CN Yang Scholars Programme

Project title: Parameterization Study of The Efficiency of a Piezoelectric Flutter Based Harvester

Student name:Yi Jiahe

Supervisor:Asst Prof Ng Bing Feng

INTRODUCTION

Mechanical energy harvesters utilizing piezoelectric transduction mechanisms are an alternative to traditional wind turbine designs as a means of extracting energy from a flow. Compared to wind turbines, piezoelectric transduction devices can be deployed in small volumes and are able to harvest energy over a large range of frequencies, making them suitable for a wide range of applications from urban deployment to mountings on unmanned aerial vehicles (UAV) [1, 2].

Flutter is an aeroelastic phenomenon, involving the transfer of energy from a fluid flow to a structure within the flow. While it is usually treated as a destructive phenomenon, there is potential to utilize piezoelectric materials to harvest energy from the flow by means of the flutter phenomenon. Given the negative impacts of flutter on the performance of the various structures and its contribution to fatigue damage and even structural failure, there has been extensive work done on flutter control [2]. On the other hand, research done on energy harvesting devices from flow induced vibrations are fairly recent. Therefore this project aims to parameterize the efficiency of flutter-based harvesters, so we may extract power from what is considered an unwanted phenomenon [1].

OBJECTIVES

The objective of this project is to parameterize the efficiency of a flat plate piezoelectric flutter-harvester and to suggest optimal design considerations based on the identified parameters.

METHOD

Experiments were conducted in the open loop wind tunnel, Figure: 3 1, with a test section of dimensions width, 1.1m, height, 0.9m length, 2.0m and test speeds 3 – 30 ms^{-1}.

Samples were prepared by securing a balsa wood sheet to a piezoelectric stalk by means of screws. The samples were then mounted in the test section with a retort stand, ensuring the balsa wood plate was within the test section. The retort stand was additionally weighted with a 10kg weight to secure it, as seen in the picture. The setup was used to test how a number of variables, namely the orientation, thickness, length and location of masses on the sample affected the efficiency of the harvester setup. The efficiency was measured by means of an oscilloscope, which reflected the voltage produced by the piezoelectric stalk.

The setup shown here shows a 33cm long, 1/32 inch thick balsa wood sheet reinforced at the base in a vertical orientation with weights placed spanwise along the harvester.

The samples were prepared according to the parameters to be tested and placed in the test section. After which, the wind speed was brought up to $3ms^{-1}$ and the variation of voltage with time was recorded from the oscilloscope. The wind speed was increased by $0.5ms^{-1}$ intervals and the voltage recorded until the flutter speed was reached. Above the flutter speed, the wind speed was increased by $0.25ms^{-1}$ and data was only recorded when the system reached equilibrium, so the voltage produced and frequency domain of the LCO could be recorded. Under the same conditions, a fast Fourier transform (FFT) was also performed on the signal. This was repeated until one of 3 end conditions, divergent amplitudes were observed, excessive vibration by the support structure or structural failure of the sample.

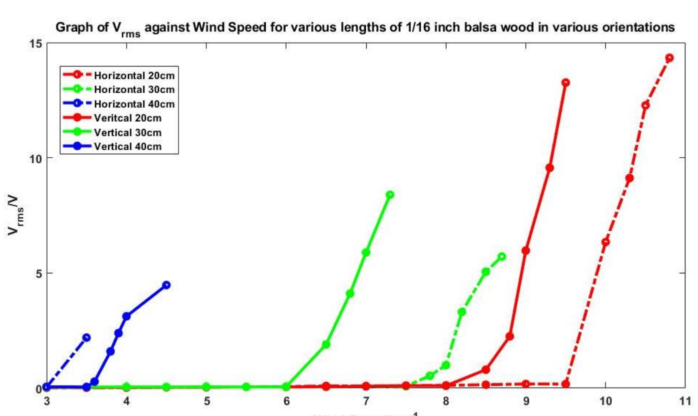
RESULTS

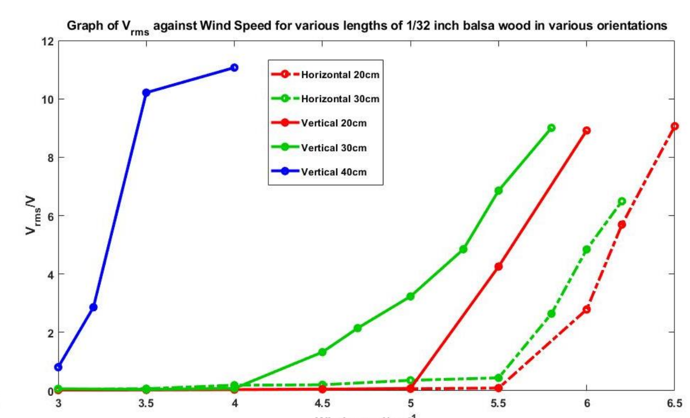
The voltage-time graph produced by each sample at different wind speeds was recorded, from the root-mean squared value of the voltage (V_{rms}) was calculated and subsequently plotted in the graphs below.

