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LIVEWORX

A NEW ERA IN PRODUCT LIFECYCLE INNOVATION

SESSION ID: CA1522C

ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES

SPEAKER(s): **Andreas Vlahinos**

CTO, Advanced Engineering Solutions

Jose Coronado

Product Management Director, PTC

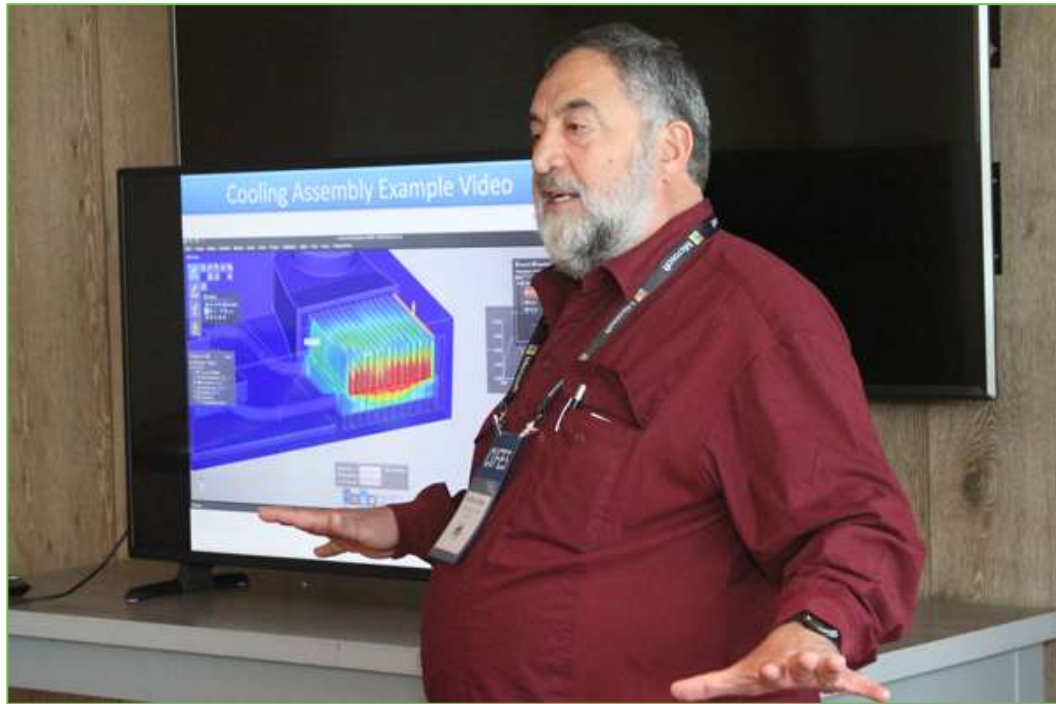
MAY 15, 2023

