High Performing Free-Form Design and Material Optimization for Additive Layer Manufacturing

MOX, Politecnico di Milano & Thales Alenia Space

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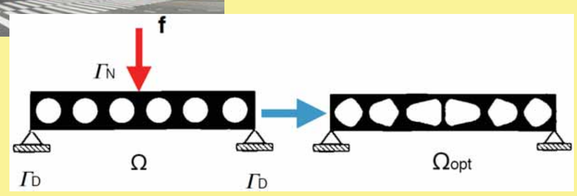
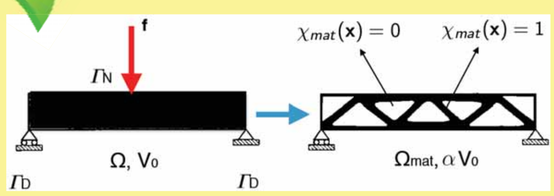
Advanced mathematical techniques yield structures and forms that classical industrial processes are not able to design.

FREE-FORM



shape optimization



topological optimization

The reference physical-mathematical model is based on the linear elasticity system :

$$\textbf{(E)} \quad \begin{cases} -\nabla \cdot \sigma(\mathbf{u}) = \mathbf{0} & \text{in} \quad \Omega \\ \mathbf{u} = 0 & \text{on} \quad \Gamma_D \\ \sigma(\mathbf{u})\mathbf{n} = \mathbf{f} & \text{on} \quad \Gamma_N \\ \sigma(\mathbf{u})\mathbf{n} = \mathbf{0} & \text{on} \quad \Gamma_F \end{cases}$$

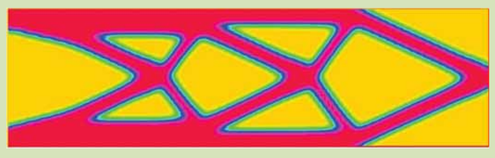
Topological optimization leads to solve the constrained optimization problem for the compliance I:

SIMP

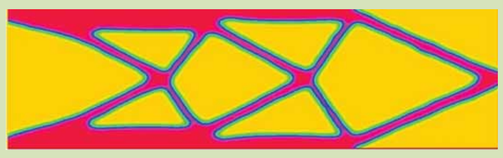
$$\textit{Find } \rho : \Omega \to [0,1] \text{ with } \rho \in L^\infty(\Omega) \textit{ such that}$$

$$\min_{\mathbf{u}(\rho) \in U} I(\mathbf{u}) \; + \; \begin{cases} \textbf{(E)} \\ \int_\Omega \rho d\Omega = Vol(\Omega^{mat}) \leq \alpha V_0 \\ \rho_{min} \leq \rho \leq 1 \end{cases}$$

Two optimization strategies :



IPOPT (interior point optimizer)

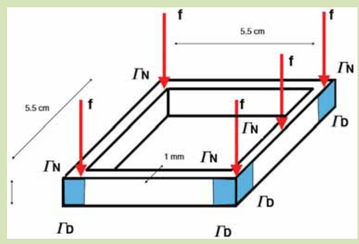


OC (optimality criteria)

$$\begin{cases} \min\limits_{\mathbf{x} \in \mathbb{R}^n} f(\mathbf{x}) \quad s.t. \\ x_i^{lb} \leq x_i \leq x_i^{ub} \qquad i = 1:n \\ c_i^{lb} \leq c_i(\mathbf{x}) \leq c_i^{ub} \quad i = 1:m \end{cases}$$

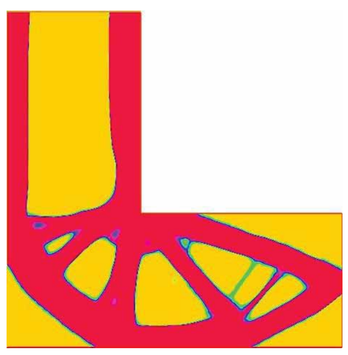
	IPOPT	OC
COMPLIANCE [m/N]	0.0016	0.0025
VOLUME FRACTION	0.5	0.37

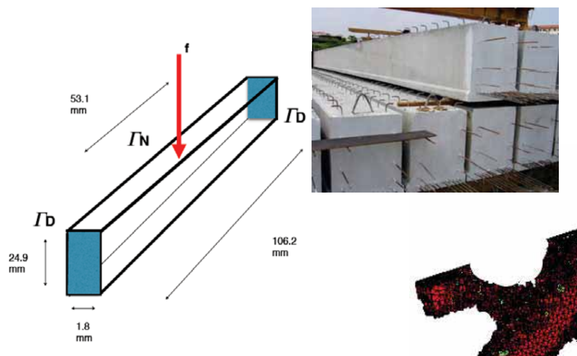
Topological optimization enhances the performances :

