DISPLACEMENTS INDUCED IN PIEZOELECTRIC STRUCTURES

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ABSTRACT

From the knowledge of piezoelectric material tensorial components one can. by the finite element method, calculate the electrical impedance vs. frequency and simulate the mechanical deformation of piezoelectric bars. In order to che k the validity of the simulation, interferometric measurements of the mechanical deformation amplitude were performed. It is shown that these measurements are able to reveal the inhomogeneity of the materials under study and that a small error in the tensorial parameter absolute values leads to an inconsistent picture of simulated mechanical deformation.

INTRODUCTION

We have simulated the vibrations of two parallelipedic transducers with identical geometrical shapes but made from two different piezoelectric materials. Both are commercialy avalaibleunder the following designations: PXE-5 (Philips), a commonly used, lead zircono-titanate piezoceramic and C-24 (Toshiba), a lead titanate piezoceramic with a modified composition leading to a strong electro-mechanical anisotropy which enhances pure compressional thickness mode [1]. The simulation has been performed using a finite-element-method software package extended to the calculation of the state of vibration of piezoelectric structures. The calculated resultshave been compared with the direct measurements of the mechanical displacement amplitudeby means of alaser interferometer.

RESULTS

For PXE-5 we note a good overall correlation obtained between the simulated and experimental curves of the impedence modulus vs. frequency. There is excellent agreement between measured and simulated values of the maximum displacement of the front surface of PXE-5 transducer. However discrepancy between the simulation and the experimental data is observed when the shapes of displacement profiles are compared. Whereas the experimental measurements show a maximum displacement in the center of the sample, the simulated curve presents a minimum at the same point. It must be pointed out however, that a variation by 20 % of the piezoelectric onstant C_{13} value used in the simulation willlead to a simulation profile closeto the experimental one. Such an inaccuracy can be observed in the determination of tensorial components of piezoelectric materials. In fact in these measurements some of the constants like C_{13} are obtained by using a combination of experimentalresults which are rarely determined with an accuracy better than 5 %

In the case of C-24 the shapes of displacement profiles are similar, but the measured values of displacement strongly depend on the position. Because of the strong variation of the measured displacement values with position and the observed differen e between the simulated and the experimental curves of impedance modulus vs. frequency, we suspected that this transducer was made with a highly inhomogeneous material. In order to check the validity of this hypothesis we sawed the C-24 sample in five parts and performed impedance modulus measurements on each element. For each individual element a triplet resonance frequen y predicted by simulation was observed.

CONCLUSION

From the knowledge of piezoelectric material tensorial parameters one can predict the behaviour of parallelipedic transducers. The predicted characteristics - impedance vs. frequency and the shape of front surface deformation of vibrating transducers - were compared with experimental values.

For both materials studied here, we observe a good agreement between the expected and the measured shapes of impedance vs. frequency curves and the fundamental thickness-mode resonance frequency is determined with an accuracy better than 5 %. Furthermore we have shown that any discrepancy between the predicted and the measured shape of impedance curve strongly indicates the inhomogeneity of the material under study ; as it was the case for C-24. This inhomogeneity was also detected by interferometric measurements of the vibration displacements of the transducer front plane. Here again, the predicted and the measured values of the maxima and minima of the amplitude of vibration are in reasonably fair agreement. The most striking discrepancy omes from the comparison between the simulated and measured deformation profile. The experimental measurements show a maximum displacement in the center of the front plane of the transducer whereas the simulation leads to a minimum. However. as we stated above. a variation of 20 % in the value of some tensorial parameters used in the simulation gives a more onsistent picture of the transducer vibration.

Thus extreme care must be taken to avoid any bias for the characteristics used in the simulation. In fact 1% accuracy in tensorial components used in simulation is needed to correctly fit the experimental data. This could be done by increasing the number of one-dimensional samples used in the classical characterisation method, and by taking into account the anisotropy of me hani al and electrical losses.

REFERENCES

[1] M. GINDRE, V. URBACH, R.H. COURSANT, M. FINK, J. PERRIN : "Mechanical displacement induced in a piezoelectric structure Experimental measurement by laser interferometry and simulation by a finite element method," J.A.S.A. to be published

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