DESIGN AND CHARACTERIZATION OF AN OSCILLATING ENERGY HARVESTER WITH PLANKED PIEZOELECTRIC FOR OBSERVATORY OBSEA.

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Abstract

For the expansion of the OBSEA underwater cable observatory, which is run by the UPC and is located at 4 km away from the coast of Vilanova i la Geltru, new underwater wireless sensors are envisioned. Therefore, a solution is required to generate power to wireless sensors using only sea. In this project we will solve this problem using a prototype based on a Bristol cylinder which can generate electrical voltage using vibration piezoelectric. These vibrations are generated by plectrums impacts which create continuous free vibration in piezoelectric after impacting them. The results give us an acceptable power and it describes a plectrum distribution based on frequency and amplitude of usually OBSEA sea wave behavior.

Keywords: Energy Harvesting, Piezoelectric, Bristol cylinder, Prototype, Free vibration.

INTRODUCTION

In recent years, green energy have been getting more and more important in our world, especially in the field of engineering. Therefore, the aim of this project is to study how to get enough energy to power underwater wireless sensors installed at 20 meters below sea level using the energy produced by the sea motion in the bottom. To achieve the transformation of mechanical energy to electric energy we use piezoelectric converts installed in a Bristol cylinder.

The idea of using a Bristol cylinder to create a pendulum EH with plectra's impacting the piezoelectrics comes as a result of reading the work presented by S.Crowley, R.Porter and D.V. Evans from the Bristol University [1]. Moreover, from the work presented by P. Pillatsch, E.N. Yeatman and A.S. Holmes from the Imperial College London [2], we could get the expected behavior when the piezoelectrics are vibrating freely.

Energy Harvester Prototype

To carry out the experiments for the EH prototype, different tolls have been used. First, we have made several previous studies done in ORCAFLEX software, which offers the possibility of dynamic simulations, in order to display data on the behavior of the submerged body, where the pendulum will be hosted on the seabed. All these data obtained from computer simulations have been then used in a testbed simulating the real oscillatory movements using a waveform generator, amplifier, and an oscilloscope for measurements. Most studies have been made for an input frequency of 300 mHz simulating wave periods of 3.3s and an amplitude varying between 50 mV and 450 mV to simulate the rotation of the cylinder produced by waves of 0.5m to 4m which have been obtained from ORCAFLEX simulations as shown in figure 1.

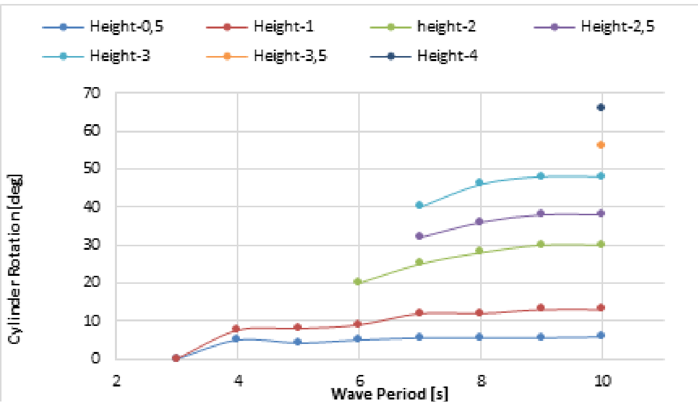

Figure 1 ORCAFLEX simulation results

Observations are based on an initial prototype made from a first design. In the initial prototype we find the base of the pendulum, support for piezoelectric, the piezoelectrics and the plectra's as described in figure 2.

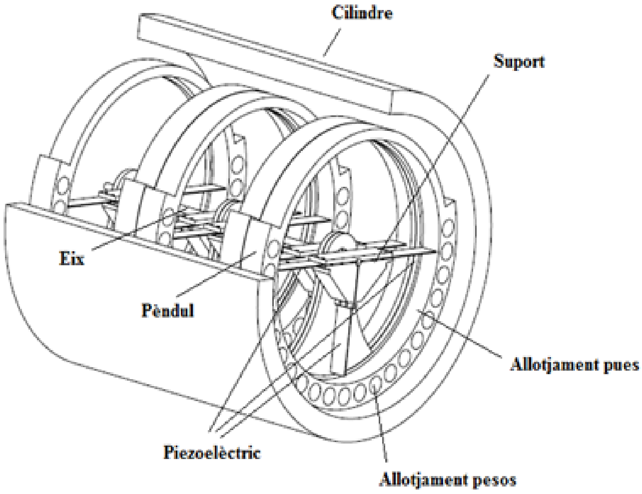

Figure 2 Schematic representation of the proposed underwater energy harvesting systems

Once manufactured the prototype, we begun the experiments, which have been divided into two parts, the first to describe the behavior of plectra's and the second part to describe the behavior of piezoelectric depending on the electrical connection.

In the first case we had to consider what material to choose by finding the optimum material to generate the electricity wearing as little as possible the piezoelectric material. Following this study we had to see how it should be designed the plectra for optimal behavior in the planked based vibration generator.

Regarding the piezoelectric, we have to obtain the electrical resistance to generate the maximum output power, and what should be the distances between plectra's to obtain maximum performance. Moreover we have to see what may be the optimal distribution of three piezoelectric installed inside the pendulum system. Finally will be necessary to know what connection should be used between piezoelectric. To carry out this study we use the testbed as described in the figure 3.

