# Energy Harvesting in Rotating Body

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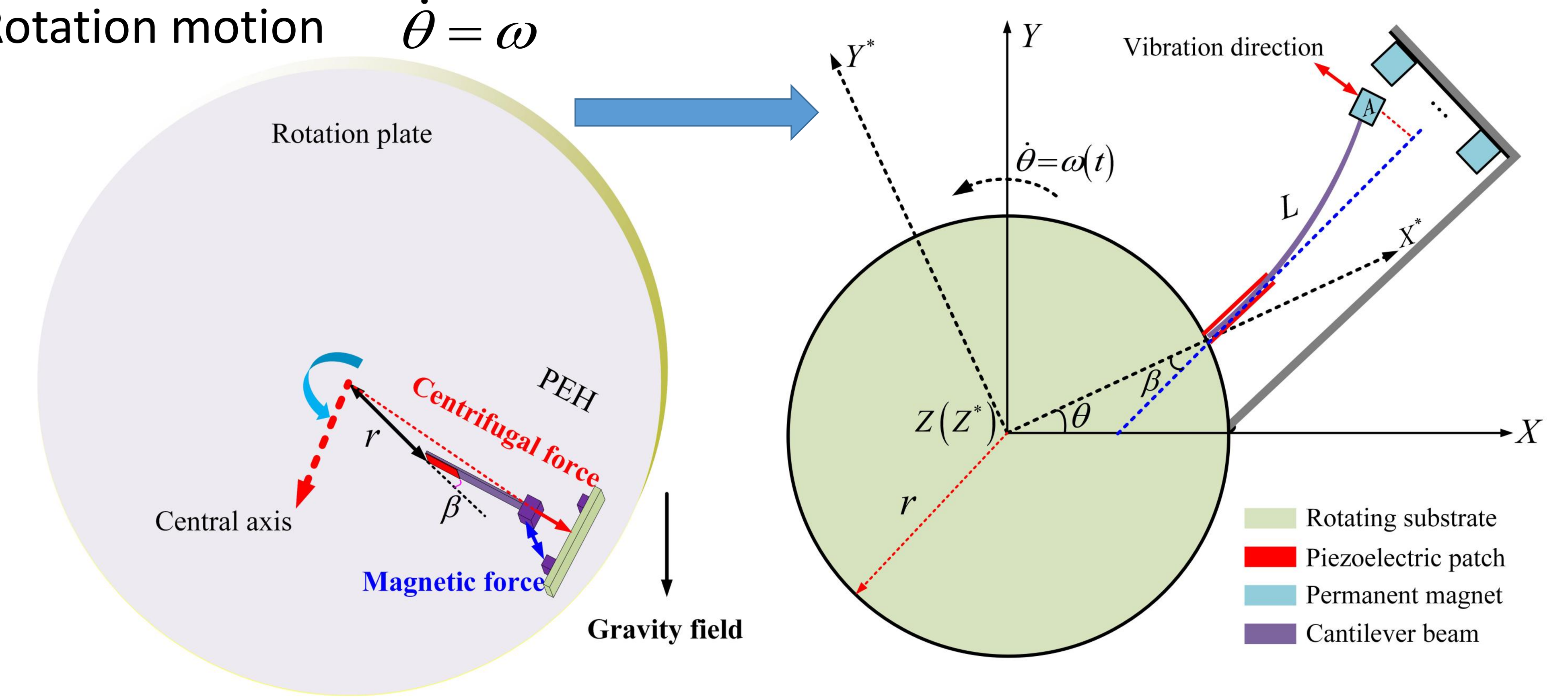
## Introduction

- This is an energy harvester in rotational motion which can convert the vibration and rotation energy into electricity based on the piezoelectric effect. Thus, the promising application is to power the wireless sensors installed in the rotational environment, such as the tire pressure monitoring system (TPMS).
- To enhance energy harvesting performance, a multi-stable nonlinear energy harvester is proposed in rotational motion.

➢ Broadband energy harvesting ➢ Low frequency enhanced response

## System design and modeling

Rotation motion $\dot{\theta} = \omega$




*Notes:*

$XYZ$ is the reference frame
$X^*Y^*Z^*$ is the rotational coordinate system.
$\beta$ is the installation angle
$\theta$ is rotation angular displacement
$\dot{\theta}$ is rotation angular velocity
$\ddot{\theta}$ is rotation angular acceleration
$q(t)$ is the displacement of the tip mass A
$r$ is the radius of rotating hub
$d$, $h_1$ and $h_2$ are the parameters of the harvester.

