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Multi-material topology optimization design for continuum structures with crack patterns

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Abstract

This study proposes a compliance multi-material topology optimization design of continuum structures with the dependence of crack patterns. Multi-material optimal topology and shape are produced as an alternative to prevent the propagation of crack patterns. The extended finite element method (X-FEM) is used to be a mechanical description approach of strong discontinuity state such as the present cracks. Heaviside enrichment and linear elastic asymptotic displacement fields are added to the finite element approximation without mesh generation near initial cracks. Element density distribution contours of mixing multiple material densities are linked to Solid Isotropic Material with Penalization (SIMP) as a design model. The mathematical formulation of multi-material topology optimization problem solving minimum structural compliance is an alternating active-phase algorithm with the Gauss-Seidel version as an optimization model of optimality criteria. Several numerical examples considering the number, length, angle and location of cracks with or without retrofitting solid passive multi-material verify the efficiency of the present design method using of multiple materials and with the dependence of different crack patterns occurring at continuum structures.

Keywords: multiple materials; topology optimization; X-FEM; continuum structure; crack pattern; level set method.

1. Introduction

Structural topology optimization is a computational technique for distributing material efficiently across the design domain in order to improve stiffness and reduce mass in the resulting design. Since the pioneering study by Bendnsøe and Kikuchi [1], topology optimization has made remarkable progress as an innovative numerical and design method, attracting an enormous amount of attention from the scientific community. Due to significant advantages [2] in topology optimization, it has been developing this powerful tool for different problems such as macro-structures [3], laminated composite structures [4, 5], thermoelastic structures [6], multi-functional designs [7–10] and topology optimization design of cracked structures [11].

In the field of topology optimization, multi-material topology optimization finds the optimal density distribution of different types of material in given conditions. Zhou and

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