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A NON-PARAMETRIC FREE-FORM OPTIMIZATION OF SHELL STRUCTURES FOR REDUCING RADIATED NOISE

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Shell or folded structures are important structural elements of many industrial products. Although their lightness and thinness contribute to cost and weight savings, they often cause the undesirable noise and vibration problems. One of the countermeasures for such problems is a curvature design, since the dynamic characteristics are strongly influenced by the curvature distribution. However, the curvature design involving bead pattern is complicated by its many degrees of freedom. For that reason, techniques for optimizing such designs are strongly required.

This paper focuses on a curvature design problem for reducing the radiated noise from vibrating shell structures in an open space (Fig.1). Many studies related to the shell-acoustic problem have presented [1]-[4]. In this paper, we newly present a parameter-free free-form optimization method for this problem based on the free-form optimization method [5][6]. Squared sound pressure, which is evaluated by solving fully coupled shell-acoustic interaction system, is selected as the objective function to be minimized. The optimum design problem is formulated as a distributed-parameter shape optimization problem under the assumptions that shell structures are varied in the out-of-plane direction to the surface and the thickness is constant. The shape gradient function and the optimality conditions for this problem are derived by using the material derivative method and the adjoint variable method. The shape gradient function derived is applied to the gradient method with Laplacian smoothing in the Hilbert space to determine the out-of-plane shape variation, or the design velocity $\boldsymbol{V}$, where the shape gradient function is applied to the shell surface as a fictitious distributed force under Robin condition for varying the shell surface, for minimizing the objective functional and for regularizing the mesh, simultaneously. With this method, the smooth optimal free-form of shell structures is obtained without any shape design parameterization, while minimizing the squared sound pressure in specified points in the open space.

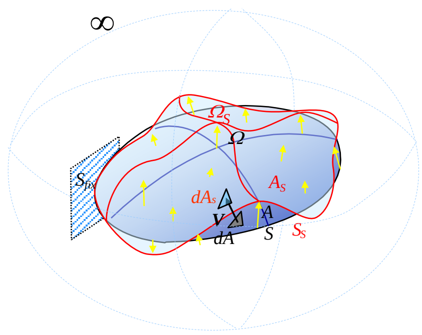
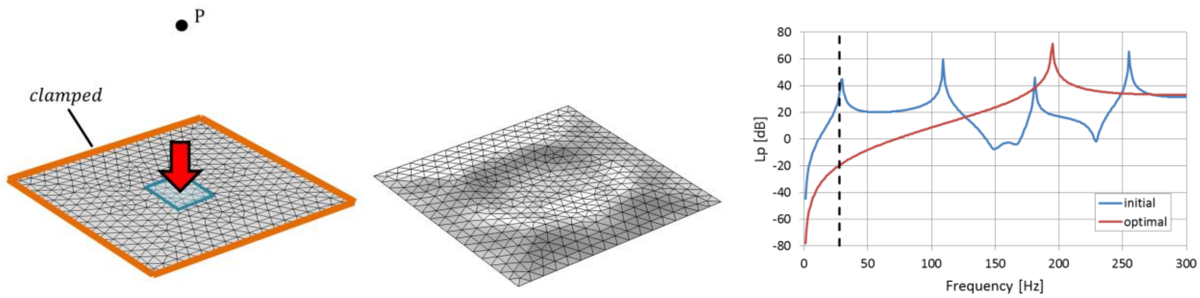


Fig. 1 Vibrating shell in an open space and its shape variation by $\boldsymbol{V}$.



(a) Initial shape (b) Optimized shape. (c) Frequency responses

Fig. 2 Optimization results of square plate clamped at all edges.

Figure 2 shows the calculated optimization results of square plate. In the structure-acoustic analysis, the centre area was vibrated at 28 (Hz), and all edges were clamped. The sound pressure was evaluated at the point *P* over the plate centre (Fig. 2 (a)). Figure 2 (b) and (c) show the optimized shape and the comparison of frequency response curves between the initial and the optimized shape, respectively. It was confirmed that the initial flat plate was changed to the optimal free-formed plate, and the sound pressure level was largely decreased by the optimization. The validity of this method for the radiated noise reduction from vibrating shell structures is demonstrated through the design example.

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