A hollowing Topology Optimization method for additive and traditional manufacturing technologies

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keywords: hollowing; topology optimization; additive manufacturing; lightweight design

ABSTRACT

Thanks to the greater availability and technological evolution of rapid prototyping, attention has recently grown on the ability to design topologically optimized components in order to reduce their weight but at the same time maintain good mechanical resistance characteristics.

In this work, a topological optimization method is proposed starting from a grid of prefixed points in space to which the information obtained from a finite element analysis is associated. Topological optimization is performed by the Rhino's plugin Grasshopper, and consists of a parametric environment in the form of graphical algorithms.

The points on the grid represent the seeds from which the hollowing of the component will start.

The proposed method uses a monoparametric algorithm that varies the diameter of the holes that hollow the component as an inverse function of the intensity of the stresses acting. Through FE analysis conducted within Ansys Workbench, the distribution and intensity of the stresses on the specimen are obtained, which once insert on the algorithm are used to parametrize the diameter of the holes.

The potential of the method is represented by the ability of the algorithm to modify the CAD directly, guaranteeing topologies ready to be made, without further post processing by the designers. Thanks to the simplicity of the hollowing pattern, the result is it suitable to be made with both additive manufacturing and traditional subtractive technologies.

In a case study, once the model has been obtained, a beam sample has been printed by means of FDM 3D printing technique and tested with a 3-point bending test. A comparison of the original and the optimized beam has been carried out, monitoring the printing time, with about a 50% increase, and the strength/weight ratio, with about a 20% increase.

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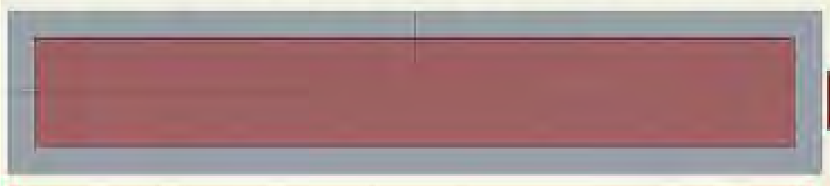
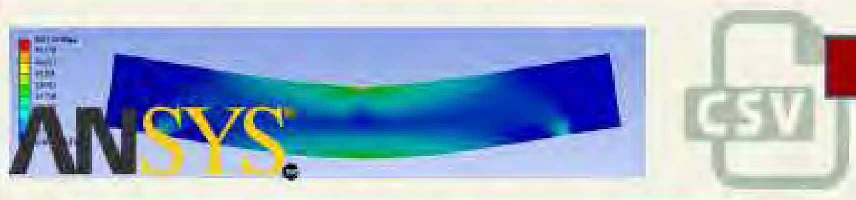
Materials and Methods

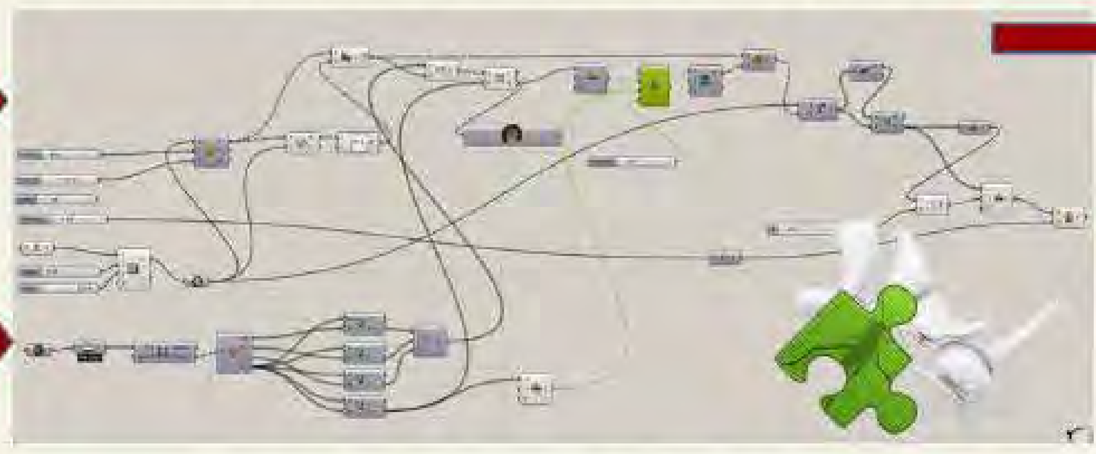
A rectangular beam specimen (280 x 20 x 40 mm) has been printed in PLA. All the tests were performed with a servo-hydraulic axial load machine INSTRON 8854 with maximum load capacity of 250 kN. Experimental 3-point bending test with distance between the support rollers equal to 220 mm. The CAE software were ANSYS Workbench for FEAs and Rhino Grasshopper for the algorithm generation.



