base excitation was used to find the absorbed energy by the harvester damper. Maximum absorbed power was found to depend on the frequency and amplitude of the base and the damping ratios in the linear system. Simulations will be carried out for a single DOF harvester with periodic time-variant stiffness.

CURRENT RESULTS

Two harmonic frequency dependant and independent signals were subjected to a single DOF system separately:

Equation of motion $m\ddot{z} + c\dot{z} + kz = -m\ddot{x}$



System Parameters

m = 7.5×10^{-4} kg	m = 7.5×10^{-5} kg
k = 107.4 Nm^{-1}	k = 10.74 Nm^{-1}
c = 0.08, 0.16 and 0.24 Nsm^{-1}	c = 0.008, 0.016 and 0.024 Nsm^{-1}

Base Excitation

$x(t) = X\cos(\omega t)$ $\qquad$ $x(t) = Y\cos(\omega t - \sigma)$

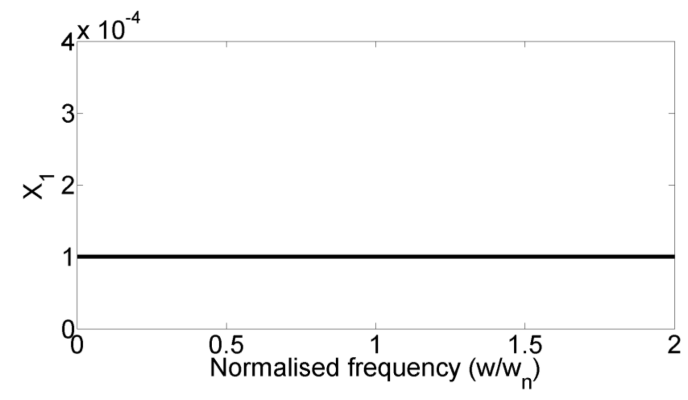


Fig 1. Frequency-independent excitation

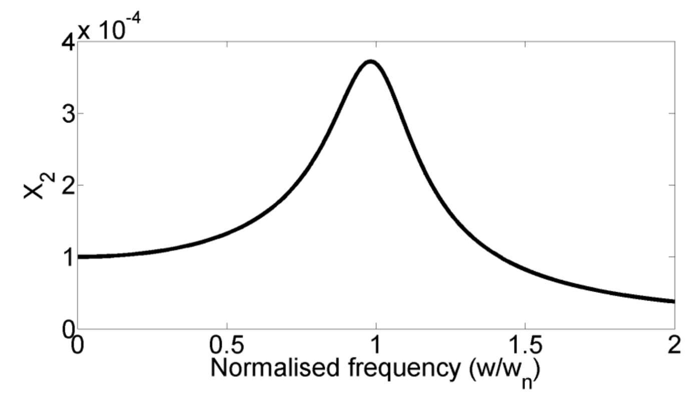
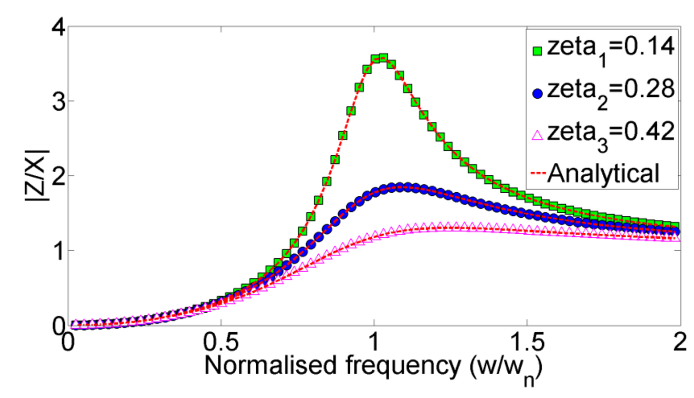
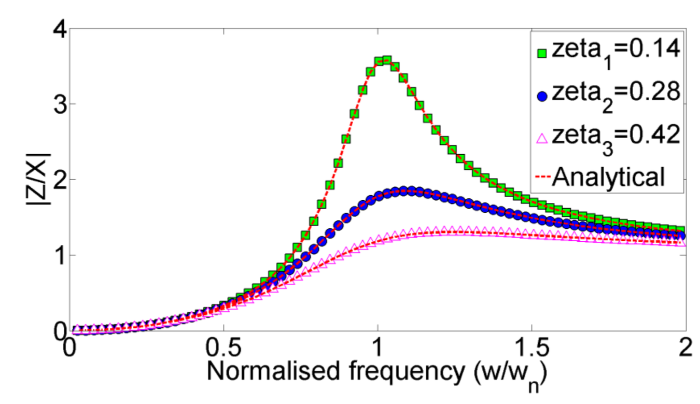


