Topology optimization of structural frames formulated as MISOCP
-Comparison between branch-and-cut method and meta-heuristic approach-

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Abstract

It is known that the topology optimization (TopOpt) problem of frame structures can be formulated as a mixed-integer second-order cone programming problem (MISOCP), when the compliance is minimized and the cross-section of each member is chosen from a set of predetermined candidates[1]. An MISOCP problem can be solved globally with a branch-and-cut method (B&C). Previous studies have demonstrated the effectiveness of TopOpt by MISOCP for the simple stiffness maximization problem of medium-sized structural frames[2]. In the latest research of such optimization approach, it is confirmed that various constructability constraints, such as upper bounds for the member lengths and the number of nodes or lower bounds for the joint angle of members, can be additionally taken into account[3]. However, since the calculation time of B&C is not small, it is difficult to solve optimization problem of large-sized structural frames.

On the other hand, as another method of solving MISOCP, there is a meta-heuristic approach, which is general approach to obtain solution of optimization problem with discrete design variables. The meta-heuristic method is a very versatile method. In recent years, algorithms based on meta-heuristics have been implemented as components such as Rhino/GH and are widely used not only in frame TopOpt but also various computational design approach. However, in general, it takes a lot of computation time in order to obtain a good solution and there is no guarantee that the obtained solution is a global optimal solution. However, by comparing with the result of the B&C, it can be determined whether or not the meta-heuristic optimization result is a global optimum solution. Even if the optimization result by the meta-heuristic approach is not the global optimal solution, it can be objectively judged whether or not it is a good solution.

In this paper, Mixed-integer distributed ant colony optimization method (MIDACO)[4] is used as the algorithm for solving MISOCP heuristically. By comparing the results of the B&C and the MIDACO to various analytical models, the computational cost required to obtain a good solution in the vicinity of the global optimum solution by using meta-heuristic approach is quantitatively evaluated. In addition, the applicability of metaheuristic approach (especially MIDACO in this papar) to large-scale problems which cannot be solved within realistic computational time by using B&C is discussed.

References

[1] Y. Kanno, Mixed-Integer Second-Order Cone Programming for Global Optimization of Compliance of Frame Structure with Discrete Design Variables, *Structural and Multidisciplinary Optimization*, Vol.54, pp. 301-316, 2016.

[2] S. Fujita and Y. Kanno, Topology Optimization of Three-dimensional Frame Structures Using Mixed-integer Second-order Cone Programming (in Japanese), *Journal of Structural and Construction Engineering (Transactions of AIJ),* Vol. 82, No. 732, pp. 193-201, 2017.

[3] S. Fujita, Y. Kanno, "Global Topology Optimization of Structural Frames Considering Constructability", *IASS 2018 Annual Symposium*, Boston, USA, 2018.

[4] M. Schiueter, S. O. Erb, M. Gerdts, S. Kemble, J. Rückmann, MIDACO on MINLP space applications, *Advances in Space Research*, Vol.51, No.7, pp. 1116-1131, 2013.