Analysis of Magnetoelastic Sensors

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Magnetoelastic sensors (resonators) are commonly used in anti-theft tags. They utilize a combination of magnetostriction and acoustic resonance to provide a physical detection mechanism through magnetic fields. The sensors have a simple rectangular shape that allows the acoustic waves to resonate giving the sensors a specific frequency response. The resonant frequency is sensitive to environmental conditions such as temperature, pressure, liquid density and viscosity and mass loading. Magnetostriction refers to strain induced by change in magnetization which allows the acoustic resonance of the sensor to be detected without any physical connections such as wires. This remote query aspect along with the sensitivities makes magnetoelastic sensors a novel sensing platform. Joule first discovered magnetostriction in 1847 and it has since been determined that for the materials used in these sensors the strain is proportional to the square of magnetization. However these sensors operate according to a small signal approximation. The sensors are biased at a non-zero level of magnetization and excited with a small ac signal such that the relationship between strain and magnetization may be approximated as linear using the slope at the bias point. Operating under this regime makes the sensors directly analogous to quartz crystal microbalances (the impedance of the magnetoelastic sensor relates directly to the admittance of the piezoelectric). The focus of this work is to investigate at what power the approximation breaks down and noticeably affects the sensor operation. Shifts in the resonance frequency and the amplitude of the resonance are observed as a function of excitation power. Sensors of varying length are studied at multiple bias points. The results will help to understand the operational limits of magnetoelastic resonators and provide guidance to determine optimal sensor size and excitation field strength.