CONTINUUM-BASED TOPOLOGY DESIGN OPTIMIZATION OF NONLINEAR STRUCTURES USING REPRODUCING KERNEL METHOD

Seonho Cho, Juho Kwak, and **Yoondo Ha**

Department of Naval Architecture and Ocean Engineering
Seoul National University, San 56-1 Sillim-Dong,
Kwanak-Gu, Seoul, Korea
secho@snu.ac.kr

A continuum-based topology design optimization method for geometrically nonlinear structures is developed using a reproducing kernel method (RKM). The design variable of material property has a point-wise distribution in this continuum approach whereas an element-wise distribution is present in the conventional one. Thus, the material points can be located anywhere in the continuum domain, which can lead to more accurate and adaptive results. Also the material points can be freely excluded or included in the analysis whenever design modifications are necessary during design optimization. Moreover, the construction of boundaries is relatively easy compared with the finite element method. The convergence difficulty of analysis in nonlinear topology optimization is frequently reported in the other literatures and mainly caused by extremely sparse material distribution in some spots. We prevent the difficulty to some degrees by removing some particles of low material property and constructing the boundaries during the optimization.

In topology design optimization, it is the most crucial and time-consuming task to evaluate the design sensitivity of performance measures such as compliance and material volume. The first-order variations of energy form, load form, and structural responses with respect to non-shape design variable of material property are derived. Generally, a large number of design variables associated with the material property of each particle are necessarily involved in the continuum-based topology optimization. For the design sensitivity analysis, an adjoint variable method is generally preferred because it is computationally efficient and accurate especially for the problems having many design variables but a few performance measures. The RKM is utilized to evaluate the continuum variational equation for the boundary value problems. Global nodal shape functions derived on the basis of the RKM using the kernel function of cubic splines are employed to formulate the discrete equations. Essential boundary conditions are enforced using a penalty method. Total Lagrangian formulation with the Green-Lagrange strain and the second Piola-Kirchhoff stress are employed to describe the response of geometrically nonlinear structures. The material property between particles is interpolated at numerical integration points taking advantage of the obtained RK shape functions. The obtained nonlinear system of equations is solved using a Newton-Raphson iterative method. For the topology design optimization, we use a density approach that uses the bulk material density, varying from zero (void) to unity (solid), to distribute the materials in the structural design domain. The relative material density is distributed to each particle in the structural design domain. As the optimization is progressed, some particles are added to the spots where design refinement is necessary. On the other hand, those particles of low relative material density are removed and, at the same time, a new boundary is formed along the removed points.

Numerical validation for the developed DSA method is performed by comparing the analytical design sensitivity with the finite difference one, which shows excellent agreement. Combining the developed DSA method and a gradient-based design optimization algorithm, an automated topology design optimization method is developed and utilized to obtain optimal material layouts of several example problems. In this paper, an interpolated material property between particles using RK shape functions is employed, which generally leads to non-layered or no grille type distribution. Some of the well-known topology design problems found in the literature have been tested to show similar or better results than the conventional mesh-based methods. Also, by using the point-excluding method, it is observed through several examples that the meshfree topology optimization can be accomplished in more efficient way.