



CHARACTERIZATION OF PIEZOELECTRIC COMPOSITE MATERIALS AS A SENSOR, ACTUATOR AND POWER HARVESTER FOR SMART JOINT / SMART STRUCTURE APPLICATIONS

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ABSTRACT

Piezoelectric materials have the ability to provide a desired transformation from mechanical to electrical energy and also from electrical to mechanical energy. When a mechanical force is applied to the piezoelectric material an electrical voltage is generated and even vice versa is also possible i.e. when an electrical voltage is applied to the piezoelectric material, it gets strained/ deformed. Owing to these characteristic piezoelectric materials can be used as a sensor, actuator and a power generator.

An adhesively bonded smart joint can detect stresses, control embedded functional elements, reduce stress concentration, and even self-heal the composite joint. The function of the Piezoelectric material in the adhesively bonded smart joint is threefold: (i) to act as a sensor for detecting the dynamic forces acting on the smart joint, (ii) to act as an actuator to provide a counter balancing force to the loads on the smart joint, and (iii) to act as an energy harvester element for providing electrical power to the actuator and to absorb partial mechanical energy by transferring it into electrical charges. The main aim of this study is to explore the capability of the MFC to detect the forces acting on the system as a sensor; and its capability to provide a counter-balancing force to the externally applied forces acting on the system by actuation thereby to reduce or nullify the imposed externally excited forces; which may eventually reduce the imposed stresses on to the structures. The piezoelectric materials that we used for our experiments are Macro fiber composite (MFC) and Quick pack (QP).

A series of experiments have been performed in this study to investigate the above mentioned characteristics of the MFC and QP at various range of operating conditions. A cantilever beam configuration was used for these set of experiments. In the first set of experiment the sensing capability of MFC and QP was investigated at various frequencies and amplitudes of the vibrations. A TA Instruments 2980 Dynamic Mechanical Analyzer (DMA) was used to provide controlled frequency and amplitude of vibration.

The frequency and amplitude values are varied from 2 Hz to 60 Hz and from 10 μ m to 300 μ m, respectively. The corresponding output voltage values of the MFC & QP were recorded in the computer through a DAQ interface. The MFC output as the function of a vibration with 40 μ m amplitude and 15Hz frequency is plotted in Fig. 1. Even at relatively small displacement values of microns level, the MFC and QP's output response is large enough to be detected without the complicated pre-amplification/noise-reduction treatment. The plot also illustrates that MFC has a very good dynamic frequency response, which will be suitable for high frequency dynamic loading monitoring. The Voltage vs. Displacement amplitude plots of the MFC

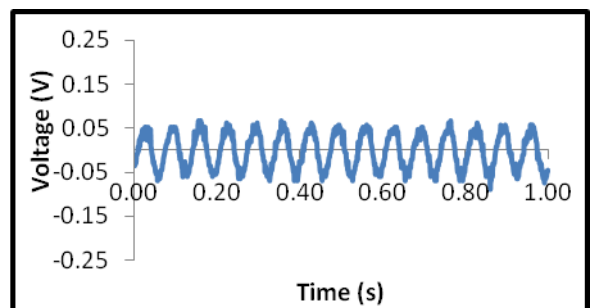


Figure 1: MFC Voltage response at 40 μ m amplitude and 15Hz Frequency

and QP show the linear behavior for the frequencies ranged from 0 to 60 Hz. The Plots in the figure 2 &3 illustrates voltage vs. displacement amplitude at 5Hz frequency.

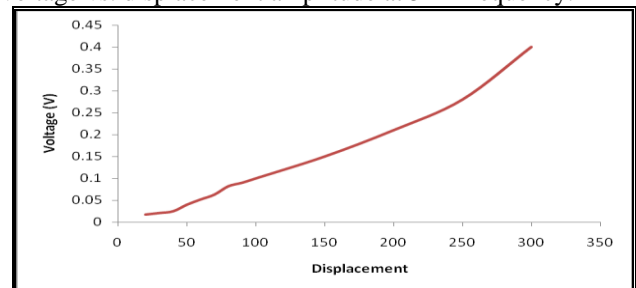


Figure 2: Voltage vs. Displacement amplitude at 5 Hz frequency for MFC

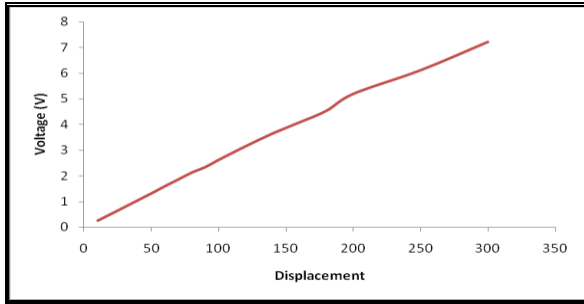


Figure 3: Voltage vs. Displacement amplitude at 5 Hz frequency for Quick Pack

The linear behavior of voltage output versus the displacement amplitude indicates that MFC and QP are good sensors to detect the dynamic loading conditions.

The second set of experiments is performed to explore the actuation capabilities of the piezoelectric composites i.e. its capability to produce the force or stress. An input DC voltage (5V to 30 V) was imposed on to the MFC & QP’s cantilever beam configuration and corresponding stress/force produced were recorded using the DMA machine. The plots in the figure 4 & 5 illustrate the capability of the MFC and QP to generate force.

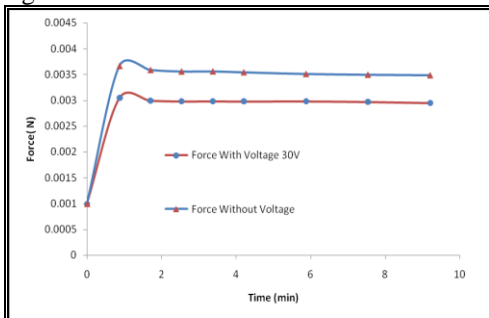


Figure 4: DMA Force changes with 30V input DC voltage at 0.3% strain level for MFC.

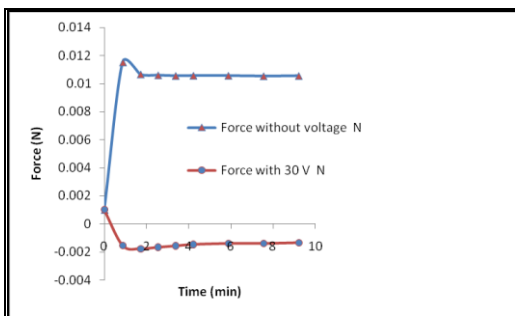


Figure 5: DMA Force changes with 30V input DC voltage at 0.3% strain level for QP.

From the plots of figure 4 & 5 it can be concluded that QP can produce more force when compared to MFC.

Finally an optimized thickness of the top layer of a bimorph piezoelectric cantilever beam is investigated for the various configurations like series benders and parallel benders to achieve maximum actuation capability /tip displacement of the bimorph cantilever beam.

In this study, we investigated the sensing and actuation characteristics of the MFC and QP for smart joint application. The experimental results illustrate that MFC and QP are perfect material as a sensor component to detect various dynamic loadings in composite joint structures. MFC and QP can produce a good output signal even at micron level displacement. As an actuator, MFC and QP can produce considerable amount of counter-balance force, which can be used to reduce the stress concentrations in the smart joint.

ACKNOWLEDGMENTS

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