Nonlinear restoring force subspace identification of negative stiffness nonlinear oscillators

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Abstract. This paper proposes a time-domain nonlinear subspace identification method to get the nonlinear restoring force of negative stiffness oscillators. Four types of multistable oscillators with rotatable magnets coupling on the cantilever beam are established to exhibit negative stiffness characteristics. The numerical simulation under different noise levels demonstrates that the identified accuracy of polynomial stiffness force coefficients is above 93%. And frequency-swept experiments for different multistable oscillators are conducted under various acceleration levels to get the suitable identification data sets and also construct their restoring force surface. Experimental results verify that the identified results are in good agreement with the measured restoring force surface.

Introduction

In recent years, many negative stiffness structures have been developing to enhance the ability of energy harvesting or vibration control. However, it is hard to get the accurate nonlinear restoring force (NRF) in negative stiffness oscillators for dynamic analysis. Traditional methods of acquiring NRF in negative stiffness nonlinear oscillators, such as analytical theory and direct measurement using dynamometer which is only suitable for ideal conditions. Therefore, reverse modeling based on experimental identification of NRF is necessary. For identification of NRF in typical nonlinear oscillators, the subspace-based identification algorithm has been already used in a variety of structures, including clearance type nonlinearity, impact stiffness in SmallSat spacecraft, contact stiffness in bolted connected solar array structure, etc. It's attractive that this identification technology can be used to identify NRF in negative stiffness oscillators, because of its robustness and high numerical performances. Therefore, this paper will numerically and experimentally investigate the subspace-based identification method for getting the NRF of different negative stiffness oscillators. Moreover, the experimental restoring force surface(RFS), which can truly map the force-velocity-displacement relationship in real vibration structures, will be used in this paper to verify the accuracy of the subspace identification algorithm.

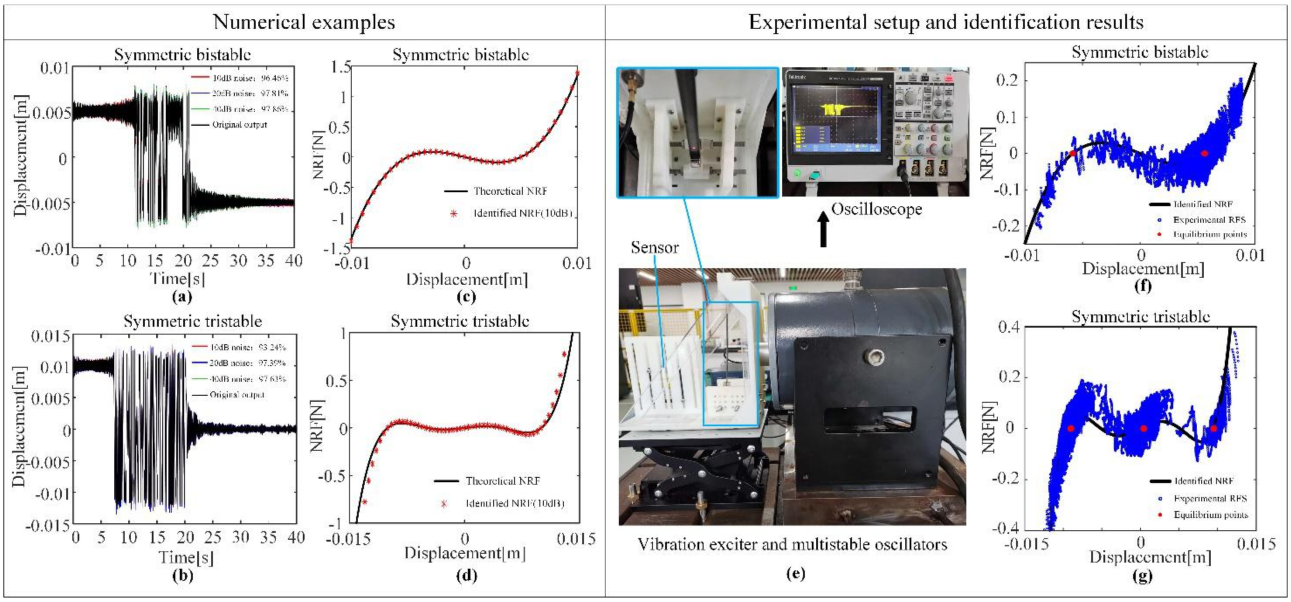

Figure 1: The NRF of negative stiffness nonlinear oscillators: numerical examples, experimental setup and identification results

In this paper, the multistable oscillators (including symmetric, asymmetric bistable and tristable) are realized by coupling cantilever beam with rotatable magnets. Then, the time-domain nonlinear subspace identification method is introduced and the acquisition process of experimental RFS is also given. The numerical simulation under different intensities of White Gaussian noise(40dB, 20dB and 10dB) demonstrates that the identified accuracy of polynomial stiffness force coefficients is at least above 93%. Finally, frequency-swept experiments for different multistable oscillators are conducted under various acceleration levels to get the suitable identification data sets and also construct their RFS. Experimental results verify that the identified results are in good agreement with the measured RFS.

References

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