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Topology Optimization of 3D Printed Metal Parts

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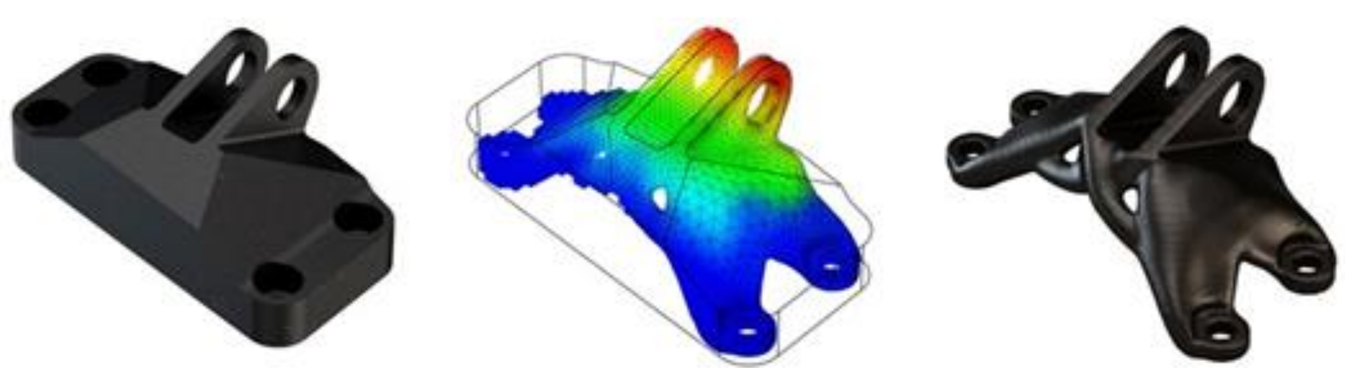
Abstract

Topology Optimization has a major impact in the field of 3D printing. Since this method of manufacturing is almost limitless in terms of producible shapes and configurations, the process of optimization becomes highly more dominant.

One of the recent breakthroughs in technology is printing of metals. Therefore, the topology optimization process has a main role. The materials used for the printing (e.g. Titanium) are very expensive, and by removing unnecessary regions of the part, the cost can be reduced drastically.



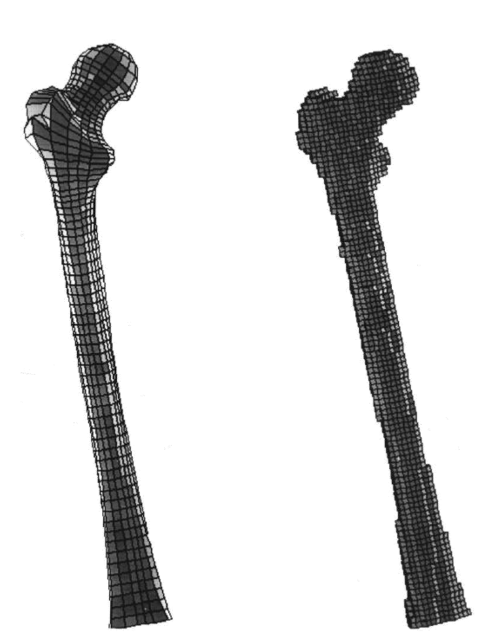
Example of a topology optimization process

This process is complex algorithmically. First, the regions that should be removed are sometimes hard to determine. Second, while removing material from the part, it might need extra supports to be printed which must be taken into consideration.

