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Nodal Line Optimization and Application to Violin Top Plate

Summary

Natural frequencies and mode shapes are the most important physical properties of free vibration. In the literature, most problems of structural vibration have been formulated to adjust frequency spectrum for example to maximize the first natural frequency. However, in musical instruments like a violin, mode shapes are also important, because these are related to sound quality while natural frequencies to octave. In case of a violin top plate, a quality factor is predicted by the shape of several nodal lines, which represents the natural mode shapes.

Among the little literature on optimization of mode shapes, a typical one was about optimization of nodal point location for vibration reduction of a beam structure and another about shape optimization to match a prescribed mode shape. However nodal line optimization required in the study of a violin plate is not yet considered. In this thesis, the idea to control the shape of nodal line is suggested and then applied to a violin top plate.

The formulation proposed is to minimize the square sum of displacements of some selected nodes located along the target nodal lines. A violin top plate was modeled using shell finite elements. The design variables are the thicknesses of finite elements. A preliminary study of engenvector and eigenvalue sensitivities has been made for plate problems and compared well with finite differencing. The methods include approximate eigenvector sensitivities by linear combination of eigenvectors and Ritz vectors, and adjoint methods. The adjoint method used requires only the eigenvalue and eigenvector for the mode being differentiated. The two methods are tested and the better one is selected to optimize the violin top plate.

A coarse model and a fine model of the violin top plate were used for optimization. The refined one has more elements than design variables. This model has shown better match with the target shapes of nodal lines. The study includes mode shape optimization of the second, or the fifth, and also both the second and the fifth at the same time. The sensitivities and trend of the thickness obtained can be useful for trimming the top plate when manufacturing.