Simulation of functionally graded materials using V-Reps and the Isogeometric Finite Cell Method

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ABSTRACT

Functionally graded materials offer the possibility to combine the benefits of different materials within one workpiece. An application is the combination of metals with different properties, such as strength and corrosion resistance. Another application is the combination of metal and ceramics, which is of high relevance for load carrying components which need to withstand high thermal stresses. Additive manufacturing plays a key role in developing and manufacturing such components [1].

A numerical simulation for such components requires a geometrical model, which is naturally provided by Computer Aided Design (CAD). Unfortunately, most CAD tools are based on Boundary Representation and thus do not provide an explicit volume description. Also, models constructed with procedural CAD tools, following the Constructive Solid Construction idea and hence technically consist of volumetric bodies, typically lack the possibility to describe a functionally graded material within the volume. To overcome this issue Massarwi et al. [2] developed V-Reps or V-Models which are based on (trimmed) trivariate spline patches. Additional coordinates on the control points of these patches allow the encoding of heterogeneous materials within the splines.

Based on the Finite Cell Method (FCM) it is possible to directly simulate these V-Models. As an immersed boundary method the FCM only requires a reliable Point Membership Classification (PMC) from the CAD model. Typically, the domain outside is considered to have no (or very soft) material, whereas the domain inside is considered to have full material [3]. However, this PMC can readily be extended to obtain also material properties at the integration points from the V-Models. Our implementation of the FCM can use hierarchical Legendre p-type shape functions as well as tri-variate B-splines. As the immersed boundary approach provides a very natural solution for spline-trimming, the proposed combination of Finite Cells, B-spline shape functions, and V-Models efficiently implements an Isogeometric Analysis for trimmed solids with graded materials. It thus extends the original idea of Isogeometric Analysis: Not only geometry and field equations are described by splines, but also the distribution of material properties is formulated following this paradigm.

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