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PIEZOELECTRIC ENERGY HARVESTING SUSPENSION SYSTEM FOR A HALF CAR MODEL: ANALYTICAL AND EXPERIMENTAL STUDY

by

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Abstract

One of the essential techniques for energy harvesting is the clean energy collection from ambient vibration. Recently, piezoelectric energy harvesting systems became a hot topic and attracted many researchers. This is due to their simple structure, relatively high output power among the other mechanisms (electromagnetic and electrostatic), compatibility with MEMS, and operation in a wide frequency range. The main objective of the current work is to develop a mathematical model to evaluate the potential of harvesting power from the car suspension system. Quarter and half car models with a built-in piezoelectric stack were modeled mathematically using Laplace transformation and simulated using MATLAB/Simulink. The piezoelectric stack was installed in series with the suspension spring to maintain the performance of the original suspension system in ride quality and comfortability. The harvested voltage and power were tested in both time and frequency domain approaches. The results from a quarter car model showed that, the maximum generated voltage and power under harmonic excitation with an acceleration amplitude of 0.5 g and frequency of 1.46 Hz were 19.11 V and 36.74 mW, respectively. By comparing the quarter car model with a half car model, the results illustrated that the output voltage and power of the half car models were increased to 33.56 V and 56.35 mW (75.6 % and 53.4 %), respectively. Furthermore, the quarter and half car models were subjected to random excitation and tested under three different road classes (A, C, and H). The findings confirmed that the harvested voltage and power were increased with the road roughness levels and car velocity. From very smooth to very rough road levels, the harvested power was increased by 434 mW for quarter car model and 537 mW for half car model. The influence of the different parameters of the piezoelectric stack (number of stack layers and area to thickness) and car suspension (sprung and unsprung stiffness, damping coefficients, and masses) were examined for half car model subjected to harmonic excitation. Also, the effect of road amplitude unevenness was considered. The analytical results of the quarter car model were verified with the experimental test under harmonic excitation. The results exhibited good agreement with the analytical results at different excitation frequencies (0 – 25 Hz). A significant contribution of our work is developing a half car model with a built-in piezoelectric stack. The findings of this work illustrated that there is a significant potential for harvesting energy from the car suspension system. This energy could be utilized in different ways. The study will encourage automobile manufacturers to develop and produce cars that are equipped with multiple energy harvesters to make the dissipated energy available for utilization. Such utilization of regenerated energy improves the fuel efficiency and the economy significantly.

Keywords: Energy harvesting, piezoelectric stack method, car suspension system, half car model, analytical modelling, experimental analysis.