EXPERIMENT 9
PIEZOELECTRIC ENERGY HARVESTING AND STRUCTURAL HEALTH MONITORING USING THIN SURFACE BONDED PZT PATCHES

OBJECTIVES

This simulation based experiment is designed to teach the concept of piezoelectric energy harvesting through a combination of animation and the analytical model developed by Kaur and Bhalla (2014, 2015). The basic idea is to harvest vibration energy using thin surface bonded piezoelectric ceramic (PZT) patches embedded in a bridge and to use the generated energy for structural health monitoring (SHM).

OVERVIEW

This simulation experiment is based on the basic analytical model and experimental study involving surface bonded PZT patches operating in the d_{31}-mode for energy harvesting covered in the doctoral thesis of Dr. Naveet Kaur (http://web.iitd.ac.in/~sbhalla/thesispdf/naveet.pdf). The d_{31}-mode is explored for the possibility of energy harvesting from the PZT patch owing to its well established suitability for SHM, by means of either the global vibrations or the local vibrations based EMI technique. The principle of integrated SHM and energy harvesting is illustrated below.

The structure is assumed to be operating in two states: *idle* state and *SHM* state. During the *idle* state (when SHM is not being performed), the PZT patches will harvest the energy and store it in an appropriate storage device, such as a battery or a capacitor. In the *SHM* state, the stored energy will be utilized for the SHM of the host structure by the same PZT patch, either in the global mode (standard vibration techniques) or the local mode (EMI technique) or both. It is assumed that the total duration of the *SHM* state will be very small as compared to the *idle* state. In this experiment, the voltage and the power generated by a PZT patch surface bonded in the d_{31}-mode on a bridge beam are measured experimentally.

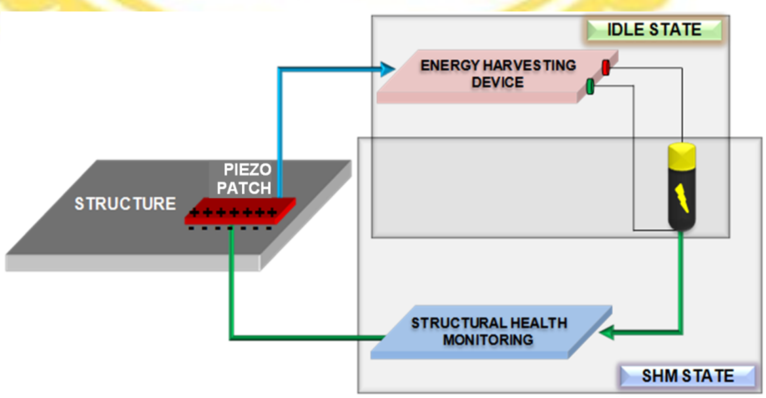
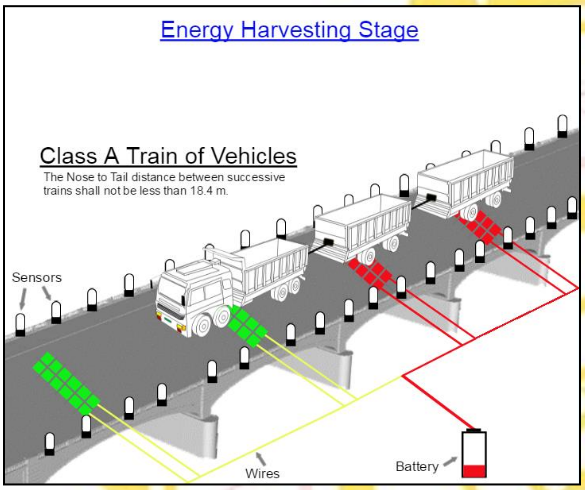


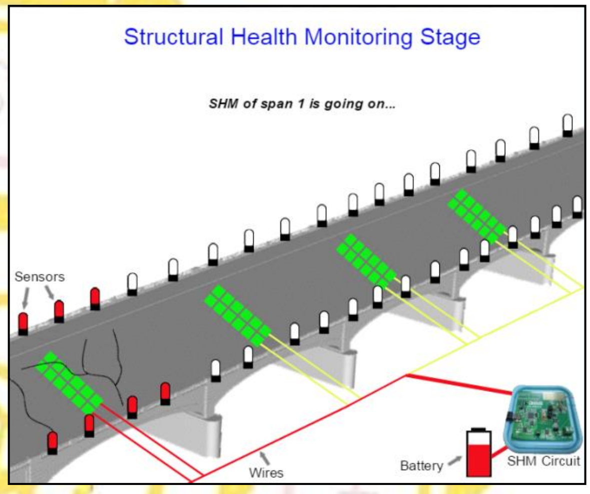
Fig. 1 Principle of integrated SHM and energy harvesting

