Contributions to topology optimization of structural components made by additive manufacturing

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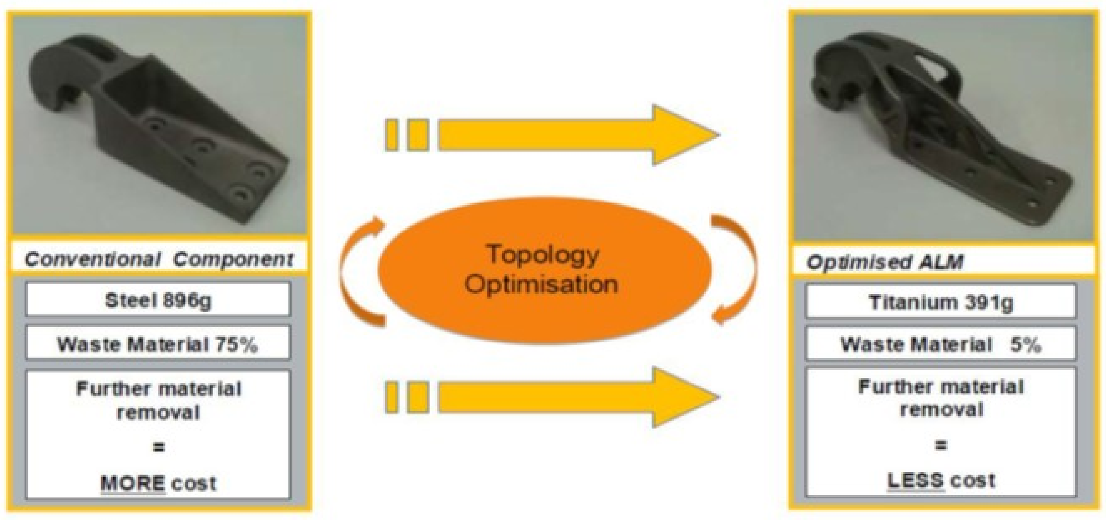
Motivation

Topology optimization (TO) is used as a design tool for innovative and optimal components. In most cases, these components are non machinable and new techniques of additive manufacturing (AM) can overcome this issue[1].



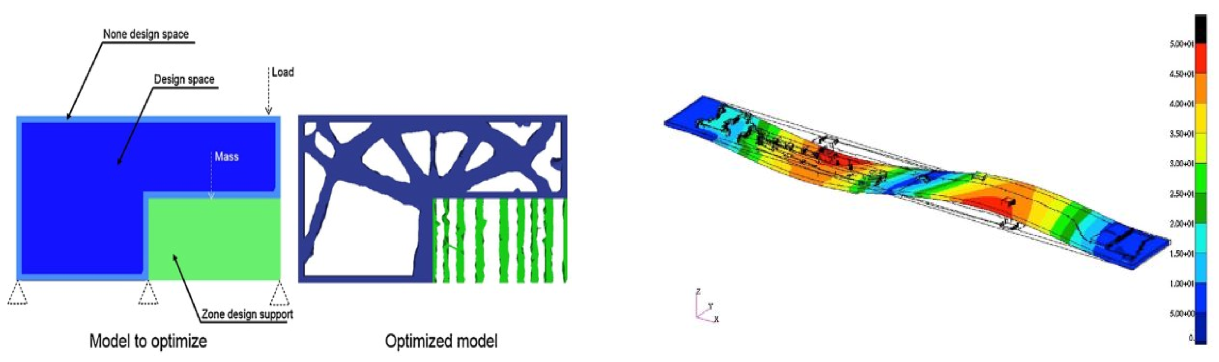
One can however pinpoint some limitations:

- Design stage requires too many steps
- Non functional parts obtained with classical TO

Additive manufacturing constraints

Numerous constraints are needed to be taken into account when machining parts with AM technology. In this work we will focus on :

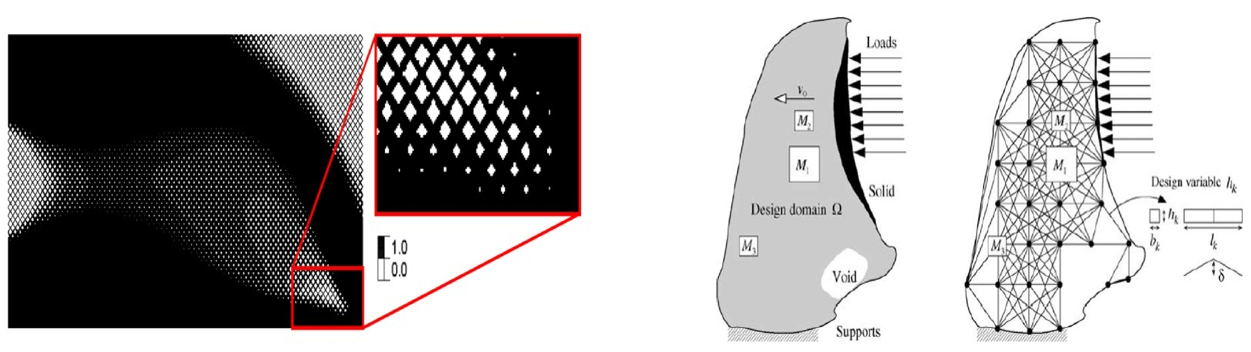
- Supports within the optimization problem to optimize the use of (support) material (a)[2]
- Thermal consideration to prevent residual stresses within the components (b)[3]