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Andreas Vlahinos



CTO, Advanced Engineering Solutions



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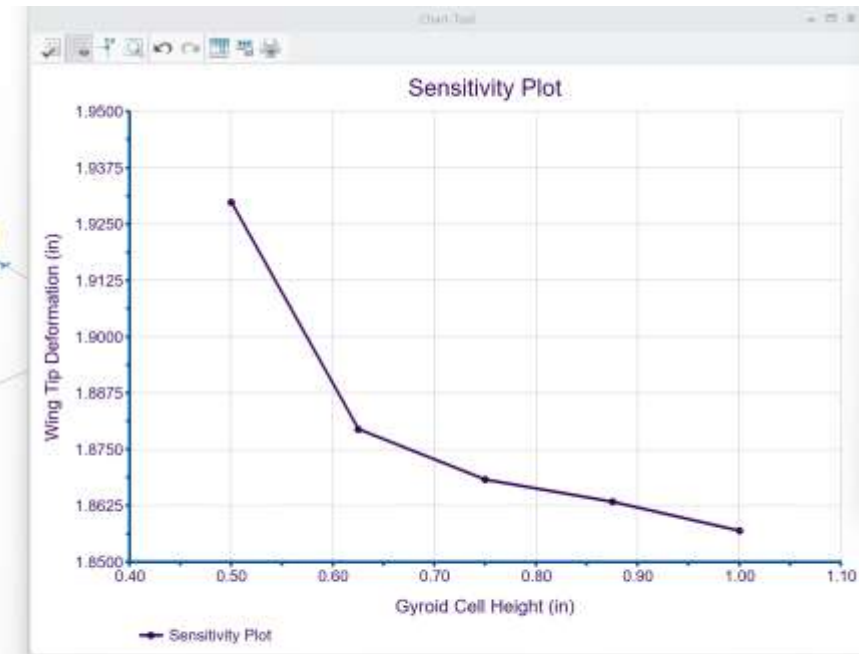
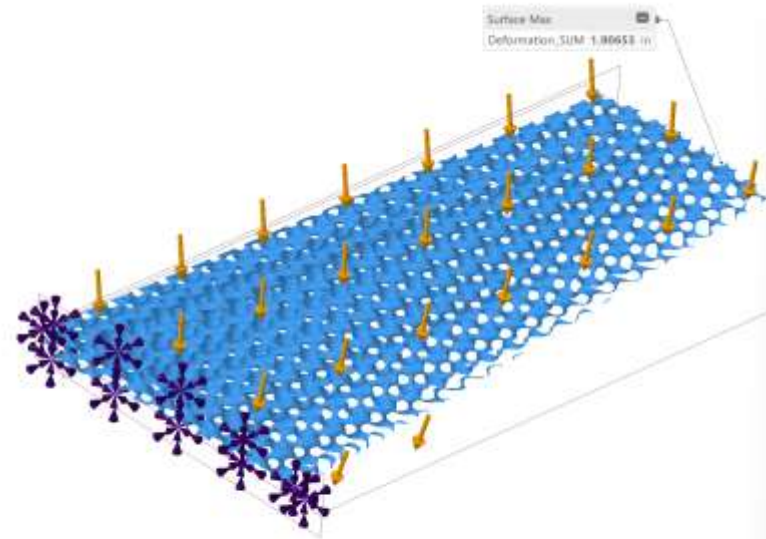


Product Management Director, PTC



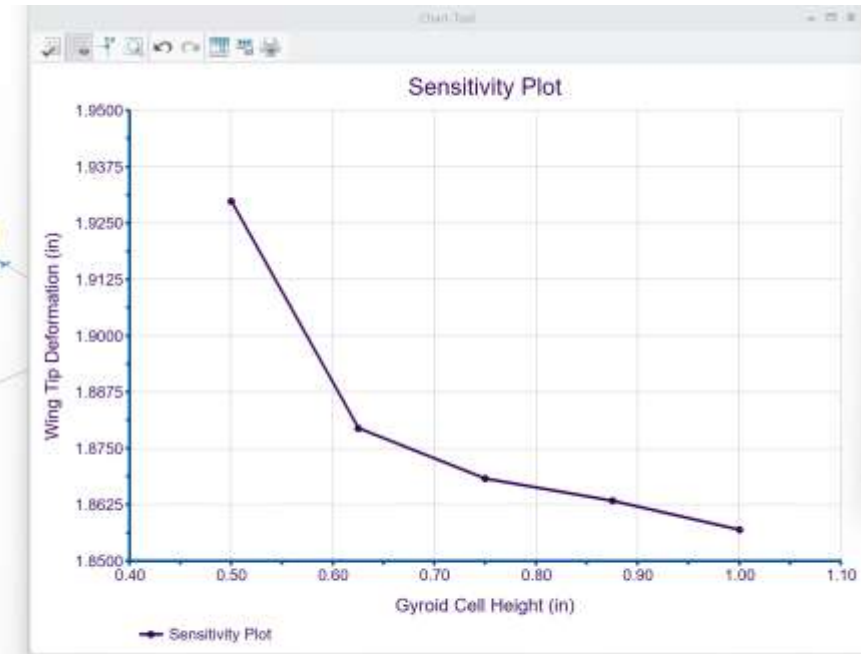
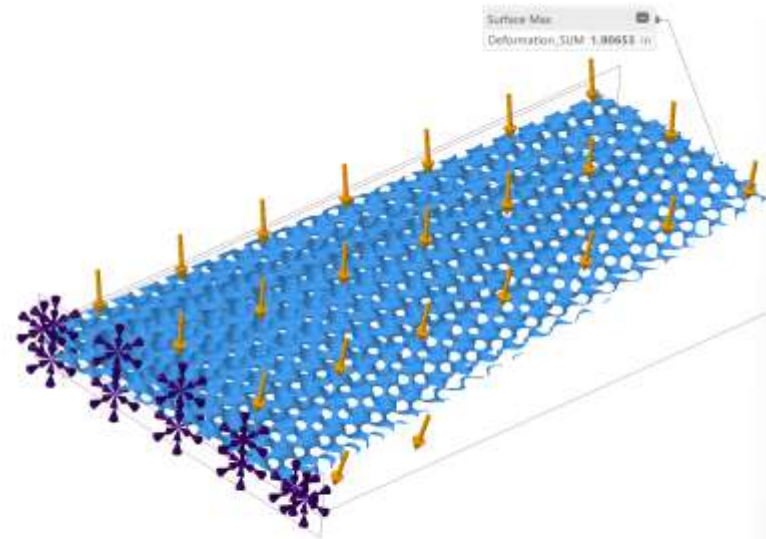
ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES