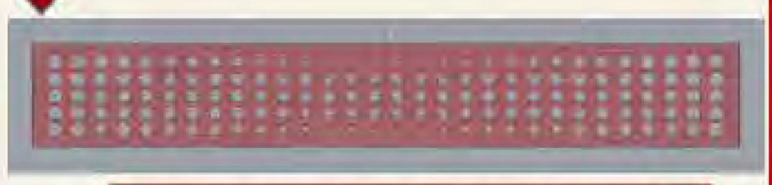
The CAD Rhino Geometry



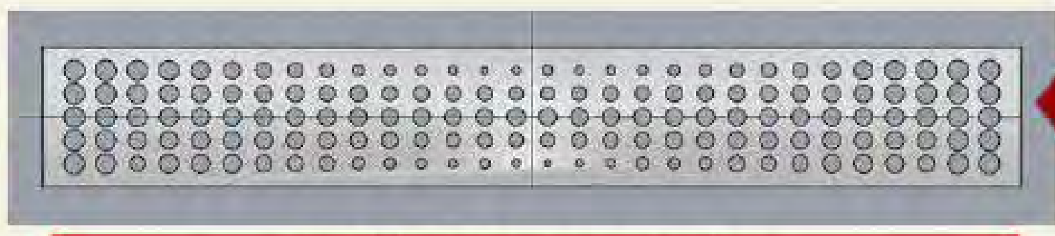
The data FEA export



The Grasshopper algorithm



The region is hollowed



Solid CAD generation

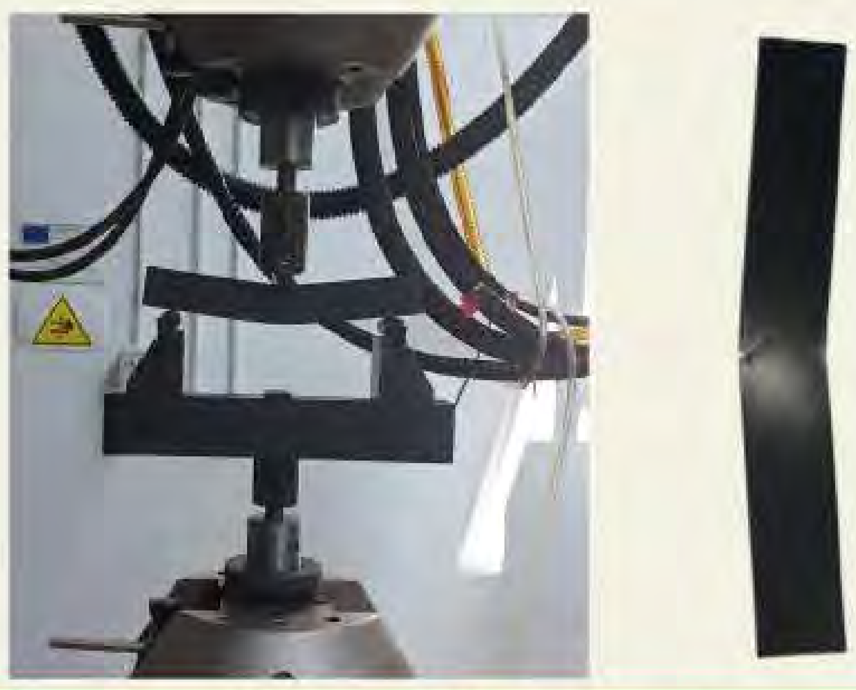
STL

3D

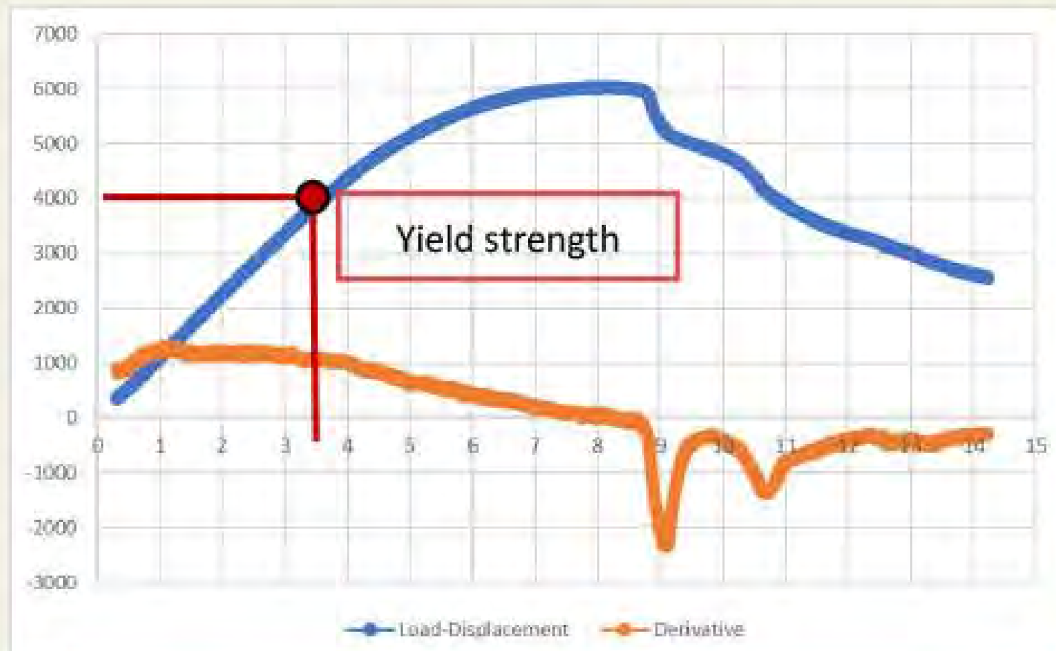
