Evaluation of Impact Based Piezoelectric Micro-Power Generator

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***Abstract*—This paper reports on energy harvesting from a mechanical impact by using a piezoelectric micro-power generator. An useful electrical power is generated when the impact of a human weight is applied on a piezoelectric disk transducer. An experimental set-up of a single foot step on piezoelectric disk for harvesting the impact energy was being conducted with variable forces and impact velocity. A 44mm diameter and 10mm thick of piezoelectric disk is sandwiched between two wooden plates to be used for transforming impact from foot step into electrical energy. A range of output power of 3.8µW up to 14.5µW was measured across a variable resistive load of 10kΩ up to 1110kΩ respectively for a single foot stepped onto the device. In another experiment, a varying of impact velocity is being applied to the piezoelectric micro-power generator.**

***Index Terms*—Energy Scavenging, Impact to Electrical Energy Transformer, Mechanical Impact Energy, Piezoceramic Application.**

I. Introduction

The energy harvesting technique using piezoelectric material are gaining popularity due to its high power density particularly for the application of powering low-power electronic devices with various types of sensors which offers an advantage for systems in which battery replacement is challenging which would be limiting the system's life-span. Piezoelectric micro-power generator is commonly deriving energy from vibration sources [1, 2].

Mechanical impacts are also ubiquitous in our ambient environment, however the major issue for mechanical impact based energy harvesting is its irregularity, where compared to vibration sources, mechanical impact force is much more random and instantaneous which make it difficult to store using energy. There was a report on transforming impact based energy using piezoelectric into electrical energy in a shoe sole as described in [3] and using rotating gear as reported in [4]. They show that impact based energy harvesting is another alternative application using piezoelectric to derive using electrical energy.

In this paper, a series of experiments have been conducted to evaluate the operation of a piezoelectric disc in powering Arduino and an RF transmitter when a varying mechanical force is being applied on the micro-power generator. Six experiments has been conducted to evaluate the amount of voltage and power (for raw and rectified output voltage) generated via piezoelectric disk when it is subjected to varying impact forces and velocity.

II. Energy Harvesting From Impact Force

Force of impact can be calculated as,

$$F_i = \frac{Wa}{g} \tag{1}$$

where F_i is force of impact, W is object weight, a is rate of deceleration and g is acceleration due to gravity. The voltage that generated from a piezoelectric material is dependent on the stress that derived from the impact force that applied on to the material, which can be written as,

$$V_o = d_{33}\frac{F_i}{l}\left(\frac{1}{\varepsilon_{33}^T}\right) \tag{2}$$

where d_{33} is the piezoelectric charge constant, l is the length of the piezoelectric materials and ε_{33}^T is the permittivity of the piezoelectric material.

III. Experimental Set-Up

Figure 1 shows the construction of the foot step platform where a round shape piezoelectric disk with 44mm diameter and 10mm thick which has sensitivity of 5.8V/kN was sandwiched between two wooden plates and surrounded by a sponge to absorb excessive impact.

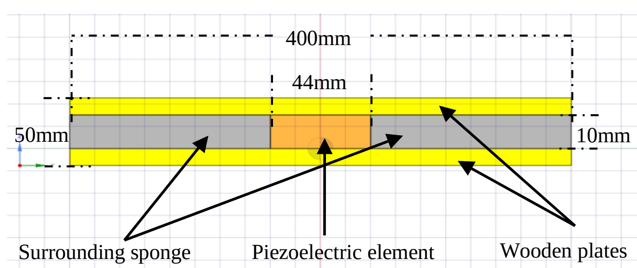

Figure 1: Schematic diagram of the foot step impact force platform.

Various impacts/velocities were generated by using AUTOGRAPH AG-I 100kN hydraulic pressing equipment to simulate a single human foot step as illustrated in Figure 2.

IV. Experimental Results And Discussion

The voltage and the power output presented in the experiment results are measured at instantaneous manner whereby piezoelectric material as it clear in Figure 3 only generates electrical charges when there is a changes of stress applied onto the material.

