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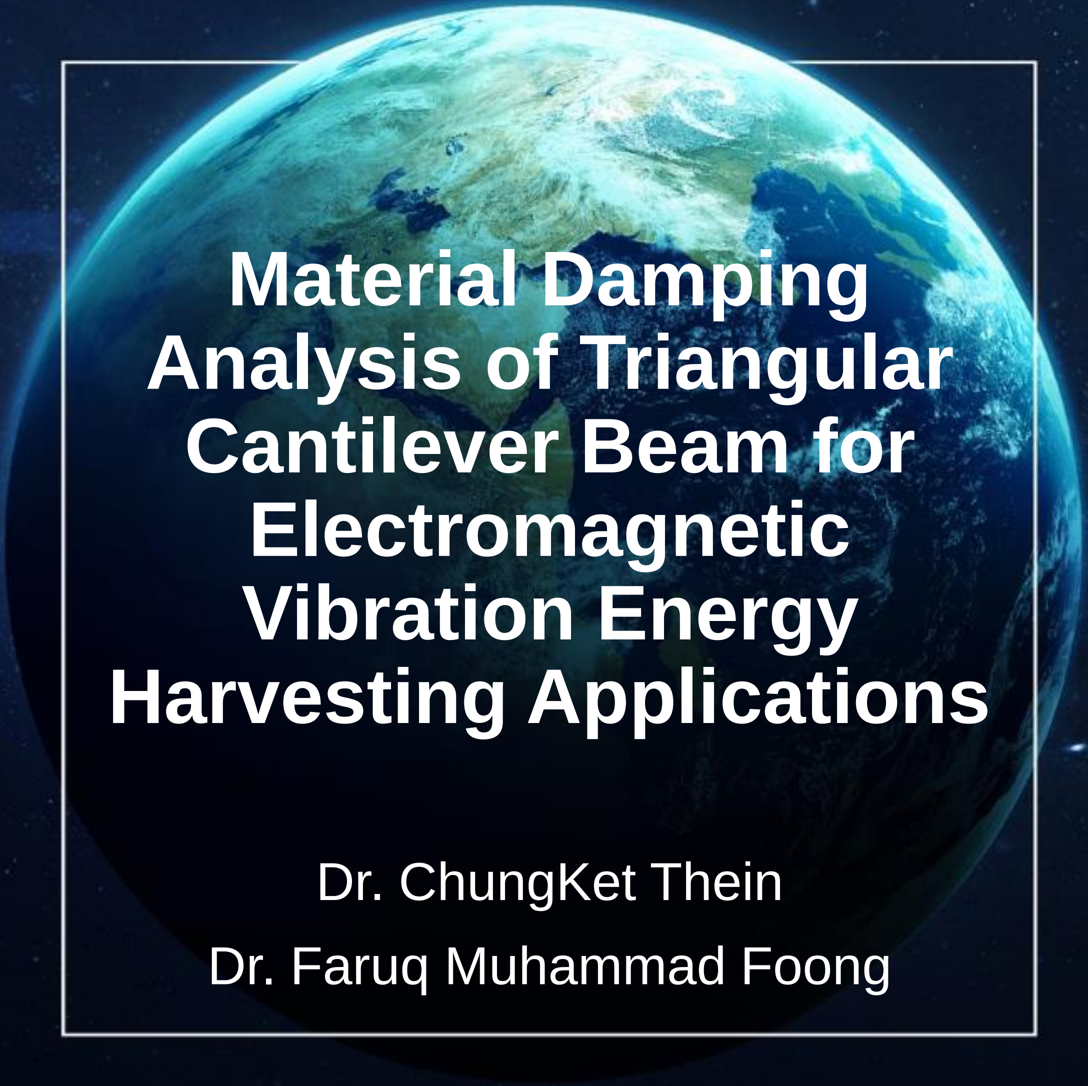

