Optimisation of Piezoelectric Vibrational Energy Harvesters

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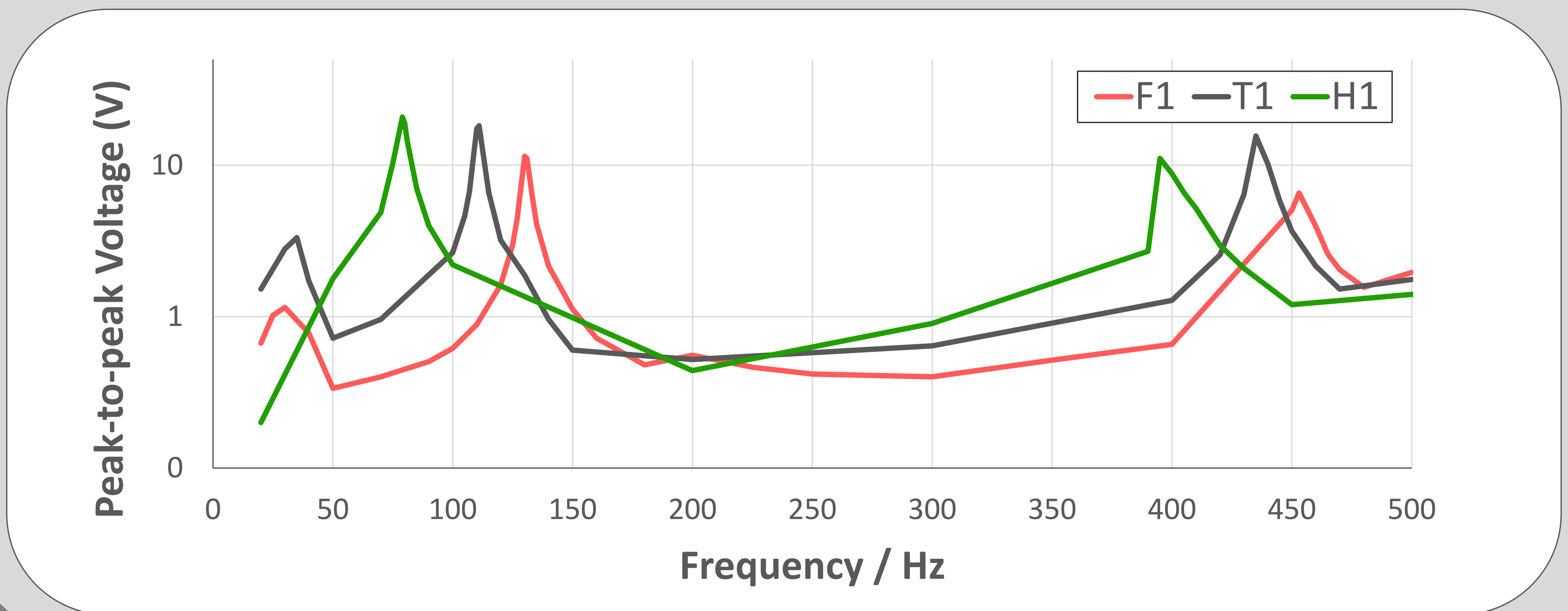
Introduction

The introduction of continuous Structural Health Monitoring (SHM) for primary aerospace structures using techniques such as acoustic emission, which detects the stress waves originating from active damage, provides the potential to move from periodic to condition-based maintenance, significantly reducing costs whilst maintaining high levels of safety. However, installing a wired system to power such a distributed sensor network incurs a heavy weight penalty, and the alternative use of batteries is also unacceptable due to safety requirements and the added maintenance required to replace them. Energy harvesting provides a potential alternative. This work explores the use of an optimised system of piezoelectric vibrational energy harvesters.

