Efficient Structural Optimization for Large-Size Transient Problems Using Krylov Subspace-Based Model Order Reduction

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Dynamic responses of a large-size finite element model can be solved nowadays within a reasonable computation time owing to rapid improvement in both numerical schemes and computing resources. However, increasing demands for accurate simulation and complicated modeling have led to larger and more complex finite element models, which consequently result in considerably high computational cost. In addition, when structural optimizations include dynamic responses such as time-dependent displacement, velocity, and acceleration, the optimizations often do not end within a reasonable process time because the large-size simulation must be repeated many times. In order to reduce the computational cost in this respect, model order reduction (MOR) for the original full-order model (FOM) can be used for the calculation of both transient response and its design sensitivities. In this paper, a transient response analysis using Krylov subspace-based MOR and its design sensitivity analysis with respect to sizing design variables are suggested as an approach to the handling of gradient-based structural optimization for large-size problems. In the suggested method, the reduced order models (ROMs) generated from the original FOMs by implicit moment-matching through the Arnoldi's process are used to calculate both transient response and its design sensitivity, with the result that the speed of numerical computation for the transient response and its design sensitivity is maximized. Newmark's time integration method was employed to calculate transient responses and their design sensitivities. In the case of the transient sensitivity analysis, we applied a temporal discretization scheme to the design sensitivity equation derived by directly differentiating the governing equation with respect to design variables. A couple of application examples are provided to demonstrate the numerical accuracy and efficiency of the suggested approach. The use of Krylov subspace-based MOR to calculate transient dynamic responses and their sensitivities in the structural optimization shows a sizeable reduction in computation time and a good agreement with those calculated by the FOM.

Keywords: Optimal design, Model order reduction, Krylov subspace, Transient design sensitivity