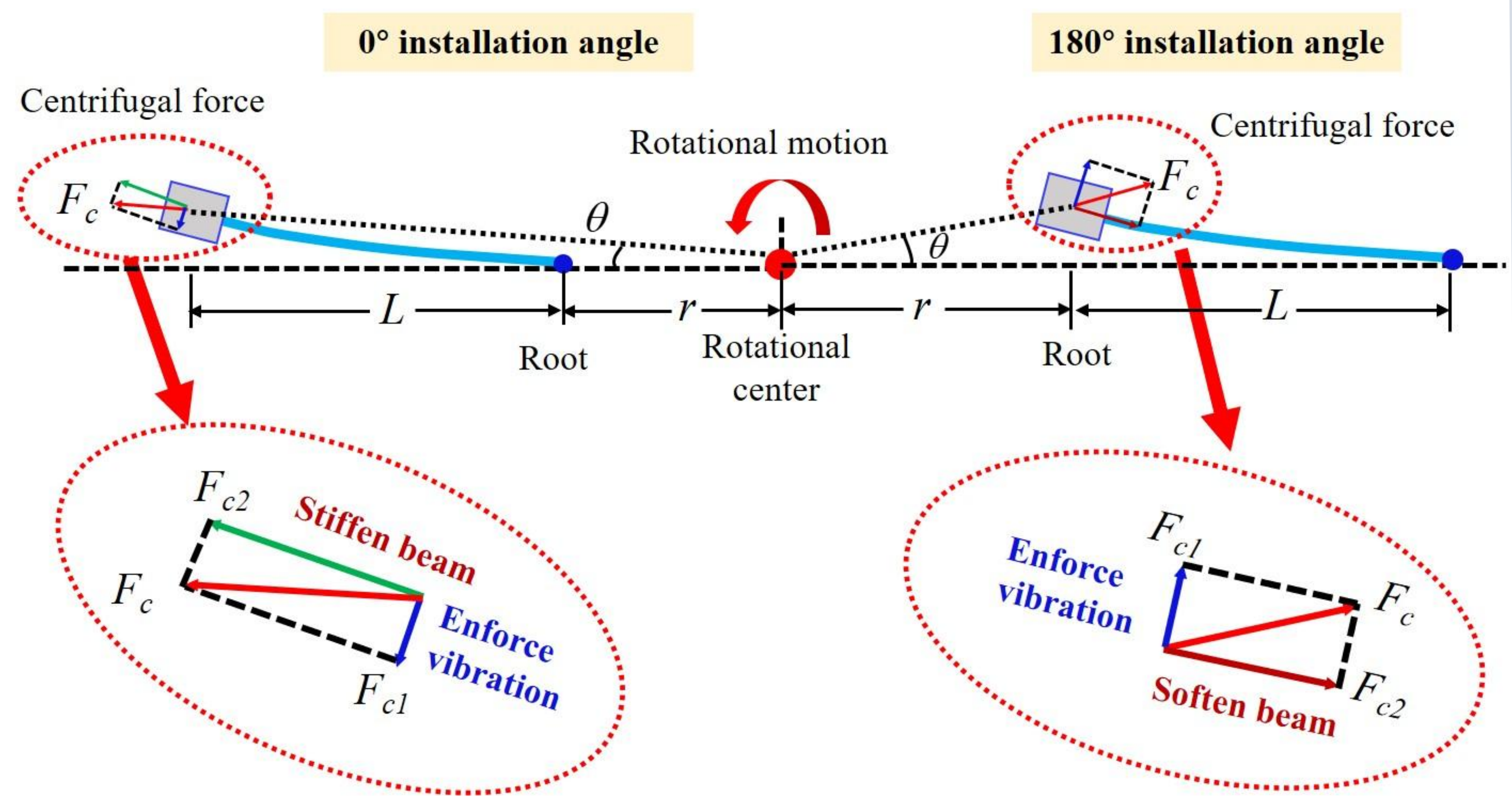
(1) Based on the Lagrangian equation, the electromechanical equations of the proposed harvester in rotation motion is derived as follows:

$$M_e\ddot{q}(t)+C\dot{q}(t)+\left(K_e+K_c\dot{\theta}^2\right)q(t)+\chi\ddot{\theta}-\vartheta_p v(t)+F_m=-\Gamma g\cos(\theta+\beta)+\Psi\dot{\theta}^2\sin\beta \quad (1)$$

