Design and additive manufacturing process simulation of a bracket using finite element method

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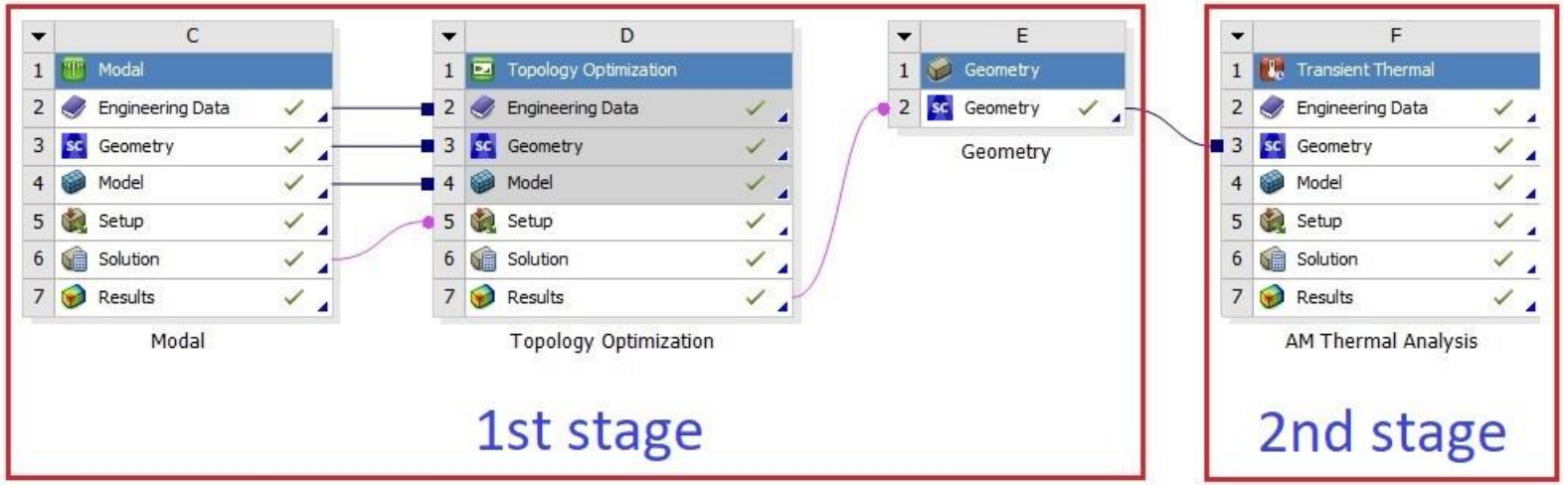
1st Winter School on Trends on Additive Manufacturing for Engineering Applications
Polytechnic University of Timișoara (UPT) Timisoara, Romania, 24th -28th January 2021

Steps to follow

- The aim of this study is obtaining an optimized “lattice” model for a mounting bracket of a robotic arm using the ANSYS Workbench 2020 R2 software. The case study has two main stages:

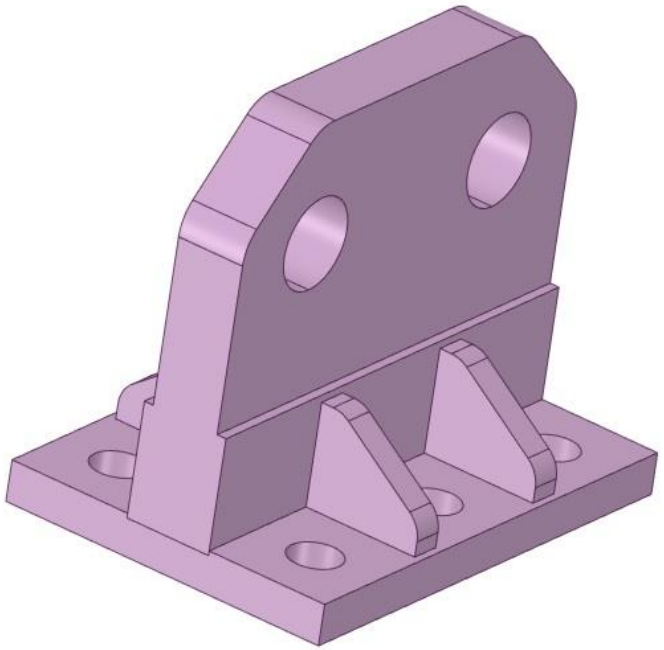
  - in the first stage is optimized the orthotropic lattice material by establishing an optimal variable cubic cell lattice density distribution in the geometric model;

  - the second stage consists of additive manufacturing process simulation using the “lattice” model resulting from the first stage.

