A Comparative Study of Two Types of Bifurcation-Based Inertial MEMS Sensors

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Abstract. This paper compares the use of two types of bifurcations to implement MEMS inertial methane sensors, namely a cyclic-fold in the vicinity of the primary resonance and a primary Hopf in the vicinity of the subharmonic resonance of order one-half. We experimentally demonstrate a sensitivity enhancement, by more than 40%, for the latter over the former at the same operating conditions.

Introduction

Urban sprawl and industrial expansion are massive sources of pollution as they release large quantities of hazardous waste. Detecting and monitoring pollutants are essential in environmental management and control. Therefore, we need to deploy highly sensitive sensor arrays that can detect low concentrations of hazardous gases. MEMS gas sensors have been a leading technology in this field over the last two decades due to their small size, lightweight, low power consumption, and high functionality in real-time applications [1]. Researchers have lately pursued bifurcation-based sensing as a means to enhance the sensitivity and robustness of MEMS sensors by exploiting the sudden, typically large, jump in vibration amplitude experienced through bifurcations [1-3]. Here, we experimentally report an enhancement in the sensitivity of an out-of-plane electrostatic MEMS methane sensor in terms of both the amplitude of the detection signal and the shift in the location of bifurcation frequency subsequent to methane detection, comparing two different types of dynamic bifurcations under the same operating conditions.

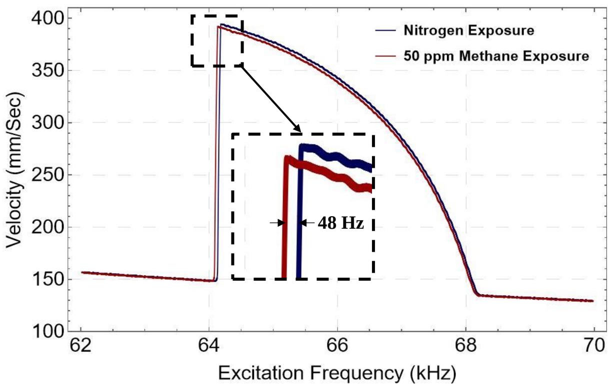

Figure 1: Subharmonic resonance before and after gas exposure

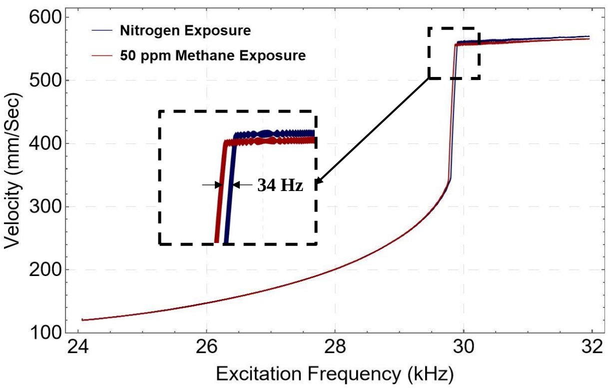

Figure 2: Primary resonance before and after gas exposure

Experimental setup and results

The MEMS sensor, a microplate supported by two cantilever beams, was fabricated in the PolyMUMPs process and functionalized with a potential polymer to detect methane. It was tested inside a test enclosure with an anti-reflective glass port for optical access. The sensor was electrostatically actuated with a biased AC signal using a function generator and a voltage amplifier. The velocity of the plate center was optically measured using a Laser Doppler Vibrometer (LDV) and digitized using a digital oscilloscope. The time domain data were post-processed using in-house software to obtain the frequency response. Figure 1 shows the sensor response in the vicinity of its subharmonic resonance of order one-half, and it shows that the frequency of the Hopf bifurcation at the left end of the non-trivial window dropped by 48 Hz upon exposure to a mixture of dry nitrogen and 50 ppm methane. Figure 2 shows the sensor response in the vicinity of the primary resonance, and it shows that the location of the cyclic-fold bifurcation at the end of the lower branch shifted by 34 Hz upon exposure to the same gas mixture. According to the obtained results, it appears that the Hopf bifurcation is more sensitive than the cyclic-fold bifurcation by more than 40%.

References

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