Energy Harvesting from Structural Vibrations Using Piezotransducers

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ABSTRACT

This paper focuses on the harvesting of energy from the ambient vibrations that occur in the environment, such as structural vibrations of rail and road bridges, which can possibly be used to power devices requiring power in microwatt range. The main principle involved is that a parasitic cantilever structure is fabricated and fixed on the host structure. Piezosensors, which are used to sense the strains and convert them into voltage, are attached on the parasitic structure. When the host/main structure is subjected to vibrations, these are transferred to the parasitic structure, as a result of which strains are produced, resulting in the generation of the voltage and hence power across the piezosensor, which can be stored. In the present research, a parasitic cantilever model is fabricated and a 4m long RC beam is used as the main structure.

The cantilever is made of stainless steel with dimensions 220×24.5×0.72mm is used. The main structure is subjected to vibrations using LDS Dynamic Shaker, with the parasitic structure placed on the main structure, and the voltages generated are measured using TDS oscilloscope. Power is measured using a power measuring circuit. In this case, a maximum power output of 4.34 µW is obtained at 16 Hz, which is the natural frequency of the beam structure.

Keywords: Piezosensor, LDS Dynamic Shaker, Energy harvesting

1. INTRODUCTION

Almost all the civil engineering structures such as rail and road bridges are subjected to vibrations [1]. This ambient energy can potentially be harvested, stored and used to run miniature electrical devices for monitoring the structure continuously. Use of low cost wireless sensors has become since they can be installed even in the remote location of the structure without the hassle of handling long cables. However, as they are wireless sensors, they need constant power supply. Conventional electrochemical batteries are finite power sources, and they need to be replaced at regular intervals, causing inconvenience. The process of replacing batteries is very expensive in the long run. The piezosensors work on the principle of direct and indirect piezoelectric effects.

2. EXPERIMENTATION

The parasitic structure consisted of vertical member on which horizontal rectangular cantilever is attached. The cantilever was made of stainless steel, of dimension 220×24.5×0.72mm is used as shown in the Fig. 1. Four PZT patches of size 10×10×0.3mm were installed on the horizontal cantilever. A 4m long RC beam was used as the host structure on which the cantilever assembly was fixed as shown in the Fig. 1.

The beam is subjected to harmonic vibrations using LDS Dynamic shaker at an acceleration of $2m/s^2$ which is controlled using an accelerometer. Pure harmonic signal was applied with frequency ranging between 3 and 24 Hz with a step interval of 1 Hz and at an excitation level of 10 V. The strains produced in the parasitic structure resulted in the generation of the voltage, which was recorded using TDS oscilloscope. The power was measured using power measuring circuit [2] by connecting them in single, parallel and comparing their values. Graphs are plotted against Power and Frequency for both the cases.

