Alternative quasi-optimal solutions in evolutionary topology optimization

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Abstract

In the article an application of evolutionary topology optimization procedure to searching alternative quasi-optimal solutions is presented. In the work, the constant criterion surface algorithm of evolutionary topology optimization is used. The algorithm is equipped with the procedure of restarting the search after reaching the subsequent quasi-optimal solution. This procedure uses a simulated annealing mechanism that is suitable for finding an optimal solution, but also provides a set of alternative solutions. As shown in the test example, this method enables effective search within the solution space and finding alternative design layouts.

Keywords: alternative quasi-optimal solutions, CCSA, topology optimization, simulated annealing

1. Introduction

Getting many alternative solutions to structural problems is an important issue for today's industry. These typically include complex, multimodal problems that takes into account several objectives and constraints [1,2]. Commercial solutions available on the market usually are unable to meet these needs.

The methodology presented in the paper allows to obtain many alternative solutions by using the method of evolutionary topology optimization combined with simulated annealing procedure.

For this purpose, the constant criterion surface algorithm (CCSA) will be used. The algorithm belongs to evolutionary topology optimization methods [3]. The CSSA algorithm consists of procedure of the removal and adding procedure of FE elements and gives the possibility to do optimization with various constraints as well as to solve multi-constraint problems (see Fig. 1) [4].

The elimination procedure is controlled by a ΔF parameter of volume percentage reduction. To select the constant value of ΔF, a constraint criterion increasing parameter Δg at every volume decreasing iteration is calculated. The FE elements with values of constraint criterion parameters g below the g_{MIN} limit are eliminated from the structure. However, when criterion function is over the limit $\overline{g}$, a layer of finite elements is added to the entire boundary of the structure. The procedure of increasing the volume of the structure is continued until the criterion parameter g returns to admissible values. By increasing and decreasing the structure volume, the algorithm delivers better solutions after reaching the subsequent quasi-optimal solution. This scheme is analogous to the simulated annealing [5]. For multi-constrained topology optimization problems normalized constraints are introduced [4].

For the purpose of finding alternative solutions, a new procedure for recording potential solutions is proposed. The procedure saves the quasi-optimal solution when the objective function value reaches the efficiency limit (for example is not worse more than 1% of the last optimum).

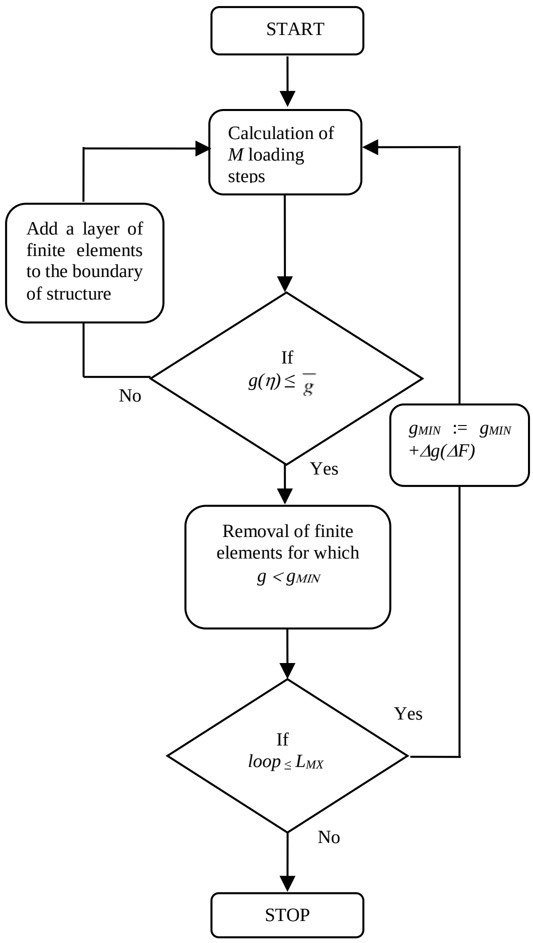

Figure 1: The constant criterion surface algorithm.