(a) (b)

Large deformations & lattice structures

- Definition of the optimal sub-structure of the original optimization problem (a) ⟶ Structures with variable porosity[4].
- Design of structures able to sustain shocks, that is to solve a highly dynamically loaded TO problem (b) but for the continuous case [5].



(a) (b)

Objectives of the thesis

Three themes are explored in this work:

- Contributions to stress–based TO embedding fatigue failure constraints ⟶ improve the solution method.
- Dealing with manufacturing constraints specific to AM within the optimization procedure, e.g. residual thermal stresses.
- Optimal structures with variable density machinable with AM techniques. Application to shocks absorbers (e.g.lattice structures).

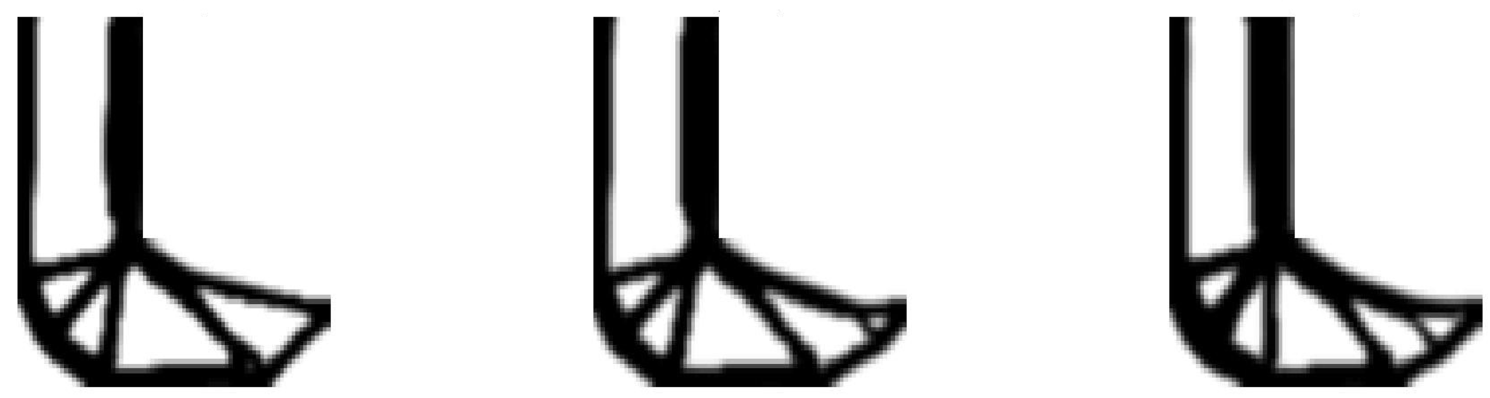
Stress–based TO for fatigue design

Bruggi and Duysinx (2012) and Bruggi and Duysinx (2013) have proposed a scheme of stressed–based topology optimization which can be extended to consider fatigue constraints:

$$\begin{cases} \min\limits_{x_0 \le x_e \le 1} & \mathcal{W} = \sum\limits_N x_e V_e \\ \text{s.t.} & \mathbf{K}(\mathbf{x})\,\mathbf{U} \;=\; \mathbf{F}, \\ & \mathcal{C}\,/\,\mathcal{C}_L \;\le\; 1, \\ & \|\sigma\| \le 1, \end{cases}$$

where $\|\sigma\|$ is a relevant fatigue criterion such as Sines, Crossland or Goodman.

Goodman **Sines** **Crossland**



When dealing with Stress–based TO embedding fatigue constraints some specific features can be pointed out:

- More CPU time required due to the high number of active constraints
- Thicker members of the structures (heavier structures) but with more rounded shapes ⟶ purpose of fatigue design in mechanical engineering

Stress- based TO with fatigue failure constraints needs to be solve more efficiently:

- New structural approximations, or
- New optimization algorithms.

References

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