Micro Energy Generation in Different Kinds of Water Flows on Lead Zirconium Titanate/PVDF

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Abstract

Piezoelectric energy is produced using smart piezo materials like Lead Zirconium Titanate/PVDF by the application of dynamic load. This load can be applied using various means like fluid force, impact load etc. In this article, significant research for piezoelectric energy harvesting using flowing fluid force are discussed. Here, the force is applied on patch with in various systems like open channel system, closed channel system; flow through nozzle etc, this force is converted in to electric energy by piezo patch. Piezoelectric materials have been used for sensing and actuating applications at a wide range. The article overviews the different ideas of piezoelectric energy harvesting using hydraulic pressure and provide a potential research work in the field of utilizing fluid vibrational energy.

Keywords: Energy harvesting, piezoelectric effect, piezoelectric materials, hydraulic pressure, fluid vibrational energy

1. INTRODUCTION

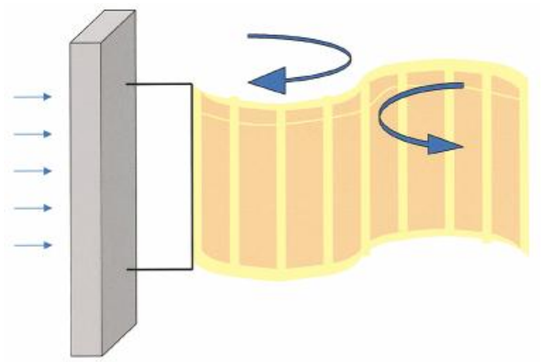
Energy generation is the operation of extracting, storing and converting energy to high grade energy from the environment. Conventional batteries are the power sources for mobile electronics and remote detectors, but their use is somewhere restricted due to the short and finite life of the battery. Piezo electric energy harvesting systems were act as a power source for the wireless sensors and portable electronics. Micro energy harvesting technology is capable of producing small power and is based on mechanical vibration, heat energy, solar energy etc.
When stressed, piezoelectric materials can generate electrical power. This feature makes attractive for harvesting energy from vibrations in the environment. The sources of vibrationcan be a machine, wind, rain, tide, waves, etc. With the advancement in wireless technology sensors is being produced which requires a small amount of power to operate. As these are wireless, they involve their own power supplies. An alternative resolution to establish self-powered system is to produce a system which can convert available ambient energy into electrical energy. More or less the ambient energy sources are light energy, mechanical energy, thermal energy, hydro energy etc.

This article overviews the different ideas of piezoelectric energy harvesting using hydro dynamism and provides a work in the field of utilizing waste fluid vibrational energy.

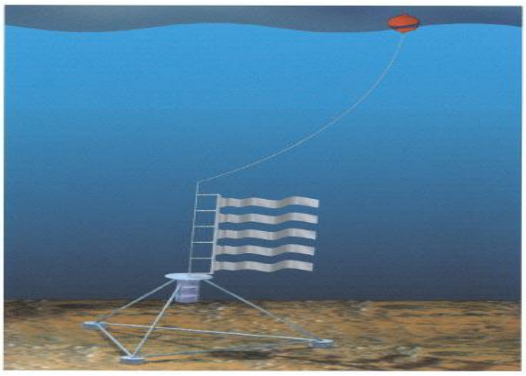
State of art of Lead Zirconium Titanate/PVDF

Energy harvesting from water is not a new concept. Much of the research has been done on this concept. Hydropower plant is a best example of harvesting energy from water. But it can bring about energy at mega level and also requires installation cost and upkeep cost. On the other side the devices with low force or small power need a power source which can offer a continuous supply of power to run. Piezoelectric material can be the best alternative to powering them as batteries has a drawback of limited life span. This article provides different ideas of piezoelectric energy harvesting using water vibrations.