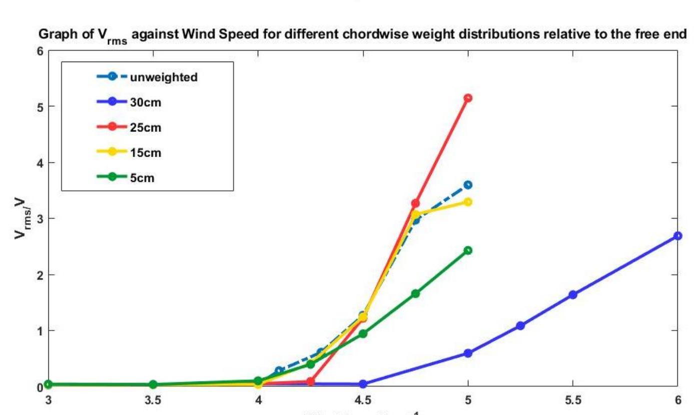
The first two graphs show that a vertical orientation as well as a thinner sheet resulted in a lower cut-in speed as compared to the horizontal orientation and thicker sheets respectively.

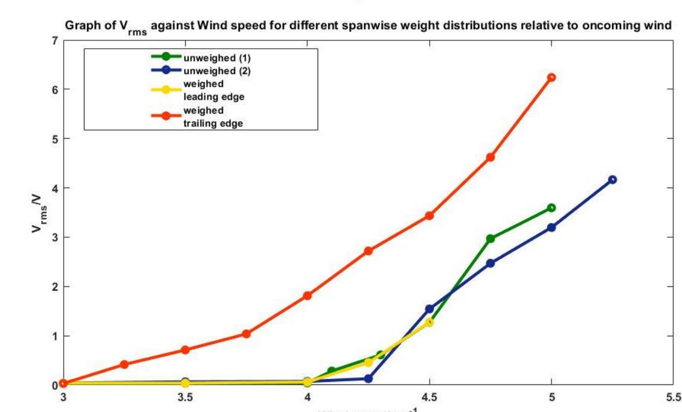
The following two graphs show how different weight distributions chordwise and spanwise affected the voltage produced by the sample at each wind speed. The main observations were that the weights placed at the base of the harvester resulted in lower output voltages when compared to other positions at the same wind speed, while weights placed along the trailing edge produced greater voltages at comparable wind speeds.

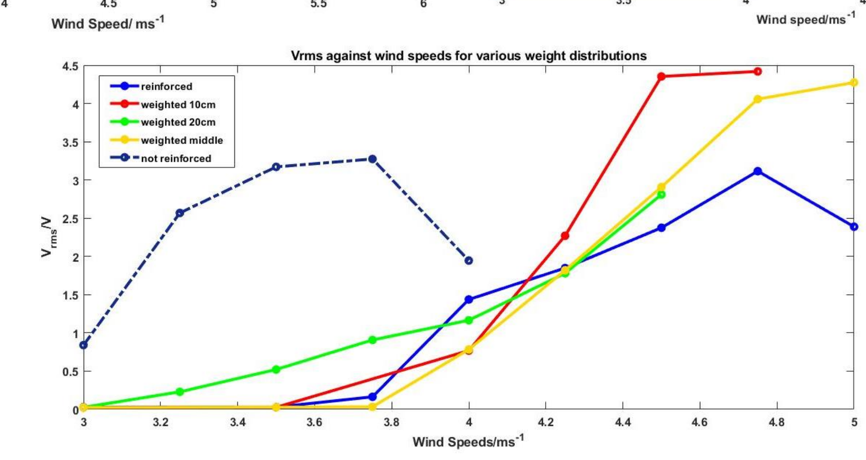
The final graph shows how the non-reinforced plate experienced the early onset of structural failure, while weights placed along the middle axis did not greatly affect the output voltages.











SUMMARY

The results showed that long thin plates generated higher voltages at low wind speeds but also failed easily. While reinforcement of the plate was able to address the problem of structural failure, it also resulted in the delay of the onset of flutter.

FUTURE WORK

The balsa wood used in this project was susceptible to fatigue damage, hence different materials could be tested for more reliable results. Furthermore, the electromechanical responses of the system could also be investigated, to find how different loads and piezoelectric could be chosen to increase harvester efficiency. Finally, as structures experience different types of responses in different flows, the variations which arise can be investigated further.

REFERENCES

1. Abdelkefi, A., Aeroelastic energy harvesting: A review. International Journal of Engineering Science, 2016. 100: p. 112-135.
2. Li, D., Wu, Y., Da Ronch, A., and Xiang, J., Energy harvesting by means of flow-induced vibrations on aerospace vehicles. Progress in Aerospace Sciences, 2016. 86: p. 28-62.