Structural displacement requirement formulation in a NURBS-based SIMP topology optimization method

Thibaut Rodriguez*[†∇], Marco Montemurro[†], Paul Le Texier[∇], Jérôme Pailhès[†]

[†] Arts et Métiers ParisTech,
I2M CNRS UMR 5295, F-33400, Talence, France.
Email: thibaut.rodriguez@ensam.eu, marco.montemurro@ensam.eu, jerome.pailhes@ensam.eu
Web page : https://artsetmetiers.fr/

[∇] CEA/CESTA (French Atomic Energy Commission)
Route des Gargails, 33114 Le Barp, France.
E-mail: thibaut.rodriguez@cea.fr, paul.letexier@cea.fr
Web page: http://www.cea.fr/

ABSTRACT

As a fledgling technology, Additive Layer Manufacturing (ALM) makes use of new methods to design components; among them, topology optimization (TO) [1] is one of the most common approaches to design part manufactured by ALM. This work focuses on the formalisation of a general displacement function in the framework of a special TO algorithm. The formalism makes use of a Non-Uniform Rational Basis Splines (NURBS) hyper-surface [2, 3, 4] to represent the pseudo-density field describing the part topology in the framework of the well-known Solid Isotropic Material with Penalisation (SIMP) approach. The SIMP method aims at computing a fictitious density $\rho(\boldsymbol{x}) \in [0,1]$ for each element of a predefined mesh of the domain. Regardless of the problem nature, one of the main limitations of the classical SIMP approach is that the optimised topology is strongly mesh-dependent. Moreover, when the problem formulation includes several design requirements (especially those involving local responses like failure criteria, local displacement, damage phenomena, etc…) the optimisation constraints on the reassembled geometry (i.e. that obtained after a threshold operation on the pseudo-density field) are not met. Unlike the classical SIMP formulation, the NURBS-based SIMP method developed in [3, 4] separates the pseudo-density field from the FE model mesh. More precisely, for general 3D TO problems, a 4D NURBS hyper-surface is used to represent the pseudo-density field. In this way, the topology descriptor relies on a purely geometric entity which is fully CAD-compatible. In this background, the optimisation variables are the density at the control points and the associated weights [4].

In this study, the structural displacement requirement has been formulated in the framework of the NURBS-based SIMP approach. In particular, this requirement is often integrated into the problem formulation as an optimisation constraint and can be smartly exploited to study compliant mechanisms [1]. In the NURBS-based SIMP approach, the structural displacement function can be set either as an objective or as a constraint function thanks to a flexible implementation. The formulation of such a requirement in the framework of the NURBS-based SIMP method takes full advantages of the properties of such geometric entities: in particular of the local support property of the NURBS blending functions [2].

REFERENCES

[1] M. Bendsoe et O. Sigmund, Topology Optimization - Theory, Methods and Applications, Springer, 2003.

[2] L. Piegl et W. Tiller, The NURBS book, Berlin, Heidelberg, New York: Springer-Verlag, 1997.

[3] G. Costa, M. Montemurro, J. Pailhès. A 2D topology optimisation algorithm in NURBS framework with geometric constraints. *International Journal of Mechanics and Materials in Design*, v. 14 (4), pp. 669-696, 2018.

[4] G. Costa, M. Montemurro et J. Pailhès, NURBS Hypersurfaces for 3D Topology Optimization Problems. Mechanics of Advanced Materials and Structures, URL : https://doi.org/10.1080/15376494.2019.1582826, 2019 (in press).