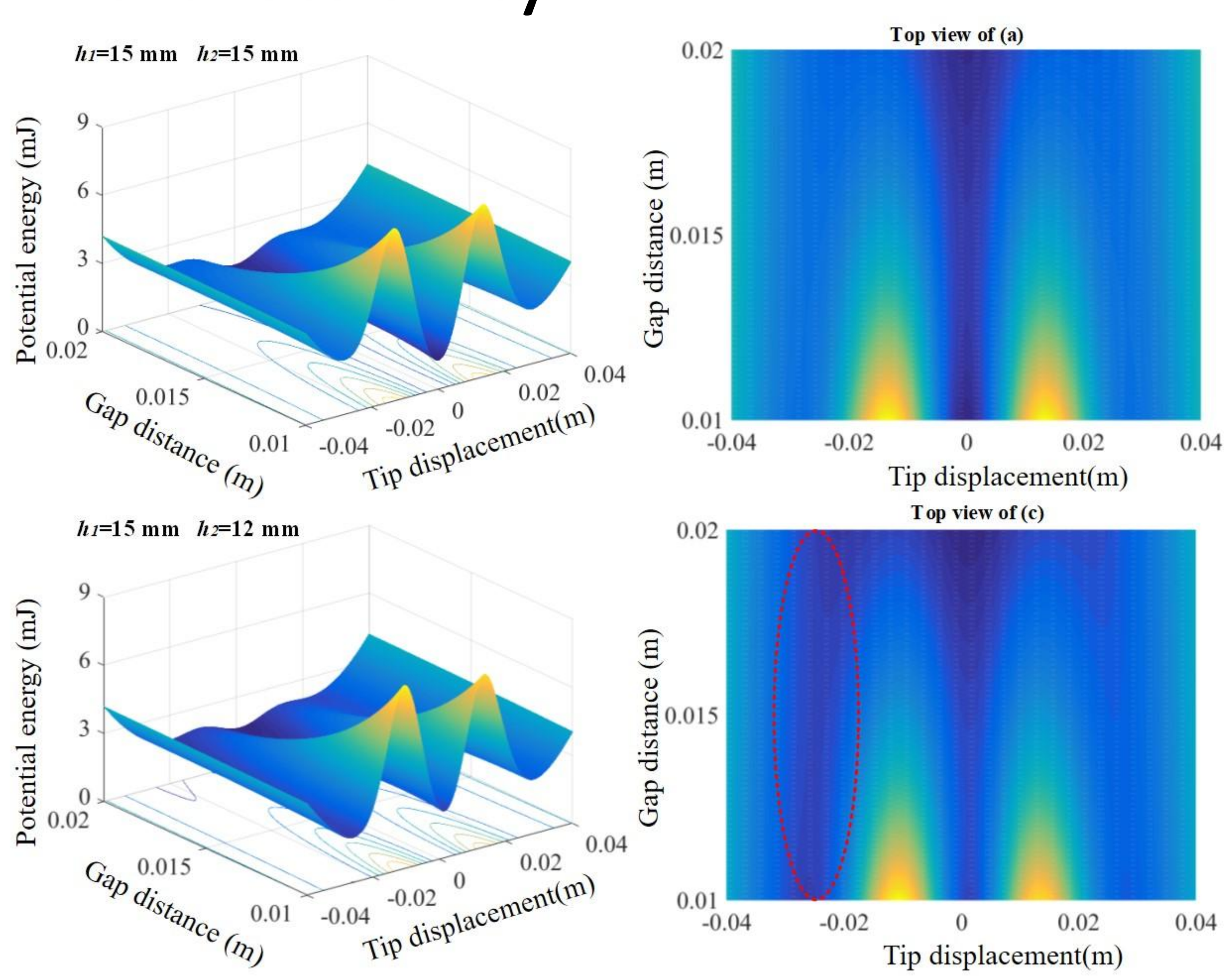
$$c_p\dot{v}(t)+v(t)R_l^{-1}+\vartheta_p\dot{q}(t)=0 \quad (2)$$

Equivalent excitation; Centrifugal effect; Coefficient of acceleration; Magnetic force; Gravity component; Installation angle

