On the adaptive ground structure approach for multi-load truss topology optimization

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Michell trusses are the most efficient structures capable of transmitting the given load to the given supports using the smallest amount of structural material. In fact they are not the real trusses because they are composed of an infinite number of bars. Nevertheless, they define the shape and topology of the optimal structure, thus they play a significant role in structural topology optimization. The exact analytical solutions of Michell trusses are very hard to obtain but can be accurately approximated numerically by trusses composed of large but finite number of bars. It requires, however, solving large-scale optimization problems which can be handled only by appropriate optimization methods. One possibility is using the adaptive ground structure approach proposed by Gilbert and Tyas (2003) and later modified by Sokół (2011). The latter method enables to find an optimal layout using the ground structure with billions of potential bars. In the present paper, this method was extended for trusses with multiple load conditions. The theoretical background of multi-load case problems will be presented during WCSMO-10 in a separate paper by Rozvany and Sokół. Here we focus our attention on numerical aspects of multi-load case problems.

The ground structure approach has one important advantage: the coordinates of nodes are fixed (they are not the design variables). Consequently, the truss topology optimization problem can be defined as a linear programming problem. On the other hand, the ground structure has to be dense enough to achieve good estimation of the exact solution (the volume and the layout of the optimal truss). The number of potential bars, equal to the number of links of every pair of nodes, increases rapidly giving a huge number of design variables. This problem is even more complex for the case of multiple loads since then we have to deal with independent member forces (design variables) for every load condition. Hence the size of the optimization problem increases several times.

The method proposed in the present paper results in a significant reduction of the problem because most of unnecessary zero bars, and hence design variables are eliminated. The solution is obtained in the iterative way using the suitably chosen small subsets of active bars. From this point of view, this method can be treated as a special case of the active set method (ASM). Nevertheless, the sub-problems connected with succeeding iterations are large, hence we also make use of the fast primal-dual interior point method (IPM) in every iteration. Concluding, both ASM and IPM are used. The strategy of activating or deactivating of bars plays an important role and has a great influence on the efficiency of the proposed method. This topic will be thoroughly investigated in this paper.