Additive manufacturing is a new manufacturing technology with high geometrical flexibility. Additive manufacturing and topology optimization are highly compatible. However some manufacturing constraints has to be taken into account.

The work is divided in two main parts:

1. Considering manufacturing constraints related to “LBM” and “EBM” additive manufacturing techniques in the topology optimization formulation
2. Considering the geometrical uncertainties induced by the manufacturing process

**Manufacturing Constraints**

The additive manufacturing techniques are a step forward to the coupling of manufacturing and the optimization process. Although there are still a few constraints.

- Minimum and maximum width control
- Maximum overhanging angle
- Part orientation
- Dimension precision
- Minimum size of canals
- No closed cavities
- Surface state with post machining of working surfaces and screw thread

**Geometrical Uncertainties**

Due to geometrical uncertainties of the manufacturing process it could be useful to insert some stochastical principle into the optimization process such as:

- Monte Carlo method [1]
- Sensitivity analysis [1]
- Uniform and random filters [2][3]

**Minimum Width Control**


- Create a circle of the minimum radius \( R_{min} \) considered
- Search the elements inside the circle around an element \( e \)
- Project linearly the density on the element \( e \)

\[
\tilde{\rho}_e = \frac{\sum_{j \in C_{R_{min}}} \rho_j \ast \omega_j}{\sum_{j \in C_{R_{min}}} \omega_j}
\]

Where \( \omega_j \) is the weight function:

\[
\omega_j = \begin{cases} 
\frac{R_{min} - R_{j}}{R_{min}} & \text{if element } j \in C_{R_{min}} \\
0 & \text{otherwise}
\end{cases}
\]

Other geometrical sets could be used to account for other manufacturing constraints; eg. the maximum overhanging angle.

- Or even using other filters such as [6]:

\[
1 e^{-\beta \tilde{\rho}_e} + \tilde{\rho}_e e^{-\beta} \quad \text{Dilate Heaviside step-function}
\]

\[
e^{-\beta (1-\tilde{\rho}_e) - (1-\tilde{\rho}_e)} e^{-\beta} \quad \text{Erode modified Heaviside step-function}
\]

**Uniforme Filtering**

Using image morphology-based filters Sigmund(2009) has shown an efficient way to account for geometrical uncertainties[2]. The two filters here used are:

\[
1 - e^{-\beta \tilde{\rho}_e} + \tilde{\rho}_e e^{-\beta} \quad \text{Dilate Heaviside step-function}
\]

\[
e^{-\beta (1-\tilde{\rho}_e) - (1-\tilde{\rho}_e)} e^{-\beta} \quad \text{Erode modified Heaviside step-function}
\]

**References**

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