Structural Optimization of frames or lattices with beam elements

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Abstract

Structural optimization offers a number of opportunities with the so-called topology optimization been the most fundamental one. It determines the location and connectivity of material in a design space. The discrete topology optimization with beam elements is employed in this research effort. A mesh of beams connected at nodes is initially defined in a predetermined area where the mesh can either be formulated for the whole domain, such as a spatial framed structure (instead of a truss with bars under tension and compression only), or it is based on unit cells (i.e. in lattices). The optimization problem is formulated in order to minimize the structural weight of the beam-like arrangement subjected to stiffness, volume, density, cross sectional and/or other constraints. These constraints account for a number of design objectives (i.e. maximum stress, displacements, lengths etc.).

Starting from a dense mesh of beam members for a unit cell or a spatial frame, topology optimization seeks the most important elements of the problem in order to define the best connectivity by removing those with insignificant contribution and resize the cross section of the most efficient ones. Different cross section shapes are investigated with respect to structural efficiency through limitations in the set of constraints and compared to corresponding configurations with circular cross sections. The stiffness matrices (local and global) of each design are derived employing Isogeometric Analysis (IGA) tools [1] to model the deformations of all unit cells of the lattice or frame elements. In order to allow for more general loading (axial, flexural, torsional and/or distortional) and boundary conditions contrary to traditional Timoshenko model, Advanced Beam Elements either straight or curved have been developed [2]. These elements account for cross-sectional warping (higher-order phenomenon), which vary along the length of the beam exponentially. They are integrated to model the aforementioned unit cells or the spatial frame. Different patterns of unit cells are employed and compared with a cubic grid of circular cross sections, which is considered to be the reference configuration [3].

The novel features of the proposed formulation are: 1) the introduction of IGA tools in the proposed framework in order to both increase accuracy of the results and allow for aesthetics criteria, through curved geometries (directly into the topology optimization process), 2) the use of straight or curved beam models considering warping effects in order to introduce more elaborate beam models than those typically used in the optimal design of lattice or truss structures and 3) different patterns of lattices for the calculation of their stiffness and various cross sections of beams have been considered in the simulations, instead of only using circular cross sections and rectangular patterns [3].

References

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