Ultrasonics

Volume 60, 2015, Pages 41-50

A comparison of 1D analytical model and 3D Finite Element Analysis with experiments for a Rosen-type piezoelectric transformer

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Abstract: This article is dedicated to the study of Piezoelectric Transformers (PTs), which offer promising solutions to the increasing need for integrated power electronics modules within autonomous systems. The advantages offered by such transformers include: immunity to electromagnetic disturbances; ease of miniaturisation for example, using conventional micro fabrication processes; and enhanced performance in terms of voltage gain and power efficiency. Central to the adequate description of such transformers is the need for complex analytical modeling tools, especially if one is attempting to include combined con- tributions due to (i) mechanical phenomena owing to the different propagation modes which differ at the primary and secondary sides of the PT; and (ii) electrical phenomena such as the voltage gain and power efficiency, which depend on the electrical load. The present work demonstrates an original one-dimensional (1D) analytical model, dedicated to a Rosen-type PT and simulation results are successively compared against that of a three-dimensional (3D) Finite Element Analysis (COMSOL Multiphysics software) and experimental results. The Rosen-type PT studied here is based on a single layer soft PZT (P191) with corresponding dimensions 18 mm x 3 mm x 1.5 mm, which operated at the second harmonic of 176 kHz. Detailed simulational and experimental results show that the presented 1D model predicts experimental measurements to within less than 10% error of the voltage gain at the second and third resonance frequency modes. Adjustment of the analytical model parameters is found to decrease errors relative to experimental volt- age gain to within 1%, whilst a 2.5% error on the output admittance magnitude at the second resonance mode were obtained. Relying on the unique assumption of one-dimensionality, the present analytical model appears as a useful tool for Rosen-type PT design and behavior understanding.

Keywords : Piezoelectric transformer, Rosen-type transformer, 1D analytical modelling, 3D FEA simulations, Experimental characterisation