ENGINEERING

McMaster University

Project 3 – Independent Research Summary

Piezoelectric Force Sensor (Scale)

ENGINEER 1P13 – Integrated Cornerstone Design Projects

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Summary of Working Principle

The main function of piezoelectric force sensors is to detect physical stimuli (dynamic forces) applied without external power through the piezoelectric effect [1]. This effect facilitates the transformation of mechanical parameters into electric signals [2]. These sensors function for magnetic force microscopy with its working principle, a mechanical force amplifier, located between the piezoelectric resonator and the magnetic probe [2]. The amplifier ties to the main function as it enables one to attain the minimal detection of force (MDF) when the system is arranged where the oscillation amplitude of the resonator and resonant arm is much smaller than the micro-rod with the probe [2]. The thermal force noise of the micro-rod with the probe determines the MDF of the entire sensor [2]. Moreover, the magnitude of this noise depends on the coefficient of friction of the micro-rod, thus, the smaller the micro-rod, the lower the level of the noise [2].

Summary of Significant Material Properties

One common material found in piezoelectric force sensors is PZT-5H (a piezoelectric ceramic material), its crucial material component being the electrodes located at the surface [3]. In terms of how its material properties affect the device's performance, the maximum load that can be applied to the piezoelectric sensor is determined by the compressive strength of the material [4]. In fact, the comparison between the predicted stress and material strength shows that the piezoelectric sensor has a maximum load capacity within a specific safety factor [4]. The larger strain due to an external force on a piezoelectric sensor generates higher voltage which ultimately increases its force estimation accuracy [3]. The static loading force applied on a piezoelectric component generates constant voltage that decreases with time, ultimately causing difficulty in static loading force estimation for the sensor [3]. This showcases the major role material properties play in the performance of this sensor.

References

[1] Y. R. Lee, J. Neubauer, K. J. Kim, and Y. Cha, "Multidirectional Cylindrical Piezoelectric Force Sensor: Design and Experimental Validation," *Sensors*, vol. 20, no. 17, p. 4840, Aug. 2020, doi: 10.3390/s20174840.

[2] A. P. Cherkun, G. v. Mishakov, A. v. Sharkov, and E. I. Demikhov, "The use of a piezoelectric force sensor in the magnetic force microscopy of thin permalloy films," *Ultramicroscopy*, vol. 217, p. 113072, Oct. 2020, doi: 10.1016/j.ultramic.2020.113072.

[3] S.-H. Wang, "The optimization design of thin piezoelectric force sensor and theoretical analysis of static loading estimation," *Journal of Low Frequency Noise, Vibration and Active Control*, p. 146134841988127, Oct. 2019, doi: 10.1177/1461348419881276.

[4] M. A. Royandi and J.-P. Hung, "Design of the Force Measurement Device Using Piezoelectric Sensor," *Smart Science*, vol. 7, no. 3, pp. 218–229, Jul. 2019, doi: 10.1080/23080477.2019.1648635.