EXPERIMENTAL METHODOLOGY

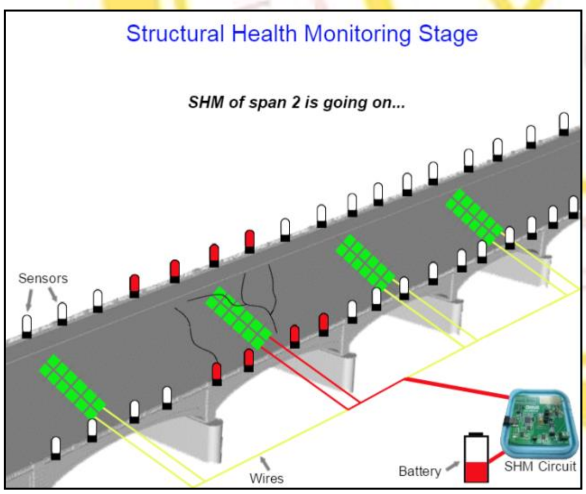
This simulation experiment covers three setups: Class A train of vehicles, Class B train of vehicles and Class AA (tracked and wheeled) train of vehicles (Class 70 R). A bridge is considered on which four sets of PZT patches are embedded. Each set contains 12 PZT patches. Hence in overall, the bridge has 48 sensors installed on it. The bridge has four spans. Initially in energy harvesting/ *idle* state, each set of sensors are connected to the battery through wires. The user can choose the vehicle class (A or B or AA) to pass over the bridge. As the vehicle moves, the mechanical vibrations in the bridge result in generation of charge across the PZT patches. The generated energy is stored inside a battery. In *SHM* state, the SHM device (AD5933) is attached to the damaged span and the fully charged battery for acquisition of signatures of the PT patches. The energy stored inside the battery is used for SHM of each damaged span.



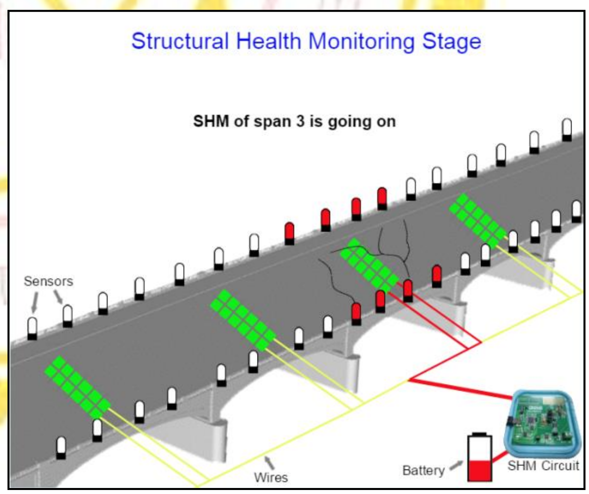
(a)



(b)



(c)



(d)

Fig. 2 (a) Energy harvesting stage for Class A train of vehicles (b) SHM of damaged span 1 (c) SHM of damaged span 2 (d) SHM of damaged span 3

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By clicking the appropriate links, the user can download the signatures corresponding to the baseline (undamaged) and damaged states. To statistically quantify damage, compute root mean square deviation (RMSD) in conductance by following equation directly in MS excel:

$$RMSD(\%) = \sqrt{\frac{\sum_{i=1}^{n}(G_i^1 - G_i^0)^2}{\sum_{i=1}^{n}(G_i^0)^2}} \times 100 \qquad (1)$$

where

G_i^0 = Baseline conductance value at i^{th} frequency.

G_i^1 = Conductance value after damage at i^{th} frequency.

n = No. of frequency data points

As an exercise, the user may plot a histogram of RMSD for the various damaged states, note the observations and draw conclusions.

REFERENCES

1. Kaur, N. and Bhalla, S. (2014), "Feasibility of Energy Harvesting from Thin Piezo Patches via Axial Strain (d_{31}) Actuation Mode", Journal of Civil Structural Health Monitoring, Vol. 4, No. 1 (Feb), pp. 1-15, DOI: 10.1007/s13349-013-0048-1.

2. Kaur, N. and Bhalla, S. (2015), "Combined Energy Harvesting and Structural Health Monitoring Potential of Embedded Piezo-Concrete Vibration Sensors", Journal of Energy Engineering, ASCE, Vol. 141, No 4 (Dec), pp. D4014001 (1-18).

3. Literature on piezoelectric sensors: **http://ssdl.iitd.ac.in/vssdl/piezo.pdf**

4. Kaur, N. (2015), "Integrated Structural Health Monitoring and Energy Harvesting Potential of Adhesively Bonded Thin Piezo Patches Operating in d_{31} Mode", Ph. D Thesis, Department of Civil Engineering, IIT Delhi (http://web.iitd.ac.in/~sbhalla/thesispdf/naveet.pdf)