Material Damping Analysis of Triangular Cantilever Beam for Electromagnetic Vibration Energy Harvesting Applications

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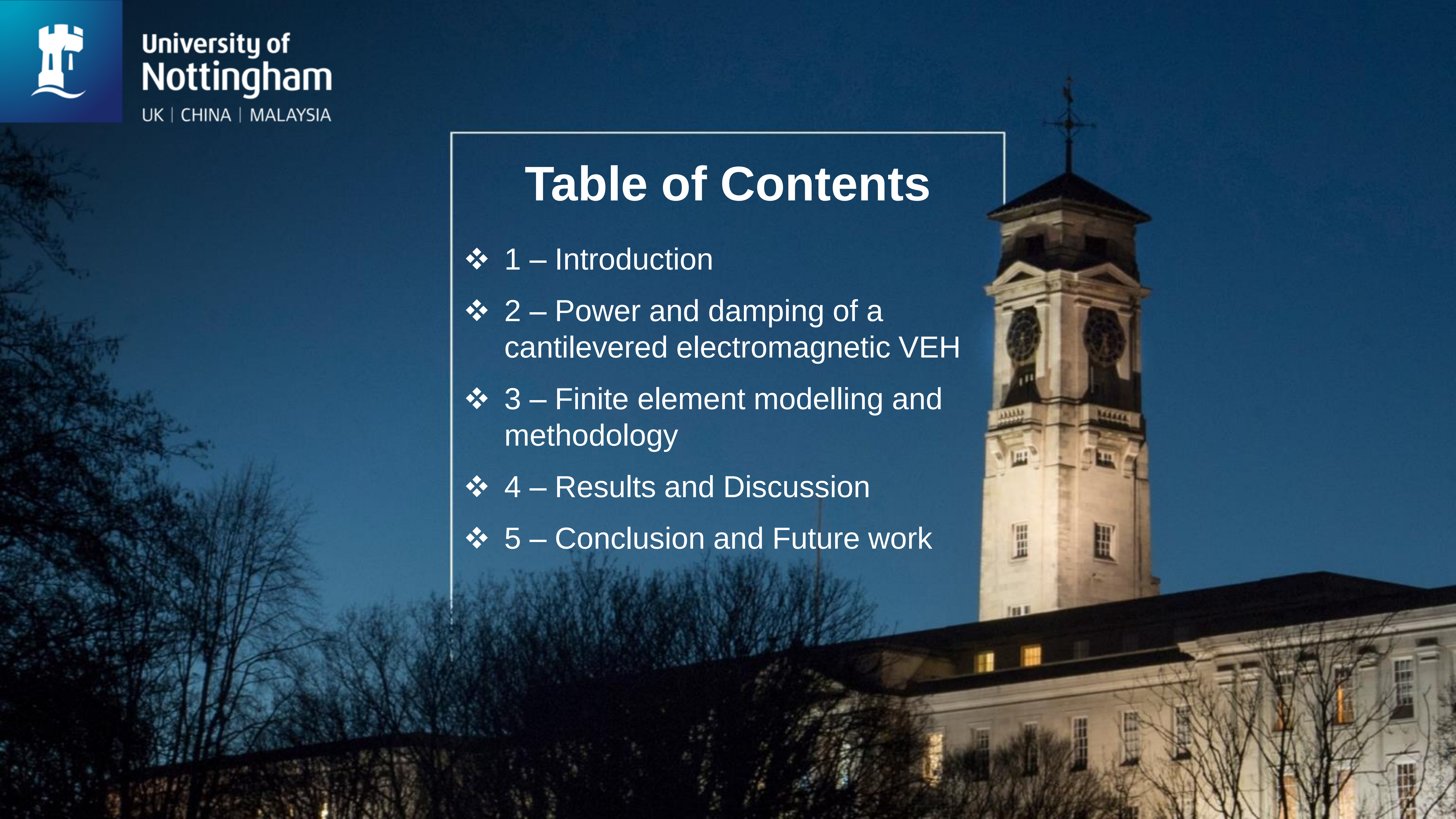

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Introduction

Background:

- Vibration energy harvesting (VEH) have emerged as one of the most promising sources of sustainable energy to power low-powered electronics.
- Mechanical vibrations into electricity, the two most common applied methods are piezoelectric transducers and electromagnetic induction.