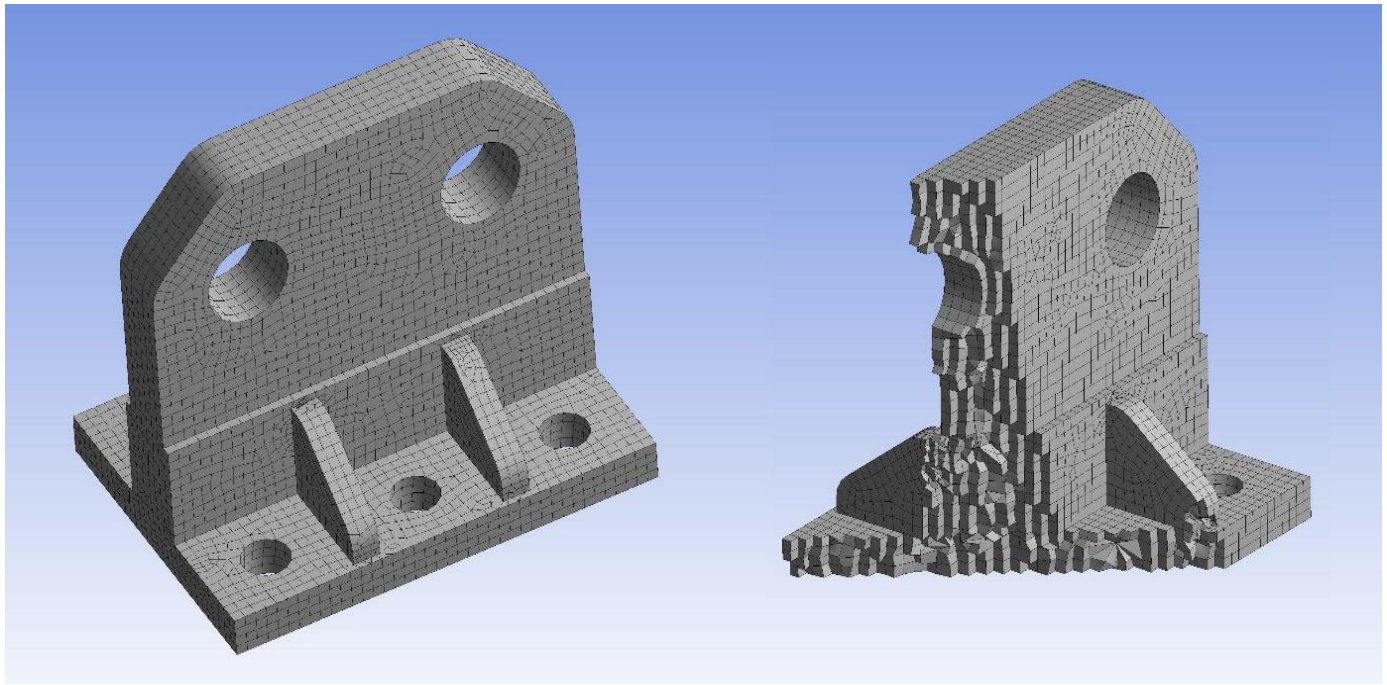


Initial finite element model

- Finite element type Solid 185 (specific to structural analysis)
- Element size 4 mm
- Number of nodes: 13631 ; number of elements: 14609