G. W. Taylor (2001) presented a new device called Eel which uses piezoelectric material (PVDF) to convert mechanical strain produced by flow of oceans and rivers into electrical power. Eel generator uses the travelling vortices formed behind a bluff body to strain PVDF. Complete analysis of the Eel model has been done by placing it in a wave tank. Depending on flow velocity and size of the system, such Eels can generate a wide range power from milli watt to many watts. Figure 1 show schematic diagram of Eel and Eel system deployed



(a)

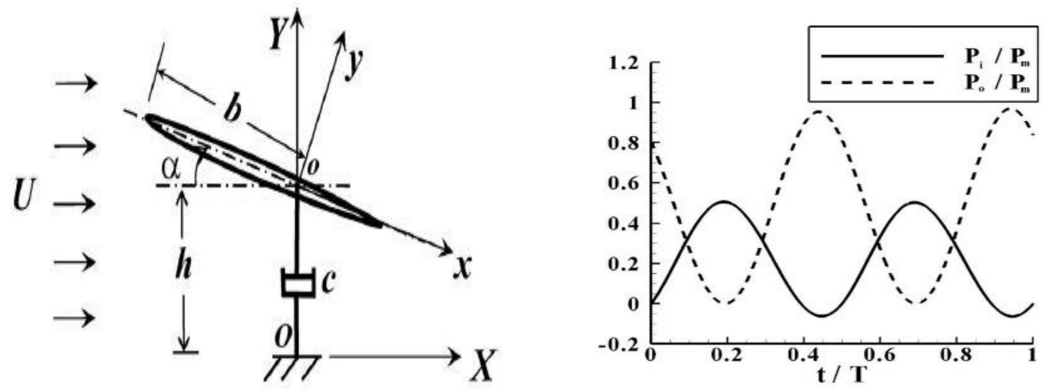


(b)

FIGURE 1 (a) Schematic Diagram of Eel (b) Eel System Deployed

Q. Zhu and Z. Peng (2009) examined the performance of device, having flapping foil mounted on damper, at low Reynolds numbers. Navier-Stokes equations have been used to make the numerical model of flapping foil which is further used to analyse the effect of mechanical design and operational parameters. Energy is harvested by creating the pitching motion and using the resulted heaving motion to harvest energy. Difference of energy recovered and energy input is the overall energy recovered. Figure 2 shows an energy harvesting system and variation of input power and output power.

h= heaving motion, α = pitching motion, a= chord length, c is damper and U is incoming flow



(a) (b)

FIGURE 2 (a) Schematic Diagram of System (b) Variation of Input Power (P_i) and Output Power (P_o) Over One Period

L. Tang et al. (2009) proposed a model of flutter mill which can be used for harvesting energy from fluid generated vibrations. After reaching high flow velocity a cantilever beam is placed in the axial flow becomes unstable and flutter takes place. New device called flutter mill is use to utilize these flutter to harvest energy. Performance of flutter mill was evaluated and power output capacity was compared with a real horizontal axis wind turbine. And it was found that high performance can be achieved by using compact size flutter mill. Figure 3 shows the layout, wiring of flutter mill and average power versus flow velocity graph for the system.

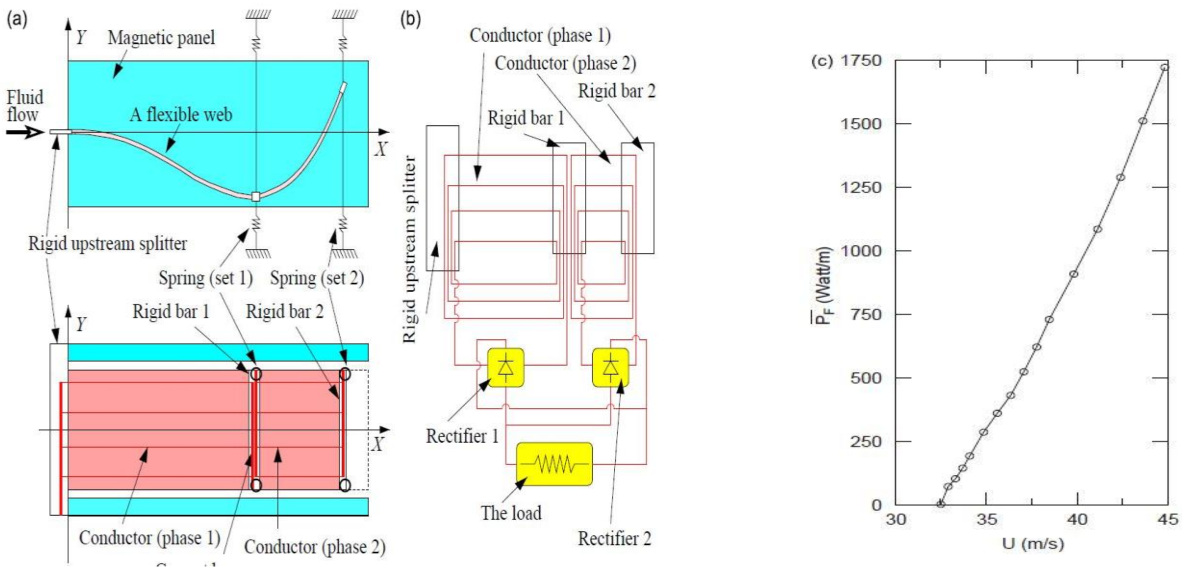


FIGURE 3 (a) Layout of Flutter Mill (b) Wiring of Flutter Mill (c) Time Average Power Vs Flow Velocity of Fluid Flow

