K. Nakano Lab

Energy Harvesting in Rotating Tires Using Stochastic Resonance

Partner：The University of Sheffield
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Introduction

In view of the principle of stochastic resonance, a multi-stable nonlinear model is proposed to validate that the phenomenon of stochastic resonance can occur at the rotating environments, is exploited to enhance the energy harvesting under practical automobile tire.

① Ambient noise + ② Periodical force + ③ Nonlinear multi-stable

The suggested application for this harvester is to provide electrical power for a tire pressure monitoring system.

- Low frequency enhanced response
- Broadband energy harvesting

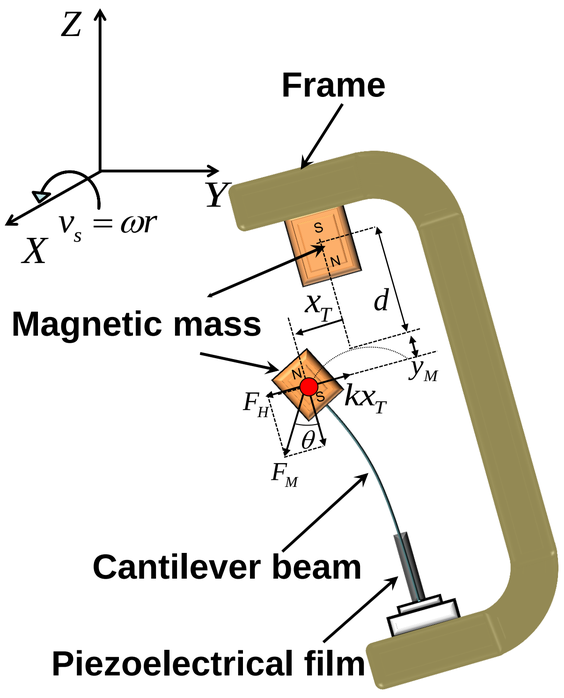
Stochastic Resonance:

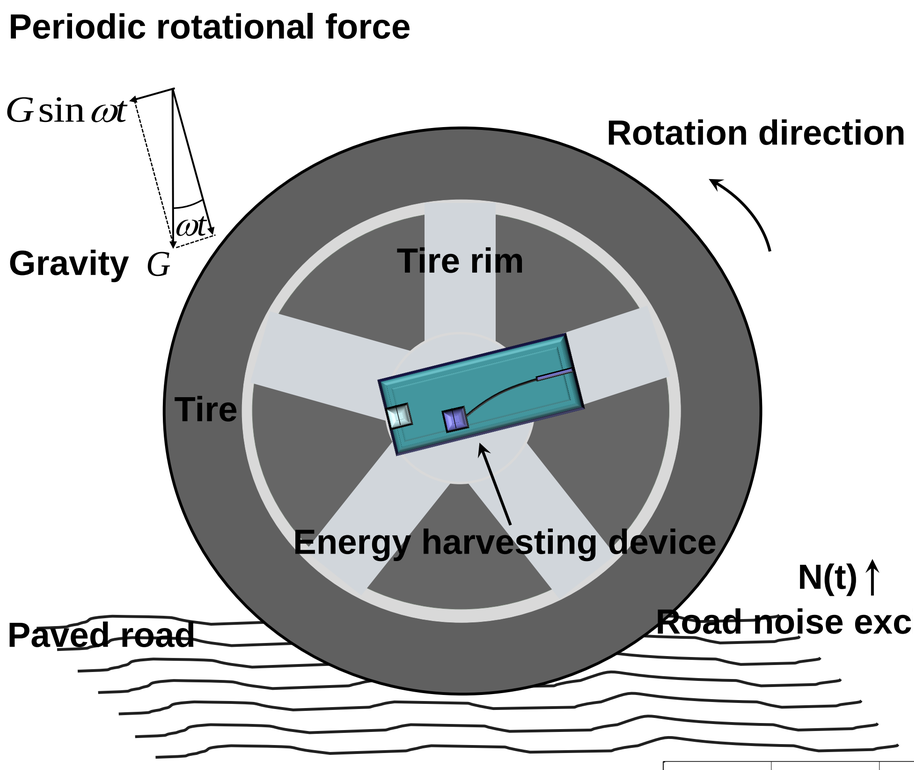
$$\omega_0 = \sqrt{\frac{2a}{m}}$$

$$f = \frac{1}{2} r_K < \frac{\omega_0}{4\pi} \exp\left(-\frac{a^2}{4bD}\right)$$

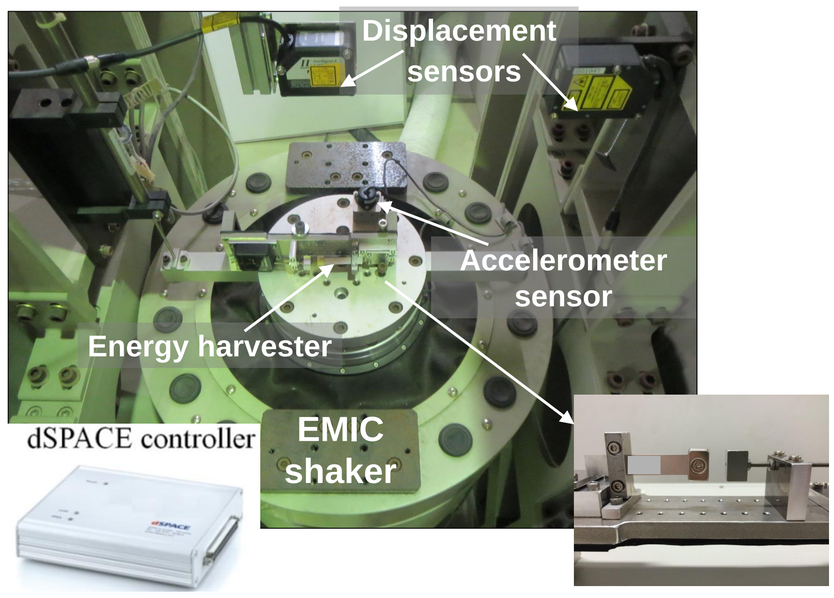
stochastic resonance is easy to occur at which the frequency of modulation force is smaller than 7 Hz.

