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Voltage Generated Characteristics of Piezoelectric Ceramics Cymbal Transducer

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Abstract

In this study the relation between the generated open circuit output voltages of the piezoelectric ceramics Cymbal transducers with applied impact mechanical energy is studied. The output voltages of piezoelectric ceramics Cymbal transducers are increased with the increasing of the applied mechanical energy. Under the same impact mechanical energy, the generated open circuit output voltages of the piezoelectric ceramics Cymbal transducer is much higher than that of uncapped piezoelectric ceramics disk alone. The generated open circuit output voltages of the piezoelectric ceramics Cymbal transducer depend on the geometry parameters and the metal thickness of end-cap. The generated open circuit voltage of piezoelectric ceramics Cymbal transducer with thick metal thickness is small than that with thin metal thickness.

Keywords

Cymbal Transducer, Piezoelectric, Energy Harvester

1. Introduction

After developed by Dogan *et al*. in 1997 [1], the piezoelectric ceramics Cymbal transducer has been applied in many fields because of the ease of fabrication and the ability to tailor performance, especially to be used as the key element of vibration controller, actuator of microstructure, and hydrophone etc. [2]-[6]. Besides being used as the actuator and sensor, the piezoelectric ceramics Cymbal transducer also can be used as the energy harvester [7]-[12]. Cymbal structure can produce a large in-plane strain under a transverse external force, which is beneficial for the micro energy harvesting. Kim *et al*. [7]-[10] reported that piezoelectric energy harvesting showed promising results under pre-stress cyclic conditions and validated the experimental results with finite element analysis. The piezoelectric ceramics Cymbal transducer has the ability to generate more electric voltage output and power output as compared to conventional flextensional mode transducer. In the future research, the output electrical characteristic of piezoelectric ceramics Cymbal transducer is generated by mechanical vibrations in a dynamic environment. But in this study, the output electrical characteristic of piezoelectric Cymbal transducer is generated by mechanical vibrations in a static environment study.

2. Experimental Processes

The PZT piezoelectric ceramics used in this study were supplied by Eleceram Technology Co., Ltd., Taiwan.

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The PZT piezoelectric ceramics presented a free dielectric constant ε^T_{33}(1 kHz) = 2100, a piezoelectric voltage constant $g_{33} = 24 \times 10^{-3}$ Vm/N, a piezoelectric charge constant $d_{33} = 470 \times 10^{-12}$ C/N and $d_{31} = -230 \times 10^{-12}$ C/N, a planar electromechanical coupling factor $k_p = 0.70$, a thickness electromechanical coupling factor $k_{33} = 0.72$, a mechanical quality factor $Q_m = 65$.

The structure of piezoelectric ceramics Cymbal transducer was show in **Figure 1**. The diameter and the thickness of PZT piezoelectric ceramics disk was 15 mm and 0.9 mm, respectively. The diameter of the end-cap dp was the same as that of the PZT piezoelectric ceramics disk and equal to 15 mm, the cavity depth is keep constant for each sample and equal to 2.0 mm, the dimple diameter de1 = 2, 3, 4 and 5 mm, and the cavity diameter de 2 = 5, 6, 7, 8 and 9 mm. Two types of brass foil were used as end-cap metal of the Cymbal transducer, one with the thickness tb equal to 1.0mm (T-series), and the other equal to 0.6 mm (D-series). There are total 12 types Cymbal transducers with different end-cap parameters were used in this study, 7 for T-series and 5 for D-series, as shown in **Table 1**.

