An isogeometric analysis framework for optimization of functional rod structures in additive manufacturing applications

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ABSTRACT

Isogeometric analysis (IGA) has earned its merits as a viable alternative to more established computational simulation methods such as finite element analysis (FEA) due to its superior mathematical approximation properties and better prospects on integration of computer-aided design (CAD) and analysis. Moreover, it has been shown that IGA is particularly advantageous for shape optimization problems, where the control points of the spline representation of the geometry can directly serve as optimization variables, without the need for re-parameterization and re-meshing.

In this work, we apply the concept of isogeometric analysis for combined shape, topology and design optimization of nonlinear, 3-dimensional rod structures. The mechanics of slender 3D rods are modelled by the geometrically exact Cosserat rod theory and discretized by an efficient and accurate isogeometric collocation method [1], which includes a mixed formulation for thin and composite rods, as well as rod-to-rod contacts [2]. By introducing NURBS parameterizations not only for the undeformed geometry, here the centerline positions and cross-section orientations of the rods, but also material and geometric cross-sections parameters of spatially-variable and functionally-graded rods, i.e. Young's modulus, radius, and ratios of layered composites, as well as density, we can optimize shape, design and topology of rods and rod structures in a unified isogeometric framework. The resulting nonlinear optimization problem is implemented with analytical design sensitivities using the adjoint method and solved by standard gradient-based optimization methods.

We demonstrate our method in several additive manufacturing applications of functional rod structures, including nonlinear lattice structures, active multi-material structures and 4D printed self-assembly structures [3]. With our isogeometric design-to-manufacturing framework, we show the viability of using of isogeometric analysis and optimization for industrial-type applications.

REFERENCES

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