The .stl file is ready to manufacturing

Objectives

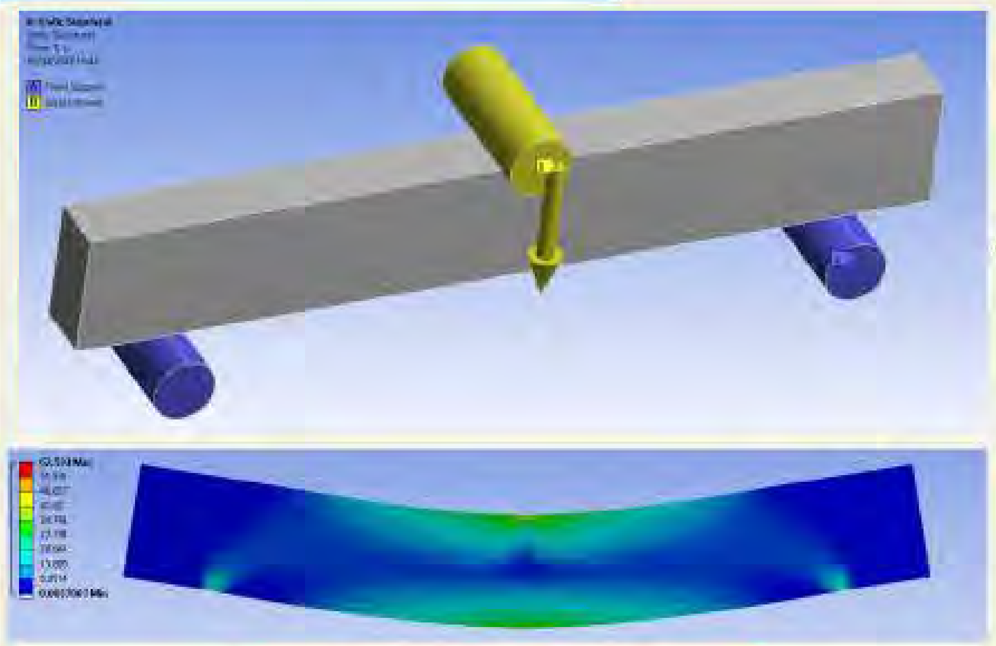
- Weight reduction
- Load/weight increase
- Higher utilization coefficient of the structure
- Easy-to-build structure



The specimen during and after bending test



Load-displacement curve and its derivative (moving average)