The electrical output performance of piezoelectric ceramics Cymbal transducer during applying mechanical compressive stress was measured using drop weight impact techniques, in a way as shown in **Figure 2**. A steel

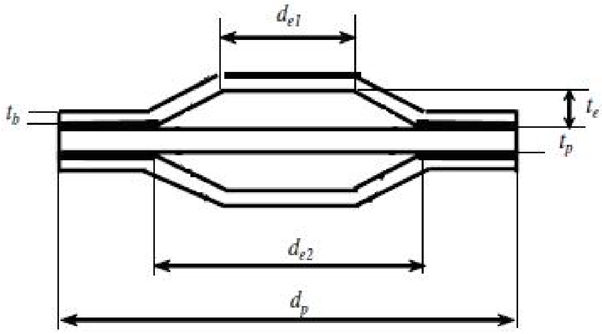


Figure 1. The structure of piezoelectric Cymbal transducer.

Table 1. (a) The end-cap parameters of the T-series Cymbal transducers; (b) The end-cap parameters of the D-series Cymbal transducers.

(a)

No.	d_p (mm) transducer diameter	d_{e1} (mm) dimple diameter	d_{e2} (mm) cavity diameter
T-1	15	2	9
T-2	15	3	8
T-3	15	4	7
T-4	15	5	6
T-5	15	2	7
T-6	15	3	6
T-7	15	2	5

(b)

No.	d_p (mm) transducer diameter	d_{e1} (mm) dimple diameter	d_{e2} (mm) cavity diameter
D-1	15	3	8
D-2	15	4	7
D-3	15	2	7
D-4	15	3	6
D-5	15	2	5

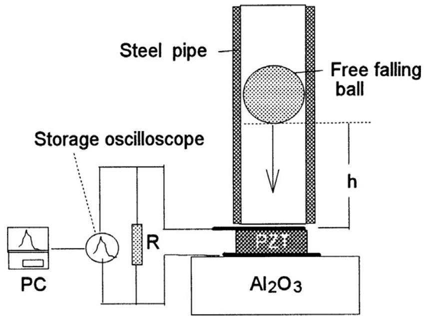


Figure 2. Schematic drawing of the impact testing.

ball (38.6 mm in diameter, 16.5 g in weight) was dropped from a height from 30 to 120 mm, through a steel guide pipe, there by applying an impact to the test piezoelectric ceramics Cymbal transducer. The electrical response of piezoelectric ceramics Cymbal transducer to applied stress was displayed on a digital storage memory oscilloscope (Agilent MSO-X 3054A) with an input resistance R of 10^7 Ω, which was connected to a personal computer (PC) for data acquisition and analysis.

3. Results and Discussions

Figure 3 and **Figure 4** have shown the relation between applied mechanical energy and generated open circuit voltage of piezoelectric ceramics Cymbal transducer with the thickness of end-cap metal equal to 1.0 mm (T-series) and 0.6mm (D-series), respectively. From the results of **Figure 3** and **Figure 4**, it found that no matter how is the geometry parameter of end-cap, the generated open circuit output voltage of each piezoelectric ceramics Cymbal transducer is increased with the increasing of applied mechanical energy.

In compared with the previous study [13], it found the generated open circuit output voltage of piezoelectric ceramics Cymbal transducer is much larger than that of uncapped piezoelectric ceramic disk alone. From the results of previous study [13], it found when the applied mechanical energy is equal to 45 mJ, the generated open circuit output voltage of uncapped piezoelectric ceramic disk with diameter equal to 15 mm and thickness equal to 0.9 mm is about 10 V, but when the same piezoelectric disk used as the piezoelectric element in piezoelectric ceramics Cymbal transducer, the generated open circuit output voltage will increased to about 160 V to 220 V, dependent on the end cap geometry. The amplification factor of piezoelectric ceramics Cymbal transducer used in this study is equal to 16 to 22, depend on the geometry of the end-cap.

The generated open circuit output voltage of piezoelectric ceramics Cymbal transducer is depend on the geometry of the end-cap structure, and is varies with the ratio of (dimple diameter d_{e1}/cavity diameter d_{e2}). The generated open circuit output voltage of piezoelectric ceramics Cymbal transducer is increased with the increasing of (dimple diameter d_{e1}/cavity diameter d_{e2}) ratio, as shown in **Figure 5** and **Figure 6**. In which, **Figure 5** is the results of T-series piezoelectric ceramics Cymbal transducer, and the **Figure 6** is the results of D-series piezoelectric ceramics Cymbal transducer.

