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The Calculation of Electrical Properties of Quartz Crystal Resonators with Parallel Finite Element Analysis Based on the Mindlin Plate Theory

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Summary

The finite element analysis of quartz crystal resonators is increasingly important due to the precise design requirements in frequency and electrical properties with the consideration of crystal blank, processing, mounting, and packaging. To reduce the computational cost, one proven approach is to use the Mindlin plate theory for the thickness-shear vibrations of crystal plates with electrodes and other complications. This approach has been implemented in parallel finite element method with the sophisticated software components for the solutions of linear systems in terms such as eigenvalues, mode shapes, and amplitudes, which in turn can be used for the evaluation of certain parameters of quartz crystal resonators. Of course, if material and structural damping or viscosity can be considered in the vibration analysis, electrical parameters such as the resistance and quality factors can also be obtained if the increased computing cost can be overcome with efficient algorithms and hardware. This implementation has considered improvements of the Mindlin plate theory and the latest computational algorithms and libraries with new features in the matrix and linear system computation for better performance with Linux clusters. Our emphasis will be on the selection of viscosity parameters and resulting electrical properties in comparison with measurements of some important features such as the quality factor, resistance, and capacitance ratios. It is expected that the determination of the electrical parameters of resonators will improve the estimation of viscosity for the accurate prediction of the process for the determination of device properties. The improved performance of the computing algorithms will make it possible to determine the resonator properties with the finite element method for the analysis of effects of design parameters and process features. For computational algorithms, the current implementation includes the SuperLU package for the matrix and vector manipulations in connection with the PARPACK eigenvalue solver. An improvement on the increased computational speed-up has been made in comparison with our earlier efforts by similar algorithms and software components. The current finite element platform will allow us to implement refined algorithms for the calculation of resonator properties and the consideration of device structure and manufacturing processes more accurately.