Y. K. Ramadass et al. (2010) developed a bias-flip rectifier circuit which helps in improving the power extraction from piezoelectric harvesting system by 4 times than conventional full bridge rectifier and voltage doublers. It was found that the power extracted was 2 times more than the simple circuit. W. M. Aureli et al. (2010) studied analytically and experimentally the energy harvesting capability of base excited ionic polymer metal composite (IPMC) strip immersed in water and shunted with electric impedance. Surface area and thickness of IPMC were 1.5 cm^2 and 200µm respectively and experiment was carried out in frequency range 2-50 Hz. The maximum power harvested was 1nW for a base excitation of the order of 1mm.

T. M. Kamel et al. (2010 predicted the power output of MEMS-based piezoelectric harvesting devices. Such model was also designed with power output of 140µW. Akaydin et al (2010) presented the analysis of energy harvested from unsteady turbulent flow of fluid using piezoelectric generator. The piezoelectric beams were placed inside turbulent boundary layer and wakes of circular cylinder and the output voltage is recorded. The output voltage depends on location of generator and frequency of fluid flow. Maximum output voltages recorded when frequency of fluid flow is matched with natural frequency of piezoelectric generator. Simulation of the complete system agrees with experimental data. Figure 4 shows interaction of flowing fluid with piezo material.

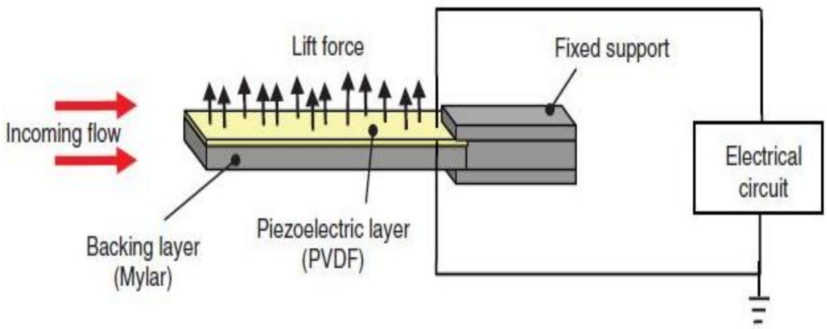
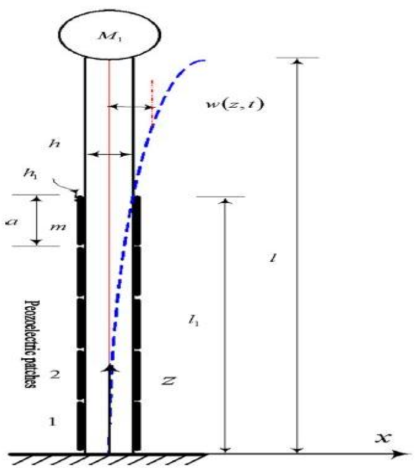


FIGURE 4 Interaction of flowing fluid with piezo material

S. D. Kwon (2010) developed a device with T-shaped cantilever to harvest energy. The device worked on the principle of aero elastic flutter. T-shape of cantilever increases the occurrence of flutter at low speed of fluid. The device can produce power from wind at minimum speed of 4m/s and maximum power generated was 4.0mW. R. Patel et al. (2011) showed the effect of geometric parameters on the output of a micro scale piezoelectric cantilever energy harvester. They showed that on reducing piezoelectric layer length there is significant increase in energy storage. M S Bhuyan et al. (2013) presented a micro-energy harvester based on a piezoelectric cantilever that was attached to a bluff body. The pressure in the flow channel fluctuates in a cross fluid flow, and this pressure fluctuation causes the piezoelectric cantilever to vibrate in a normal direction to the direction of fluid flow. COSMOL software has been used to evaluate different harvester mechanical analysis.The modelling and simulation results were comparable. X.D. Xie et al (2014) developed a model to harvest sea wave energy by converting kinetic energy of sea water into useable electric energy. A cantilever beam attached with patches and point mass was used for collecting energy as shown in figure 8. Practical observation and mathematical simulation showed that generated power increases with width to thickness ratio of cantilever, ratio of point mass with cantilever mass, sea depth, wave height. Generated power from the model is 55 W.