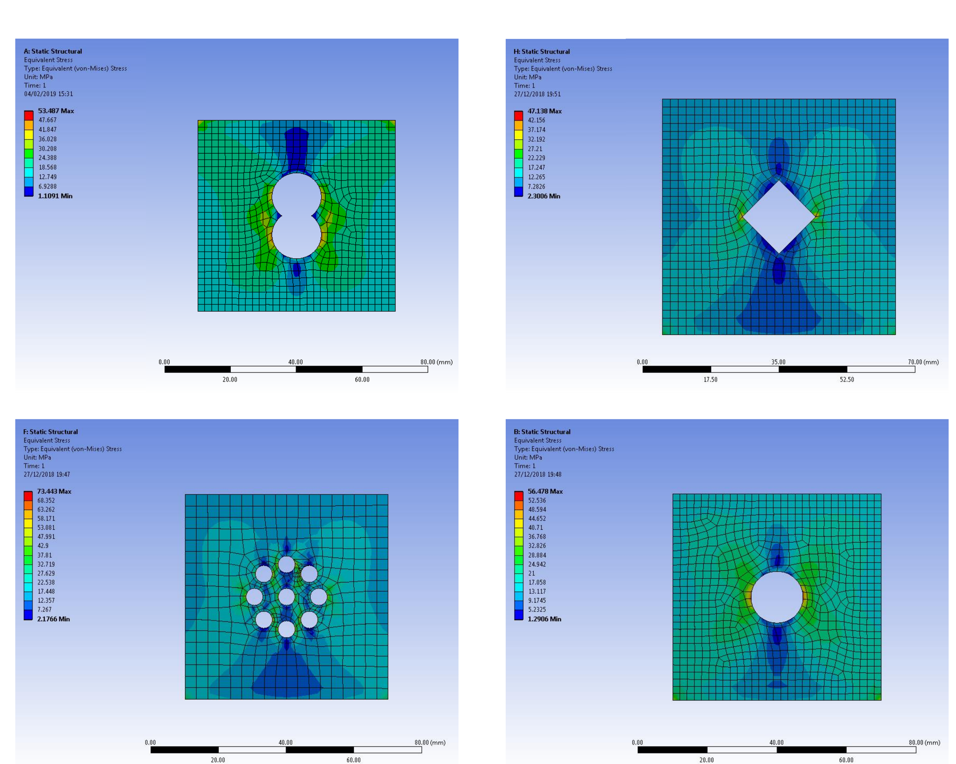
Project Goal

The main goal of this project is to develop an efficient process for Topology Optimization of a 3D printed metal part. Several optimization issues:

- Define an effective material removal policy.
- Select a 3D model representation.



A model representation and by volumetric elements (left) and by voxels (right)



Stress analysis of different hole shapes and patterns

Material removal policy

There are several removal policies that we compared according to the optimization criteria: stress threshold, model geometry and 3D metal printing restrictions.

1. Reducing and simplifying supports: Defining all removed cuts that are to be extruded from the model and will be cut in the printing direction.
2. Examining different shapes and their resulting stresses. Moreover, we compared the process of removing a pattern with holes vs. a single hole with equal volume removed. Results are shown in the table.

Hole Shape	Max Stress [MPa]	Removed Volume [mm^3]
Big Circle	56.478	1766.25
9 Small Circles	73.433	1767.15
Square	47.138	1768.9
Square 45°	81.808	1768.9

Comparison table of different hole shapes and patterns

Project approach

The proposed method is an iterative method. The part is analyzed and according to the results a single hole is created. After the hole is made, the part is reanalyzed. The process is repeated until it satisfies the stop criteria. Then, the part is ready to be printed. The reason for the cycle process is that each step of the material removal has a potential of damaging the structural stiffness of the part and therefore it must be analyzed between steps.

