CONTINUUM-BASED DESIGN SENSITIVITY ANALYSIS AND OPTIMIZATION USING MESHFREE METHOD

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For shape design problems, mesh distortion of the finite element (FE) model is a major concern when large shape design changes occur. In addition, if the structure experiences a finite deformation in nonlinear analysis, the FE method has further difficulty due to mesh distortion. The meshfree method is an ideal choice for shape optimization since, unlike the FE method, the solution is less sensitive to uneven particle distributions [1,2]. In addition, a major bottleneck in integration of the FE method with a CAD tool is the generation of well-shaped meshes that are consistent with the complex CAD model to provide accurate results. A meshfree-based numerical method can be used for seamless integration of CAD modeling, simulation, and shape design optimization.

Continuum-based design sensitivity formulations are proposed for linear and nonlinear structures. For linear structures, sizing, shape, and configuration design variables are considered for 2-D elastic problems and 3-D shell structures. A large shape changing design optimization problem was solved without remodeling process, while the accuracy of the analysis is maintained. For the shell structure, a unified design sensitivity analysis (DSA) method for sizing, shape, and configuration design variables is proposed. A shear deformable shell formulation is characterized by a CAD connection, thickness degeneration, meshfree discretization, and nodal integration. The design parameter is selected from the CAD parameters, and a consistent design velocity field is then computed by perturbing the surface geometric matrix and the shell thickness. The material derivative concept is used to obtain a design sensitivity equation in the parametric domain.

For nonlinear structures [1,2], a design sensitivity formulation for the 3-dimensional finite deformation elasto-plasticity with frictional contact problem is developed using a material derivative concept. The multiplicative decomposition of the deformation gradient into elastic and plastic parts is used for the plasticity constitutive model. For the frictional contact problem, a penalty method is used to approximate the contact variational inequality, and a non-associative plasticity theory is used to model the frictional mechanism. A material derivative of the variational equation is taken to obtain a design sensitivity equation that uses the same tangent operator at the converged configuration as the response analysis. The design sensitivity equation is solved at each converged load step without iteration. The path-dependency of the sensitivity formulation is derived from the evolution of the intermediate configuration and the internal plasticity variables as well as the frictional effect in the contact constraint. The feasibility of the proposed methods is demonstrated through a shape optimization of several design problems.

References

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