# The Oscillating Frequencies and Energy Harvesting of a Piezoelectric Bimorph with Various Tail Structures in Different Hydraulic Flow Rate

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*Summary*.
The piezoelectric bimorph (PZT) was adopted as an energy harvester for a newly underwater application basing on the combination of piezoelectricity and flow induced vibration. The shape of piezoelectric energy harvester was optimized through the theoretical simulation code, ANSYS. Then, the energy harvesters with seven different types of tail fins were tested in flow field experiments with a large hydraulic recirculating flume from 0.6 to 5.37 m/sec. We discover there are two main regions of oscillating frequencies for PZT and the spectrum modes depend on three swing modes for this underwater energy harvester. The amount of power generation does not only positively correlate with the increase of flow rate, but also depend on the oscillating frequencies of PZT. When it produces an obvious and unique oscillating frequency, there is a larger amount of power it can get.

## Abstract

Piezoelectric Materials are recently adopted as energy harvesters besides sensors or switches. Especially there is recently a new energy harvesting concept proposed to convert hydraulic kinetic energy into useable electrical energy with piezoelectric bimorph. This concept is based on the combination of piezoelectricity and flow induced vibration. In the research, we propose an innovative fixation method, hyperplastic adhesive, resolved fracture and waterproof for piezoelectric component (PZT-brass-PZT). And we also conduct a thorough theoretical simulation and a full-scale flow field experiments to optimize the energy harvester and analyze the relevance between power generation and oscillating frequencies of piezoelectric energy harvester from hydraulic flow rate 0.6 to 5.37 m/sec.
The designed energy harvester includes three structures, the bluff body, the piezoelectric material and the tail fin. A three-dimensional simulation code, ANSYS, based on the finite element numerical calculation was used to simulate dynamic state of fluid field through the bluff body with/without a tail fin to identify the optimal shape to be "the triangle prism with a tail fin" (Figure 1).
Then, the energy harvesters with seven different types of tail fins were tested in flow field experiments with a large hydraulic recirculating flume (Figure 2). A giant venturi tube was customized to increases the hydraulic flow rate 9 folds from 0.6 to 5.37 m/sec which was the highest record in Taiwan on piezoelectric energy harvesting researches. In addition, a customized micro-power rectifier and counter module was applied to accurately evaluate on the electromechanical transferring energy.
From the flow field experiments, based on fluid characteristic the hydraulic flow rate 0.6 to 5.37 m/sec can be separated into three regions - Low Flow Rate Region(below 3.1m/sec), Transition Region(3.1 ~ 4.2m/sec) and High Flow Rate Region(above 4.2m/sec). We discover there are two main regions of oscillating frequencies for PZT and the spectrum modes depend on three swing modes. The ratio of magnitude under the two frequency regions changes with flow rate (Figure 3). This means, the energy harvester can measure the real-time flow rate by PZT plate oscillating frequencies. Another discovery is that the amount of power generation does not only positively correlate with the increase of flow rate, but also depend on the oscillating frequencies of PZT. When it produces an obvious and unique oscillating frequency, there is a larger amount of power it can get (Figure 4).

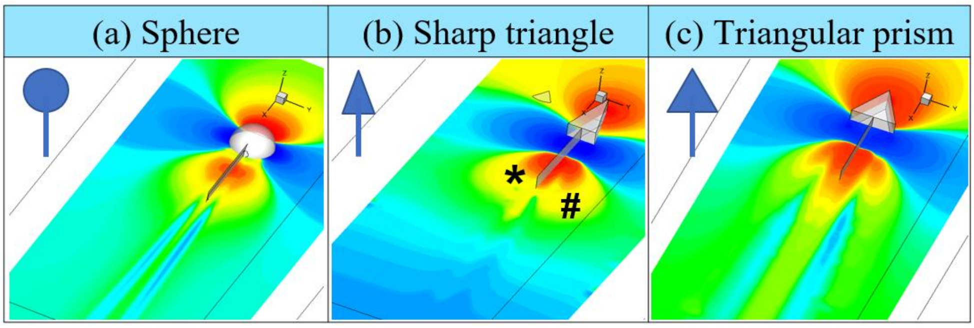


Figure 1. How bluff body shapes change the dynamic analysis of the flow field.