2. An example of alternative solutions search

As example illustrating the procedure of alternative solution search, the "Michell cantilever" benchmark problem of optimizing truss topology was selected [6] (see Fig. 2). In the numerical example, the rectangular design space is discretized with 24000 elements. In the example mass minimization with application of stress constraint is considered. The 4-node plane stress elements, Young’s modulus E = 76 GPa, Poisson’s ratio v = 0.3, load value F = 200N are assumed. The tests were performed for 25000 iterations.

The results of topological optimization in the form of many alternative solutions are presented in the Fig. 2c-f. In addition to the changing topology for the obtained solutions, the changing sub-space of the search is shown with a different color.

3. Conclusions

In the article an application of evolutionary topology optimization algorithm to searching alternative quasi-optimal solutions is presented. For this purposes, the CCSA algorithm was enriched with a new procedure for recording alternative solutions.

As shown in the test example, this method enables effective search within the solution space and finding alternative design layouts.

Proposed methodology can be easily adopted to complex industrial problems.

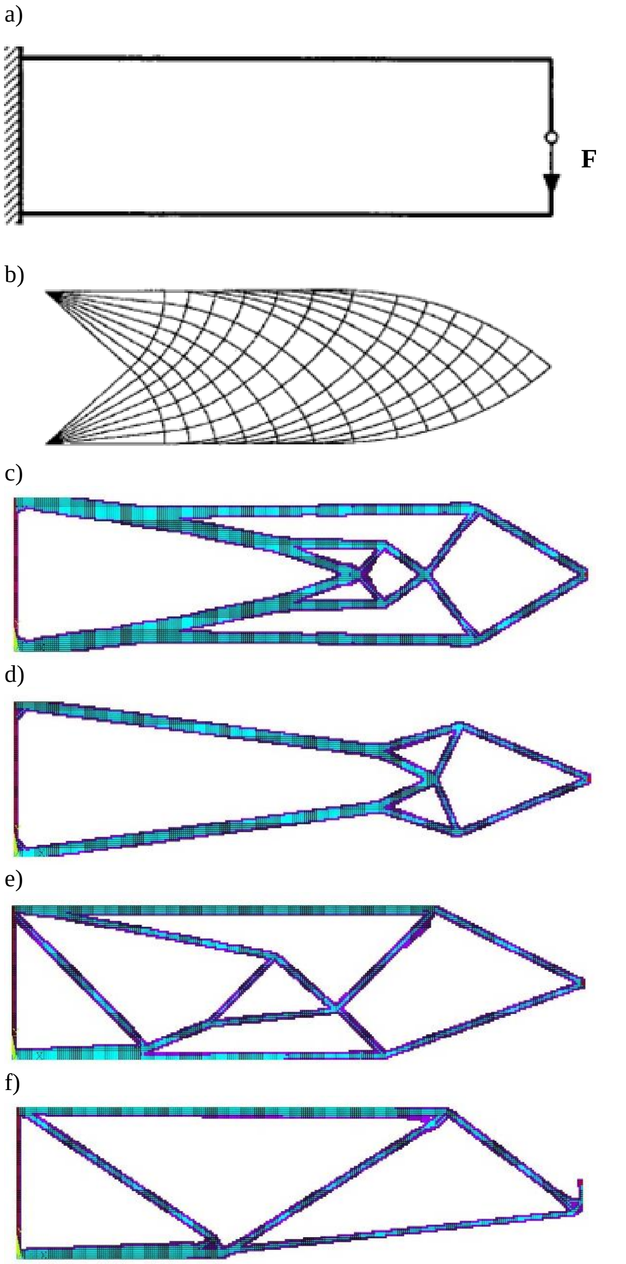

Figure 2: Benchmark problem: problem description (a), analytical solution (b), example of alternative quasi-optimal numerical solutions (c-f)

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