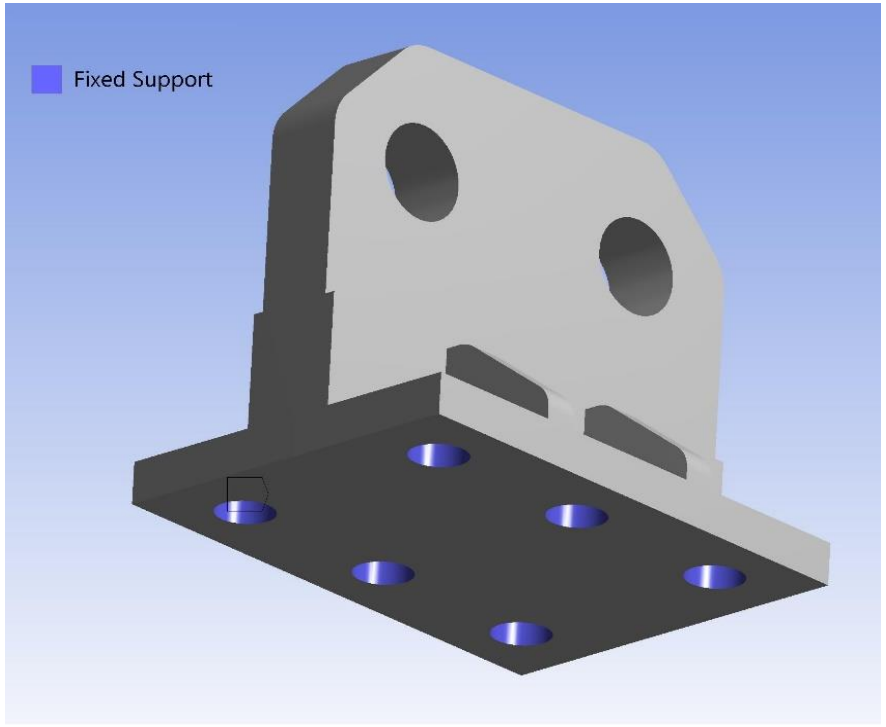
Geometry of the bracket



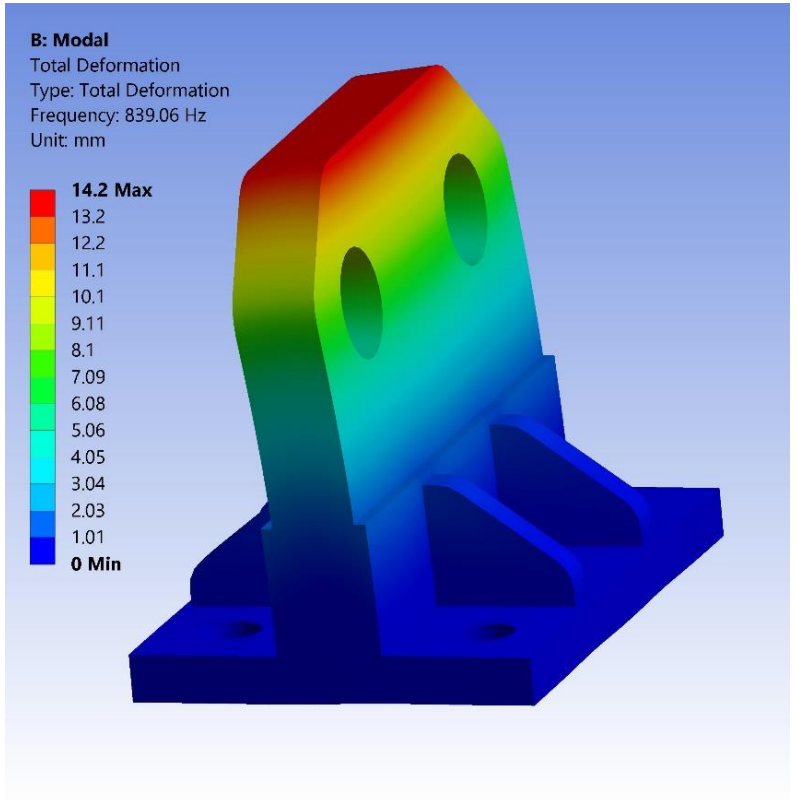
Initial FE model

Modal analysis

I used a Block Lanczos algorithm for computing a few of the smallest eigenvalues and the corresponding eigenvectors of the symmetric matrix. The Block Lanczos eigenvalue extraction method can be used for large symmetric eigenvalue problems and employs an automated shift strategy to extract the number of eigenvalues requested.



Boundary conditions



Fundamental frequency f1=839 Hz

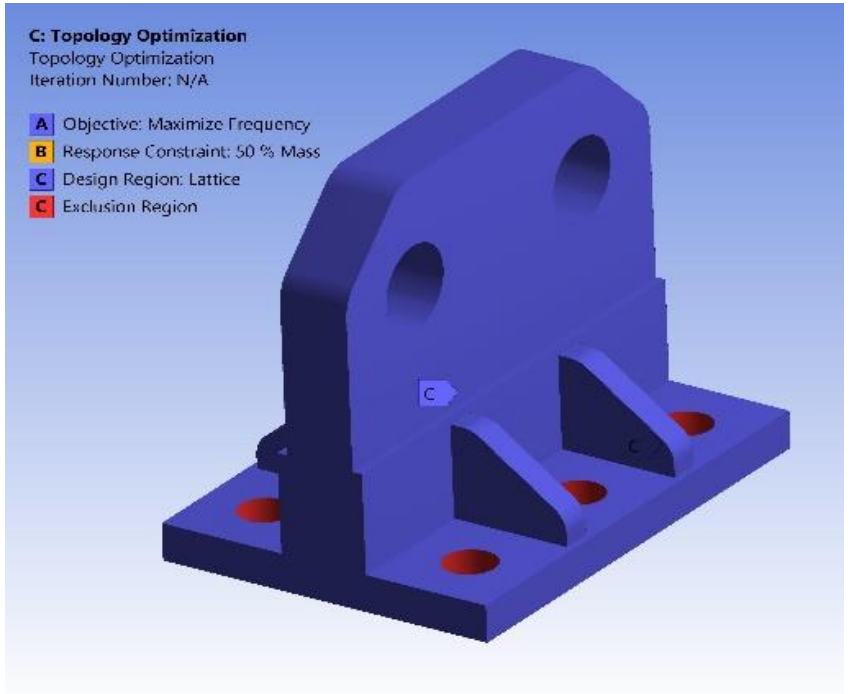
Lattice type topological optimization

Optimization objective:

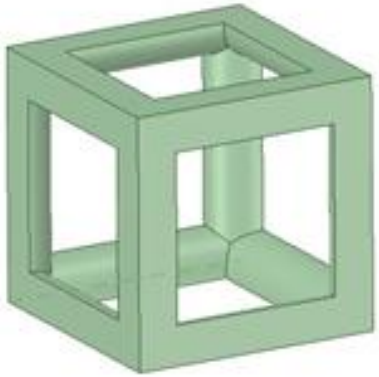
- Increasing the value of the first natural frequency

Specific input data:

- Optimization constraint: new mass has to be at least 50% from the initial one.
- Region to be optimized in marked by the blue color.
- The cubic lattice cell has a variable density, having values between 0,1 and 1.
- Lattice element size was chosen to be 1 mm as difficulties to use smaller size were encountered.

