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An experimental study on relation of nonlinearity and transduction coefficient of an electromagnetic energy harvester

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ABSTRACT – This paper brings about the study of relationship between the degree of nonlinearity and transduction coefficient of an electromagnetic energy harvesting device. The device that exhibit softening nonlinear characteristic is used to perform dynamic test and the transduction coefficient, $\boldsymbol{K}$ across the resonance frequency range is obtained through the relationship of $\boldsymbol{K}=\frac{\boldsymbol{V}}{\boldsymbol{v}}$ where $\boldsymbol{V}$ is the voltage generated per unit of relative velocity, $\boldsymbol{v}$. Experimental results show that the performance of the transduction coefficient increases as the degree of nonlinearity increases.

1. INTRODUCTION

In an electromagnetic energy harvesting device, the energy conversion performance is greatly reliant on the transduction coefficient, K of the system. According to Challa et al. [1], transduction coefficient defines the relation of mechanical and electrical domains where $K=\frac{V}{v}$ having units of V s m^{-1} with V representing the voltage generated per unit of relative velocity, v. Transduction coefficient is claimed by [1] to have high importance on the coupling strength of an electromagnetic energy harvesting device.

In previous research [1-3], role of linear coupling for electromagnetic energy harvesting device has been studied analytically and experimentally. Sneller and Mann [4] on the other hand studied the performance of nonlinear coupling across the coil axis. In another research, Owens and Mann [5] made comparison of linear and nonlinear coupling with their findings stating that nonlinear coupling performs better under certain circumstances.

However, the relation between coupling strength and degree of nonlinearity is yet to be studied and therefore, in this research, a relation between transduction coefficient and degree of nonlinearity will be studied. Next, the results of transduction coefficient will be used in near future time to draw a relationship between coupling strength and degree of nonlinearity which will not be discussed further in this paper at the moment.

2. METHODOLOGY

An experimental study is carried out in to draw a relationship between degree of nonlinearity and transduction coefficient of an electromagnetic energy harvester device. This device is designed to exhibit the characteristic of a softening nonlinearity.

2.1 *Experiment parameter and setup*

The nonlinear electromagnetic energy harvesting device is set to parameters listed in Table 1 to undergo the experiment which is known as dynamic test.

Table 1 List of parameter values.

Properties	**Data**
Coil turn, diameter (mm)	3500, 0.15
Input displacement (mm)	1.0
Length of beam (mm)	50

Figure 1 shows the experimental setup for dynamic test in this research. The device is placed on a LDS V406 shaker and two accelerometer is used during the test, one on the base of the device in order to control the input displacement and another one on the beam of the device to capture the acceleration of the beam across the frequency range of 10Hz to 40Hz. The data from accelerometer is then recorded by a Data Physic analyser. At the same time, an oscilloscope is used to gather the voltage generated from the coil. The nonlinearity of the device is adjusted through magnet gaps of 2mm, 3mm and 8mm representing the decrease in nonlinearity respectively.

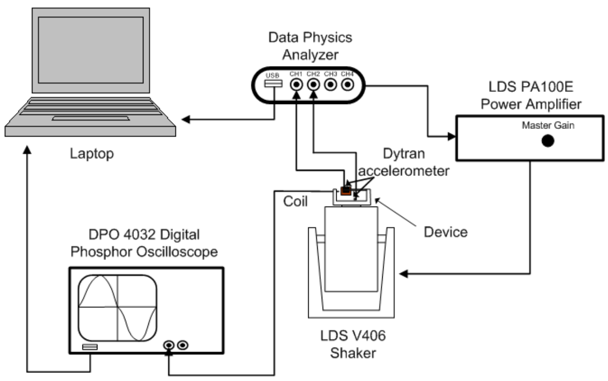

Figure 1 Schematic of dynamic test setup.

3. RESULTS AND DISCUSSION

Transduction coefficient is calculated from the relationship of $K = \frac{V}{v}$ where V is the voltage generated per unit of relative velocity, v across the resonance frequency range of 10Hz to 40Hz. Figure 2 shows graph of transduction coefficient versus frequency for a linear electromagnetic energy harvesting device with an average value of about 3.2 V s m^{-1}.