Schematic of the system





Experimental setup



Beam dimensions: 42 mm × 10 mm × 4 mm
PZT dimensions: 22.9mm × 10mm × 0.1mm

When the proposed energy harvester model revolves with a radius of r at the frequency of ω, the motion equation is derived as follows:

$$m\ddot{x}_T + c\dot{x}_T + \left[k - \frac{F_M}{d}\right] x_T + \frac{F_M}{2d^3} {x_T}^3 = N(t) + G\sin\left(\omega t + \theta_0\right)$$

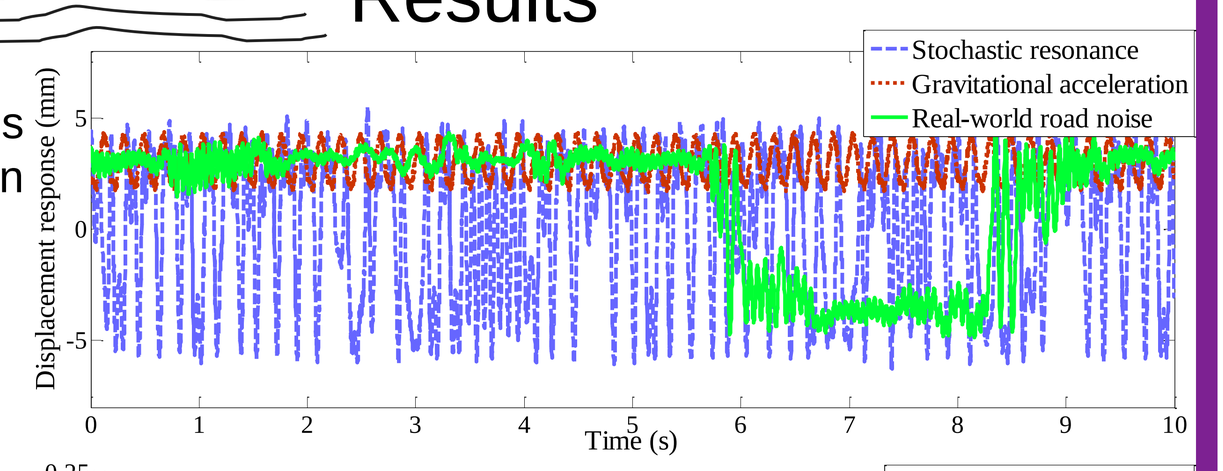
Rearrange Equation

Duffing equation:

$$m\ddot{x}_T + c\dot{x}_T - ax_T + b{x_T}^3 = \underline{G\sin\left(\omega t + \theta_0\right)} + \underline{N(t)}$$

- Periodically rotational gravity
- Ambient noise excitation

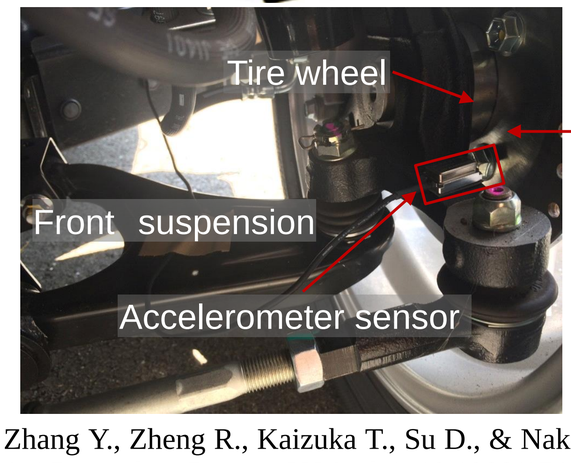
Results



Noise measurement

wireless sensor

approx. 30m



Conclusions and future works

The phenomenon of stochastic resonance can occur at the low-speed automobile driving.

Enhancement of the energy harvesting efficiency with a valid bandwidth of 25 km/h ~ 50 km/h.

The proposed system realized a high-performance of energy harvesting from 25 km/h ~ 129 km/h.

Publications

Zhang Y., Zheng R., Kaizuka T., Su D., & Nakano K., 2015, Study on Tire-attached Energy Harvester for Low-speed Actual Vehicle Driving, PowerMEMS 2015, Vol. 660, pp. 12126-12130, 1-4 December, Boston, USA, doi: 10.1088/1742-6596/660/1/012126.

Zhang Y., Zheng R., Kaizuka T., Su D., Nakano K., & Cartmell M.P., 2015, Broadband Vibration Energy Harvesting by Application of Stochastic Resonance from Rotational Environments, The European Physical Journal, Vol. 224, No. 14, pp. 2687-2701, doi: 10.1140/epjst/e2015-02583-7.