A robust approach of topologic optimization of mechanical and aeronautical components fabricated by additive manufacturing

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Introduction/Goal

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.

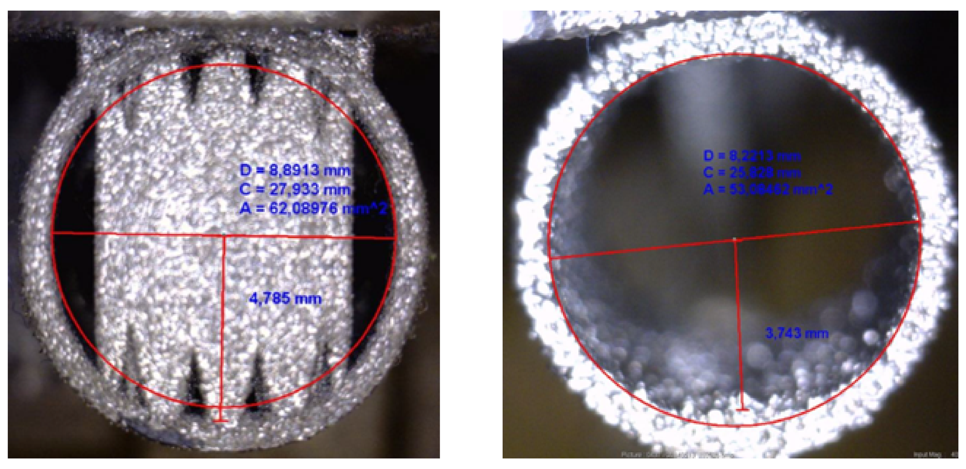
The work is divided in two main parts:

1. Considering **manufacturing constraints** related to "LBM" and "EBM" additive manufacturing technics in the topology optimization formulation
2. Considering the **geometrical uncertainties** induced by the manufacturing process

Manufacturing constraints

The additive manufacturing technics 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



[5]

Geometrical uncertainties

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

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

Minimum widht control

Guest et al. (2004) [4] proposed an ingenious method to ensure an minimum length in topology optimization.

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

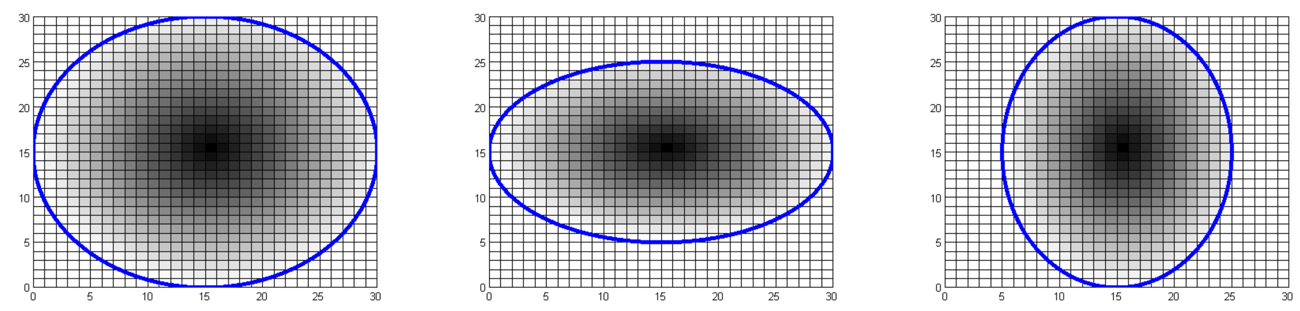
$$\tilde{\rho}_e = \frac{\sum_{j\in C_{R_{min}}} \rho_j * \omega_j}{\sum_{j\in C_{R_{min}}} \omega_j}$$

Where ω_j is the weight function:

$$\omega_j = \begin{cases} \frac{R_{min}-R_{ej}}{R_{min}} & \textit{if element } j \in C_{R_{min}} \\ 0 & \textit{otherwise} \end{cases}$$

R_{min} = 1 $\quad$ R_{min} = 8

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]:

$$\tilde{\rho}_e = \prod_{j\in C_{R_{min}}} \rho_j^{\omega_j} \qquad \textit{geometric mean}$$

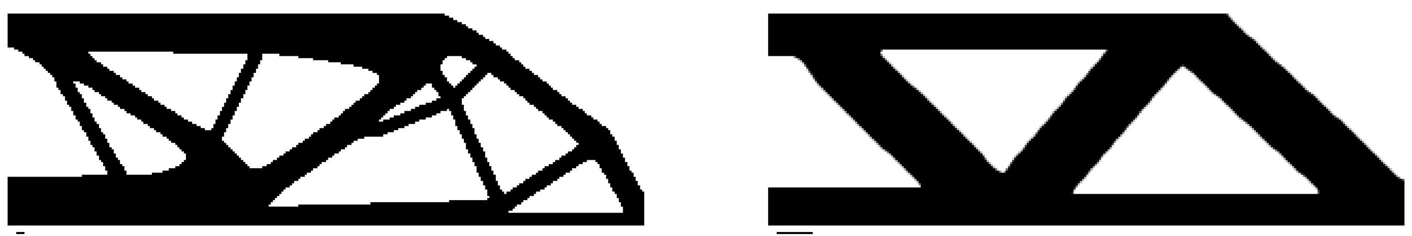
$$\frac{1}{\tilde{\rho}_e} = \sum_{j\in C_{R_{min}}} \frac{\omega_j}{\rho_j} \qquad \textit{harmonic mean}$$

Uniforme filtering

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

$$1 - e^{-\beta\tilde{\rho}_e} + \tilde{\rho}_e e^{-\beta} \qquad \textbf{Dilate Heaviside step-function}$$

$$e^{-\beta(1-\tilde{\rho}_e)} - (1-\tilde{\rho}_e)e^{-\beta} \qquad \textbf{Erode modified Heaviside step-function}$$



R_{min} = 1 $\quad$ R_{min} = 8

Assure a minimal structure ⇒ more robust solution but : thickness ↗ lead to thermal deformation issues. Solution : maximum + minimum width control should be implemented.

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Acknowledgements

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