Measurement of Minute Stiffness Change by Virtual Cantilever Virtually Coupled with Real Cantilever

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Abstract. In this study, we propose a highly sensitive method to measure the stiffness of a sample using weakly coupled identical cantilevers. We realize a weakly coupled identical cantilevers by making one of the two cantilevers on a computer which numerically calculates the dynamics of the virtual cantilever in real time. Using this system, we measured small change of the stiffness acting on the tip of the other real cantilever from the mode shift. In experiments, the mode shift is identified by the amplitude ratio of the self-excited coupled cantilevers. Changing the gap between the cantilever and the magnet in the static equilibrium state, we measure the change of the amplitude ratio, i.e., sensitivity. Experiments showed that the virtual cantilever can measure minute changes in stiffness high sensitivity accuracy.

Introduction

Much attention has been focused on a method of measuring the mechanical properties of a small substance using a weakly coupled identical cantilevers with high measurement sensitivity. Spletzer et al.[1] developed a method for measuring micro mass using micro-sized coupled cantilevers. Yabuno et al.[2] proposed a method using self- excited coupled cantilevers for the mass measurement in viscous environments. Lin et al.[3] suggested a method for measuring minute stiffness changes using a weakly coupled identical cantilevers, considering the fact that mass and stiffness are physically related via natural frequencies. Besides, Kasai et al.[4] proposed a method for measuring micro mass with higher sensitivity using a measurement method called virtually coupled cantilevers. In general, it is difficult to fabricate two identical cantilevers and to realize the weakly coupling of them. The idea of virtual coupling and virtual cantilever seems a solution to this problem. The displacement of the virtual cantilevers is numerically calculated on a computer in real time. Moreover, the force is applied to the real cantilever based on the coupling effect generated by the numerical calculation. In this study, we measure the minute change in stiffness using a virtual cantilever virtually coupled with a real cantilever.

Results and discussion

In order to realize the weakly coupling stiffness, we apply the displacement to the supporting point of the two cantilevers, which is based on the feedback with respect to the difference between their displacements. Figure 1 shows the change in the amplitude ratio depending on the stiffness corresponding to gap between the real cantilever and the magnet in the static equilibrium state. The proposed method is about 100 times more sensitive than the method based on the natural frequency shift of a resonator.

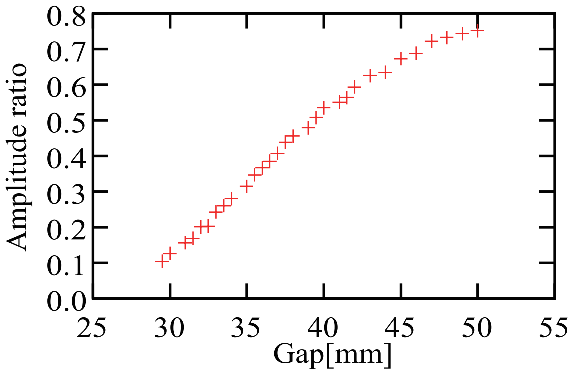

Figure 1: Change of amplitude ratio mode shift depending on the distance between the magnet and the cantilever with magnetic material.

References

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