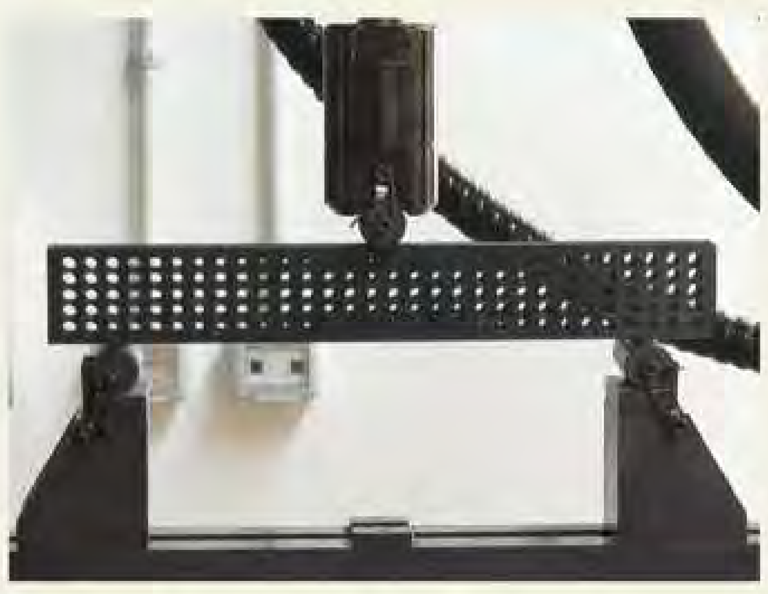


The FE analysis

The FDM manufacturing

Results

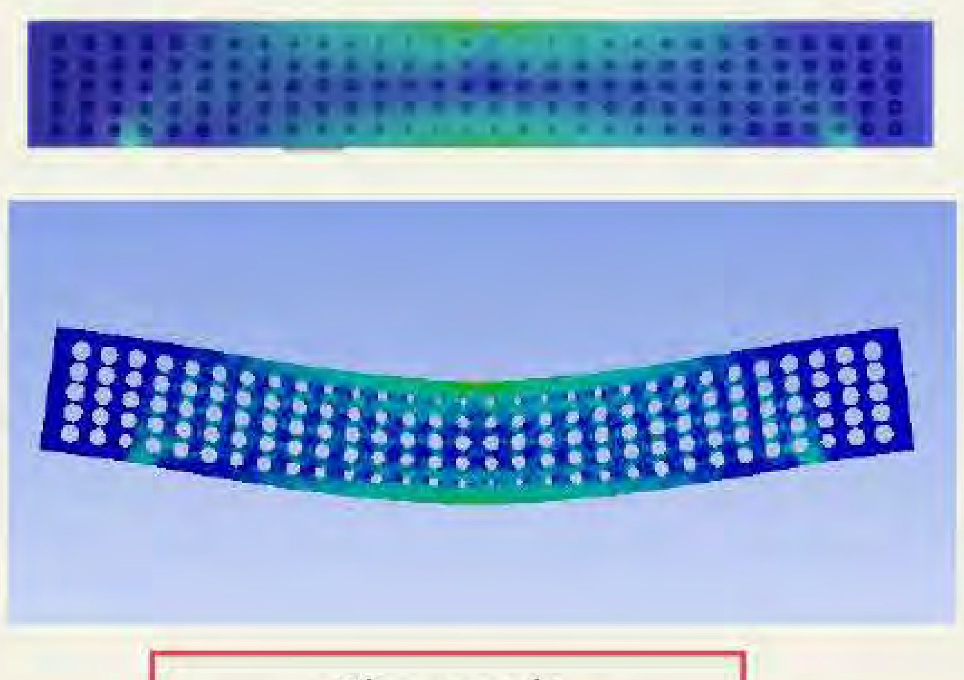
- The effect due to the outer fibres, neutral axis and contact pressures on the supports is well visible.
- Experimental tests validate the correctness of the FEA model.
- The load/weight ratio increases by 20% in the optimized specimen.
- The utilization coefficient, evaluated as the average stress on the sample, increases by 50% under the same load.
- However, the manufacturing time increases by 50%. This is due to the to the constant changes of direction of the print head.



The 3-point bending test of optimized specimen

The broken specimen after 3-point bending test

Conclusions



The result

- A topology optimization method, based on a monoparametric hollowing has been developed and tested.
- The algorithm, interfacing with the results of the FEA, hollows the component with holes inversely proportional to the intensity of the stress.
- A rectangular-shaped beam has been optimized, as case study, with a good increase of load/weight but also of time/weight ratios.
- The same approach can be used with components of any shape and nature and is useful for both additive or traditional manufacturing technologies, by using CNC drilling or milling-machines .