An implicit, geometric method to consider the Minimum Length Scale in Topology Optimisation

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ABSTRACT

Controlling the size, or length scale, of geometric features issued by a Topology Optimisation (TO) analysis is of paramount importance from a manufacturing point of view. Accordingly, a generic TO problem formulation should be enhanced with a dedicated constraint, demanding that the size of topological features is higher than a threshold length scale. This is usually referred as a Minimum Length Scale (MLS) constraint. In the Solid Isotropic Material with Penalisation (SIMP) method [1], the MLS constraint is imposed through a control of the monotonicity of the pseudo-density function [2], or by means of projection methods [3]. In this framework, the main drawback of the SIMP approach is that the MLS requirement is formulated by making use of the underlying mesh and not on a geometric entity: consequently, the MLS constraint is not met on the actual reassembled geometry after the post-processing the result provided by the TO.

In this work, a special SIMP method based on Non Uniform Rational Basis Splines (NURBS) entities is used [4, 5]. It is assumed that the pseudo density function is a NURBS surface or a hypersurface in the case of 2D and 3D problems, respectively. Beyond a complete CAD compatibility of solutions in 2D, this representation allows for several advantages, as an implicit filter zone, which is related to the NURBS local support property. The smaller the local support the smaller the allowable size of geometrical features characterising the current topology (and more efficient solutions are provided). As the local support size depends on the NURBS discrete parameters (number of control points and degrees of the basis functions), the idea is to determine, *a priori*, suitable *design abaci* to predict the MLS by opportunely adjusting the NURBS parameters without introducing an explicit optimisation constraint. To this purpose, *ad hoc* design tools need to be produced. Firstly, a degree and a number of control points are set. Secondly, the MLS condition is artificially reproduced on a NURBS entity and the corresponding MLS is measured on the artificial simulation. Then, the MLS is related to the NURBS parameters (suitable *abaci* are derived). In order to validate the effectiveness of these *abaci*, a TO analysis is performed by making use of the chosen set of discrete parameters and the MLS is measured on the actual geometry, post-treated after the TO run. Finally, it is verified that the actual MLS is higher than or equal to the forecast MLS. This procedure has been carried out for 2D and 3D test-cases and several combinations of degrees and numbers of control points. Results show that the *abaci* actually constitute a robust design tool, capable of providing a consistent prediction of the MLS.

REFERENCES

[1] M.P. Bendsøe and O. Sigmund, Topo*logy Optimization, Theory, Methods and Applications*, 2nd Edition, Springer, 2003.

[2] T.A. Poulsen, A new scheme for imposing the minimum length scale in topology optimisation, *Int J Numer Methods Eng* (2003) **57(6)**:741-760.

[3] J.K. Guest, J.H. Prévost and T. Belytschko, Achieving minimum length scale in topology optimisation using nodal design variables and projection functions, *Int J Numer Methods Eng* (2004) **61(2)**:238-254.

[4] G. Costa, M. Montemurro, J. Pailhès, A 2D topology optimisation algorithm in NURBS framework with geometric constraints, *Int J Mech Mater Des* (2018) **14(4)**: 669-696.

[5] G. Costa, M. Montemurro, J. Pailhès, NURBS Hypersurfaces for 3D Topology Optimisation Problems, *Mech Adv Mater Struc* (2019),URL: https://doi.org/10.1080/15376494.2019.1582826 (in press)