Numerical study of acoustic radiation forces to contactless excite a microcantilever

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Abstract. An object being ensonified with an acoustic wave experiences some of the wave's momentum, which accounts for an acoustic radiation force. Here, we conduct numerical simulations using the commercial software package COMSOL Multiphysics to determine the vibration response of a silicon microcantilever previously experimentally explored by Huber et al. (2010). In our model, three types of excitations are used to find the three first resonance frequencies of the silicon microcantilever, mode shapes, and the force exerted on the object: boundary loads, acoustic waves and dynamic acoustic radiation forces, are used and compared with Huber's experimental results, which were obtained at 11.2, 72.4, and 204 kHz. The first three first resonance peaks obtained at 11.4 kHz, 72.6 kHz, and 195 kHz, numerically, and in good agreement with Huber's experimental results.

Introduction

The acoustic radiation force (ARF) accounts for the integration of radiation stresses over the surface of an object within an acoustic pressure field. The radiation stresses has two parts, first is the mean excess pressure and second is the Reynolds stresses. The mean excess pressure is a second order parameter, therefore the ARF is of the 2nd and considered as a nonlinear acoustic phenomenon. A dynamic ARF can be produced experimentally by using a pair of ultrasonic transducers with slightly shifted frequencies for interference. Since there is no contact between the object and the sound sources, using the ARF could provide a more reliable means of conducting a non-contact excitation to achieve a full non-contact modal analysis for light and filigree objects [1, 2, 3]. Huber et al. (2006) suggested to conduct a non-contact operational modal analysis of a pipe organ reed using ARF [1]. However, the actual force as exerted experimentally via acoustic radiation remains unknown as yet; the force, however, as is required as quantity for a correct scaling of mode shapes and to allow the reconstruction of the modal mass and stiffness properties of the analysed system.

Results and discussion

In our numerical simulations, boundary loads, acoustic waves, and dynamic acoustic radiation forces were used to excite the microcantilever and validated experimental findings of [2]. Figure 1, A) shows a schematic of the experiment, B) shows the three first resonance frequencies which were obtained numerically by acoustic wave excitation, and the three first resonance frequencies which were obtained experimentally in ref. [2] have been marked up, and C) shows the three first mode shapes which were obtained numerically by acoustic wave excitation.

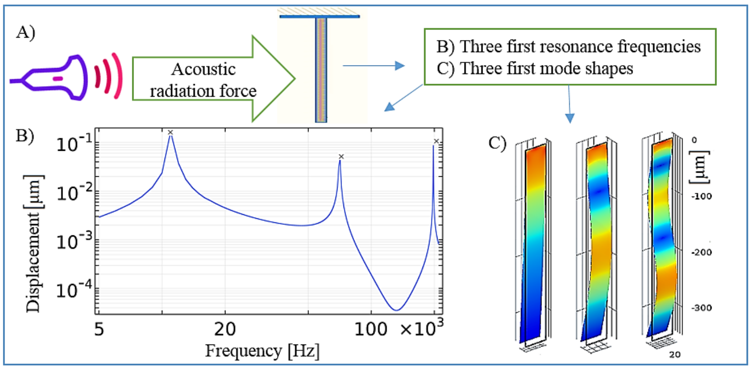

Figure 1: Using ultrasound frequency range to perform modal analysis in audible range by dynamic acoustic radiation force

In the next step, based on the numerical simulation, acoustic radiation pressure will obtain, then, the integration of the radiation pressure will perform to estimate the dynamic acoustic radiation force.

References

[1] Huber T. M. (2006) Noncontact modal analysis of a pipe organ reed using airborne ultrasound stimulated vibrometry. J. Acoust. Soc. Am. 4: 2476-2482.

[2] Huber T. M., Abell D. C., Mellema C. B., Spletzer M., Raman A. (2010) Mode-selective noncontact excitation of microcantilevers and microcantilever arrays in air using the ultrasound radiation force. Appl. Phys. Lett. 97: 21410.

[3] Huber T. M., Beaver J. R., Helps N. M., (2013) Noncontact modal excitation of a classical guitar using ultrasound radiation force, Exp. Tech. 37: 38-46.