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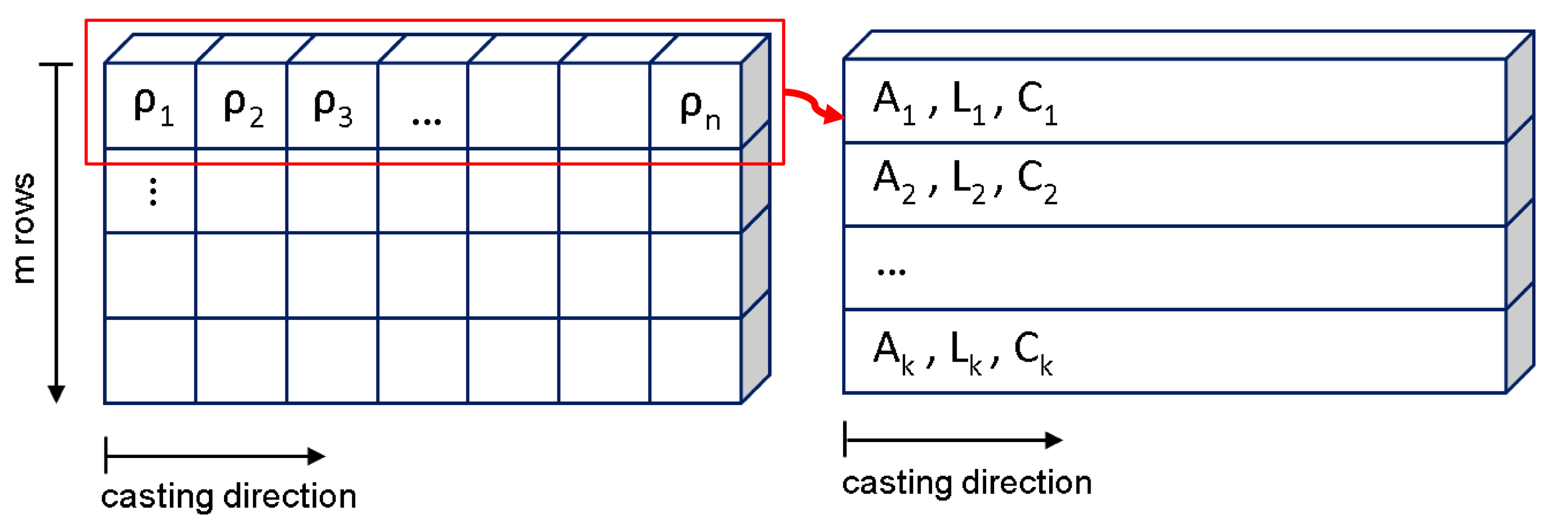
Improving demolding manufacturing constraints for gradient-based topology optimization within SIMULIA TOSCA Structure

Motivation

The casting constraint topology optimization based on the parametrization in SIMULIA Tosca Structure is formulated by grouping the finite elements based on centroids into multiple poles. Each pole has three parameters denoting the beginning and end point along with the material available in each pole. The issue with the existing parametrization is the presence of high density elements also in the void regions, preventing clear segregation of the region with material and empty region. This subsequently leads to some inconsistent results with potential undercuts or cavities in the model. Therefore, the parametrization is modified based on the volume fraction of elements, to prevent such undercuts or cavities, that occur in the existing parameterization.

Pole parameters



The three pole parameters are described as follows.

A → Density fraction of the pole;

L → Pole growth fraction; pole fraction, that is filled with material

C → Pole carve fraction; pole fraction, that has no material

Modified parametrization

The mapping function, that maps the parameters to original relative density of the finite elements is given as,

$$\boldsymbol{\rho} = F(\mathbf{A},\mathbf{L},\mathbf{C}) = f_a(\mathbf{A}).f_l(\mathbf{L}).f_c(\mathbf{C})$$

Here, the function $f_a(\mathbf{A})$ for an element i is given in terms of element volume fractions and pole parameter for each pole k.

$$f_a(\mathbf{A}) = V_{i,k}^{frac} \cdot A_k^p$$

The parameter sensitivities are also modified based on the mapping function defined before.

$$\frac{\mathrm{d}f_a(\mathbf{A})}{\mathrm{d}\mathbf{A}} = \frac{\mathrm{d}f_a(\mathbf{A})}{\mathrm{d}A_k^p} = V_{i,k}^{frac}$$

The functions $f_l(\mathbf{L})$ and $f_c(\mathbf{C})$ remain the same as existing parametrization. They are described using a heaviside function. The idea of heavyside functions is to avoid having elements with intermediate density values in the result of an optimization.