Power and damping of a cantilevered electromagnetic VEH

- Based on Faraday's law of electromagnetism, voltage is induced in the coil when the coil vibrates in the magnetic field.
- Figure 1 illustrates an example of a typical cantilevered electromagnetic VEH device.

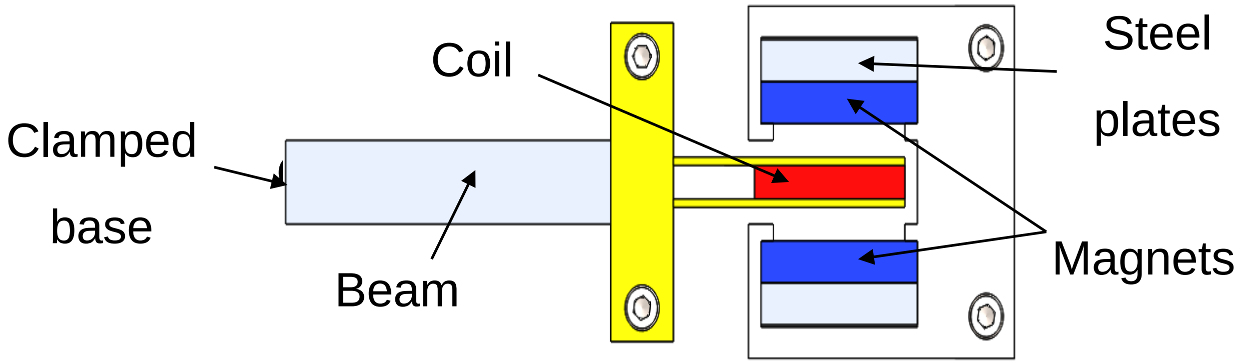


Figure 1. Design of a typical cantilevered electromagnetic vibration energy harvester.

Power and damping of a cantilevered electromagnetic VEH

- The maximum average power output induced by the harvester at the first vibration mode resonance can be written as [1].

$$P = \frac{mG^4}{16\zeta_s\omega_1} \qquad (1)$$

where P is the output power, m is the effective mass of the harvester, G is the acceleration of the input vibration, ω_1 is the harvester’s fundamental natural frequency and ζ_s is the first mode structural damping.

Power and damping of a cantilevered electromagnetic VEH

- For a stainless-steel material, the material damping ratio can be related to the critically damped stress, σ_c, by the following expression [2].

$$\zeta_m = 2.109 \times 10^{-8}(\sigma_c)^{0.8447} + 1.662 \times 10^{-3} \qquad (2)$$

where σ_c is maximum von-Mises stress from the beam

- Therefore, the mechanical/material damping can be estimated

Finite element modelling and methodology

- Model in ANSYS workbench with the element size of 0.5 mm as shown in Figure 2.
- Both beams have same natural frequency of 32.34 Hz with the same proof mass of 19 g.
- Acceleration is 1.96 ms^{-2}