Fig 2. Frequency-dependent excitation

Relative Transmissibility

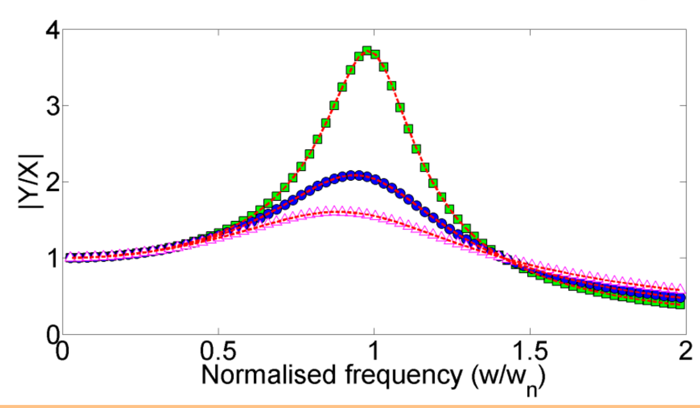
$$\zeta_s = \frac{c}{2\sqrt{mk}}, \quad \alpha_s = \frac{\omega}{\omega_n}, \quad |T_{rel}| = \frac{\alpha_s^2}{\sqrt{(1-\alpha_s^2)^2 + (2\zeta_s\alpha_s)^2}}$$

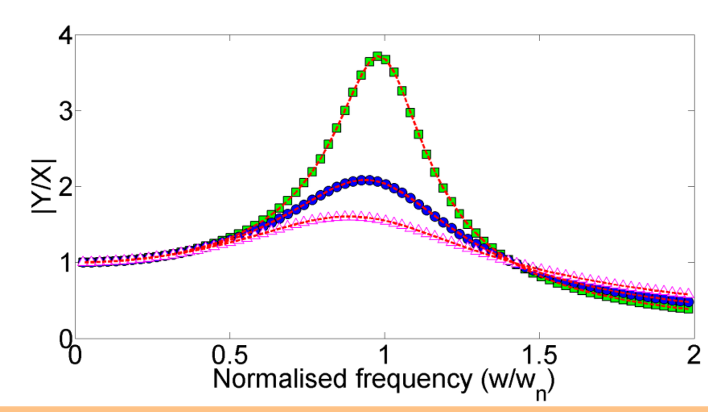




Transmissibility

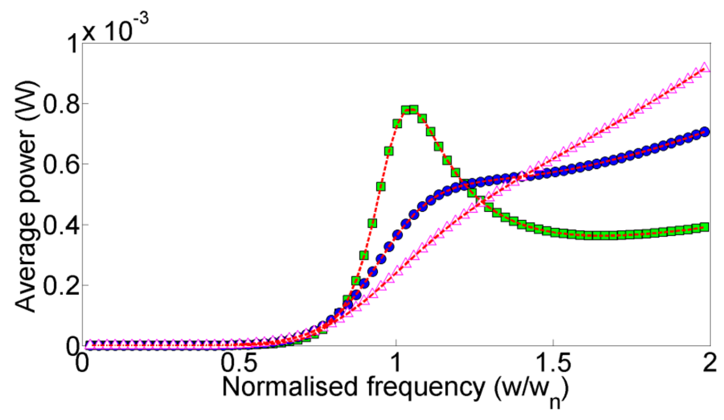
$$|T| = \sqrt{\frac{1 + (2\zeta_s\alpha_s)^2}{(1-\alpha_s^2)^2 + (2\zeta_s\alpha_s)^2}}$$

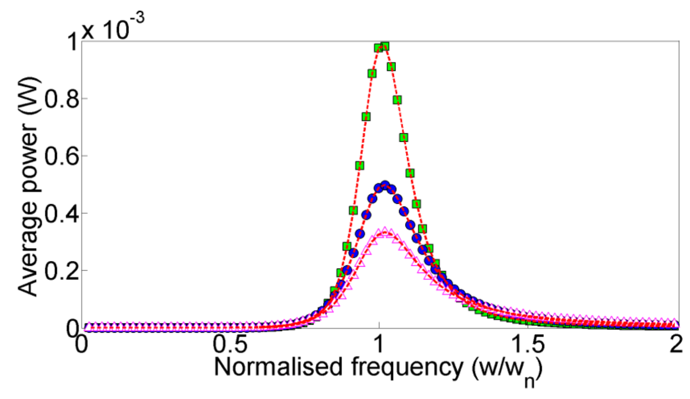




Average Absorbed Power

$$P_{ave} = \frac{1}{T}\int_0^T c(y-x)(y-x)dt = \frac{Z^2 c\,\omega^2}{2} = \frac{X^2|T_{rel}|c\,\omega^2}{2} = \frac{Y^2\left[1 - \frac{1}{|T|}\right]c\,\omega^2}{2}$$





- At resonance, the average absorbed power reduces with increasing damping.
- At low frequency, damping doesn't greatly affect the average absorbed power.
- At high frequency in a frequency-independent system, increasing damping greatly increases average absorbed power, unlike with frequency-dependant excitation which results in a negligible effect.

REFERENCES

[1] G. Park, Tajana Rosing, Michael D. Todd, Charles R. Farrar, and William Hodgkiss, "Energy harvesting for structural health monitoring sensor networks," *ASCE Journal of Infrastructure Systems* vol. 14, pp. 64-79, 2008.
[2] R. B. Y. C.B. Williams, "Analysis of a micro-electric generator for micro systems," *Sensors and Actuators* vol. 52 pp. 8-11, 1996.
[3] M.F. Daqaq, C. Stabler, Y. Qaroush, and T. Seuaciuc-Osório, "Investigation of power harvesting via parametric excitations," *Journal of Intelligent Material Systems and Structures* vol. 20 pp.545-557, 2009.

www.southampton.ac.uk | email: B.Zaghari@soton.ac.uk
SPCG & DG, Institute of Sound and Vibration Research, University of Southampton, UK, SO17 1BJ