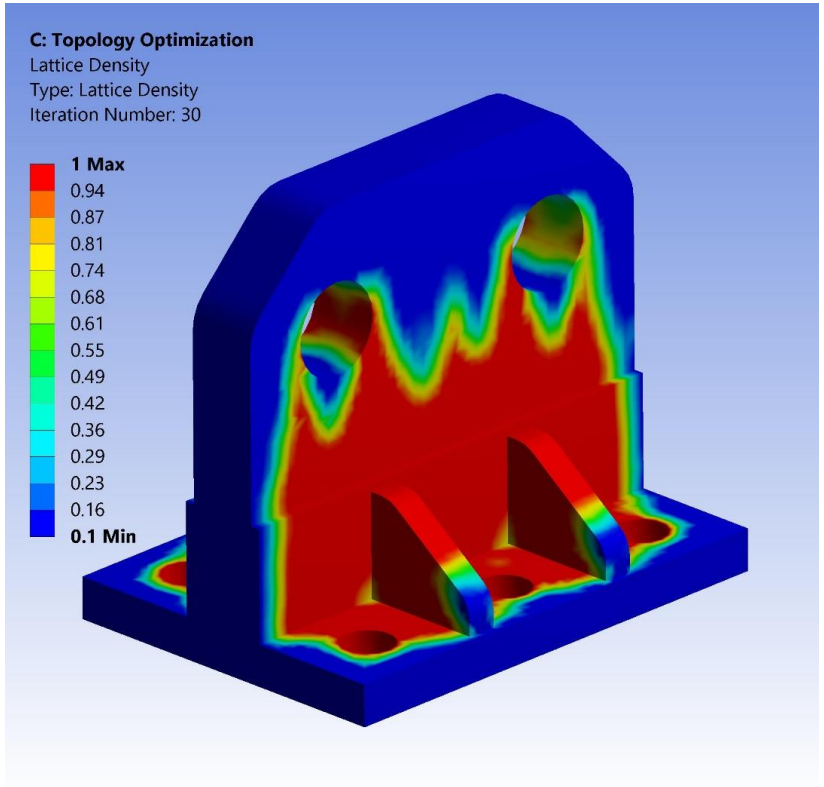


Region to be optimized in blue color

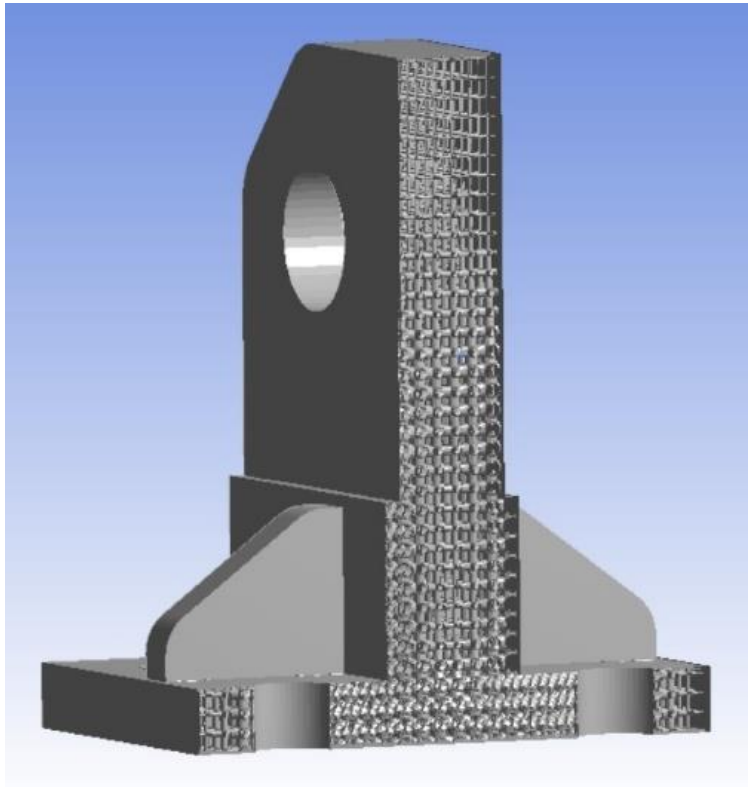


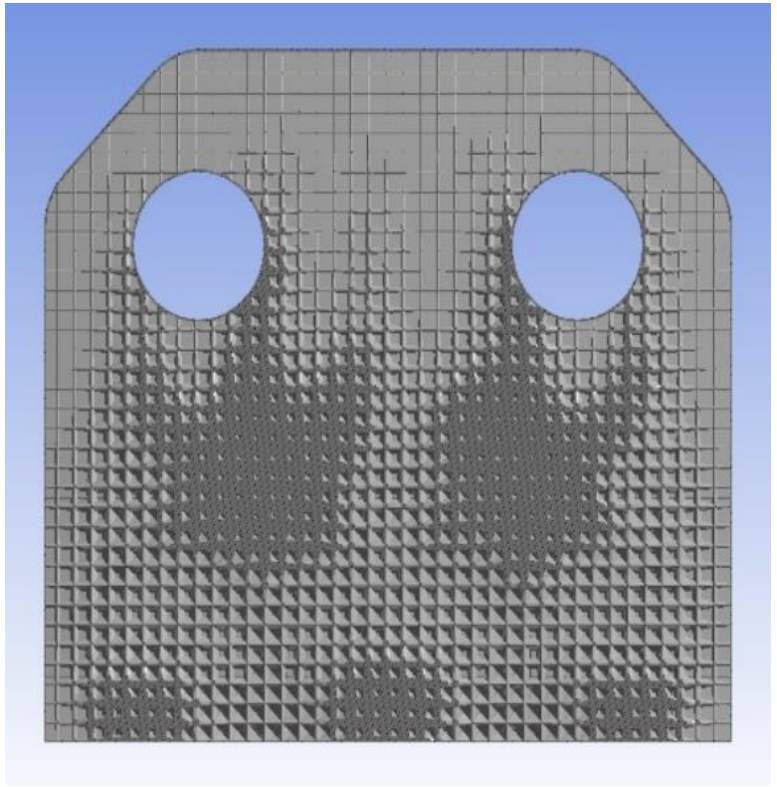