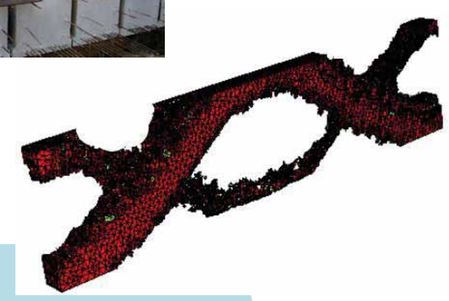


Material	AL6082 T6	TI-6AL-4V
Max Displacement [m]	5.64 E-6	3.46 E-6
Von Mises Stress [Pa]	3.72 E+6	3.49 E+6
Compliance [m/N]	10.11	6.18
First Eigenfrequency [Hz]	1967.3	1959.7
Mass [kg]	0.0059	0.0097

Material	AL6082 T6	TI-6AL-4V
Max Displacement [m]	1.34 E-5	1.21 E-5
Von Mises Stress [Pa]	4.2 E+6	4.01 E+6
Compliance [m/N]	14.2	13.1
First Eigenfrequency[Hz]	3303.9	2965.1
Mass [Kg]	0.00298	0.0048

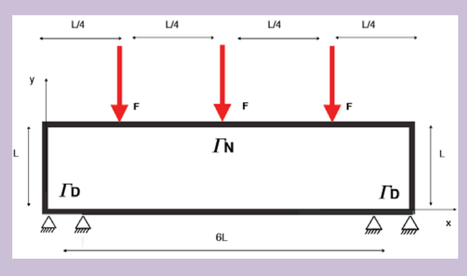






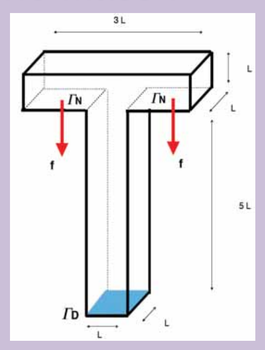
Free-form design for ALM

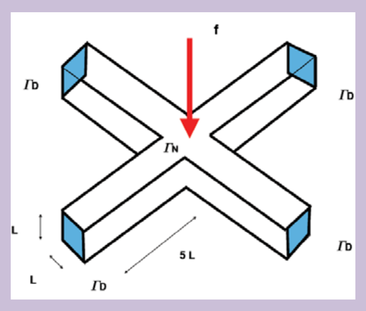
Unexpected forms are automatically designed :



BENDING STRAIGHT TRUSSES

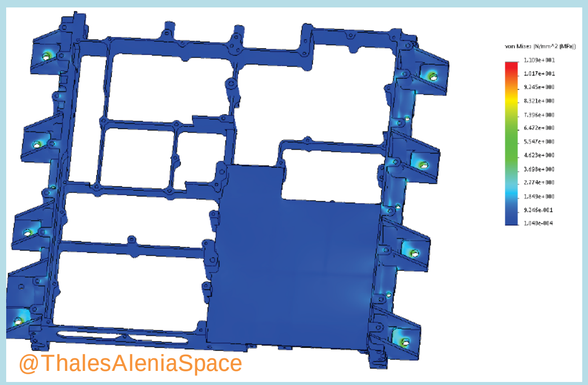
Be stiff but save the mass :

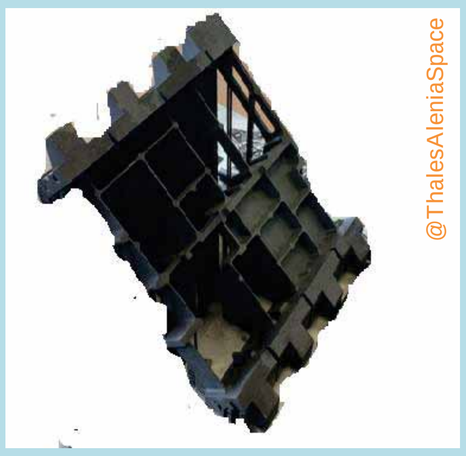




From 3D model to printing

Saving mass and cost by ALM design :





Minimizing material waste.

ALM makes your dreams come true !!

FLY TO BUY OPTIMIZATION