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Experimental Study on Piezoelectric Plate Type Power Generator for Intelligent Tire System

インテリジェントタイヤシステムへの応用を目的とした圧電板型発電素子の実験的検討

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1. Introduction

Recently, the intelligent tire system such as a tire pressure monitoring system is developing for improving the safety of automobiles. The batteries are used on the pressure sensors in intelligent tire system at present. However, as for using the batteries, there are a lot of problems, such as inconvenience, expensive costs of taking an extra wheel balance and of replacing battery and a limitation of communication frequency which originates in longevity of battery. The several techniques have been proposed for the battery-less pressure sensors, such as the mechanical vibration energy systems [1-4]. In this study, the piezoelectric plate type power generator is experimentally investigated to substitute the battery. First, the response characteristics of generated voltage were measured using the piezoelectric ceramic plates attached to rubber test plates. Next, it was experimentally examined that the relationships between the dimensions of ceramic plates and the generated voltages and energies.

2. Experimental investigation on piezoelectric plate type power generator

2.1 Experimental set up

From the experimental results to date on deforming the automobile tire, the strains inside of tire were measured by 0.15% for the direction where the automobile ran and by 0.1% for the perpendicular direction, respectively [5]. In this study, for simplifying the experimental set up, the compressive load force was impressed to the test pieces using EZ-test (SHIMADZU Co.) shown in Fig.1 instead of deforming the automobile tire. The test pieces were manufactured from the rubber plates ($100\times100\times5\text{mm}^3$) attached to piezoelectric ceramic plates (N-10) and strain gage. Figure 2 shows the electrical circuits for measuring the strain and the generated voltage. The strain of rubber plate was measured with Wheatstone bridge circuit by detecting the signals of strain gage. AC voltage of 1(kHz) and V_{rms}=3(V) was applied on Wheatstone bridge and output voltage was detected by phase locked amplifier for improving the SN ratio. The generated voltage on piezoelectric ceramic plate

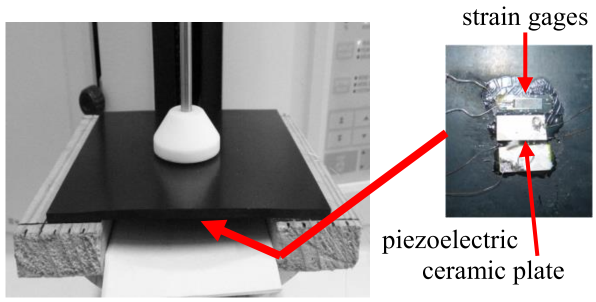

Fig.1. Experimental set up.

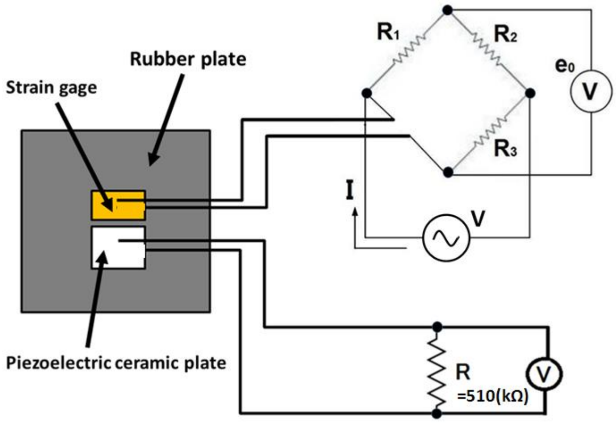

Fig.2. Electrical circuits for measurement.

and output voltage of phase locked amplifier were detected using measurement system developed with LabVIEW software.

2.2 Response characteristics on generated voltage

Figure 3 shows the response characteristics of generated voltage of piezoelectric ceramic plate and strain of rubber plate when the triangular shaped load force was impressed as the load speed of $v=8.33\times10^{-3}$(m/s). The same value of strain on deforming the automobile tire was obtained when the load force was applied as F=50(N). The waveform of generated voltage was corresponded the shape of differentiation on strain. The value of generated voltage increased with the ceramic plate in small thickness. This reason is that the strain of thinner ceramic plate is large on the same compressive force. The maximum voltages were generated as -70(mV) for the ceramic plate with the width W=5(mm) and the length L=10(mm) on

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thickness t of 0.25(mm) and as -25(mV) for t=1.0(mm).

2.3 Relationship between dimensions and generated voltage

Figure 4 shows the characteristics of generated voltage on power generator as a parameter of length. The generated peak voltage and effective voltage increased as the length of piezoelectric ceramic plate became larger and as the thickness became smaller. This seems to be due to the same reason to those described in § 2.2. It is quantitatively clarified that the generated peak voltage of $|V_{max}|$ =200(mV) and the effective voltage V_{rms}=65(mV) were obtained using the piezoelectric ceramic plate with 5×15×0.25(mm^3).