Figure 7 shows the relation between generated open circuit voltage and de1/de2 of T-series and D-series piezoelectric ceramics Cymbal transducer with same end-cap structure under different impact mechanical energy. From the results of **Figure 7**, it found with the same applied mechanical energy and the same end-cap structure, the generated open circuit voltage of piezoelectric ceramics Cymbal transducer with thick metal thickness is small than that with thin metal thickness. The decreased of generated open circuit voltage with the increased of metal thickness is due to the d_{eff} decreased with an increase in the end-cap metal thickness [7].

4. Conclusion

Open circuit output voltage of piezoelectric ceramic Cymbal transducer increased with the increasing of the applied mechanical energy. Under the same impact mechanical energy, the generated open circuit output voltages of the piezoelectric ceramic Cymbal transducer are much higher than that of uncapped piezoelectric ceramic disk alone. The generated open circuit output voltage of piezoelectric ceramic Cymbal transducer depends on the geometry parameters of the end-cap structure, and is increased with the increasing of (dimple diameter

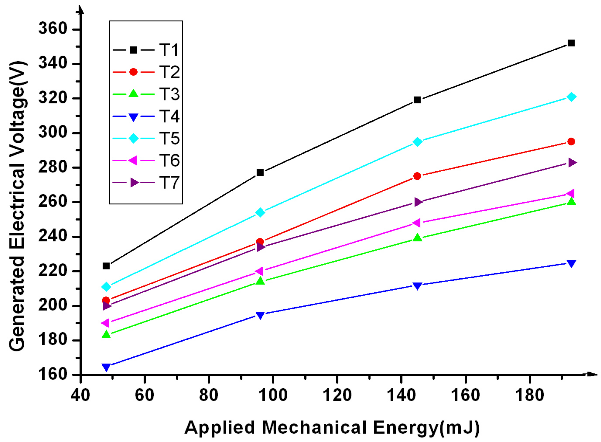


Figure 3. Relation between applied mechanical energy and generated open circuit voltage of T-series piezoelectric ceramics Cymbal transducer.

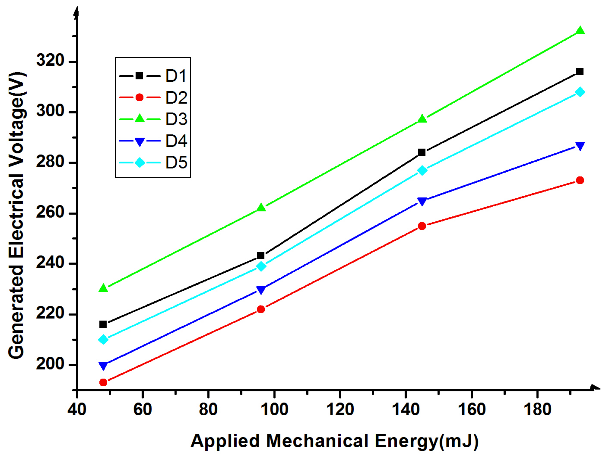


Figure 4. Relation between applied mechanical energy and generated open circuit voltage of D-series piezoelectric ceramics Cymbal transducer.

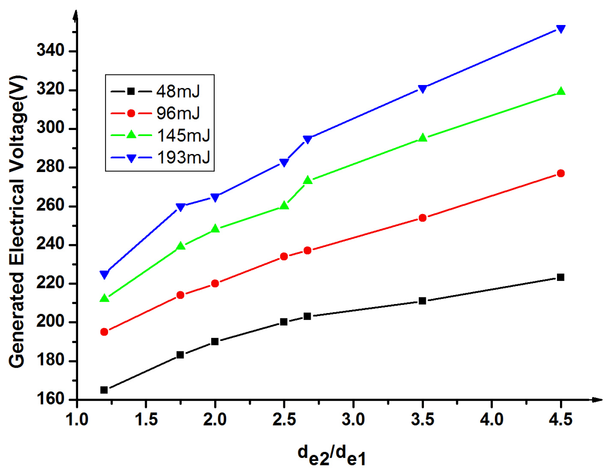


Figure 5. Relation between generated open circuit voltage and d_{e1}/d_{e2} of T-series piezoelectric ceramics Cymbal transducer.

