High Power Piezoelectric Characterization System
– New Generation –

Kenji Uchino
International Center for Actuators & Transducers, The Pennsylvania State University
University Park, PA, 16802, USA
*Kenji Uchino: kenjiuchino@psu.edu

With accelerating the commercialization of piezoelectric actuators and transducers, reducing hysteresis and heat generation, and increasing the mechanical quality factor to amplify the resonance displacement become more and more significant. In these 30 years we have been improving our HiPoCS (high power piezoelectric characterization system) continuously for measuring the admittance/impedance curve precisely around both the resonance and antiresonance peaks, from which the mechanical quality factors for the resonance (Q_A) and the antiresonance (Q_B) can be obtained. From the values of Q_A, Q_B, and the electromechanical coupling factor k, we can obtain all three dielectric, elastic and piezoelectric loss factors precisely. The measurement simplicity and accuracy of this method are very attractive, and our proposal will be widely accepted as a standard method in the piezoelectric actuator community. The inclusion of these three losses is essential to obtain accurate admittance/impedance curves in piezoelectric devices with a 'finite element analysis' computer simulation.

In the 1980s, we started to use an admittance spectrum measurement under a constant voltage method after developing a high frequency current capability up to 20 A (Generation I). However, since we found serious admittance curve distortion due to elastic non-linearity of PZT's, we suggested to use a constant current spectrum measurement in the 1990s (Gen II). This method helped to eliminate the spectrum curve distortion at the resonance, we observed now the impedance curve distortion at the antiresonance. Since we proposed in parallel the novel methodology for determining the piezoelectric three loss factors, we moved to the admittance spectrum measurement under a constant vibration velocity in the 2000s (Gen III), which realized symmetrical admittance/impedance curves for obtaining the both mechanical quality factors Q_A and Q_B around the resonance and antiresonance frequencies. Now we established a process how to derive the three losses for piezoelectrics from the values of Q_A and Q_B.

We further improved the HiPoCS recently from two ways: determining Q_m at any frequency (Gen IV) and eliminating the temperature effect to measure Q_m (Gen V).
In Gen VI, a unique approach for characterizing the quality factor in piezoelectric materials has been developed which utilizes real electrical power measurements, including precise phase measurment. The relation between mechanical quality factor and real electrical power and mechanical vibration is based off of two concepts: (1) at equilibrium the power input is the power lost and (2) the stored mechanical energy can be predicted using the known vibration mode shape. Using this model, the change in mechanical quality factor was calculated for an APC 841 ceramic plate (k_{31}) for vibration conditions of 100 mm/s RMS tip vibration velocity. The quality factor calculated at resonance was within 2% agreement with results from the impedance method. The technique revealed the behavior of the mechanical quality factor between the resonance and the antiresonance frequencies. For the experimental conditions, the mechanical quality factor reached a maximum value between the resonance and the antiresonance frequency.

In order to eliminate the temperature rise problem which leads to the Q_m measurement ambiguity, an improve burst mode method has been developed in Gen V to characterize the high power properties of bulk piezoelectric ceramics. This research provides the methodology to analyze the k_{31}, k_{33}, and k_p modes for open- and closed-circuit conditions, to analyse the piezoelectric charge constant, the open and short circuit compliances, the coupling factor, the dielectric permittivity, and corresponding loss factors. In addition, the electric field constant, a parameter relating generated voltage and displacement for the resonators in their antiresonance mode is also introduced. The results agreed with the properties measured using the impedance spectrum measurement under low power, thus the derived equations were validated. The uniqueness of this research is that these trends can be characterized using the simplicity of the burst method and at a single frequency which gives more consistent results than using an impedance spectrum method.

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