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Experimental Characterisation of Off-the-shelf Vibration Energy Scavengers

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Abstract

The behaviour of off-the-shelf commercial energy scavengers is difficult to model and to correlate to the requirements of the foreseen applications due to lack of information about their electromechanical properties. Experimental set-ups are thus developed with the aim of assessing Young's modules and optimal resistive loads. The obtained results are presented in terms of power vs. applied resistive loads.

1 Introduction

In order to be able to properly design vibration energy harvesters, their behaviour in terms of dynamics response, electromechanical coupling and charge distribution, has to be accurately studied [1-3]. Some vibration energy scavengers are already commercially available but their usage can be limited due to lack of relevant data on the values of their electromechanical characteristics. This makes the behaviour of commercial scavengers hard to model.

Performance of commercially available piezoelectric vibration energy scavengers can then be verified only with results obtained from developed experimental set-ups.

Repetitive bending tests on a tensile machine allow determining the equivalent bending stiffness of the used scavengers. Dynamics tests make then possible obtaining results in terms of power vs. applied resistive loads.

The respective experimental set-ups are described and their suitability to be used for the foreseen applications is proven. This will make possible, in the following phase of the work, to develop custom vibration energy harvesting devices with optimized performances in terms of power outputs considering various constraints.

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2. Experimental assessment of commercial energy scavenger properties

The available data sheets on the electro-mechanical characteristics of MIDE scavengers [4] allow evidencing a very intricate structure composed by nine alternating layers of: woven fibreglass reinforced epoxy laminate sheets, epoxy adhesive films, layers of piezoelectric materials and copper clad polyimide laminates (as seen by using an Olympus SZX16 stereomicroscope (Figure 1).

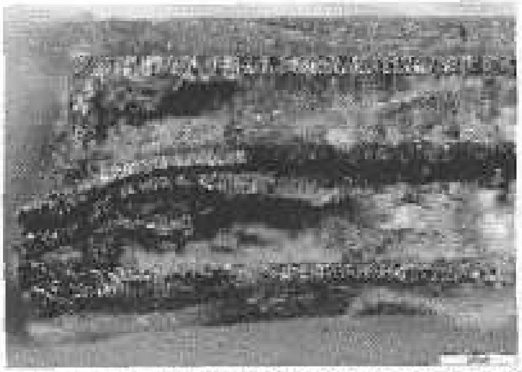

Figure 1: MIDE energy scavenger stereomicroscope cross-section

2.2. Set-up for Dynamics Analysis

The set-up is shown in Figure 2 and is based on a Schenk AG electrodynamics shaker of the type Vibroexciter 41 with the corresponding signal generator and power amplifier of the type Vibropower 41. Excitation acceleration is measured via a Schenk AS-020 piezoelectric accelerometer with a sensitivity of 10.2 mV/(m/s^2).

The vibration of the free end of the cantilever is measured by using a MetroLaser VibroMet 500V Doppler vibrometer. The measurement range of this device goes from 5 mm/s to 800 mm/s.

Variable resistive loads have then been connected to the scavenger, while the whole set-up is interfaced to a LabView v.8.5 based National Instruments DAQ system.

In a preliminary usage of the set-up, the MIDE vibration energy harvesters V21b and V25w, each with 3 different tip masses and numerous resistive loads, were tested in the dynamics range of ± 3 Hz around the first resonant frequency. The condition of having a pure resistive load connected to the electrodes is not necessarily the most realistic one, since often electric loads consist of rechargeable batteries and other capacitive loads. However, it is simple and useful not only for estimating the resulting power, but also for giving the designer more intuition about the system [5].

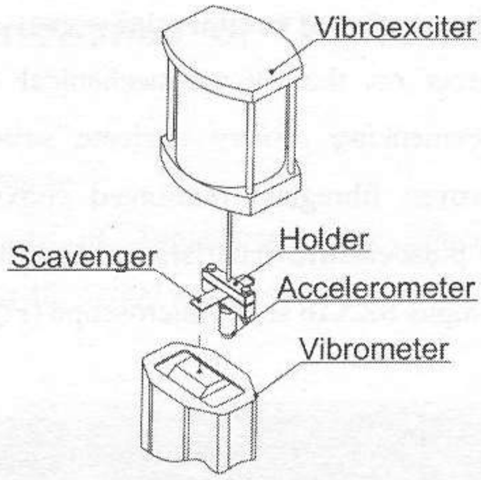

Figure 2: Experimental set-up for dynamics measurements.

The obtained output powers are shown in Figure 3 while the experiments resulted in expected performances. The V25w device with larger piezoelectric material volume outputs more power; with comparable tip masses, the resulting power levels are about twice as large as those obtained on the V21b device. Optimal resistances for the employed loading conditions are in the range of 20 - 60 kΩ.