When a strong nonlinear is applied to the device, that is when the magnet gap is set at 2mm, Figure 3 illustrates the value of K to be about 4.5 V s m^{-1} to 5 V s m^{-1} which is much higher than the linear one. This would justify that a nonlinear electromagnetic energy harvester possess a better K than the linear one. Moving across the decreasing nonlinearity, the value of K decreases to about 3.5 V s m^{-1} and 3.2 V s m^{-1} for 3mm and 8mm magnet gap respectively as shown in Figure 4 and Figure 5.

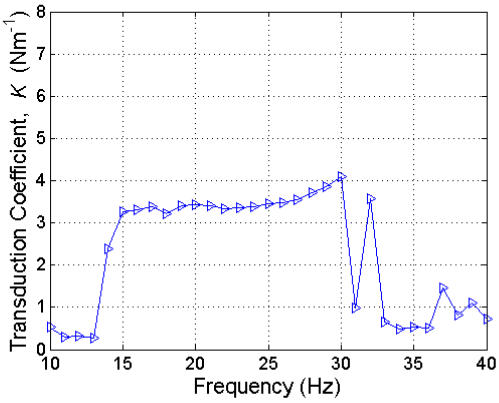

Figure 2 Linear transduction coefficient.

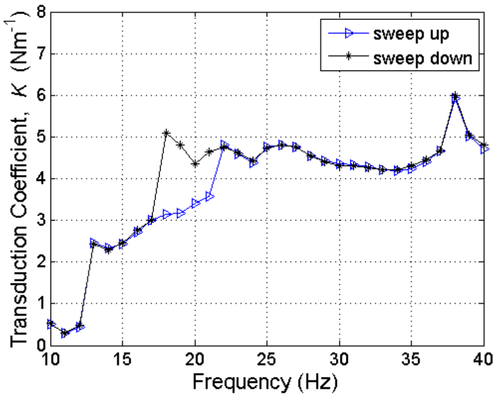

Figure 3 Nonlinear (2mm) transduction coefficient.

4. CONCLUSIONS

An experimental study has been performed to investigate the relation of nonlinearity and transduction coefficient. The results of the experimental study illustrates that the transduction coefficient of a nonlinear electromagnetic energy harvesting device is better than the linear one thus exhibiting that the energy conversion performance of a nonlinear electromagnetic energy harvesting device perform better than the linear harvester. In terms of nonlinearity, the performance of transduction coefficient increases with the degree of nonlinearity. This finding would be beneficial in studying the relation of coupling strength with degree of nonlinearity in near future time.

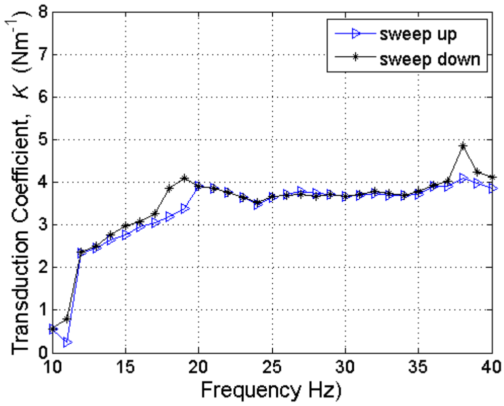

Figure 4 Nonlinear (3mm) transduction coefficient.

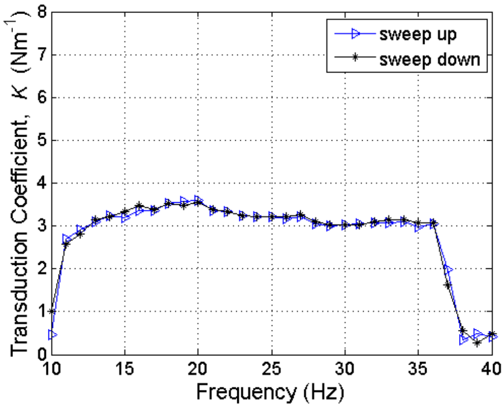

Figure 5 Nonlinear (8mm) transduction coefficient.

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