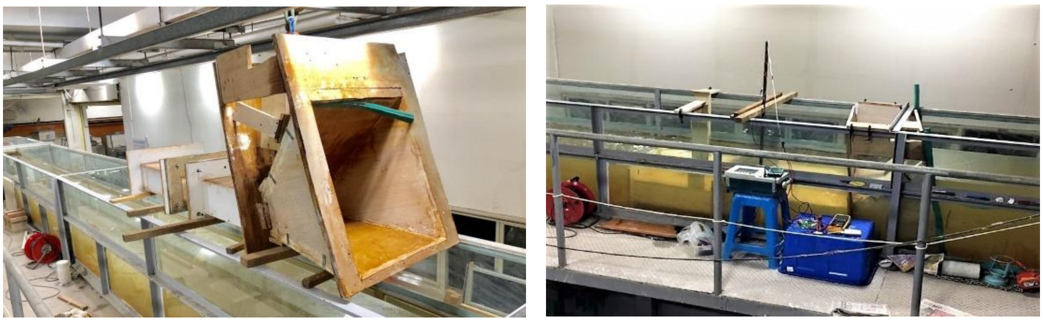

Figure 2. Flow field experimental equipment (a) Giant venturi tube, (b) Recirculating flume with giant venture

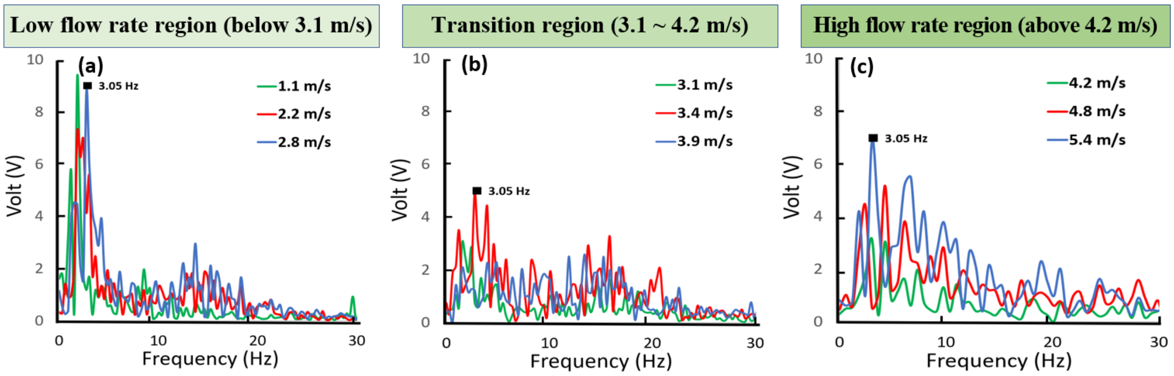


Figure 3. Oscillating frequencies in various flow rates with different system models. (a)Swing oscillation frequencies in Low Flow Rate Region. The smooth flow field produces an obvious and unique oscillating frequency. (b)Swing oscillation frequencies in Transition Region. The flow field starts to produce voids, it becomes unstable and complicated, and the oscillation frequency range becomes more irregular. (c)Swing oscillation frequencies in High Flow Rate Region. There are slug voids. The oscillating frequency resembles that of the low flow rate region, but the range in oscillation frequency from 4 - 15 Hz is significantly larger.

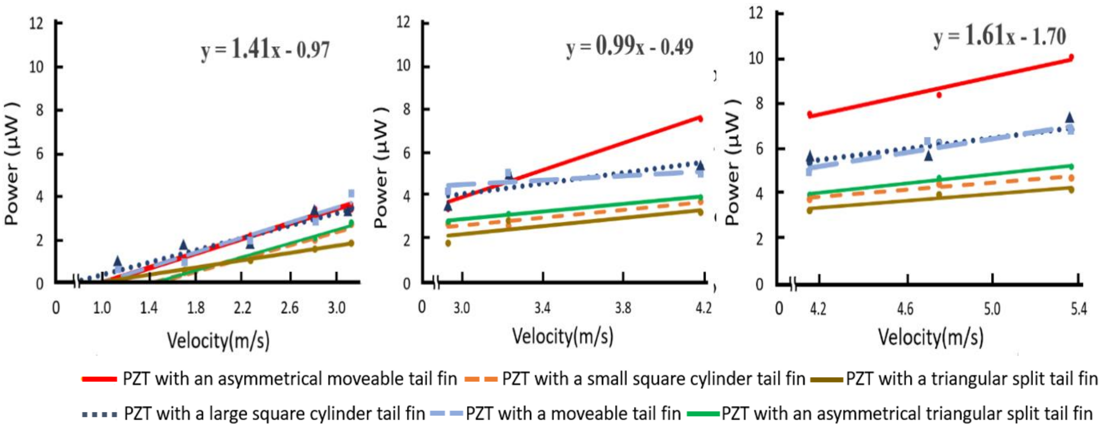


Figure 4. Comparison of power generation with different tail fin structure designs.

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