

Applications of self-excited oscillation and weakly mode coupling to ultrasensitive micro-sensors

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This talk addresses the utilization of self-excitation and weakly coupling for resonators in ultrasensitive sensors. Vibrational sensors are suited for online monitoring because of their fast response and ability to measure instantly and continuously. Also, their miniaturization realizes much higher resolution and sensitivity.

We begin by discussing the sensitivity based on the natural frequency shift of the resonator. For mass and stiffness sensing, the detection method for the natural frequency shift by self-excited oscillation is characterized comparing with that by external excitation. Self-excited oscillation automatically compensates for the viscous damping effects of the environment on the resonators, thus ensuring direct and accurate detection of the natural frequency shift in very high viscosity, where the peak of the frequency response curve is ambiguous or does not exist. Also, the shift of the Hopf bifurcation point causing the self-excited oscillation can be utilized in vibrational viscometers capable of high-viscosity measurement and for the measurement of added mass for an object oscillating in a viscous fluid.

Another method, introduced for ultrasensitive mass sensing, is based on the eigenmode shift in multiple weakly coupled resonators. Also in this system, the self-excitation compensates for the viscous damping effects to enable direct detection of the eigenmode shift. The utilization of eigenmode shift greatly improves the sensitivity for mass sensing based on the natural frequency shift and would overcome the limitations of miniaturization in manufacturing process by introducing new concepts as virtual resonator and virtual coupling.

Bio-sketch of Hiroshi Yabuno



Hiroshi Yabuno received the B.E., M.E., and Dr. Eng. degrees from Keio University, Japan, in 1984, 1986, and 1990, respectively. From 1990 to 1992, he was with the Institute of Physical and Chemical Research (RIKEN), Japan. In 1992, he joined the Institute of Applied Physics, University of Tsukuba, Tsukuba, Japan, where he is currently a Professor at the Graduate School of Systems and Information Engineering. Also, in 1997, he was a Visiting Scholar at the Virginia Polytechnic Institute and State University, and in 2002 and 2008, he was a Visiting Professor at the University of Rome “La Sapienza,” Italy. His research interests include nonlinear dynamics and control of mechanical systems and positive utilization of nonlinear phenomena to realize high-performance mechanical systems. Dr. Yabuno is a fellow of JSME and a member of ASME and the congress committee of IUTAM. He was a recipient of the John F. Alcock Memorial Prize and the Thomas Hawksley Gold Medal from IMechE, and the JSME Medal for Outstanding Paper from JSME. He serves as an Associate Editor for Nonlinear Dynamics, the Journal of Vibration and Control., and the International Journal of Dynamics and Control.