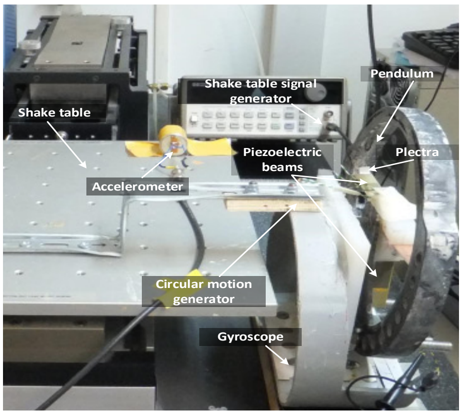

Figure 3 Illustration of the prototype energy harvesting device mounted on a tube attached to the shake table, showing the pendulum with the plectra's, the piezoelectric beam, the accelerometer and the gyroscope

RESULTS

Figure 4 plots the instantaneous output voltage of the two plunked vibration piezoelectric beams for a driving rotation of the harvesting device of 25 rad/s at 0.33 Hz and with only one plectra facing the piezoelectric beam. The maximum peak-to-peak voltage is 30 V. The generating beam's voltage is exponentially attenuated, as expected. Also for the free vibration, the vibration frequency of the piezoelectric beam is approximately equal to the resonant frequency ωp.

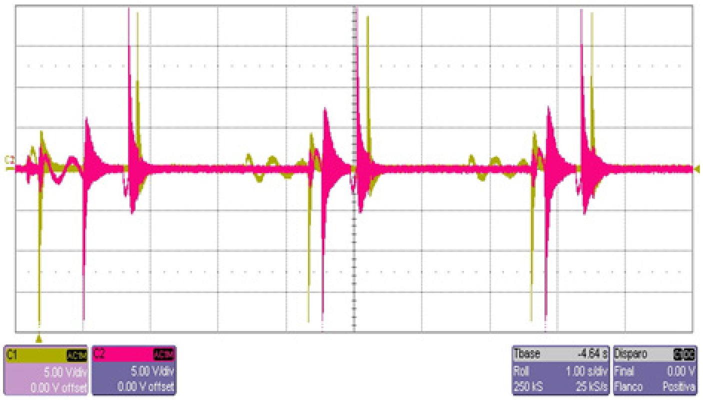

Figure 4 Output voltage of two piezoelctrics plotted versus time for a rotation of the harvesting device of 25 rad/s at 0.33 Hz and with only one plectra facing the piezoelectric beam.

Figure 5 plots the instantaneous output voltage of a single plunked vibration piezoelectric beams for a driving rotation of the harvesting device of 25 rad/s at 0.33 Hz and with several plectra's facing the piezoelectric beam and with 5mm gap. The maximum peak-to-peak voltage is 30 V. The impact phase between the piezoelectric beam and the plectra's appears several times per cycle depending on the maximum rotation angle of the harvesting device and after each impact occurs the free vibration phase.

CONCLUSIONS

Based on the operation of the pendulum in various situations we find it appropriate to conclude that the EH designed can be a useful solution to the problems posed. Moreover, using the vinyl material as plectra for vibration generator is good solution, and we can have a lifetime of piezoelectric of 5.64 x 10^15 cycles.

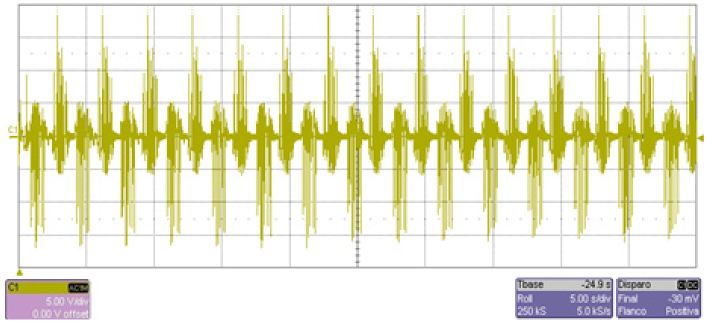

Figure 5 Output voltage of a single piezoelctric plotted versus time for a rotation of the harvesting device of 25 rad/s at 0.33 Hz and with several plectra with 5 mm gap facing the piezoelectric beam.

We should also know that timely distribution of spikes is closely related to the type of waves that exist, i.e., the amplitude acting on the cylinder. Low amplitude, less than 405 mV equivalent to less than 22˚ inclination, it works well only with one piezoelectric that should be placed at the center of the pendulum because the movement is closely related to the moment of inertia. However, for oscillation amplitudes higher than 22˚ or more, the device can work properly with all piezoelectric, because in this case the inertia of the body help to solve the problem of lack of potential energy to overcome the lateral plectra's.

ACKNOWLEDGMENT

This work has been carried out in part thanks to the project CGL2013-42557-R. Interoperabilidad e instrumentación de plataformas autónomas marinas para la monitorización sísmica and thanks to the project CTM2010-15459 (subprograma MAR) Sistemas Inalámbricos para la Extensión de Observatorios Submarinos.

REFERENCES

[1] CROWLEY, S; PORTE, R; EVANS, D. V. "A submerged cylinder wave energy converter", mathematics department of the Bristol University, 2012.

[2] PILLATSCH P; YEATMAN, E.M; HOLMES, A.S. "Real world testing of a piezoelectric rotational energy harvester for human motion", Imperial college of London, 2010