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Review of Truss Topology Optimization (TTO)

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Abstract: ***Truss topology optimization (TTO) is a design problem that entails determining an initial truss arrangement while completing shape and sizing designs later in the design process. All three design stages are frequently merged and solved in a single optimization cycle. TTO involving classical methods and advanced optimization algorithms is the topic of several of the literature reviews.***

Keywords: Truss, Truss Topology Optimization, design process, nodes.

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1. Introduction

A truss is a two- or three-dimensional structure made up of linear pieces joined at nodes and subjected to tension or compression to support load. Since the previous three decades, truss optimization has become a rapidly growing research subject in structural optimization. There are three types of truss optimization: size optimization, shape optimization, and topology optimization. The goal of size optimization is to discover the optimum cross-sectional areas of the structure's elements. Shape optimization is concerned with the movement of the structure's nodal coordinates, whereas topology optimization is concerned with the addition and removal of elements and nodes.

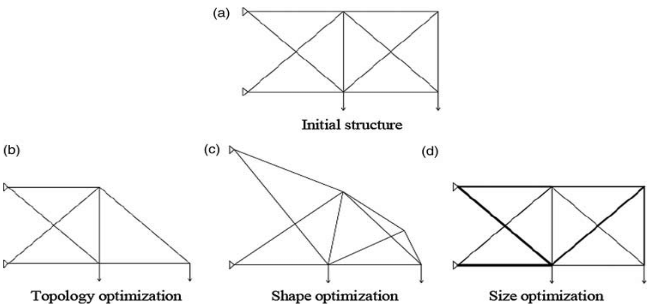

Fig. types of truss optimization

The most difficult challenge in this subject is topology optimization, because it deals with all of the created various topologies rather than a single topology, and it results in a considerable weight saving by looking for the best topology.

Fig. Truss structure with optimization

2. What does Truss Topology Optimization do?

Truss Topology Optimization whittles away material inside a 3D design area to obtain the most economical design. The technique is unconcerned about aesthetics, established methodologies, or any other design limitations that you would encounter in the real world.

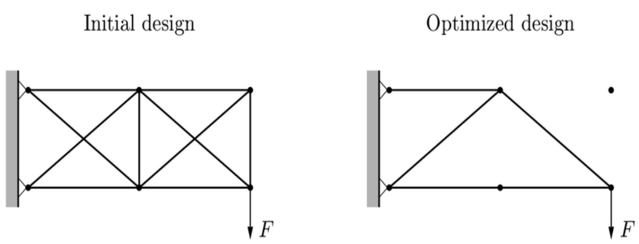

Fig. Load Transfer diagram

3. Why TTO is important?

The advantages of truss topology optimization extend beyond material reduction. Some of its other benefits include:

- A shortened design process: Truss Topology optimization can drastically reduce product development timelines which translates to reduced costs. The automated process generally leads to better-performing parts in much less time than would be needed for traditional design methods.
- Better performance: The best design for a given part isn't always intuitive, and it's possible that a design team would have never come up with it without the help of a computer. Topology optimization algorithms don't have the biases that humans do, so they tend to disregard aesthetics and common design rules in favor of improved performance.
- Greater energy- and cost-efficiency. Truss Topology optimization eliminates any unnecessary features or material, reducing both waste and cost. What's more, because these

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parts are lighter, they also tend to reduce energy demand in their end-use applications.

Fig. Support of truss structure with optimization

4. Literature Review

Forest Flager, Grant Soremekun, Akshay Adya, Kristina Shea, John Haymaker, Martin Fischer 2014 presents the Fully Constrained Design (FCD) method for discrete member sizing optimization of steel truss and frame structures. FCD differs from other deterministic techniques in that it does not need the first derivative of the objective and constraint functions with respect to the design variables, as do other deterministic methods like optimality criteria. This feature increases the algorithm's flexibility and resilience. Using three common truss problems: a 10-bar truss, a 25-bar truss, and a 200-bar truss, the FCD technique was compared against various optimization methodologies found in the literature.

Tolga Hatay Y. Cengiz Toklu (July 2003) presents this paper 'Simulated Annealing (SA)' which is an effective as other methods in finding the optimum value, although it takes too much time to reach the global optimum because of searching in a wide range of feasible design space and accepting higher values. During this study, a number of cooling rates are tried and the best results are found by to be 0.85. Increasing the initial temperature and iteration number at every temperature level affects the algorithm in a way to yield better results.

