Finite Element Simulation of Piezoelectric Transformers

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Abstract: A three-dimensional finite element approach to the characteristic prediction of piezoelectric transformers is presented. For the numerical example, a Rosen-type piezoelectric transformer is considered. The electrical input admittance and the transfer characteristics are demonstrated. The effect of the loading condition on the output voltage and the conversion efficiency are also examined. The numerical results are then compared with the experiments.

INTRODUCTION

Piezoelectric transformers[1, 2] are electromechanical devices made of piezoelectric materials in which energy is mechanically transferred through elastic vibration. They now come into practical use for the appliances when high voltage is required with small power delivery such as for the power supply of fluorescent lamps. In this paper, the three-dimensional finite element modelling[3, 4] is employed to simulate the behavior of the piezoelectric transformers. For the numerical example, a Rosen-type piezoelectric transformer is considered. The electrical input admittance and transfer characteristics are obtained in frequency domain. The effect of the loading or termination condition on the output voltage and the conversion efficiency are also examined. The numerical results are then compared with the experimental results.

FINITE ELEMENT MODELLING

The configuration of a Rosen-type piezoelectric transformer[1] is shown in Fig.1 (a). Two pairs of the input electrodes are partially provided on both surfaces of the piezoelectric ceramics plate under which the plate is polarized in the thickness (z) direction. When the each pair is driven respectively in reverse polarity, the longitudinal vibration of the 3/2λ (λ: wavelength) mode is dominantly excited. The other part of the plate is polarized in the longitudinal (x) direction and the output electrode is placed at the end. One of the input electrodes is common for the ground of the output. For the three-dimensional finite element discretization, an isoparametric cubic element with 8 nodes is used[3, 4]. The finite element division is taken to be (z : y : z) = (39 : 10 : 2) as illustrated in Fig.1 (b). In the figure, λ₀ corresponds to the wavelength of the resonance for 3/2λ mode. The mechanical boundary condition is assumed to be free all over the surface.

SOME NUMERICAL EXAMPLES

The characteristics without loading are first considered. The electrical input admittance and the open-circuited output voltage \( V_0 \) for the input voltage of \( V_i \) are shown in Fig.2. The solid lines indicate the

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**Fig. 1 A piezoelectric transformer.**
finite element solutions and the dotted lines the experimental results. The finite element solution and the experimental results show reasonable agreement while the resonant frequency is shifted. The difference is due to the material constants used in the calculation which are taken from the published reference books and may differ from the real values. The voltage gain calculated without loading is 103 while the measured is 110, which is as much as 7% higher than the calculated.

The effect of the loading is then considered. The electrical input admittance and the output voltage are shown in Fig.3 for $R_L = 10k\Omega$. The finite element solution and the experimental results are in reasonable agreement. Due to the presence of the loading the equivalent quality factor is degraded and the resonant frequency slightly decreases. The voltage gain accordingly decreases down to 13.3 (while the measured: 13.0). The output power $P_o$ of 17.7mW (16.9mW) is delivered for the input power of $P_i = 21.2mW$ (19.0mW), that is, the conversion efficiency is 83.5% (88.9%). The gain and the efficiency against the loading resistance $R_L$ are shown in Fig.4. The maximum efficiency reaches 85.3% for $R_L = 8k\Omega$ (96% for 50k$\Omega$) in this case. The difference is caused by the involvement of the nonlinear effect in the temperature used in the experiment.

![Characteristics without loading](image1)

![Characteristics with loading ($R_L = 10k\Omega$)](image2)

![Voltage gain and conversion efficiency against loading resistance $R_L$](image3)

REFERENCES


