Concurrent topology optimization for minimizing frequency responses of multiscale systems

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ABSTRACT

This work presents a concurrent topology optimization methodology for minimizing the frequency responses of multiscale systems composed of macro and micro phases. The reduction of the frequency responses of structures is widely investigated for several cases in the structural engineering. Among the various approaches that can be used to achieve this result, structural topology optimization has been contributing significantly in the last three decades.

Although the great number of works on the topology optimization of structures and optimization of the materials for this type of dynamic problem, topology optimization approaches considering both scales simultaneously are relatively limited.

The methodology proposed here aims to apply the mesh-independent bi-directional evolutionary structural optimization (BESO) method [1] to seek for the optimum layout of the both scale of the structure, macro and the micro phases, considering the reduction of frequency responses in the macrostructure. For this coupled analysis is assumed that the macrostructure is composed of periodic material whose effective properties are obtained using the homogenization theory [2-3].

In both scales of the system the analysis is carried out using the finite element method. The analysis in the macrostructure considers the boundary conditions and the external harmonically applied load. In the micro scale the finite element analysis considers the periodic boundary conditions [2-3].

A coupled design of the macro and micro structure is conducted simultaneously. The homogenized elasticity matrix used in the finite element analysis of the macro structure is calculated considering the layout of the micro structure. And the sensitivity analysis of the microstructure takes into account the displacement field from the macrostructure [4].

Finally, a number of numerical examples are presented to validate the optimization procure and to demonstrate the effectiveness of the implemented algorithm. The examples show that the concurrent topology optimization approach for structure and material can achieve better results when compared with one-scale optimization for the problem of reduction vibration of the systems.

REFERENCES

[1] X. Huang, Y.M. Xie, *Evolutionary topology optimization of continuum structures: methods and applications*, John Wiley & Sons, Chichester, (2010).

[2] B. Hassani, E. Hinton, "A review of homogenization and topology optimization I – homogenization theory for media with periodic structure. *Comput. Struct.*, **69**, 707-717 (1998).

[3] B. Hassani, E. Hinton, "A review of homogenization and topology optimization II – analytical and numerical solution of homogenization equations. *Comput. Struct.*, **69**, 719-738 (1998).

[4] Z.H. Zuo, X. Huang, J.H. Rong, Y.M. Xie, "Multi-scale design of composite materials and structures for maximum natural frequencies", *Mater. Design*, **51**, 1023-1034 (2013).