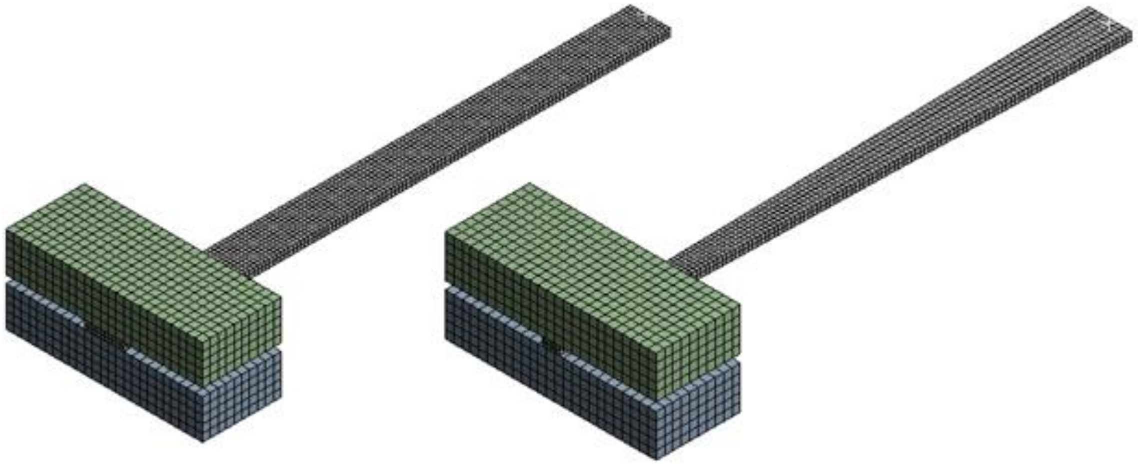
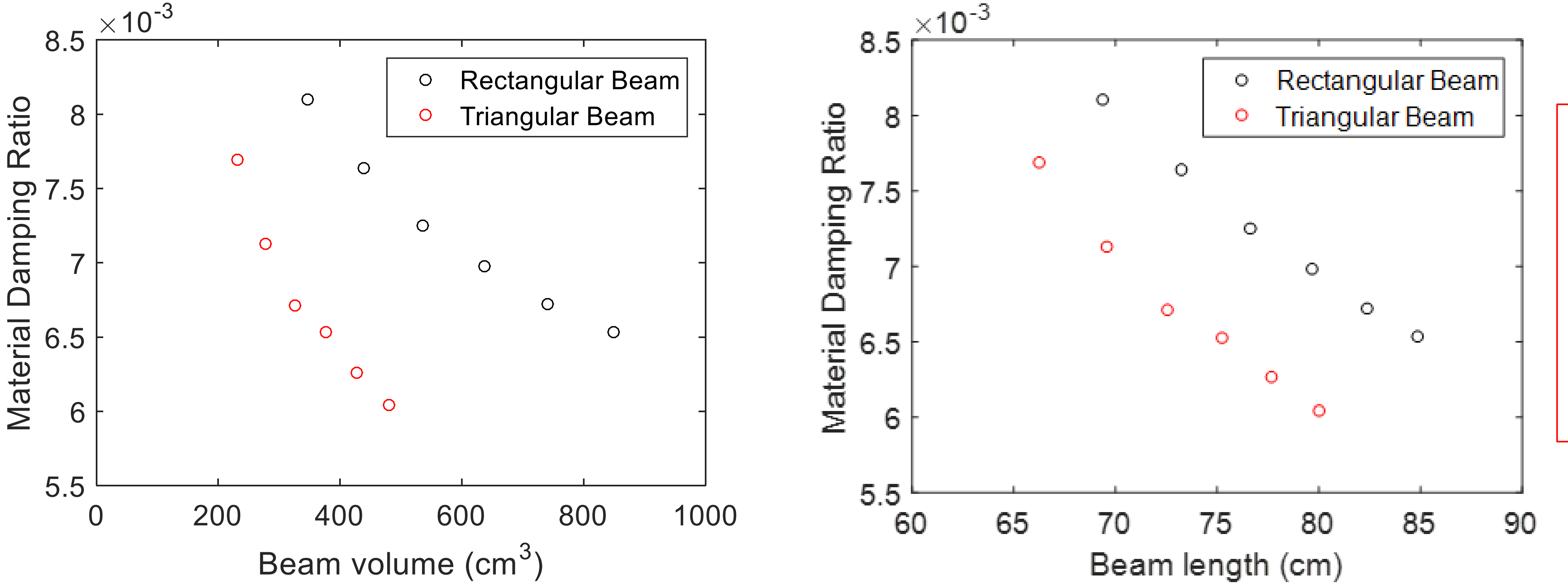


Figure 2. Finite element model of a rectangular (left) and a triangular (right) cantilever beam with added proof mass

Results and Discussion

- Figure 3 shows the variation in material damping against the beam volume and the beam length for the triangular and the rectangular cantilever beam.