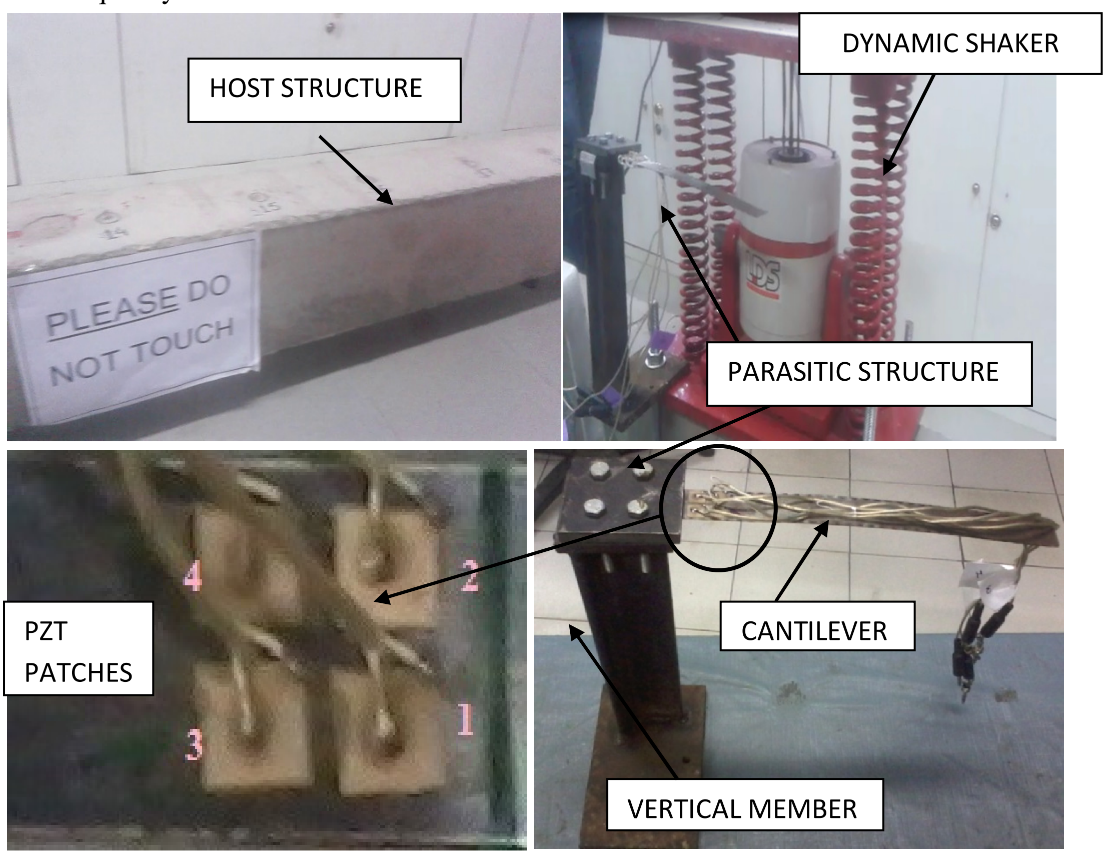

Fig. 1, Experimental setup

The power measuring circuit, proposed by Kaur and Bhalla [2], consisted of two resistors, R_1 and R_2 in series. The values of resistances were R_1= 494.7 kΩ and R_2=471.66 kΩ. There is also a provision for measuring the voltage drop across resistor R_1 as shown in the Fig. 2.

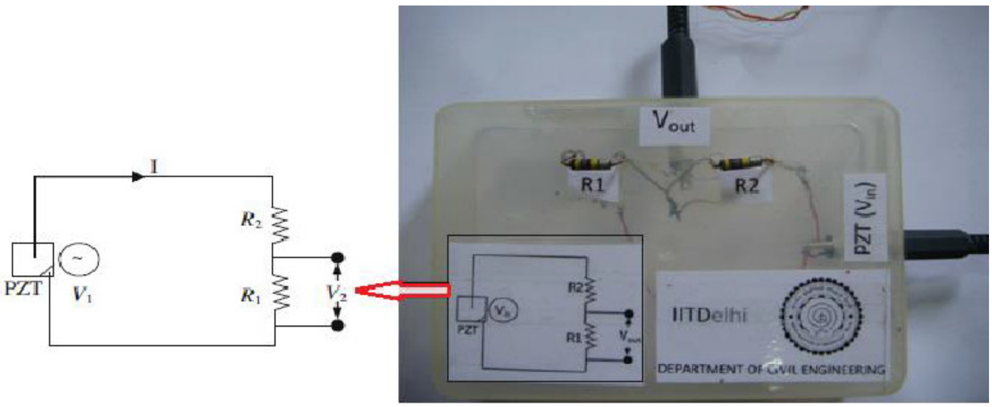

Fig. 2, Power Measuring Circuit, With Circuit Diagram [2]

Results and Discussions: The voltage and power variations with respect to frequency are shown in Fig. 3. It is observed that one peak is obtained at 8 Hz which is the natural frequency of the shaker and the other peak is obtained at16 Hz which is the natural frequency of the beam.

