

New frontiers of topology optimization

What is topology optimization?

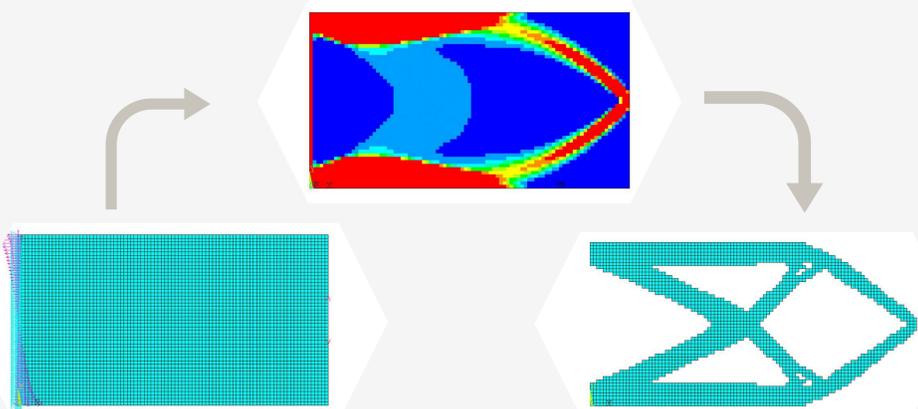
Topology optimization is a mathematical method that allows to find the best material distribution for a component. This distribution can be very complex, therefore additive manufacturing is the best technology in order to produce optimized components.



Example of a space rover in which the geometries of the wheel supports and the arm of the end effector are obtained by topology optimization. Since the remarkable shape complexity, they are producible by means of additive manufacturing. The main advantage of this design method is the achievement of a considerable weight reduction together with the guarantee of respecting prescribed mechanical performances.

Working principle

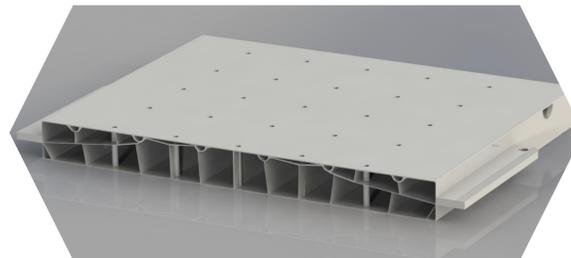
Starting from an initial design domain, the algorithm calculates which portions are useful to support the loads and which are not. These last are penalized until they disappear during the process. The remaining material bears the load equally and this is the reason why the material is fully exploited. There are no regions that are unloaded or overloaded. The result is the maximum resistance with the minimum amount of mass. Currently, the applications in the structural field are limited to isotropic materials.



On the left, it can be seen the initial discretised component, a cantilever beam loaded with a vertical force at the right end. At the top, it is shown the way the optimizer works. It selects the red elements (solid material) and discards the blue parts (empty material). Elements with intermediate colours are under analysis and they will become either blue or red after a certain number of iterations. On the right, the final optimal topology is highlighted. Clearly, it is much lighter than the initial one, but it still guarantees the mechanical performances initially prescribed.

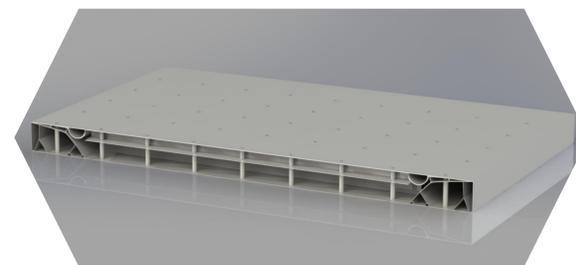
Thermo-structural optimization

Many real components are subject to both thermal and structural loads at the same time. Thermo-structural optimization is able to generate the final geometry that maximizes heat exchange and mechanical stiffness concurrently, clearly using the least amount of material possible.



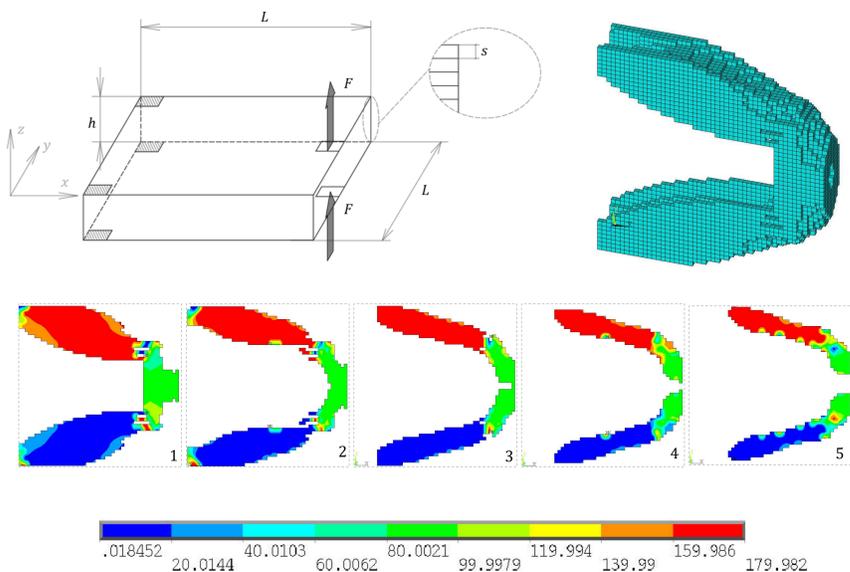
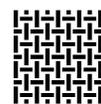
Real case: heat exchanger for aerospace applications. This component has the function of supporting electronic equipment during space missions. Since there is no air in space the equipment would tend to become too hot until failure as a result of electrical dissipation. For this reason, a coil with cooling liquid is used. Its function is to remove enough heat to ensure the proper performance of the equipment. In addition, the heat exchanger must survive the violent accelerations during the launch phase.

Therefore, this is a case where both the structural strength and the heat exchange must be guaranteed. Moreover, the lower the final mass appear to be, the lower the costs for the transport and the launch of the component itself become. The objective is therefore to obtain maximum heat exchange and maximum mechanical stiffness with the least possible use of material.



Composite Materials

Long-fibre composite materials consist of a plastic matrix containing fibres of rigid material. They are obtained in sheets that are glued together. In order to optimize this material, it is necessary to find the best distribution of the matrix and concurrently the orientation of the fibres inside it.



Top left: the initial model of the domain design with loads and constraints. Top right: the final topology of the optimized component. Below, it can be seen the stratigraphy in which the direction point by point that the fibres must have is indicated. This information is what is needed to print the part in 3D. Layer after layer the plastic matrix and the directed fibres are deposited together. In this way, a double-optimised composite component is obtained. Its properties are comparable to those of a metal material, such as aluminium.