Proposition of nonlinear sensor-less amplitude control of cantilever for micro-viscometer

Shinpachiro Urasaki[*], Yudai Tanaka[*], and Hiroshi Yabuno [**]
[*]*Graduate School of System and Information Engineering, University of Tsukuba, Tsukuba, Ibaraki, Japan*
[**]*School of Science and Engineering, University of Tsukuba, Tsukuba, Ibaraki, Japan*

Abstract. In this study, we propose an amplitude control method of sensor-less self-excitation for viscometer. Viscosity is an essential and practical parameter to be measured in many industries. While the vibration type viscometer based on forced oscillation does not provide high-sensitive measurement in high-viscosity, the method based on self-excited oscillation can measure high viscosity without deterioration of sensitivity. Further, controlling the amplitude is very important in order to measure the nonlinearity of the viscosity. By the way, sensor-less self-excited oscillation is desired to reduce costs while the production of self-excited oscillation generally requires displacement sensor. In this study, we propose a method which produces the sensor-less self-excited oscillation and control its amplitude of a cantilever beam with a bimorph type piezoelectric device. We produced the sensor-less self-excited oscillation experimentally.

Introduction

Many types of sensor utilizing the self-excited oscillation of the cantilever are proposed for mass sensing, AFM, viscometer and so on [1]. Because the self-excited oscillation [2] can eliminate the viscosity even when the cantilever is immersed to the fluid, it is very suitable for viscometer. Viscosity is an essential rheological parameter, whose linear and nonlinear characteristics are desired to be measured for elucidation of the rheological properties of cells [3]. Whilst its linear characteristic is determined experimentally from the Hopf-bifurcation point, which is changed by the viscosity and feedback gains, the nonlinear characteristic is estimated from the relationship between the change of the Hopf-bifurcation point and the magnitude of the oscillation amplitude and velocity. Hence, in order to produce any value of the oscillation amplitude and velocity, amplitude control for the self-excited oscillation is required. On the other hands, realization of self-excited oscillation without displacement sensor is desired to reduce measurement costs. Although our research group has already realized the sensor-less self-excited oscillation of a cantilever with a bimorph type piezoelectric device [4], the oscillation amplitude is not controlled. Then, our purpose in this paper is controlling the amplitude of sensor-less self-excited oscillation.

Experiment and Conclusion

The construction of the proposed system is shown in Figure 1(a) and (b). Using the electro-mechanical coupling between the cantilever and the bimorph type piezoelectric device, we make the feedback control system to produce the self-excited oscillation. The feedback control system consists of linear terms of the voltage of the piezoelectric device to produce the self-excited oscillation and a nonlinear term to settle the magnitude of the amplitude at any values.

Figure 1(c) shows the time history of the displacement of the cantilever when our prposed method is applied. It is experimentally confirmed that it is possible to derive the critical feedback gains which indicates Hopf-bifurcation point.

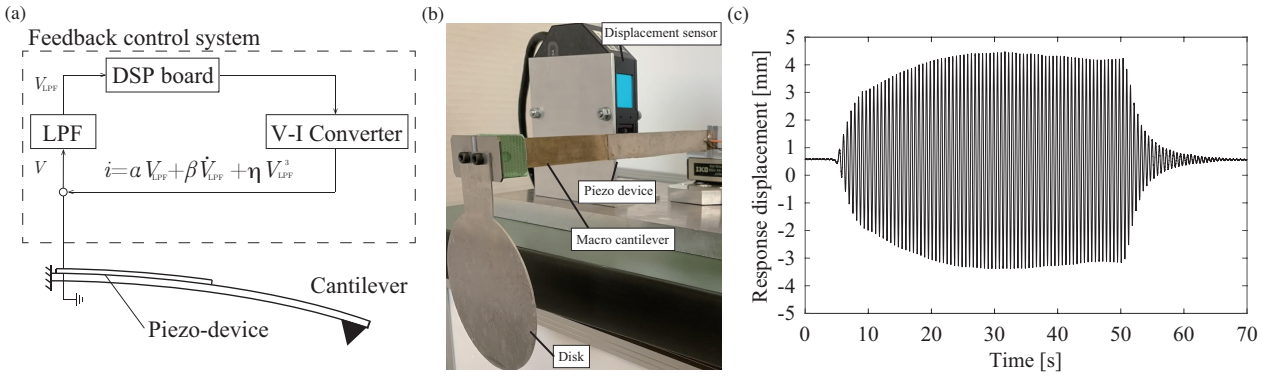

Figure 1: Construction and experimental result of the sensor-less viscometer system. (a) is a model of the proposed system. (b) is view of the proposed system. (c) is time history of response displacement which is measured by the displacement sensor.

References

[1] S. Boskovic *et al.* (2002) Rheological measurements using microcantilevers *Journal of Rheology* **46**: 891 - 899.
[2] J. Mouro *et al.* (2017) Measuring viscosity with nonlinear self-excited microcantilevers *Applied Physics Letter* **111**: 144101.
[3] J. Alcaraz et al. (2003) Microrheology of Human Lung Epithelial Cells Measured by Atomic Force Microscopy *Biophysical Journal* **84**: 2071 - 79.
[4] Y. Tanaka *et al.* (2018) Proposition for sensorless self-excitation by a piezoelectric device *Journal of Sound and Vibration* **419**: 544 - 557.