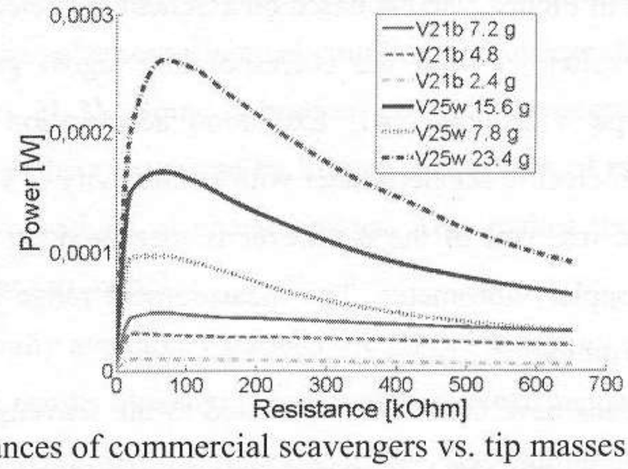

Figure 3: Performances of commercial scavengers vs. tip masses and resistive loads.

It was hence proven that the developed experimental set-ups are suited to characterize the performances of various scavenger configurations. By employing recently developed models of the electromechanical behaviour of piezoelectric vibration energy scavengers by Roundy and Wright [5] and Erturk and Inman [2], it will thus be possible not only to correlate the theoretically predicted and experimentally assessed performances of the scavengers, but also to perform the optimization of the performances so as to maximize the output powers.

2.1. Determination of Bending Stiffness

Based on the displayed structure of above mentioned scavengers, it is obvious that assessing their performances will be possible only if an equivalent elastic modulus, and thus the respective bending stiffness, is experimentally evaluated.

For this purpose a campaign of repetitive bending measurements on a VEB Thüringer Industriewerk Rauenstein tensile machine has been set-up. Tests were performed on V21b and V25w type MIDE vibration energy scavengers simply supported on a suitable holder. Load F was applied via a suitable loading system mounted on the tensile machine, while the applied load was measured by using a Z6FD1 HBM cell. The deflections w of the scavenger was measured via a HBM displacement transducer type W1T3. In the considered limited range of displacements, the measured load vs. deflection data showed a perfectly linear behaviour.

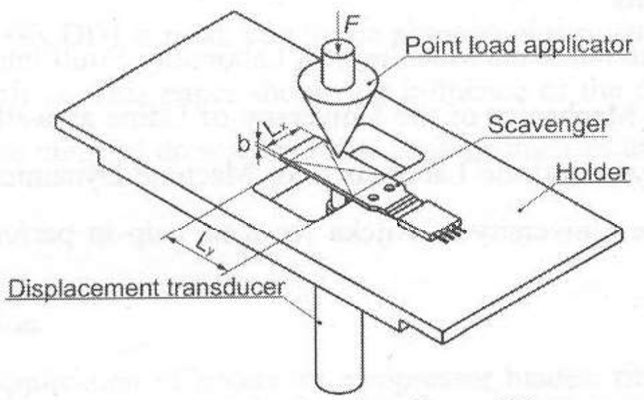

Figure 2: Experimental set-up for equivalent bending stiffness tests.

Plate theory, i.e. the expression which correlates the modulus of elasticity E of a simply supported plate to its dimensions (thickness b and width L_x) as well as with the deflection w for a given centred point load F, where k_w is a geometrical coefficient which depends on the L_y/L_x ratio, [6] is then used to obtain the value of Young's modulus:

$$E = \frac{12FL_x^2}{k_w b^3 w} \tag{1}$$

The obtained values of the equivalent modulus of elasticity of the scavengers are then, respectively, 3.24 GPa for the V25w and 4.22 GPa for the V21b scavenger (the difference being probably attributable to the different thicknesses of the various layers that make up the device).

3. Conclusion and outlook

The developed experimental set-ups proved to be suitable for assessing the significant parameters and the dynamics performances of the studied devices.

The tools needed to optimize the output power of piezoelectric vibration energy scavengers have hence been successfully developed. In the next phase of the work, they will be used, together with optimization algorithms and electromechanical coupling relations, to upgrade the performances of the studied class of energy scavenger devices for wireless sensor networks. In this framework, the algorithms for the optimization of the geometric parameters of the scavengers have already been developed by using the non linear Sequential Quadratic Programming (SQL) based optimization toolbox of the MATLAB software package.

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References:

[1] Sh. Priya and D. J. Inman (ed.), Energy Harvesting Technologies, Springer, New York, 2009.

[2] A. Erturk and D. J. Inman, "An experimentally validated bimorph cantilever model for piezoelectric energy harvesting from base excitation", *Smart Mater. & Struct.*, vol. 18, no. 2, paper 025009, 2009.

[3] A. Sodano, D. J. Inman and G. Park, "Comparison of Piezoelectric Energy Harvesting Devices for Recharging Batteries", *J. Int. Mat. Sys. & Struc.*, vol. 16, pp. 799-807, 2005.

[4] www.mide.com/products/volture/volture_catalog.php

[5] S. Roundy and P. K. Wright, "A piezoelectric vibration based generator for wireless electronics," *Smart Mat. & Struct.*, vol. 13, pp. 1131-1142, 2004.

[6] K. Stiglat and H. Wippel, *Platten*, W. Ernst, Berlin, 1973.