Energy Harvesting Estimation from the Vibration of a Simply Supported Beam

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Vibration-based energy harvesting has been investigated in this paper with the goal to utilize the ambient vibration energy to power small electronic components by converting vibration energy into electrical energy. A simply supported beam with a bonded high density piezoelectric patch to the surface is considered for the analysis. Analytical model for free vibration analysis is developed by starting with the linear constitutive relations for the beam and the patch. The equation of motion for transverse vibration of the beam is developed by considering the elastic as well as electrical properties in the generalized Hookes law and accordingly a transverse displacement function satisfying the simply supported boundary conditions is used for achieving the modal frequencies. Additionally, an analytical model is developed in order to estimate the energy generated under the action of a harmonic force applied on the surface of the patch. The results of the analytical model are validated using simulation software ANSYS and COMSOL.

The developed analytical model is used to study the behavior of a simply supported harvester with various patch dimensions and locations. This paper throws light on parametric studies of eigen frequencies as well as extracted power corresponding to operating conditions.

NOMENCLATURE

\( D \), Electric charge density displacement matrix;
\( e \), Coupling coefficient for stress-charge form;
\( \epsilon \), Strain;
\( p \), Electric permittivity;
\( E_z \), Electric Field ;
\( M(x, t) \), Moment on the beam at location \( x \), time \( t \);
\( F \), Applied Force;
\( \rho_1 \), Density of the material 1;
\( \rho_2 \), Density of the material 2;
\( E_1 \), Youngs modulus of material 1;
\( E_2 \), Youngs modulus of material 2;
\( l \), Length of the beam;
\( b - a \), Length of patch starting at location \( a \);
\( h_1 \), Height of the beam;
\( h_2 \), Height of the patch;
\( C \), Damping coefficient;
\( K \), Stiffness Matrix;
\( M \), Mass Matrix;
\( F_0 \), Applied force;
\( V_0 \), Voltage across the load resistance;
\( C_p \), Capacitance of the energy harvesting circuit;
\( R \), Load Resistance for energy harvesting circuit;
\( P \), Power Generated.

1. INTRODUCTION

The growing demand for energy in various sectors has motivated researchers to look into alternative forms of energy generation at both large and small scales. Various devices have become miniature with the advancement of nanotechnology. However, this decrease in size is limited due to sizeable batteries. Thus, it is becoming essential to find a way to replace bulky conventional batteries in order to facilitate developing micro-electronic mechanical devices. Roundy et al.\(^1\) has shown a comparison of power scavenging from various energy sources like vibrations, solar, and various chemical batteries.