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Stress-based topology optimization using bi-directional evolutionary structural optimization method

Liang Xia*, Li Zhang, Qi Xia, Tielin Shi*

State Key Laboratory of Digital Manufacturing Equipment and Technology, Huazhong University of Science and Technology, Wuhan 430074, China

Abstract

This work proposes an evolutionary topology optimization method for stress minimization design using the bi-directional evolutionary structural optimization (BESO) method. The discrete nature of the BESO method avoids naturally the well-known "singularity" problem in density-based methods with degenerated materials. The p-norm stress aggregation scheme is adopted for the measure of global stress level. A computationally efficient sensitivity number formulation is derived from the adjoint sensitivity of the global stress measure. With regard to the highly nonlinear stress behavior, both sensitivity numbers and topology variables are filtered to stabilize the optimization procedure; meanwhile, the filtered sensitivity numbers are further stabilized with their historical information. The method has been shown efficient, practical and easy-to-implement through a series of 2D and 3D benchmark designs.

Keywords: Topology optimization, BESO, Stress minimization, Sensitivity analysis

1. Introduction

As an advanced and efficient design method, topology optimization has undergone a remarkable development since the seminal paper by Bendsøe and Kikuchi [1] over the past decades in both academic research [2, 3] and industrial applications [4]. Among all research subjects, stress-based topology optimization has been recognized as a challenging problem and has been continuously attracting research interests since the pioneering paper by Duysinx and Bendsøe [5].

Le et al. [6] has summarized three main challenges of stress-based topology optimization: (i) the "singularity " problem; (ii) the local nature of stress, and (iii) the highly nonlinear stress behavior. The first challenge was reported early for truss layout designs in [7, 8]. In the case of density-based methods, it refers to the fact that elements with low densities can present high stress values, making the optimization algorithm incapable of removing them. Remedy schemes were proposed later by relaxing stress constraints such that the element stress and density can decrease simultaneously [5, 9–12]. The second challenge lies in fact that stress is a local quantity, which

*Corresponding author
Email addresses: xialiang@hust.edu.cn (Liang Xia), tlshi@hust.edu.cn (Tielin Shi)