Topology optimization of structures using the generalized finite point method

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Abstract

In this paper, the procedure of topology optimization of continuum structures is combined with a mesh-free method known as the Generalized Finite Point Method (GFPM). A density approach is employed to find the optimal material distribution in a continuum domain. GFPM is used to perform the structural response analysis as well as the sensitivity analysis. The optimization problem is solved by using the Method of Moving Asymptotes (MMA) where the objective function is the compliance energy and nodal densities are used as design variables. Optimization procedure is based on a sequential refinement strategy for the discritized field of design variables. A numerical example is presented to illustrate the feasibility of the proposed approach. It is observed that this method prevents some numerical instabilities such as appearance of checkerboard patterns and mesh-dependence phenomena.

Keywords: Topology optimization, mesh-free, Method of Moving Asymptotes, checkerboard pattern, mesh-dependence

1. INTRODUCTION

Being one of the most challenging tasks in structural designs, topology optimization seeks a suitable layout of structures for the required structural performance. In this regard, various techniques and methods have been developed during the past decade.

The first central issue in topology optimization problem is to transfer the discretized 0–1 variables formulation to a well-posed state. For this purpose many approaches are suggested including homogenization method [1], the Solid Isotropic Material with Penalization (SIMP) technique [2], the level-set method [3], the evolutionary approach [4], and the implicit topology description function (ITDF) method [5].

Checkerboard patterns and mesh-dependence phenomena are the most frequently encountered numerical instabilities in the material distribution methods mentioned above. As reviewed by Sigmund and Petersson [6], several schemes have been proposed in which solutions are obtained by employing filtering in sensitivity or density variables or adding perimeter control such as global and local gradient constraints.

In addition to the above-mentioned approaches related to optimization problems, a set of numerical methods has been developed for structural analysis. To date, the most prevalent method used in topology optimization is the finite element method (FEM). Although FEM has many advantages, it requires a remeshing procedure when dealing with large deformation or moving boundary problems. This may lead to high computational time and cost. In order to alleviate the drawbacks of FEM, new numerical schemes should be developed. To this end, recently, a number of mesh-free methods have been proposed as an alternative to classical mesh-based methods in topology optimization problems. Cho and Kwak [7] used a mesh-less method for geometric non-linearly modeling in topology optimization. Zhou and Zou [8] employed Reproducing Kernel Particle Method (RKPM) and presented a new implementation of topology optimization in a mesh-free manner. Zheng et al. [9] combined the element free Galerkin method (EFG) with evolutionary structural optimization (ESO) method to carry out the topology optimization of the continuum structures.

Generalized finite point method (GFPM) introduced by Boroomand and Najjar [10], is one of the mesh-free methods, which employs a weighted residual approach and is based on a sub-domain collocation technique. The shape functions are constructed by using the weighted least square (WLS) method, and the system of algebraic equations is constructed by the use of weak form of the generic governing equations of elasticity. Upon reducing the size of the sub-domains, this method will be considered as the well-known