The triangular beam recorded a 7.1% lower damping than the rectangular beam

Figure 3. Variation material damping ratio with cantilever beam volume (left) and length (right) for a triangular and a rectangular cantilever beam.

Results and Discussion

- Figure 4 where a coil component which was modelled based on the real item was attached to the beam instead of the proof mass.

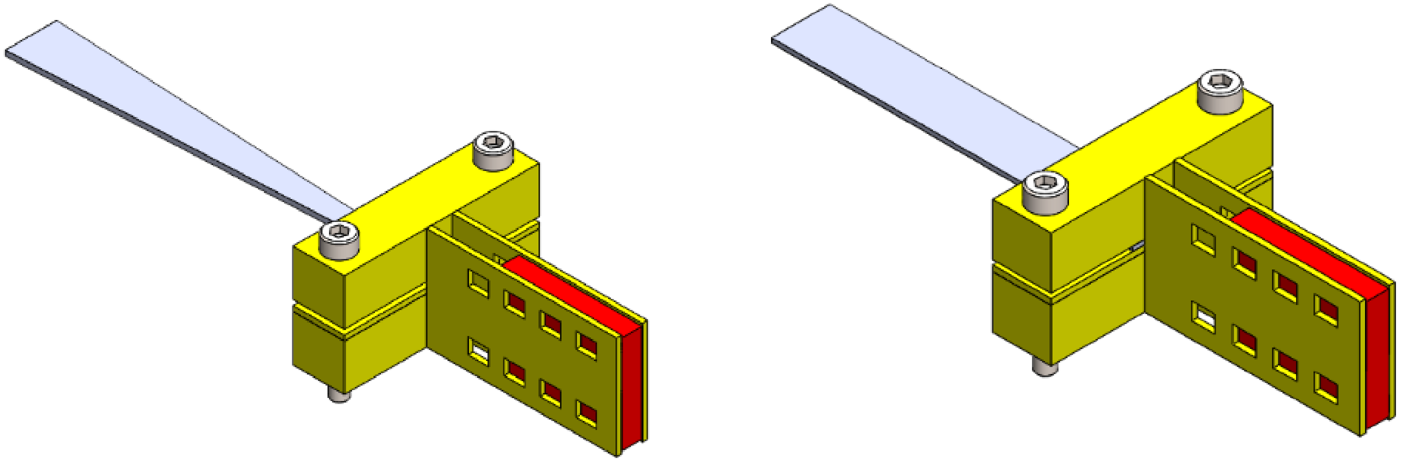
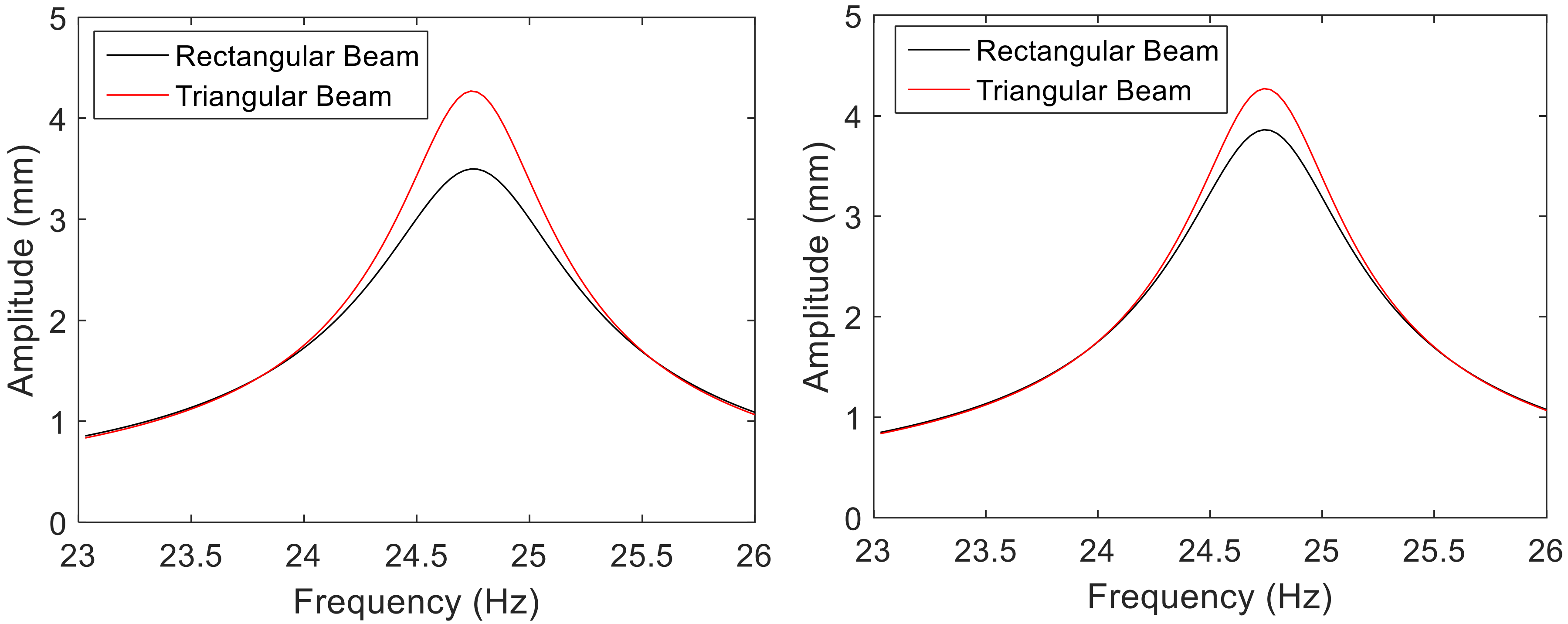


