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Reduced Model Design of Multilayer Ceramic Capacitor for Vibration Analysis

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1. Abstract

Multilayer ceramic capacitors (MLCCs) have become one kind of the most widely used electrical components in recent decades. And the technology of MLCCs is developing continuously towards a direction of high capacitance and miniaturization. While the tiny thickness and the large quantity of the layers often make it very troublesome to do analysis with the full model MLCCs. In order to solve this problem, reduced model with fewer layers of MLCC was designed and verified in this paper.

2. Introduction

Multilayer ceramic capacitors (MLCCs) received a great amount of interest due to its unique features and excellent electrical performance. The typical structure of MLCC mainly consists of alternating inner electrode layers and ceramic layers. So it is actually a number of individual capacitor stacking in parallel together and connecting via the terminations. To satisfy the continuous demand for higher properties of electric devices, MLCCs are designing with increasingly more layers to perform higher capacitance. However, the large number of layers would result in great time and labor consuming if do simulations with the full model of MLCC. Hence, the reduced model was built for the vibration analysis of MLCC according to the piezoelectric theory.

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3. Piezoelectric Materials Properties

As known, piezoelectric materials behave interaction between mechanical and electrical states, the relationship between strain and charge is shown in Eq. (1) [1].

$$\{S\} = \left[s^E\right]\{T\} + \left[d\right]\{E\} \quad (1)$$

Where $\{S\}$ and $\{T\}$ are the mechanical strain and stress respectively, $\left[s^E\right]$ is the compliance matrix, d is the piezoelectric coefficient and E is electric field intensity. In MLCC, there is no applied load which means that *T* is equal to zero. Therefore, the deformation of single piece of dielectric layer, as shown in Fig. 1, under electric load of *V* voltage can be calculated by Eq. (2) to (5). The situation in *x* direction is similar with *y* direction which was omitted in the text.

$$S_{33} = d_{33}E = \frac{\Delta T}{T} \quad (2)$$

$$\Delta T = d_{33}V \quad (3)$$

$$S_{31} = d_{31}E = \frac{\Delta L}{L} \quad (4)$$

$$\Delta L = \frac{L}{T} d_{31}V \quad (5)$$

Similarly, for the model with N layers of dielectric, the deformation can be approximately achieved by Eq. (6) and (7).

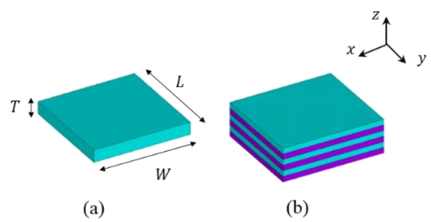

Figure 1 (a) Single layer, (b) N layers of dielectric material

$$\triangle T = Td_{33}\frac{V}{T/N} = d_{33}VN \quad (6)$$

$$\triangle L = \frac{L}{T}d_{31}VN \quad (7)$$

4. Reduced Model

According to the referred piezoelectric theory, by tuning the piezoelectric coefficient d, the dielectric model is able to be simplified with less layers. And the conversion is accomplished by in Eq. (8) and (9), where d' and N' are the piezoelectric coefficient and layer number of simplified model, respectively.

$$\triangle T = d_{33}VN = d_{33}^{'}VN' \quad (8)$$

$$d_{33}^{'} = \frac{N}{N^{'}}d_{33} \quad (9)$$

In order to verify that this method is appropriate to build a reduced model of MLCC, a series of MLCC models, as shown in Fig. 2, with same size but different layer numbers were built in details in the platform of ANSYS APDL 14.0 [2].

The full model consists of 150 layers of dielectrics. And the reduced model were built from 10 to 60 layers. Transient analysis has been performed with each of the models to obtain the displacements in each direction and the results are given in Fig.3. It can figure out by Fig. 3 that the maximum errors in both y and z direction are under 9% when the layer number was minished from 150 to 10, while the simulation time decreased more than 70 percent.

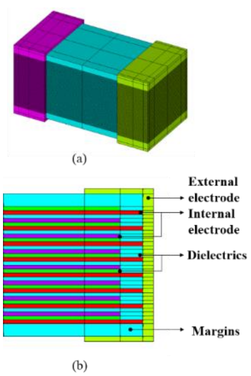

Figure 2 (a) Full view, (b) Part cross-section view of MLCC model

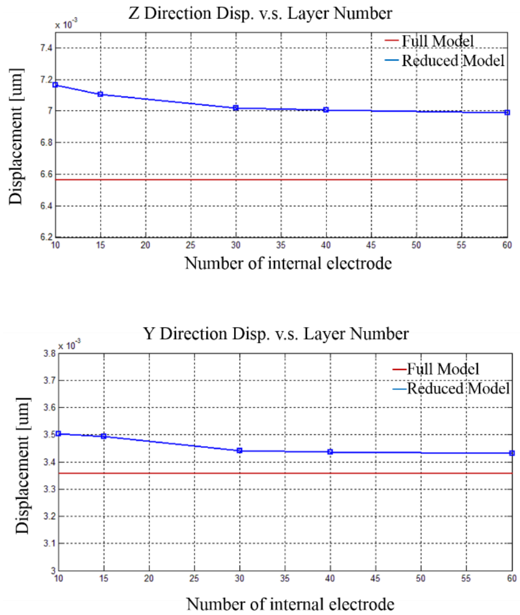

Figure 3 Simulation results comparison

5. Conclusion

The reduced model investigated in this paper efficiently save both time and labor in vibration analysis of MLCC. It also reduces the enormous size differences between MLCC and circuit board which can eliminate meshing inconvenience. Furthermore, as validated, errors of the results simulated by simplified models are small enough to be accepted.

6. References

[1] S.O. Kasap. "Principle of Electronic Material and Devices". Third edition.

[2] Byung-Han Ko, et al. "Analysis of the correlation between acoustic noise and vibration generated by a multi-layer ceramic capacitor."

6. Acknowledgment

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