Cubic “lattice” cell

Obtaining the lattice structure



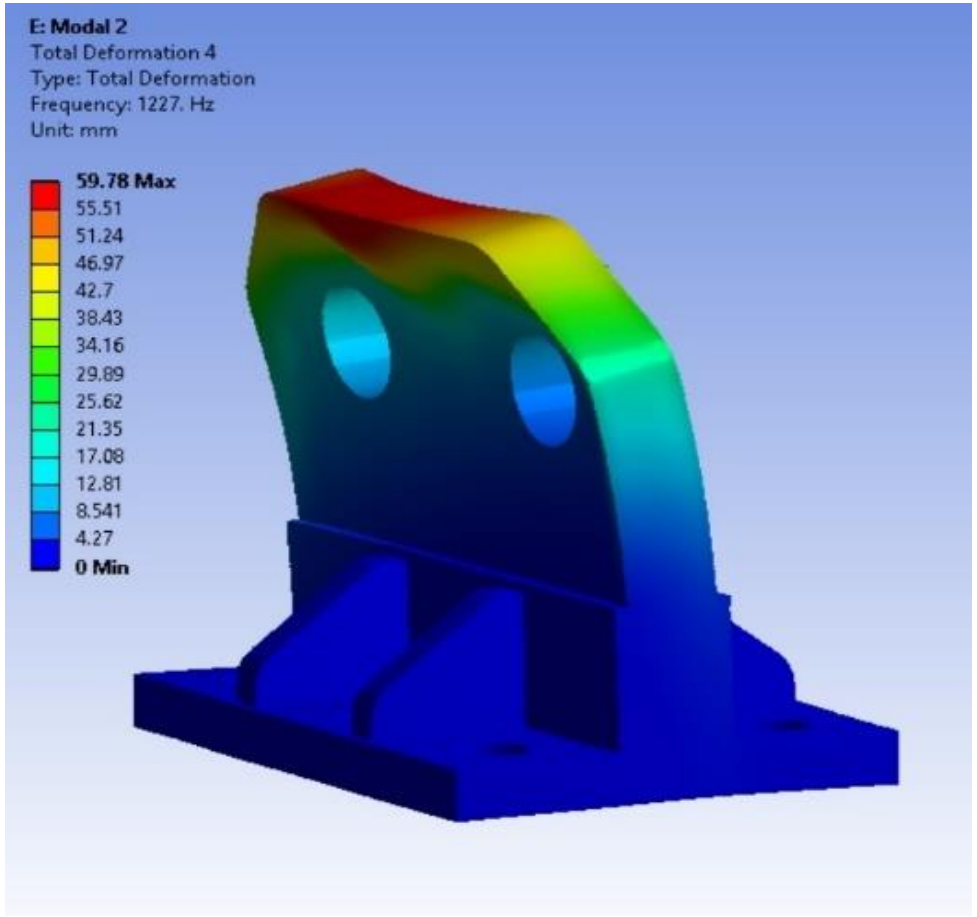
Material distribution after optimization