## Centrifugal effect



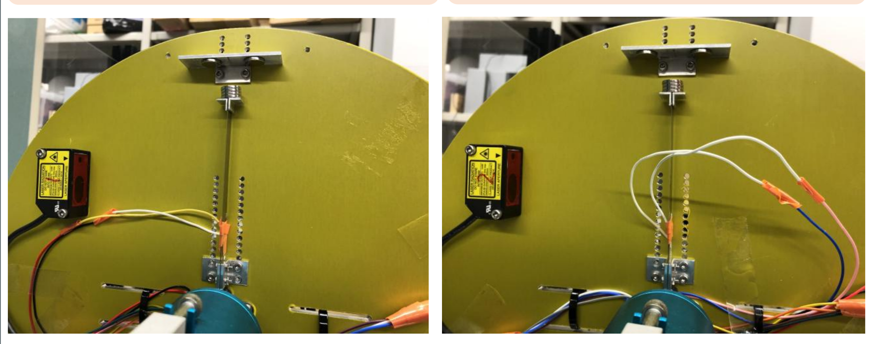

## Multi-stability

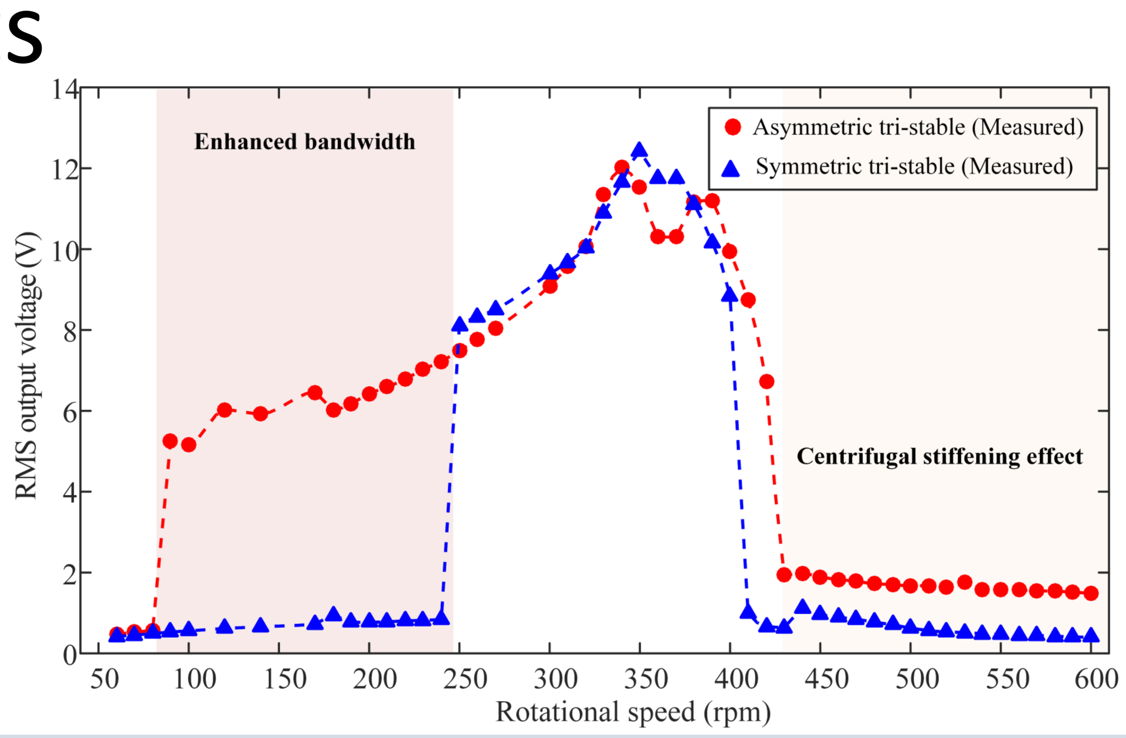



## Experimental results

**Installation angle**: 0 degree

| Asymmetric tri-stable | Symmetric tri-stable |
|---|---|
| $d$ = 13mm, $h_1$=15 mm, $h_2$=12 mm | $d$ = 13mm, $h_1$=15 mm, $h_2$=15 mm |






## Conclusions

1. The multi-stability in rotational motion can lead to time-varying potential wells, benefiting for energy generation.
2. The centrifugal effect highly depends on the installation angle. For 0 degree installation angle, the centrifugal force leads to the centrifugal stiffening effect, which can be used for self-tuning energy harvester.
3. Combination of the centrifugal effect and multi-stability results in complex dynamic performance for PEH.

[1] Mei X, Zhou S, Yang Z, Kaizuka T and Nakano K (2020) A tri-stable energy harvester in rotational motion: Modeling, theoretical analyses and experiments. *Journal of Sound and Vibration*, 469, 115142