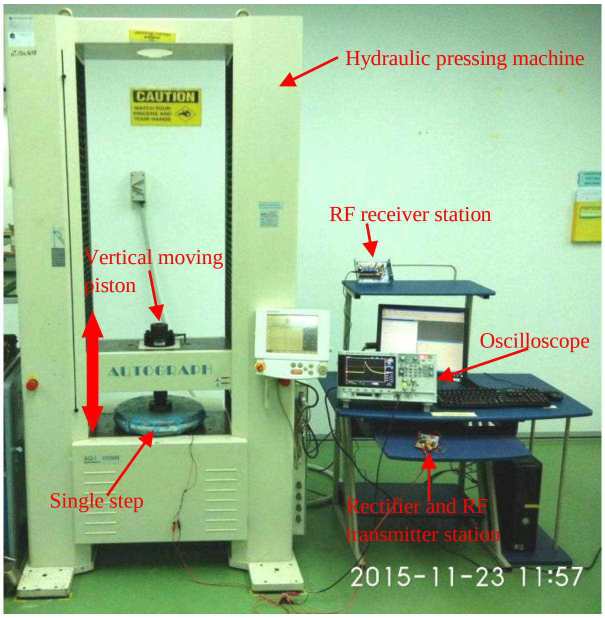

Figure 2: Experimental setup

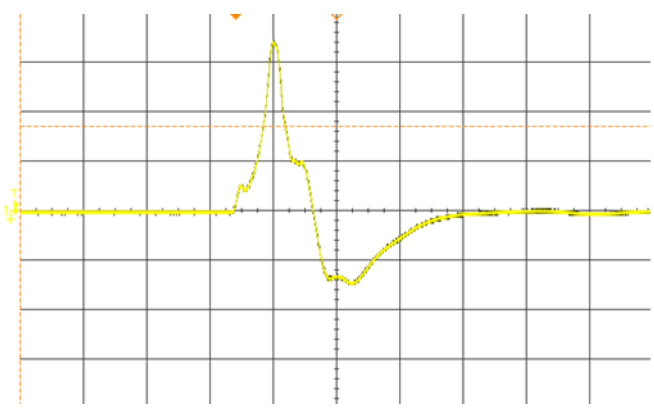

Figure 3: Instantaneous output AC voltage peak of piezoelectric generator when it's been impacted at certain force.

And as it clear in figure 4 shows AC output voltage measured from the piezoelectric terminal by fixed the amount of applied impact force to 0.5KN, at varying velocity from 100mm/minute up to 1000mm/minutes. It shows that, the output voltage increases drastically as the impact velocity increases. 27V of AC peak-to-peak value is being measured at 1000mm/min of impact velocity. In another series of experiment of varying the impact force as shown in Figure 5 which shows that the peak-to-peak output voltage increases proportionally with the applied impact force. About 17V is being recorded when 3 kN of impact force is applied on the piezoelectric device.

In order for a real application, the AC output voltage is rectified to DC voltage output. Figure 7 shows that DC voltage output after being rectified for varying impact velocity and impact force respectively. The DC output voltage is clearly reduced compared to the AC output voltage directly acquired from the piezoelectric terminal, which is due to the energy lost in rectifying circuit using diodes.

Next the output terminal of the piezoelectric is connected to a varying external electrical load at a fixed magnitude of applied force of 0.75kN which is an average human weight and at an impact velocity of 600mm/min. Figure 8 shows that at high external resistive load or at open circuit the voltage is measured at about 3.7V. In order to determine the maximum output power, Figure 9 shows that at an external resistive load of 500kΩ, a maximum output power of 14.5μW is being measured.

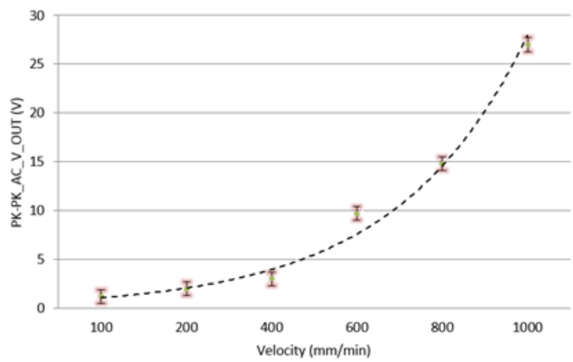

Figure 4: Peak-to-peak AC output voltage of piezoelectric micro-power generator at varying impact velocity.

