Improvements to the PWE-based methods for analyzing 2D phononic crystals with complex geometries

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Abstract

Analyzing the band structure of phononic crystals is essential for understanding their elastic wave propagation characteristics. The plane wave expansion method (PWEM) is highly efficient and accurate, making it a useful tool for analysis. However, the PWEM often encounters significant computational challenges when dealing with complex structures in phononic crystals. This work improves the computation of Fourier coefficients, enabling various versions of the PWEM to efficiently calculate the band structure of phononic crystals with complex geometries. By dividing the unit cell into multiple similar simple geometries, the complex integration domain of the Fourier coefficients can be transformed into a summation over several simpler domains. At the same time, this approach solves the problem of not having a unified formula for different geometries in the PWEM. The rasterized plane wave expansion method was developed by rasterizing the unit cell and integrating image processing techniques. The mesh based improved plane wave expansion method was introduced by dividing the geometry of the unit cell into triangles, similar to the finite element method. Extensive numerical computations validated that both improved strategies significantly reduce derivation costs while preserving the original computational efficiency and accuracy. Due to the integration of image processing techniques, the improved method provides significant advantages in applications such as training machine learning datasets and enhancing Digital Image Correlation (DIC) analyses. The improved method based on triangular meshes enables the efficient and accurate establishment of benchmarks for finite element-based approaches without requiring structural discretization. This strategy can be effectively integrated into certain commercial finite element software, enhancing their analysis capabilities. These improved methods considerably reduce the accessibility barrier and expand the range of potential applications.

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