2.4 Relationship between compression speed and generated energy

Figure 5 shows the characteristics between the compression speed and the generated energy as a parameter of length. As the compression speed added to test pieces increased, the value of generated voltage become larger and the generation time of voltage became inversely shorter. Then, the value of generated energy increased with the compression speed and became larger as the element length was larger on the same compression speed. It is quantitatively clarified that the generated energy of 17(nJ) was obtained by the compression speed of 8.33×10^{-3}(m/s) using the piezoelectric ceramic plate with 5×15×0.25(mm^3).

3. Summary

The piezoelectric plate type power generator was experimentally studied in this paper. The characteristics of generated voltage and energy were examined. It is clarified that the generated voltage and energy increased as the length of piezoelectric plate was larger and the thickness was smaller. The generated voltage for higher speed of load force such as v=10(km/h) and the construction for improving the generated voltage will be examine in detail in the next paper. The author thanks Mr. Ryo Sasaki for his assistance in the experiments.

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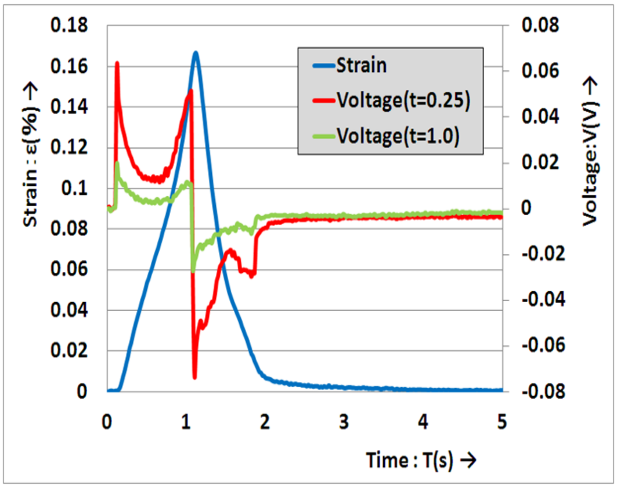

Fig.3. Waveform of strain and generated voltage. (W=5(mm),L=10(mm),v=8.33×10^{-3}(m/s),F=50(N))

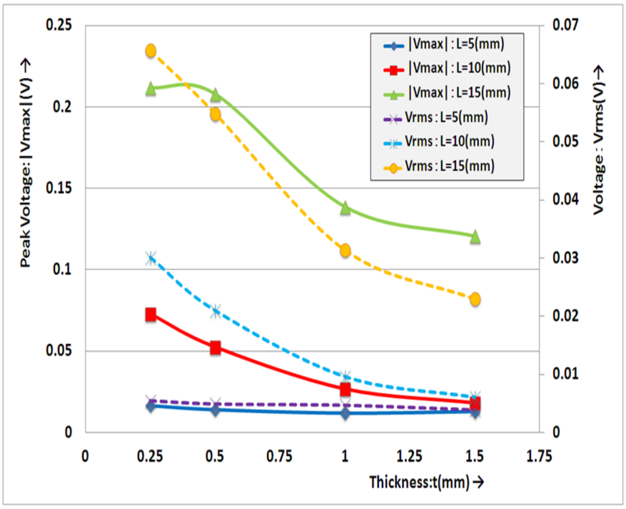

Fig.4. Characteristics of generated voltage. (W=5(mm),v=8.33×10^{-3}(m/s),F=50(N))

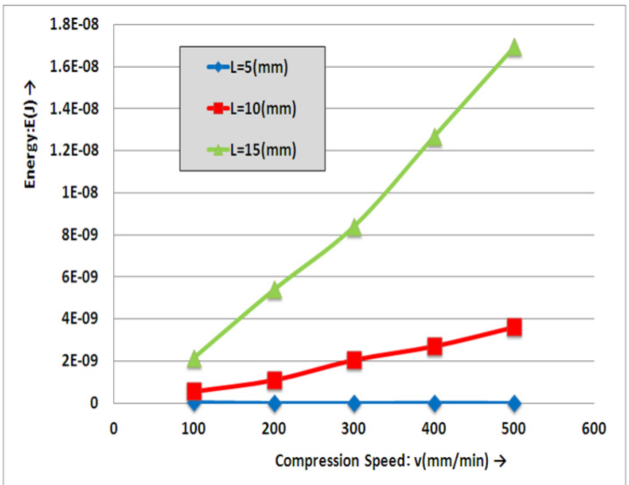

Fig.5. Experimental relationship between the compression speed and the generated energy. (W=5(mm),t=0.25(mm),F=50(N))