Truss topology optimization with simultaneous analysis and design Science.gov (United States) Sankaranarayanan, S.; Haftka, Raphael T.; Kapania, Rakesh K. 1992-01-01 presents Simultaneous Analysis and Design (SAND) which is used to optimize trusses for minimum weight subject to stress and displacement constraints. The efficiency of SAND in handling combinations of general constraints is tested. A member elimination strategy to save CPU time is discussed. It is shown that for some problems, starting from the ground structure and using SAND is better than starting from a minimum compliance topology design.

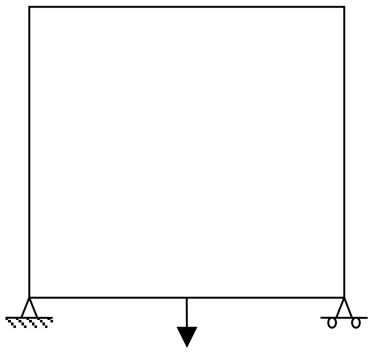
Size and Topology Optimization for Trusses with Discrete Design Variables by Improved Firefly Algorithm Directory of Open Access Journals (Sweden) Yue Wu 2017-01-01 presents Firefly Algorithm (FA, for short is inspired by the social behavior of fireflies and their phenomenon of bioluminescent communication) Two strategies are proposed to conduct size and topology optimization for trusses with discrete design variables. The essential techniques of variable elastic modulus technology and geometric construction analysis are applied in the structural analysis process.

Truss topology optimization with discrete design variables by outer approximation DEFF Research Database (Denmark) Stolpe, Mathias 2015-01-01 presents several variants of an outer approximation method are proposed to solve truss topology optimization problems with discrete design variables to proven global optimality. The objective is to minimize the volume of the structure while satisfying constraints on the global stiffness. A set of two- and three-dimensional benchmark problems are solved and the numerical results suggest that the proposed approaches are competitive with other special-purpose global optimization methods for the considered class under applied loads.

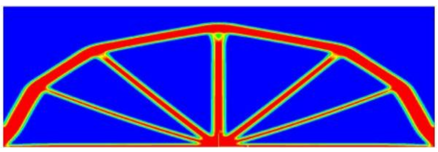
5. Case study

A wide range of known two-dimensional optimum truss designs have been demonstrated to converge quickly using the numerical technique. The load at the mid-point of a pinned and a roller support is depicted in Fig. The chosen design domain is displayed on the left, while the resulting topology is the well-known centre fan topology discovered by Michell on the right.

Fig. Load diagram with fixed and hinged support



The design domain for this issue is a thick-walled cylinder subjected to concentrated forces at the cylinder's ends, which are provided by fn in the axial and ft in the tangential directions. Figure 6 shows the optimised findings for situations ranging from pure axial loads (fn=1, ft=0) to pure torsion (fn=0, ft=1), as well as the influence of reducing



element size.

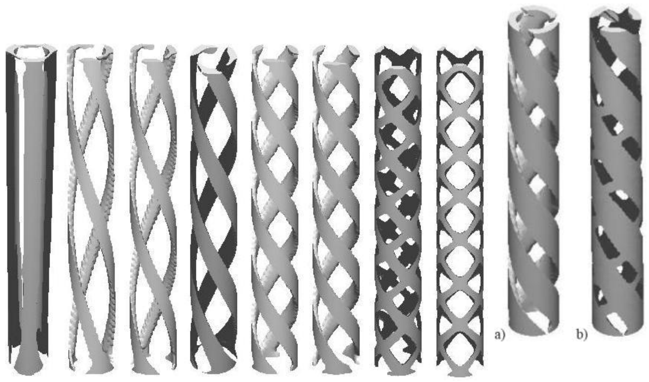


Fig. Optimal Helix angle

In every example, the numerical approach correctly predicts the optimal helix angle. It's worth noting that the helix angles and the angle of the resulting forces applied on the boundary have a significant divergence. The problem with topology optimization in this situation is that a single set of members tries to propagate from the boundary due to resultant forces, but then follows the ideal helix angle. It's difficult to come up with a matching set of supporting helical members.

The design domain for this problem is a thick-walled cylinder subjected to concentrated forces at its ends, given by fn in the axial direction and ft in the tangential direction.

6. Conclusion

A truss is a two- or three-dimensional structure made up of linear components linked at nodes and subjected to tension or compression to support load. Size optimization, form optimization, and topology optimization are the three types of truss optimization. Topology optimization, rather of focusing on a single topology, considers all of the produced topologies and results in considerable weight reductions.

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