Figure 4. A triangular and a rectangular cantilever beam with an attached coil component

Results and Discussion

- Figure 5 shows that the amplitude responses of the two beams under the two scenarios

Volume = 480 cm^3



Beam length = 80 mm

Figure 5. Comparison between the amplitude response of the triangular and the rectangular beam for the first scenario (left) and the second scenario (right).

Results and Discussion

- The maximum average power output at resonance for each beam in both scenarios was then estimated using the equation (3)

$$P = \frac{mG\omega_1 z_{max}}{2} \qquad (3)$$

- The power harvested of two different scenarios are:

Scenario	1	2
Rectangular	11.3 mW	12.4 mW
Triangular	13.8 mW (+22.1%)	13.8 mW (+11.3%)

Conclusion and Future work

Conclusion:

- Triangular beam is better in term of power output as the damping is smaller by an average of 7.1%.
- At constrained beam volume, the power output of triangular beam was higher than rectangular beam by 21.7 %.
- At fixed beam length, the power output of triangular beam was higher than rectangular beam by 11.3 %.

Future work:

Experiment work will be conducted to verify the argument.

References

[1] Li H, Tian C, Deng Z.D. Energy harvesting from low frequency applications using piezoelectric materials. Applied Physics Reviews 2014; 1: 041301.

[2] Foong F.M, Thein C.K, Yurchenko D. Structural optimisation through material selections for multi-cantilevered vibration electromagnetic energy harvesters. Mechanical Systems and Signal Processing 2022; 162, p. 108044.