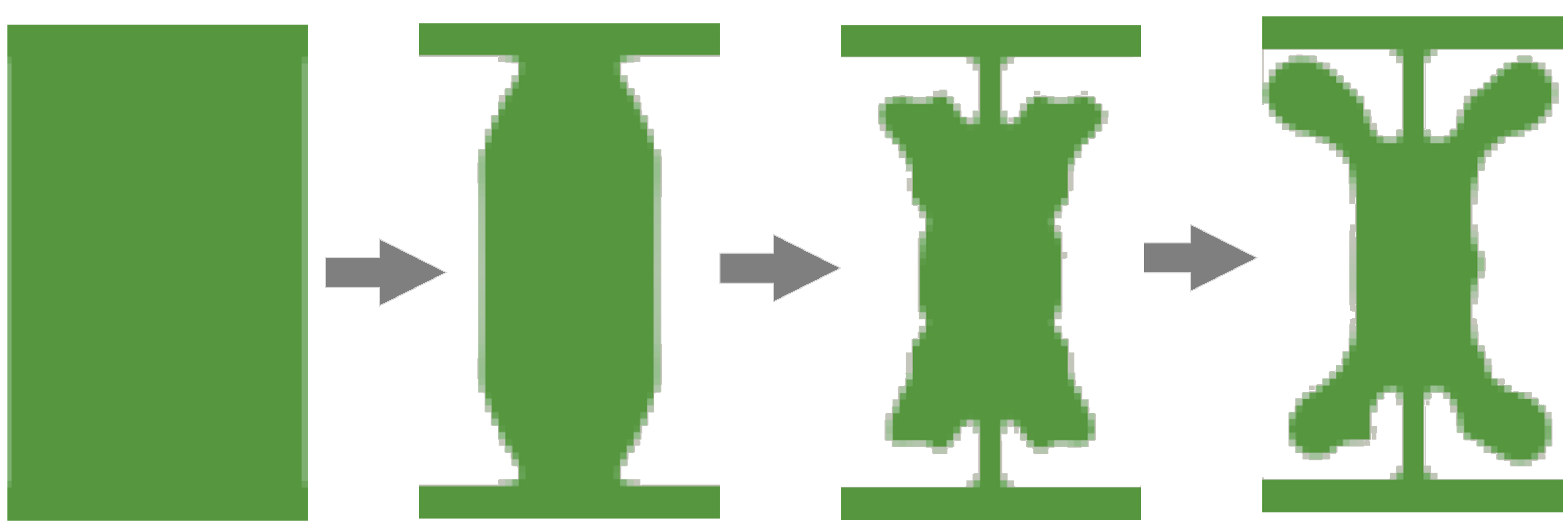


Preliminary Testing

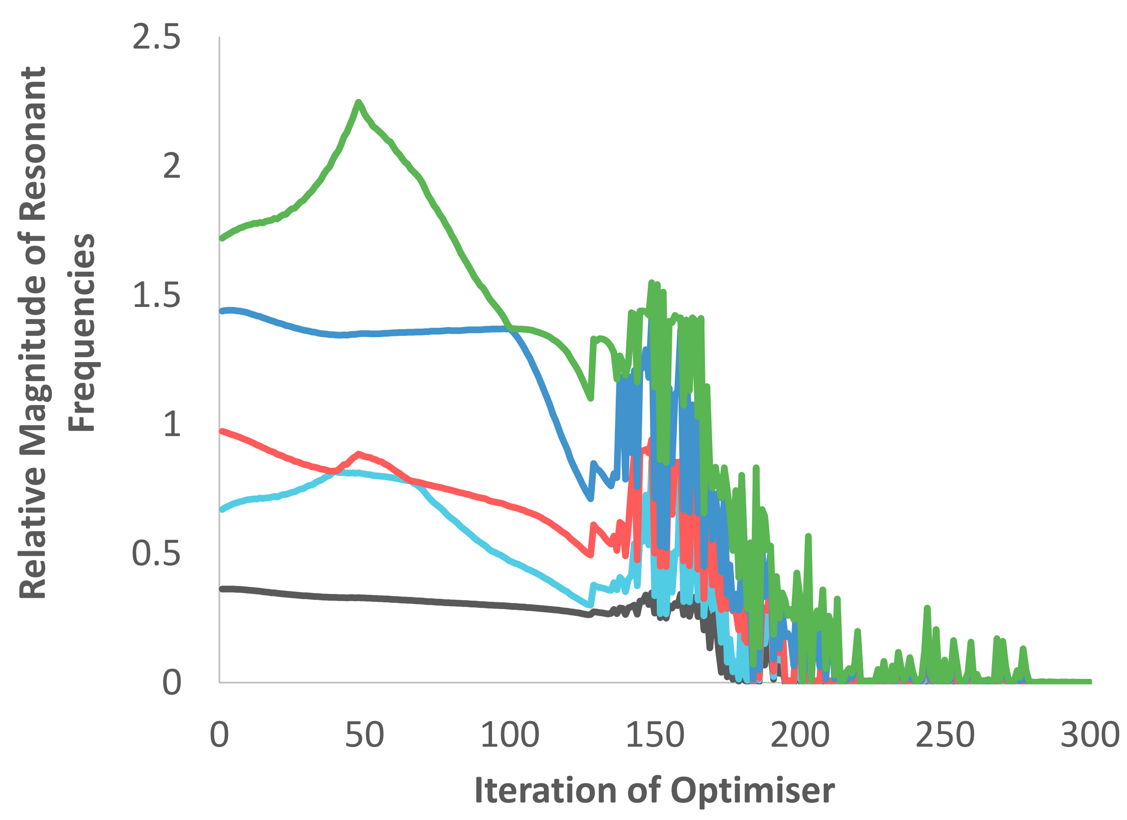
The system designed incorporated three harvesters with different resonant frequencies to create a broadband device suitable for the range of frequencies it would experience during flight. Each harvester was designed using an FEA analysis to obtain the desired response. They were then manufactured from 1mm thick steel, with an MFC piezoelectric transducer bonded to each. An oscillator excited the harvesters at frequencies in the range 20 to 500 Hz and accelerations of 0.5G, 1G, and 2G. As expected each cantilever produced maximum peak-to-peak voltage at different frequencies with a typical value at resonance in the region of 20V for a 2G excitation.

Topology Optimisation Approach

Following initial testing using the geometries seen above, a more robust approach to the optimisation of the harvesters was introduced using the topology optimisation method. The aim here was to design a harvester with a greater number of resonant frequencies inside the frequency range of interest; 20 to 350 Hz. The novel technique utilised in this project (Dunning and Kim, 2014) makes use of a level-set function during the topology optimisation. Future work on this project will involve the incorporation of strain into the optimiser, and subsequently manufacturing and testing the bespoke energy harvesters designed through the optimisation process.



Iteration 1 | Iteration 30 | Iteration 100 | Iteration 130



Acknowledgments

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References

Dunning, P. D. and Kim, A. 2015. Introducing the sequential linear programming level-set method for topology optimization. Structural and Multidisciplinary Optimization 51(3), pp. 631-643.

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