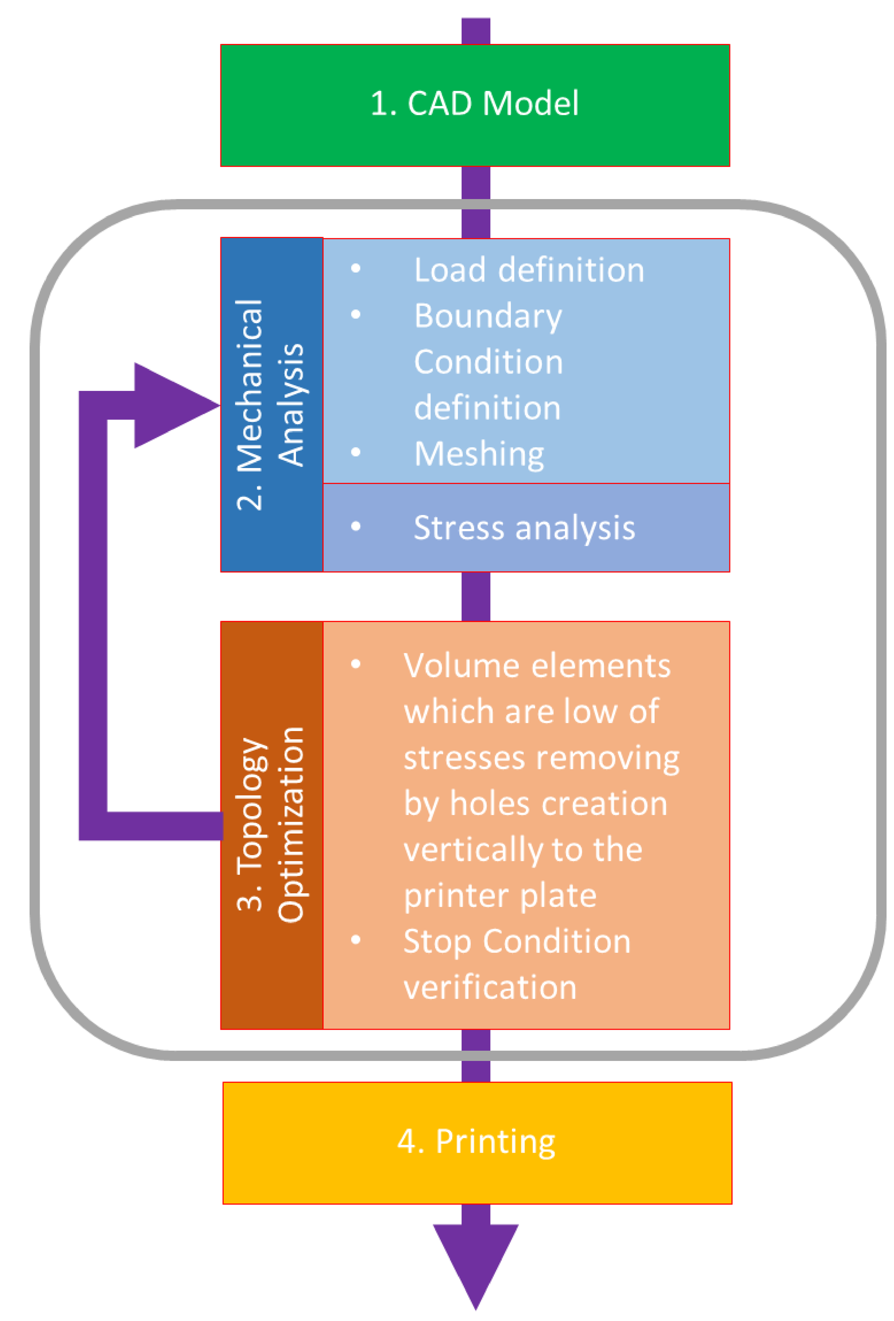
<u>*The method stages:*</u>

1. The input is a CAD model.

2. The model is analyzed, and a stress map is produced. This stage is done in the analysis software - Ansys WB.

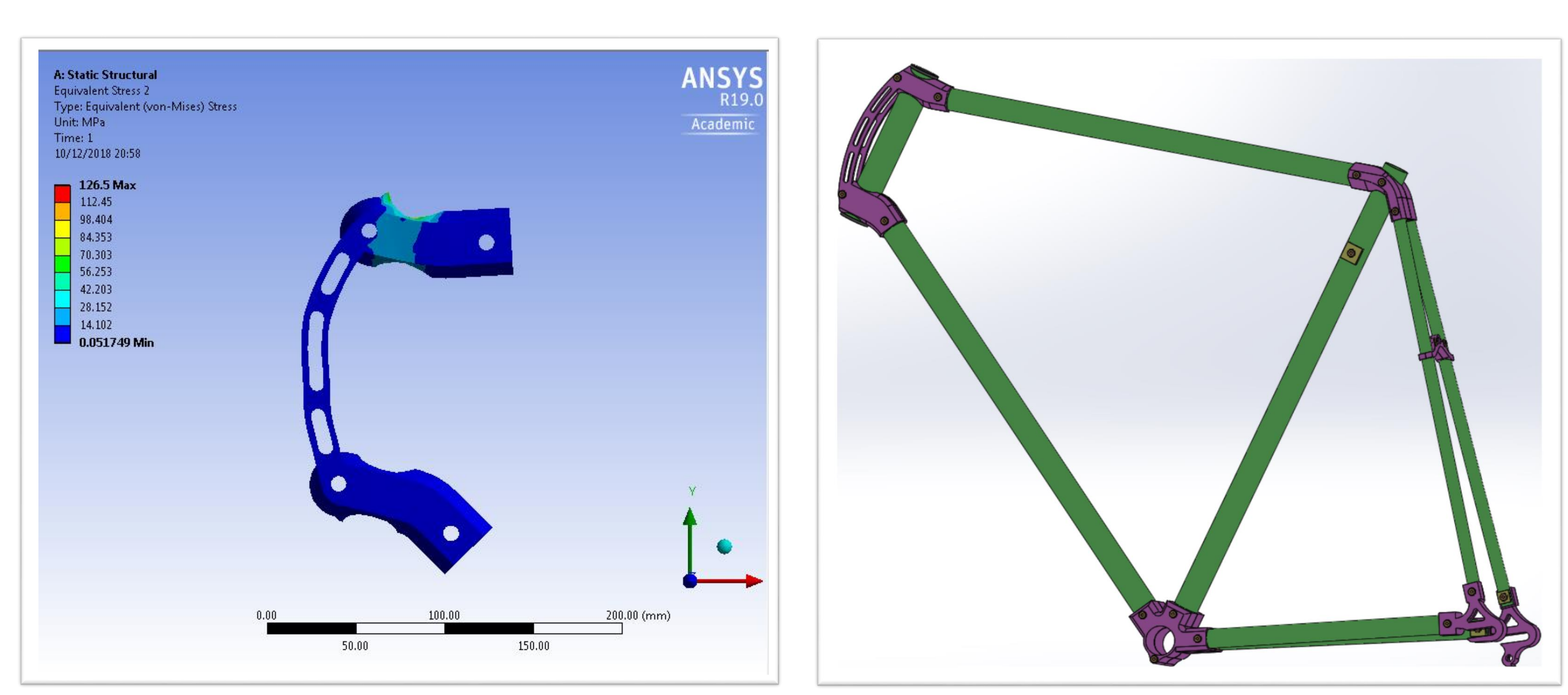
3. (a) According to the stress map and the removal protocol, the method determines the best position of the next hole. It receives the stress map and the model geometry as .The input is an STL file, and the output is a numeric solution of a hole diameter and position coordinates. It was implemented in Matlab.
(b) The CAD model is then modified by creating an additional hole. For this stage, we used SolidWorks software as the model designer. An extruded cut of a round hole with a specific diameter and a specific position is created in the model. The modified model is sent back to stage 2.

4. The cycle is to be repeated until the stop criteria is fulfilled. Then the model is ready to be printed.



Solution flow diagram

Applicable concept for optimization



Stress analysis of a part in a bicycle frame and preparation for optimization

References

1. Mechanical Analysis of a Bike Frame – Tech report, Jon Langerman
2. Topology Optimization of a 2.5D Object for 3D Printing – Sagi Porat
3. Topology Optimization of a Bicycle Frame Truss Junctions – Arik Lerner
4. 3D Printing Design of a Bicycle Frame Trusses – Omer Vikinski