Study of Cylindrical Energy Harvester and its Characteristic Evaluation Method

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Abstract

In this paper, a cylindrical energy harvester, which combines an anti-vibration rubber and PVDF, and its characteristics evaluation method is presented. A forced vibration test using a hydraulic servo dynamic testing machine was conducted to determine the power generation characteristics. As a method to evaluate the power generation performance, a characteristic evaluation method was developed based on the governing equation of longitudinal vibration of the bar, and the results were compared with the experimental results to confirm the validity of the characteristic evaluation method.

1 Introduction

In recent years, the energy harvesting, which combines functional materials and unused energy to generate electricity, has been actively studied[1,2]. Since the anti-vibration rubber and rubber dynamic absorbers are always installed in a vibration environment, those will have a high affinity with vibration power generation. The shapes of those are generally cylindrical. Therefore, the authors have focused on an energy harvester that combines a polymer piezoelectric materials and a cylindrical dynamic absorber.

In this paper, a fundamental study on the power generation performance of a cylindrical energy harvester using a hydraulic servo dynamic testing machine is presented. A characteristic evaluation method of the energy harvester is also presented. The governing equation of the method is based on the longitudinal vibration of a bar, and the transfer matrix method is utilized to solve it. The validity of the method is discussed by comparing between the experimental results and the results by the method.

2 Forced vibration experiment using hydraulic servo test system

A cylindrical energy harvester used in this study is an anti-vibration rubber (Kurashiki ,KB-55-54H) wrapped by a piezoelectric film (KUREHA, KF piezo). A photo of the cylindrical energy harvester is shown in Fig. 1. The anti-vibration rubber made of NBR is 47.6 mm in height and 47 mm in diameter. The piezoelectric film (PVDF) is 15 mm in width, 120 mm in length and 80 μm in thickness. The PVDF is not adhered on the rubber using any adhesive. The friction between the PVDF and the rubber will deform the PVDF and the output voltage will be generated. Fig. 2 shows the experimental setup. A hydraulic servo dynamic testing machine (SAGINOMIYA, FMH205) is used to apply a periodic forced displacement to the energy harvester. The energy harvester is connected to a data logger (KEYENCE, NR-500) to measure an output voltage. Its internal resistance is 1 M-Ohm. There are three patterns of periodic forced displacement: (1) precompression of 0.5 mm, amplitude of 0.5 mm, (2) precompression of 1 mm, amplitude of 1 mm, and (3) precompression of 2 mm, amplitude of 1 mm. The frequency of the periodic forced displacement is set from 10 Hz to 50 Hz in 10 Hz increments.

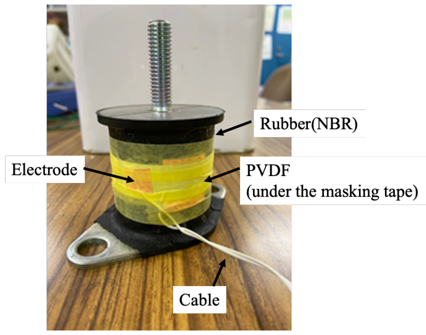

Figure 1 Photo of the cylindrical energy harvester.

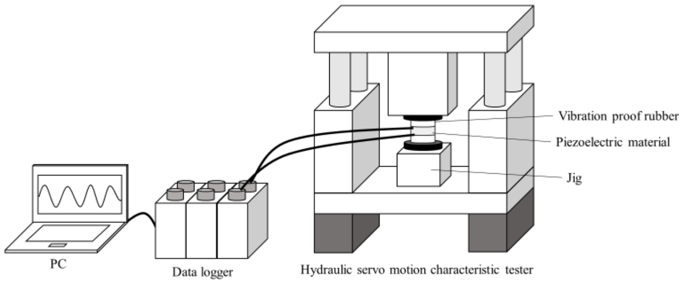

Figure 2 Composition of forced vibration experiment.

3 Characteristic evaluation method

In order to evaluate the characteristics of the cylindrical energy harvester, a characteristic evaluation method that can reproduce the power generation performance is developed. The method is based on two types of equations: the equation of motion based on the longitudinal vibration of a bar and the piezoelectric equation of PVDF. The transfer matrix method is employed to solve these equations. These equations can be discretized using the transfer matrix method and solved by using Matlab and Simulink to obtain the theoretical values of the generated voltage.

4 Results

Fig. 3 shows the voltage amplitude toward frequency for each condition obtained by the experiment. Though the friction is used to deform the PVDF, the output voltage is generated sinusoidally. Fig. 4 shows an example of a time history of output voltage obtained by the characteristic evaluation method. The amplitude by the method is larger than the experimental results because the strict adhesion between the PVDF and the rubber is assumed and the rubber is also assumed as an elastic material in the method. Therefore, the validity of the presented method is confirmed.

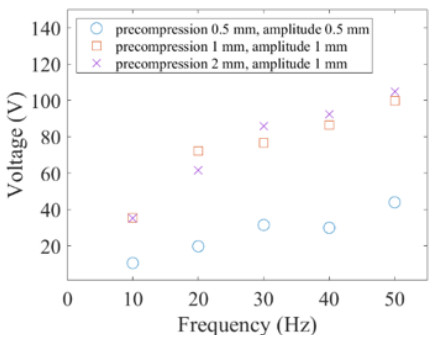

Figure 3 Voltage amplitude toward frequency for each condition

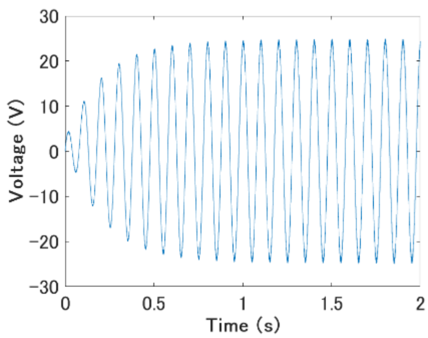

Figure 4 Time history of voltage for the condition (1) : precompression 0.5 mm, amplitude 0.5 mm, frequency 10 Hz by the theoretical model

References

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[2] Haitong Lianga, Guangbo Haoa, A review on vibration-based piezoelectric energy harvesting from the aspect of compliant mechanisms, Sensors and Actuators A: Physical, 331 (2021) 112743