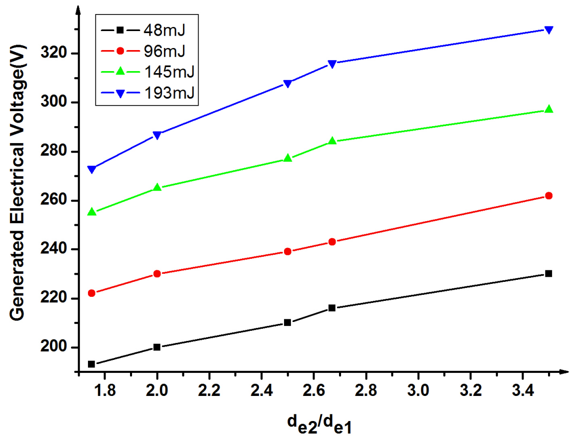
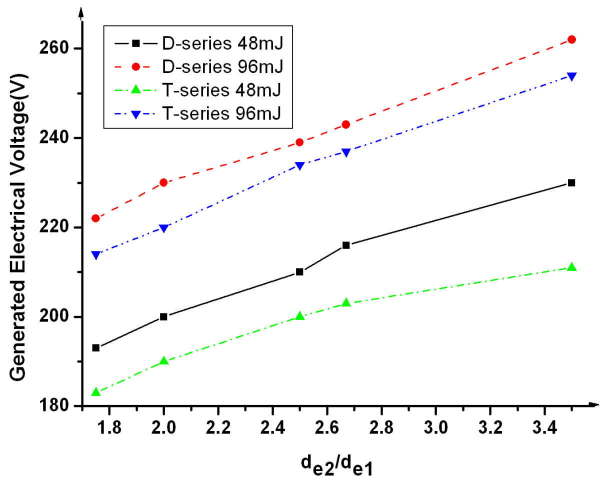
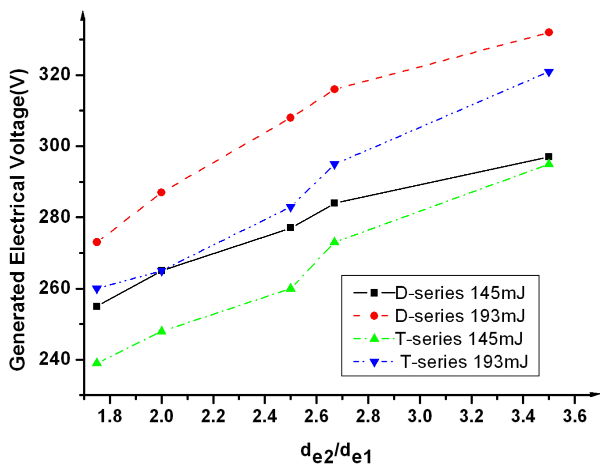


Figure 6. Relation between generated open circuit voltage and d_{e1}/d_{e2} of D-series piezoelectric ceramics Cymbal transducer.



(a)



(b)

Figure 7. Relation between generated open circuit voltage and d_{e1}/d_{e2} of T-series and D-series piezoelectric ceramics Cymbal transducer with same end-cap structure under low impact energy.

d_{e1}/cavity diameter d_{e2}) ratio. Besides the geometry of the end-cap structure, the generated open circuit output voltages of the piezoelectric ceramic Cymbal transducer also depend on the metal thickness of end-cap, the generated open circuit voltage of piezoelectric ceramic Cymbal transducer with thick metal thickness is smaller than that with thin metal thickness.

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