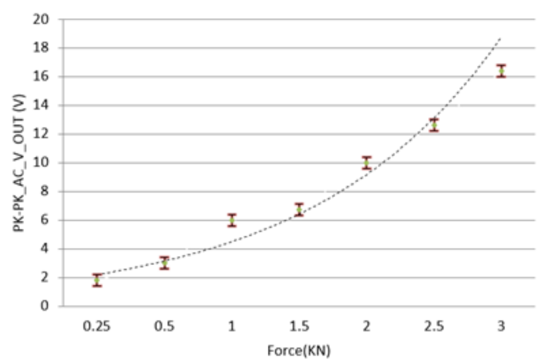

Figure 5: Peak-to-peak AC output voltage at varying impact force.

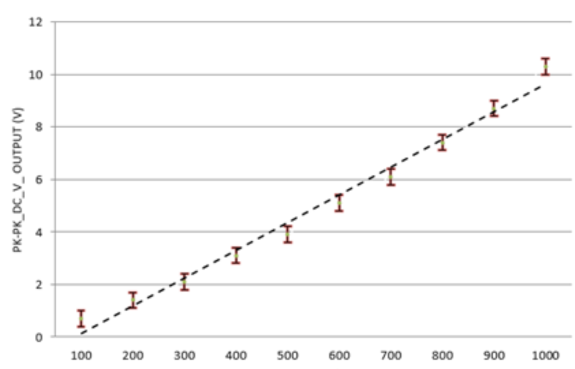

Figure 6: DC output voltage as a function of impact velocity.

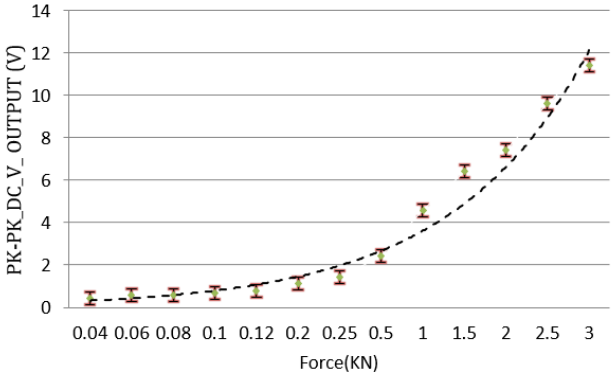

Figure 7: DC output voltage at varying impact forces.

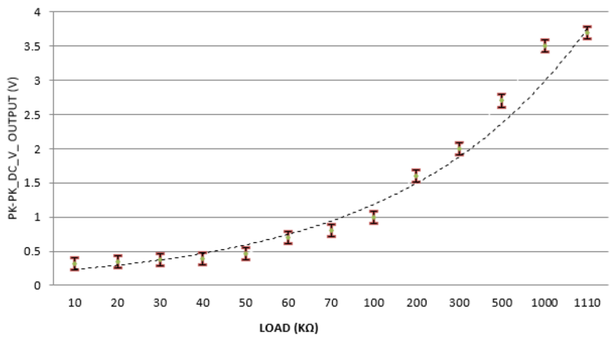

Figure 8: DC output voltage measured across varying external resistive load.

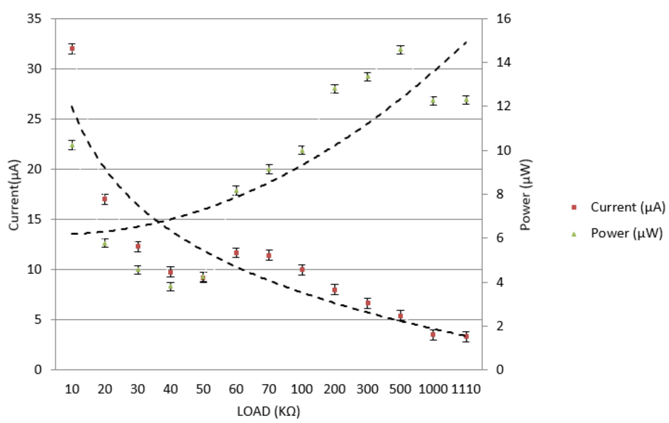

Figure 9: Output power and current at varying external resistive load.

V. CONCLUSION

An impact force micro-power generator using piezoelectric disk in transforming human foot step is presented in this paper. A hydraulic pressing machine is used to simulate a normal human step with varying impact forces and velocities to test the amount of electrical output that can be drawn from the piezoelectric material. The experimental results show that the produced energy when increased the velocity of the impact with fixed impact force is almost doubled, at 1.7 times than increasing the impact force while fixing the impact velocity.

ACKNOWLEDGMENT

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