Structural Optimization of Composite Structures using an Energy Method

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Abstract

The potential of structural optimization in the design of structures is growing rapidly with the advancement of the computer technology. In this paper, a formulation of structural optimization problem using an energy method is presented, for which solution a nested bilevel optimization is utilized. The method is applied on two practical examples, namely a nonlinear sizing problem for a two span girder and a discrete shape optimization of a truss bridge. These demonstrate the applicability of the method.

Keywords: Structural optimization; energy method; composite structures; truss optimization.

1 Introduction

Structural optimization has been widely applied in the industrial branches of engineering such as mechanical and aerospace engineering, due to importance of optimizing mass production items. The applications in the practical design of civil structures will likely also increase due to improvements in technology and methods. This would enable optimal and efficient shape of structures and to employ properties which are not feasible with conventional design techniques such as the redistribution of internal moments.

In structural optimization, a cost function is minimized under design and equilibrium constrains. Conventionally the equilibrium condition is secured through the application of the finite element method. However, in this work the *Energy method with Integral Material behaviour* (EIM) is used. The EIM ensures the equilibrium condition through minimization of the potential energy by a gradient based optimization procedure. The procedure is same for linear and nonlinear problem which is the asset of this method. Introducing an additional cost function a bilevel optimization problem is formulated. The nested optimization strategy will be employed to solve this problem which solves the two separate optimization tasks separately. Initially a brief introduction in the EIM will be given, followed by brief overview of the used optimization algorithms. Finally, the numerical implementation is discussed on two practical examples in order to discuss the applicability.

2 Formulation of the EIM

The energy method developed by Raue in [1] and [2] is based on two main principles: Lagrange's principle of minimum potential energy and the integral description of the material. The minimum of the potential energy Π, expressed by a sum of the internal Π_i and external Π_e, is secured with mathematical optimization and ensures equilibrium for linear or nonlinear structural problems:

$$\Pi = \Pi_i + \Pi_e \rightarrow min. \quad (1)$$

The integral description of the material is derived only for 1D stress strain material law and therefore it finds its application for beam

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