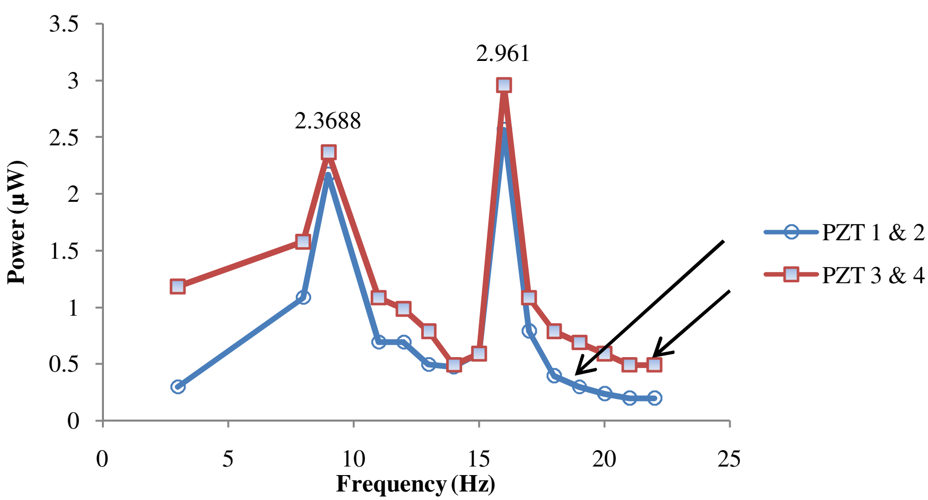

Fig. 3, Power vs Frequency plot for a single PZT

It was observed that peak power in the case of PZT patches 1 and 2 are comparatively less than that of PZT patches 3 and 4. This is because the PZT patches 3 and 4 were located near to the fixity point and thus the corresponding strains produced were higher resulting in higher voltage. It was also observed that PZT patches 1 and 2 have same strain values, thus same voltage and power when connected in single. It is the same with PZT patches 3 and 4 also i.e., they give same values of voltage and power.

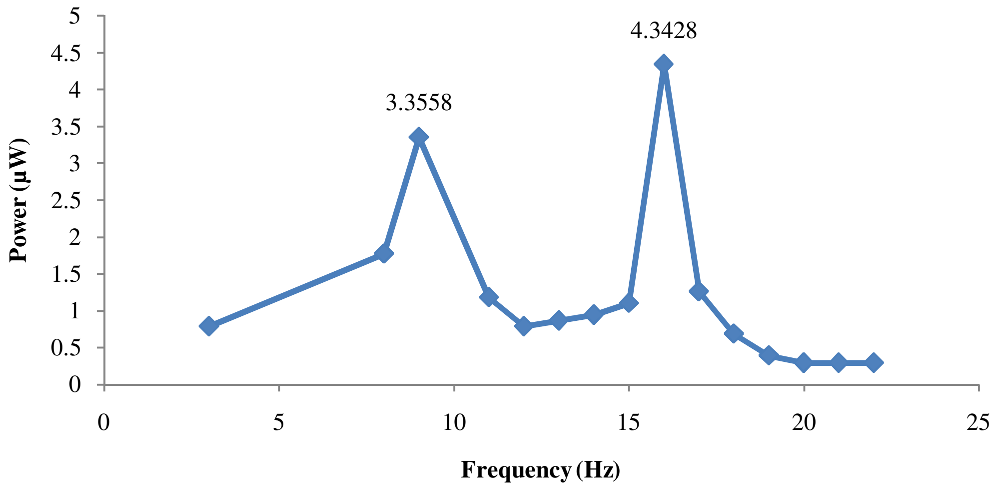

Fig. 4, Power Vs Frequency plot for a PZT's connected in parallel

Fig. 4, shows the plot when all four PZT patches were connected in parallel. It can be observed that the peak power obtained gets enhanced when all the PZT's are connected in parallel

3. CONCLUSIONS

1. The maximum peak power obtained when the PZT patches were connected in single was 2.96 µW at a frequency of 16 Hz, which is the natural frequency of main structure.
2. The maximum peak power obtained at a frequency of 16 Hz when all the PZT patches were connected in parallel was 4.34 µW i.e., it was about 8 times the peak power obtained as per the model proposed by Kaur and Bhalla [2].
3. By using the above generated power, LED's can be run which consume power in micro-watt range.

REFERENCES

[1] Aktan, A.E., Catbas, F. N., Grimmelsman, K.A. and Tsikos, C. J. *Issues in Infrastucture Health Monitoring for Management*. Journal of Engineering Mechanics 2000; ASCE, Vol. 126, No. 7, pp 711-724.

[2] Kaur, N. and Bhalla, S. *Feasibility of Energy Harvesting from Thin Piezo Patches via Axial Strain (d31) Actuation Mode.* Journal of Civil Structural Health Monitoring 2014 ; Vol. 4, No. 1, pp. 1-15.