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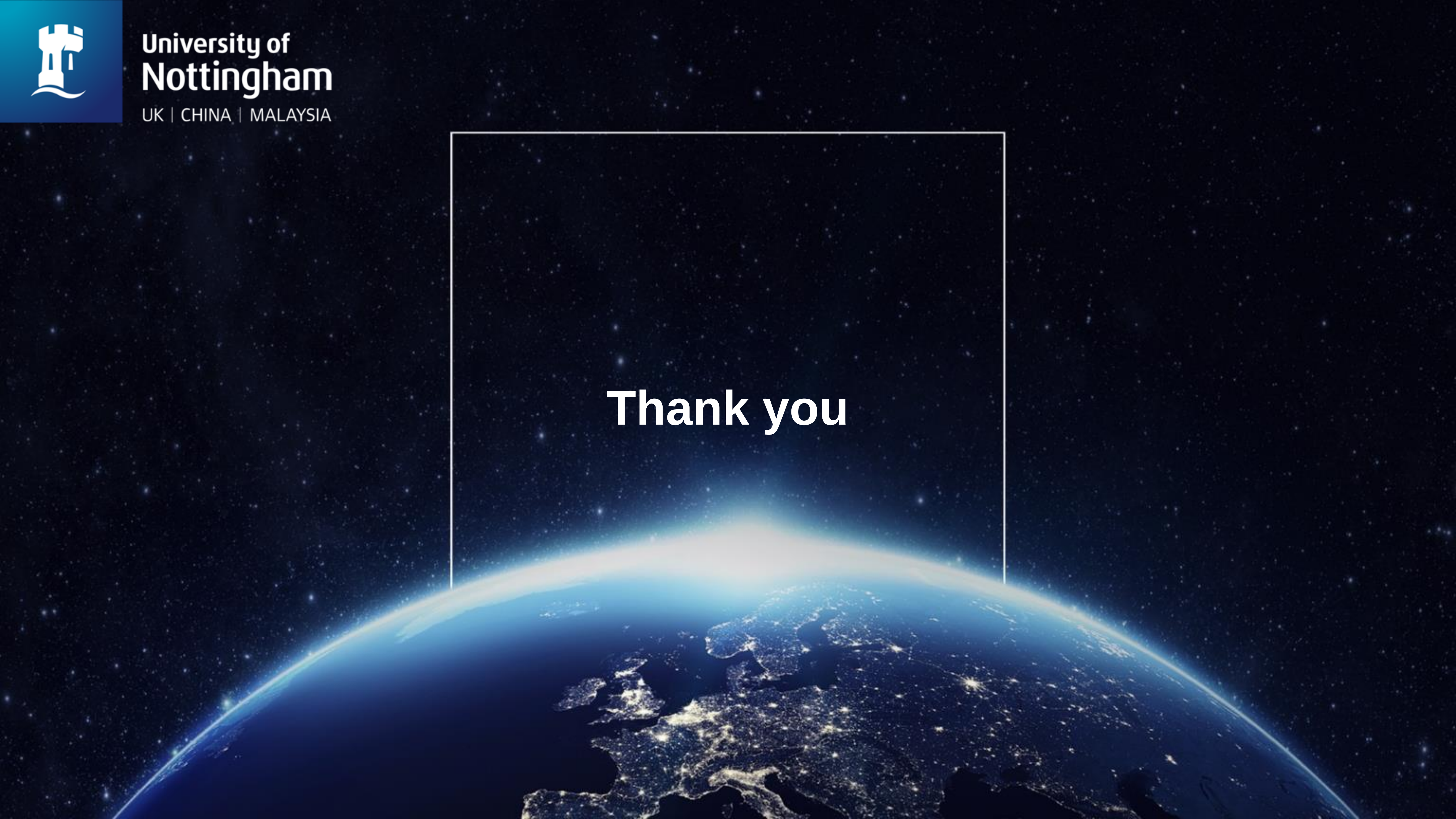

Thank you