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Industrial model

The results of casting constraint topology optimization were compared and validated for an oil pan model

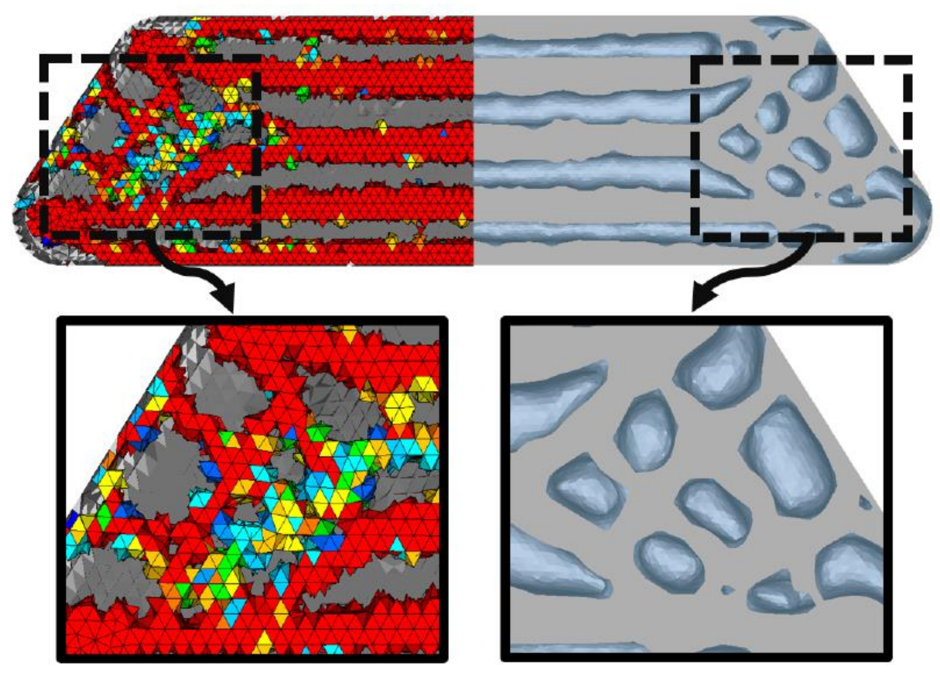

Figure 1. Density plot and Tosca Smooth for existing parametrization

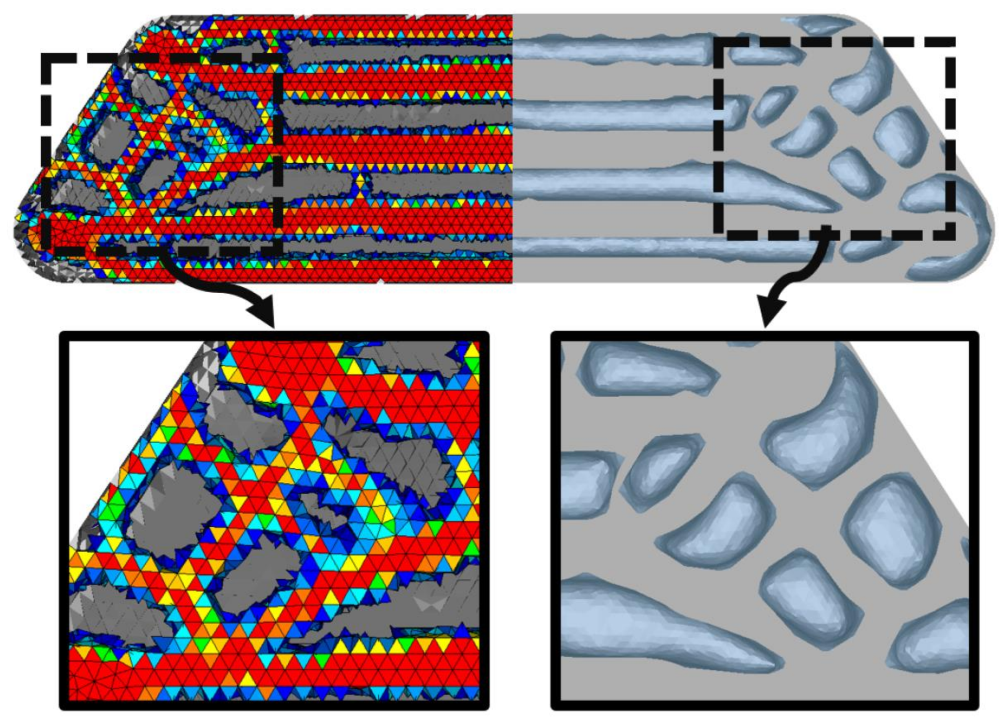

Figure 2. Density plot and Tosca Smooth for modified parametrization

Conclusion

The modified parametrization using the volume fraction of elements resulted in low or intermediate density elements along the boundaries of solid and void regions, providing a clear distinction between regions with material and no material. Thereby, it avoids potential undercuts or interior cavities in the optimal model.

Literature

Leiva, Juan; Watson, Brian; Kosaka, Iku: An Analytical Directional Growth Topology Parameterization to enforce manufacturing requirements. *Structural Dynamics and Materials Conference 2* (2004), 04. ISBN 978-1-62410-079-6

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