(a)



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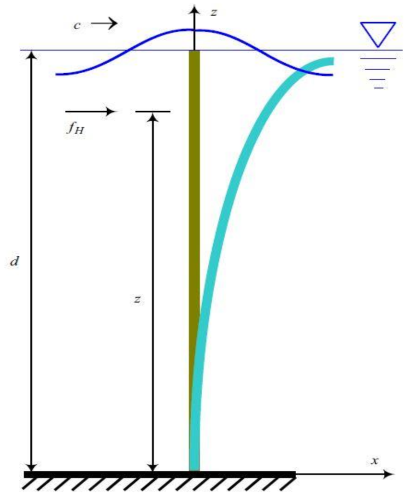

FIGURE 5(a) Setup of Piezoelectric Energy Harvester (b) Model Subjected to Sea Pressure

D. Chhabra et al (2014) has performed the experiment for AVC on a plate structure using modified heuristic genetic algorithm. Koyvanich et al. (2015) proposed an energy harvester that converts fluid flow energy into electrical energy by using a flexible piezo-film and a vortex induced vibration technique. An open circuit voltage of 6.6 mW at a matching load of 1MΩ was generated with maximum output power of 0.18μW. Efficiency power conversion of the proposed energy harvester was 4.4%. Y. Tanaka et al. (2015) performed an experiment using flexible piezoelectric devices (FPEDs) and generated power from wave energy in two alternate configurations. In one configuration FPEDs are perpendicular to seabed and in the second these are parallel to the seabed. The harvesters were made to excite in the wave and base was fixed. A theoretical model was also developed to evaluate the force created by the wave. The experimental and theoretical results agreed well for different wave heights and water depths.

P. Rani and D. Chhabra (2016) presented a model for energy harvesting by using dynamic pressure of water on a single patch of PVDF with two different circuits- voltage doubler and full bridge rectifier circuits. Voltage doubler circuit provided maximum voltage of 17.54V and full bridge rectifier circuit provided 7.01V maximum voltage at 75cm from nozzle end. A. Budhwar and D. Chhabra (2016) developed a model for energy harvesting using PVDF piezoelectric material with hydrodynamism. A dynamic water pressure has been directed on PVDF patches and a comparison has been made for output generated output on the basis of different nozzle angles, distance of nozzle from patches, number of patches and different electronic circuitry. It was found that when double patches are connected in series then there is maximum generated output voltage. J. Yadav et al (2016-2017) designed of an open channel fluid flow system for piezoelectric energy harvesting and got a voltage 2.73V. D. Yadav (2018) developed a model for energy harvesting using PVDF piezoelectric material with hydrodynamism and compares the green energy harvested using PZT piezo patch in different series configuration and also optimizes the circuitry system by testing voltage doubler and full bridge wave rectifier circuit. It was found that when double patches are connected in series then there is maximum generated output voltage. D. Yadav et al (2019) studied the modelling and simulation of an open channel PEHF system for efficient PVDF patches for energy harvesting and observed that maximum voltage is obtained with voltage doubler circuit at maximum turbulence zone.

Conclusion

Micro energy generation system using different kind of fluid flow for various smart materials has been studied. A number of research projects listed above conclude the a significant amount of energy is harvested using these smart materials system which is can be stored or utilized to power up the micro devices like phone batteries, small led’s etc. Waste mechanical energy of flowing fluid can be harvested in near future by using such type of systems.

Abbreviations

PVDF	Polyvinylidene Fluoride
MEMS	Micro Electromechanical Systems
PMA-PZT	Lead Methacrylate- Lead Zirconate Titanate
IPMC	Ionic Polymer Metal Composite.
PCGE	Piezo Composite Generating Element
PZT	Lead Zirconate Titanate
PEH	Piezoelectric Energy Harvester
POF controller	Proportional Output Feedback controller

PID	Proportional Integral Derivative control law
PECBEH	piezoelectric cantilever bimorph energy harvester
FPEDs	flexible piezoelectric devices

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