Abstract No: PO-15

Feasibility of piezoelectric based mechanical vibration detector

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Piezoelectric force sensors are widely used in various industries, including aerospace, automotive, and medical, due to their unique properties. These highly sensitive sensors can detect even the slightest changes in force or pressure. In the automotive industry, existing optical-based classification systems can be expensive, making them unsuitable for widespread implementation. Therefore, this study aimed to design and construct a low-cost piezoelectric mechanical vibration detector system capable of estimating the mass of dynamic objects, specifically for vehicle classification. The piezoelectric plate used was a Lead Zirconate Titanate (PZT) $Pb(Zr_xTi_{1-x})O_3$ and had dimensions of 25.1 mm in diameter and 0.25 mm in thickness. To understand the behaviour of the piezoelectric sensor, equivalent circuit models were proposed and analysed. The compression mode design was chosen for this study due to its high rigidity, wider frequency range, and better durability, making it suitable for vehicle classification applications. The charge-amplifier circuit, tailored for compatibility with an Arduino Uno, was incorporated to make the output signal readable and compatible with digital processing. To evaluate the device's performance, extensive testing was conducted using controlled dynamic impacts. The mechanical vibration detector demonstrated exceptional accuracy and sensitivity in detecting varying levels of impact vibrations with frequencies ranging from 0.5 Hz to 5 Hz, proving its effectiveness for vehicle classification applications. The successful development of this piezoelectric mechanical vibration detector presents a promising solution for vehicle classification systems. By integrating these detectors into urban infrastructure, traffic management can be streamlined, and data-driven decisions can be made to improve transportation efficiency and reduce congestion. The construction of the low-cost piezoelectric mechanical vibration detector has shown its efficacy in detecting impact vibrations, making it a viable solution for vehicle classification in smart cities. Future research could focus on optimizing the design and expanding its application scope to further enhance its impact on urban planning and traffic management.

Keywords: Piezoelectric, Vibration detector, Dynamic force, Vehicle classification, Compression