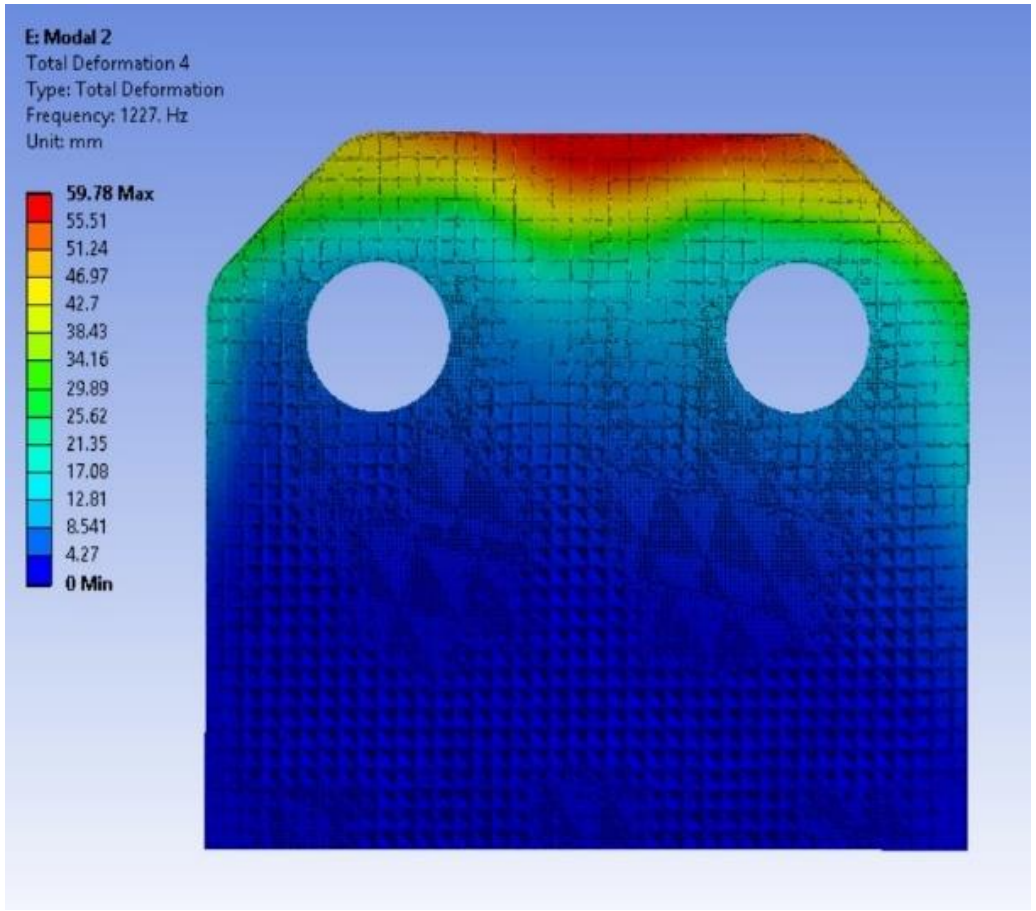




Lattice structure of the bracket in transversal and longitudinal sections

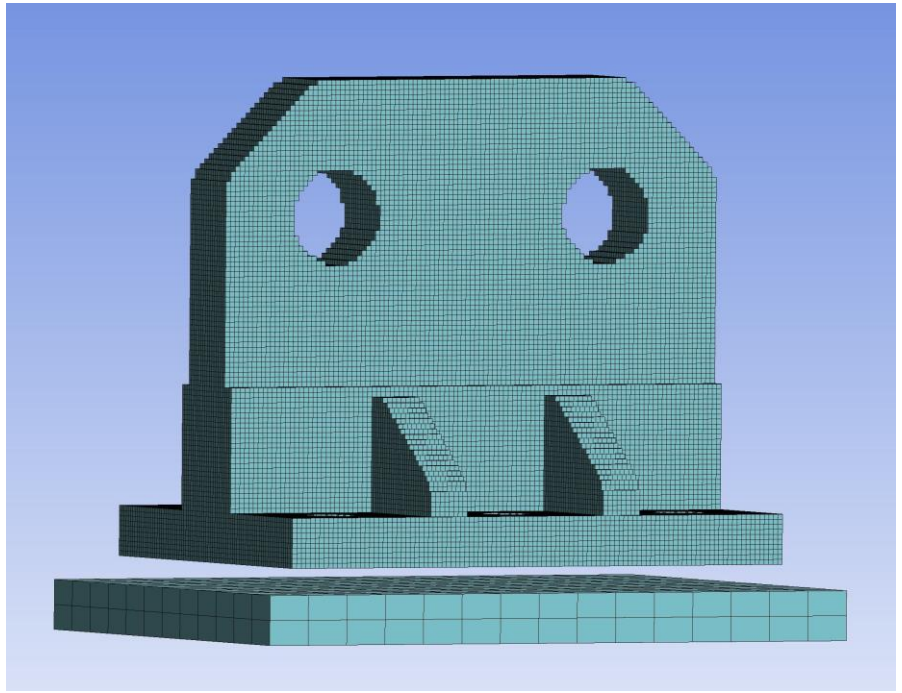
Results for the lattice model



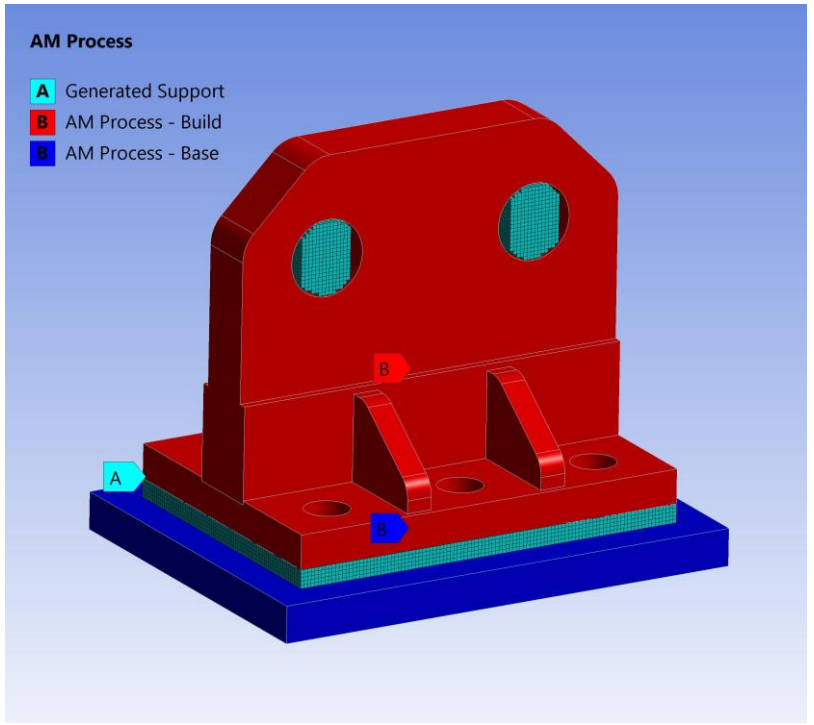


Fundamental frequency obtained after optimization is f1=1227 Hz

Additive manufacturing process simulation

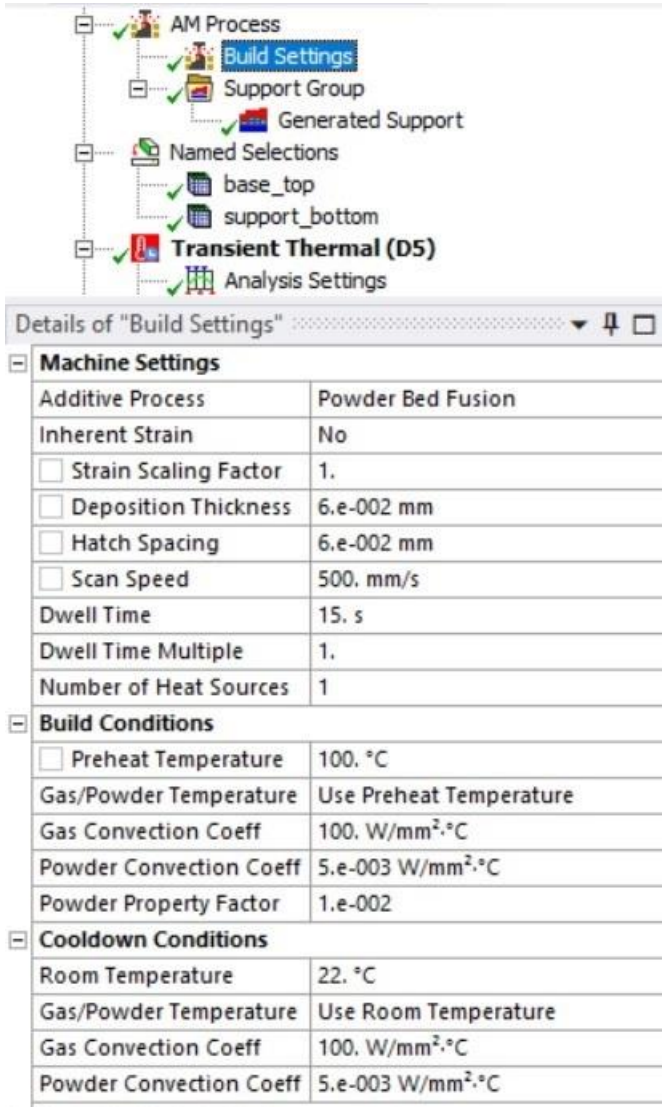


FE model for builded bracket and base



Complete model for 3D Print simulation

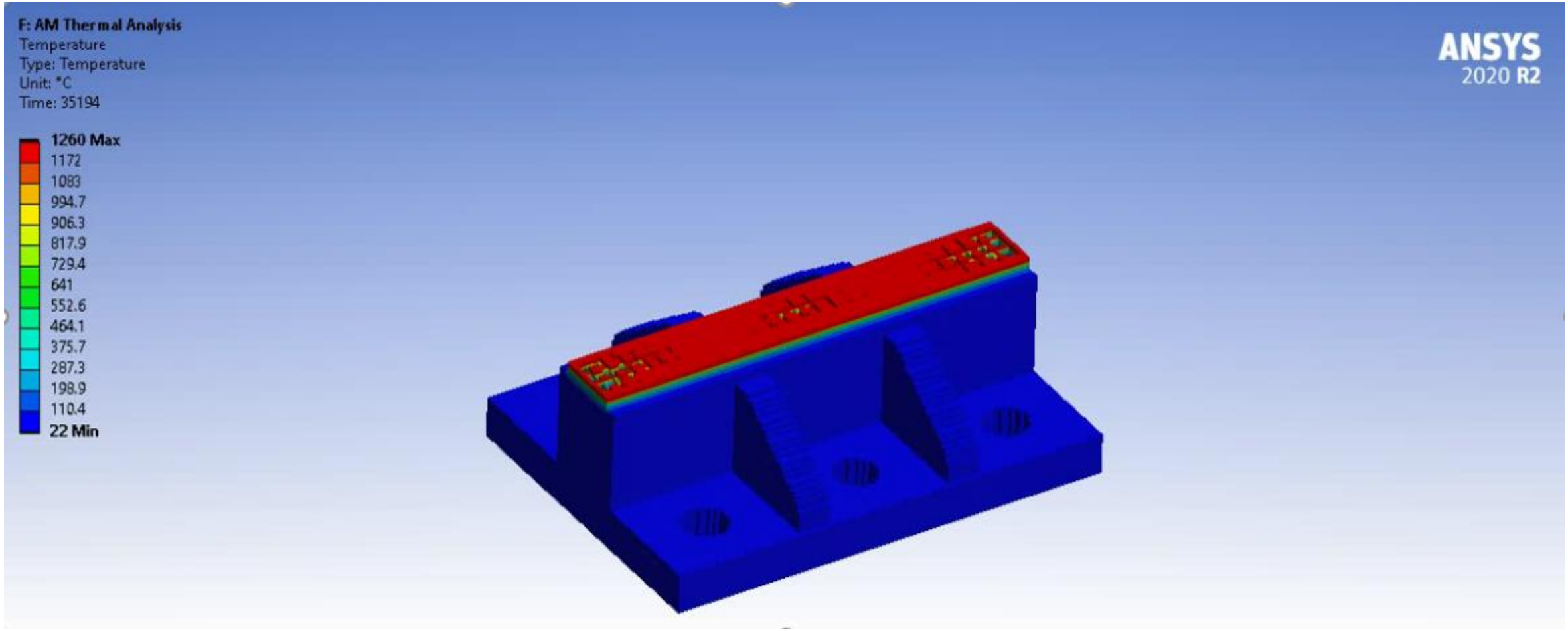
- Finite element type: Solid 278 (specific to thermal analysis)
- Element size: 1 mm
- Number of nodes: 311266 ; number of elements: 265942



Machine Settings	
