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Design and Implementation of a Piezoelectric Energy Harvesting System Embedded in a Composite Sandwich Panel

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Summary:

Piezoelectric energy harvesting (PEH) appears as a prominent field, as it helps to provide enough energy to run small electronics or MEMS. Contemporary patents on PEH systems for aerospace applications, mainly focus on different design geometries or location of PEH on the host structure. In this study a novel combination of piezoelectric harvesters and composite panels are proposed. Series of piezoelectric harvesters are embedded into the cell structure of a composite sandwich panel. The system is expected to provide enough power to run structural health monitoring sensors of an aircraft.

Keywords: Piezoelectric energy harvesting (PEH), Smart materials, Composite sandwich structures, Aerospace.

Background, Motivation and Objective

Almost all type of systems, whether electronic or mechanical, are subjected to either electrical or mechanical inputs such as voltage, current force, motion and vibration, etc. Systems such as aeronautical vehicles, suffer mechanical vibrations with various frequencies. This work proposes a novel method for harvesting ambient mechanical energy with the help of piezoelectric energy harvesters embedded into the cells of a composite sandwich panel, which is a widely used constructing material in aerospace applications. Since the PEH system is shielded by a closed envelope, it is less prone to adverse environmental effects such as fatigue or corrosion. Another advantage is that the system's power output can be closely monitored to detect the changes in mechanical response, by which the system becomes its own sensor. Similar studies have been put forward to detect cracks with piezo layers [1]. As a result of multiple PEH existing on system, broadband energy absorption is possible, when each harvester is purposefully manufactured to be sensitive to resonant frequencies. Thus, the proposed method has a great potential to become the primary power source for aerospace sensor applications.

The objective of this study is to develop new type of embedded energy harvesters to be utilized in composite sandwich panels. Computational studies are carried out using ANSYS APDL [2]. A physical model will be built to conduct experimental studies. Results generated by ANSYS and those obtained by experiments are compared. Parametric studies are conducted to give the optimum power output.

Description of the System

The system (see Fig.1) is a combination of sandwich structure and piezoelectric energy harvesters. Sandwich structures are made out of various materials such as aluminum, carbon and glass fibers etc. Various harvester geometries were developed to be sensitive to different orientation of vibration. Hence, it can be different from what is shown in Fig.1. Moreover, the harvesters can be tuned for ambient frequencies by changing the beam length and tip mass. Detailed diagram of working principle is shown in (see Fig. 2.).

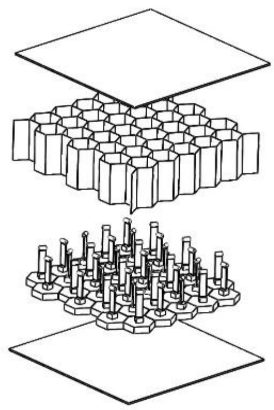

Fig. 1. Exploded view of the system

While the system is shaken by environmental vibrations, a phase difference occurs between

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the movement of sandwich panel and harvester tip masses. This difference is then harvested by the newly developed PEH and results in an electrical energy.

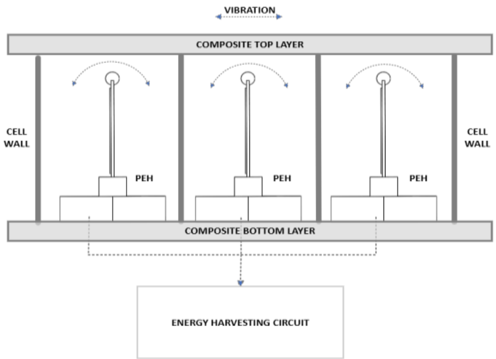
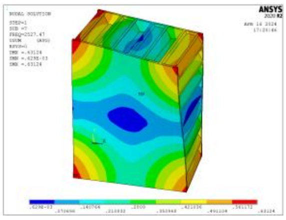


Fig. 2. 2D diagram & working principle

Results

1. Modal shapes of Sandwich Panel

First study is to simulate the physical elements under working condition. For the sake of repeatability and fastness of the simulation, an ANSYS APDL code was developed that can virtually create any sandwich panel with arbitrarily varying dimensions. Aluminum honeycomb sandwich panel with specified dimensions (30x40x16 mm) is parametrically created by the code. First four mode shapes & modal frequencies of the mentioned panel are computed and depicted below in (see Fig. 3.).



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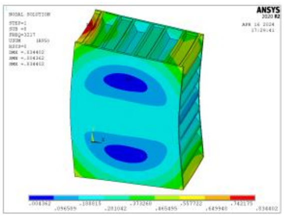

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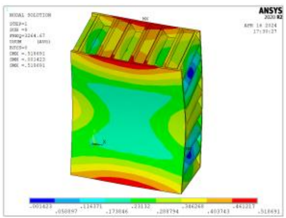

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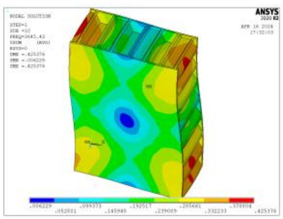
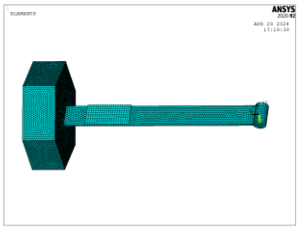


(d)

Fig. 3. Modal analysis of a 30x40x16 aluminum sandwich panel (first 4 modes respectively, a)2527.47Hz, b)3217.00Hz, c)3264.67Hz, d)3645.43Hz)

2. Single PEH modal and harmonic analysis

A single piezoelectric unimorph energy harvester of the newly developed PEH system was modelled (see Fig. 4a.). Node displacements at dominant mode was found using modal analysis (see Fig. 4b.) and nodes with highest electrical potential can be seen as red on top of the piezoelectric layer (see Fig. 4c.). Harmonic analysis between 0-2 kHz ramped input, of the PEH shows a peak in electric potential (see Fig. 4d.) when the system is excited at the base (hexagonal body) with its natural frequency (1472 Hz).



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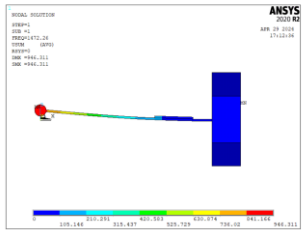

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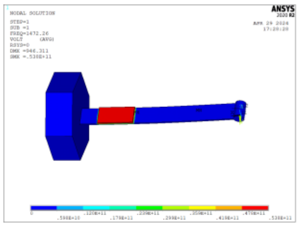

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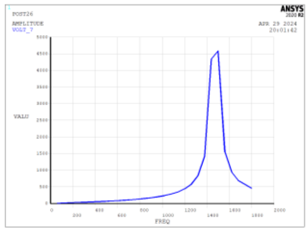

(d)

Fig. 4.Harmonic analysis of a dimensionally scaled piezo harvester a)Elemental view of single PEH, b)First mode displacements, c)Electric potential, d)Harmonic voltage response

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