BENCHMARK PROBLEM FOR STRUCTURAL OPTIMIZATION WITH MULTIPLE LOAD CONDITIONS IN 3-D

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1. Introduction

The trabecular bone adapts its form to mechanical loads and is able to form structures that are both lightweight and very stiff. In this sense, it is a problem (for the nature or living entities) similar to the structural optimization, especially the topology optimization. The presented structural topology optimization method is based on the trabecular bone remodeling phenomenon. The developed biomimetic topology optimization method allows shape modification using shape derivative without volume constraint [1]. Instead of imposing volume constraint shapes are parameterized by the assumed strain energy density on the structural surface.

2. Multiple load conditions

From an engineer's point of view, the single load case problem is rather rare. A more common problem, but also more valuable in terms of mechanical design, is the one of structural optimization under multiple loads. The biomimetic optimization method should be useful as, in real life, multiple independent loads are always present. Using he developed biomimetic topology optimization method also the problem of compliance optimization for multiple load cases can be efficiently solved.

3. Benchmark problem for structural optimization with multiple load conditions in 3-D

In the paper by Rozvany [2] the popular benchmarks problems in topology optimization were considered. All presented benchmarks were 2-D. The benchmark problem for structural optimization with multiple load conditions in 3-D is proposed here to allow comparison of different optimization methods. The benchmark box design domain with vertical bending and horizontal bending forces is depicted on Fig. 1.

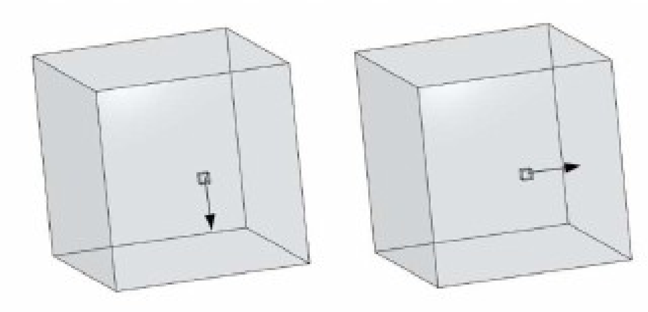

Figure 1: The box design domain: left – the vertical bending force; right – the horizontal bending force.

4. Optimization results for the benchmark problem in 3-D

Due to unique features of the presented biomimetic optimization method it is possible to find the solution, the stiffest structural configuration directly for the multiple load cases problem. The stiffest design is obtained by adding or removal material on the structural surface in the virtual space. The assumed value of the strain energy density on the part of the boundary subjected to modification is related to the material properties. The result of the 3D structural topology optimization for multiple load cases using the biomimetic approach is presented on Fig. 2.

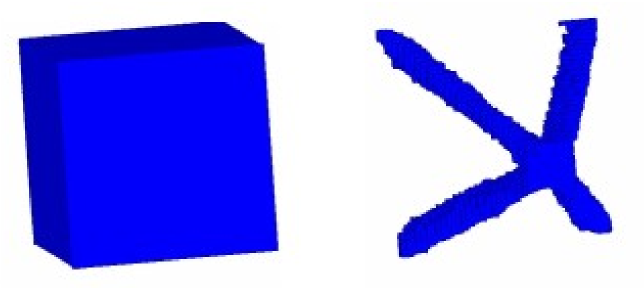

Figure 2: The box starting domain (left) and the final result of the optimization procedure for the multiple load cases for 3-D problem.

5. Conclusions

In the paper at hand, the new formulation of biomimetic optimization based on the trabecular bone remodeling applied to the multiple load problem was presented. The structural evolution is based on the shape gradient approximation by the speed method, and it is separated from the finite element method computations. The important advantage of the presented approach is that the optimization results are in the form of functional configuration. Accordingly, the assumed value of the strain energy density on the part of the boundary subject to modification could be related to the material properties. The 3-D example result shows the configuration for the real material. In view of the above, the 3-D example results with the assumed two perpendicular bending forces as multiple loads could be a good benchmark for testing other approaches to multiple load optimization problem.

6. Acknowledgments

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7. References

[1] M. Nowak, J. Sokołowski and A. Żochowski, Justification of a certain algorithm for shape optimization in 3D elasticity, *Structural and Multidisciplinary Optimization* 57/2:721–734, 2018.
[2] G. Rozvany, Exact analytical solutions for some popuar benchmark problems in topology optimization, *Structural optimization* 15: 42-48, 1998.