Additive Process	Powder Bed Fusion
Inherent Strain	No
Strain Scaling Factor	1.
Deposition Thickness	6.e-002 mm
Hatch Spacing	6.e-002 mm
Scan Speed	500. mm/s
Dwell Time	15. s
Dwell Time Multiple	1.
Number of Heat Sources	1
Build Conditions	
Preheat Temperature	100. °C
Gas/Powder Temperature	Use Preheat Temperature
Gas Convection Coeff	100. W/mm²·°C
Powder Convection Coeff	5.e-003 W/mm²·°C
Powder Property Factor	1.e-002
Cooldown Conditions	
Room Temperature	22. °C
Gas/Powder Temperature	Use Room Temperature
Gas Convection Coeff	100. W/mm²·°C
Powder Convection Coeff	5.e-003 W/mm²·°C

Input data for 3D print simulation

Additive manufacturing process simulation (Animation)



Conclusions

- Numerical exercise to approach numerical simulation for 3D printing proved to be effective as the fundamental frequency was increased from an initial value of 839 Hz to 1227 Hz in the lattice model.
- After lattice optimization, mass of the bracket was reduce from 1.82 kg to only 0.98 kg.
- In additive manufacturing process simulation the simulation generally requires a fine mesh to respect all details of the lattice structure, including those areas of the model that are thin or very thin. This generally leads to a large FE model that requires significant computing resources. HPC machines are generally preferred.