Nonlinear reduced order modelling of a buckled piezoelectric beam for energy harvesting

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Abstract. As a potential solution to continuous and convenient energy supply, piezoelectric energy harvesting from ambient vibrations has attracted extensive research interest. Particularly, the utilization of nonlinear vibration behaviours to achieve better performance received more and more attention in recent years [1], e.g., the buckling and post-buckling responses [2]. This also motivated the study of efficient computational methods for the design and analysis of nonlinear energy harvesters, where the reduced order modelling technique [3] is an attractive one. In the present study, a reduced order model (ROM) of a typical buckled beam configuration for energy harvesting is constructed in the non-intrusive way [4,5], i.e., using the data from a commercial finite element software, hence the developed method is applicable to practical complex configurations. The validation results will show that the developed ROM predicts well the critical buckling load and the post-buckling responses and is able to give accurate computation of output power for given ambient vibrations.

Introduction

Piezoelectric energy harvesting from ambient vibrations has attracted extensive research interest as a potential solution to continuous and convenient energy supply for consumer electronics, wireless sensors, portable health monitors, etc. Earlier studies were focused on the harvest of vibratory energy around a dominant natural frequency. This linear energy harvester performs well when the ambient vibration is narrow-banded close to the natural frequency but is less efficient when the environmental vibration has a wide frequency spectrum. In recent years, more and more research has been shifted to the utilization of nonlinear vibration behaviours to broaden the effective bandwidth of energy harvesting [1]. One example is to use the buckling responses of the structure [2]. The study of nonlinear energy harvester motivated the development of efficient computational methods for the coupled electro-mechanical analysis of a nonlinear energy harvester, particularly in the design and optimization. The technique of reduced order modelling appears to be an attractive one [3], and the non-intrusive reduced order modelling [4] is noteworthy since it used the data from a commercial finite element software, hence applicable to practical complex configurations.

Results and discussion

In the present study, a typical buckled beam configuration for energy harvesting [2] is considered, as shown in Figure 1. A finite element model of this beam structure has been constructed with Nastran using the shell elements. The reduced order model is being constructed following the approach discussed in [5].

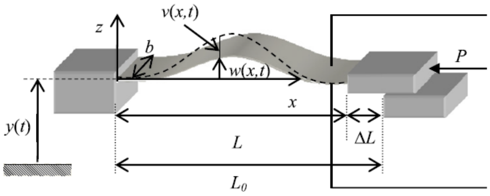

Figure 1: A buckled beam configuration for energy harvesting [2].

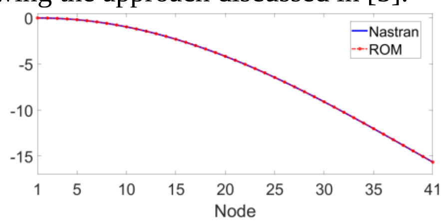

Figure 2. Buckling mode shape of the cantilever beam.

As a preliminary study, a simple cantilever beam was considered, for which a ROM has been constructed. It was found that the ROM predicts very well the critical buckling force (5.01N versus Nastran result of 5.00N) and the buckling mode shape (see Figure 2). The ROM of the buckled beam is expected to give the same good prediction of critical buckling load and further the post-buckling responses, and eventually accurate computation of the output power.

References

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