- Taxonomy of Lattice Structures
- Optimization Workflow
- Simulation-driven lattices in Creo
- Special cases

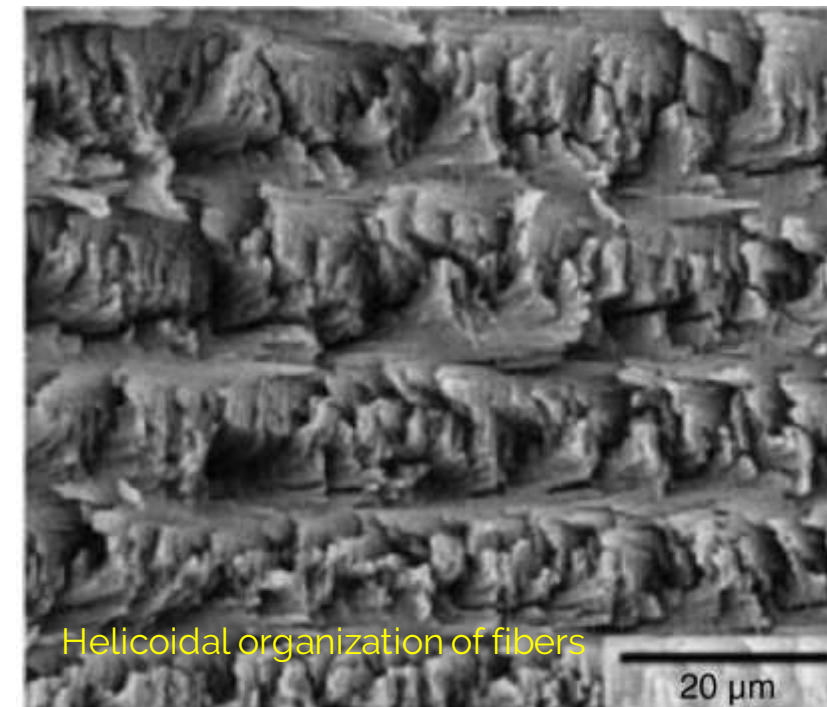
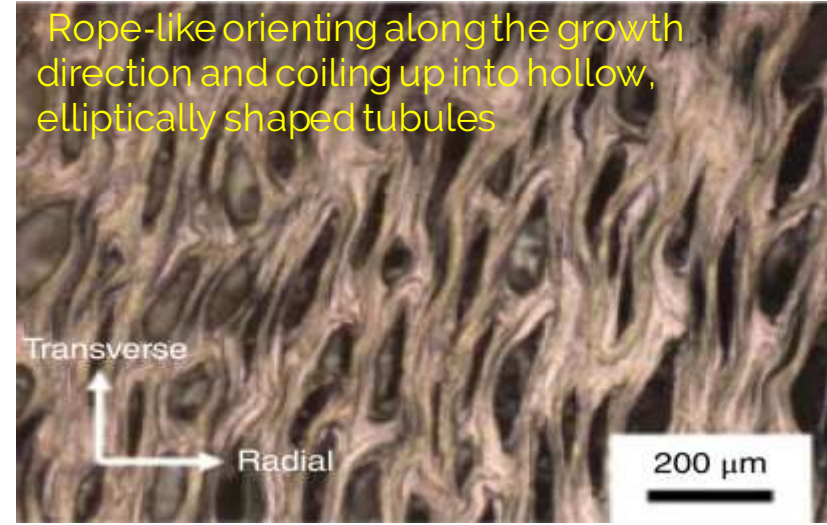


ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES

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WHAT NATURE CAN TEACH US ABOUT STRENGTH, ENERGY ABSORPTION AND LIGHT WEIGHING ?



TAXONOMY OF LATTICE STRUCTURES IN NATURE

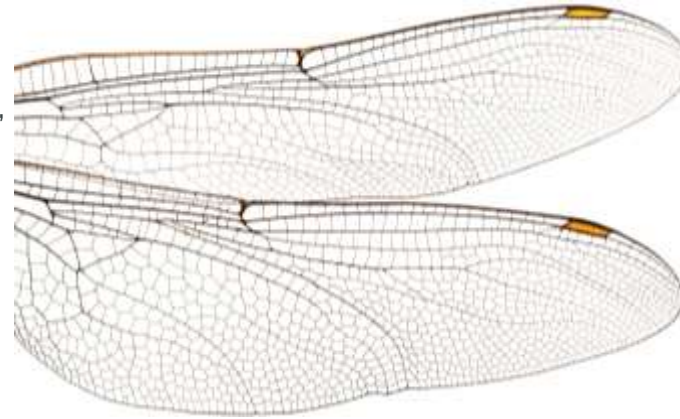
On Surface Lattice

Periodic

Triangle, Square, Hexagon,
Octagon, etc.

Stochastic

Voronoi Tessellation
Delaunay Triangulation
Uniform
Spatially Varied



Dragonfly Wings

2 1/2 D Lattice

Periodic

Cartesian Trimmed
Triangle, Square, Hexagon,
Octagon, etc.

Cartesian Conformal Edge
Polar
Herringbone



Honeycomb

3D Beam Lattice

Periodic

Cartesian,
Triangle, Square,
Octagon, etc.

Polar

Stochastic

Voronoi
Delaunay
Uniform
Spatially Varied



Venus flower basket glass sponges

3D Surface Lattice TPMS

Periodic

Uniform thickness
Variable thickness
Variable cell size
Spatially Varied

Examples:

Gyroids, Diamonds, Octets,
Lidinoïd, Schwarz D, Schwarz P,
Neovius, ...

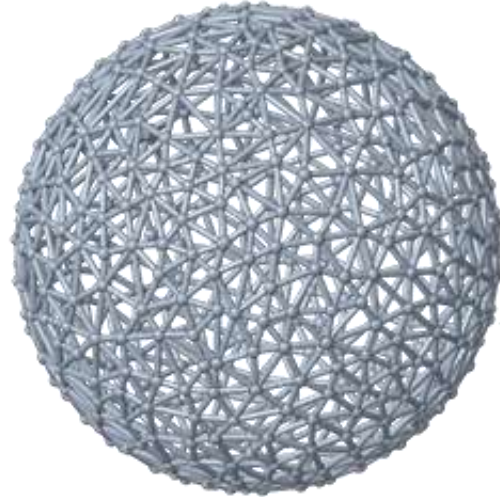


Butterfly gyroid nanostructures

TAXONOMY OF LATTICE STRUCTURES IN CREO

On Surface Lattice

- Periodic
 - Triangle, Square, Hexagon, Octagon, etc.
- Stochastic
 - Voronoi Tessellation
 - Delaunay Triangulation
 - Uniform
 - Spatially Varied

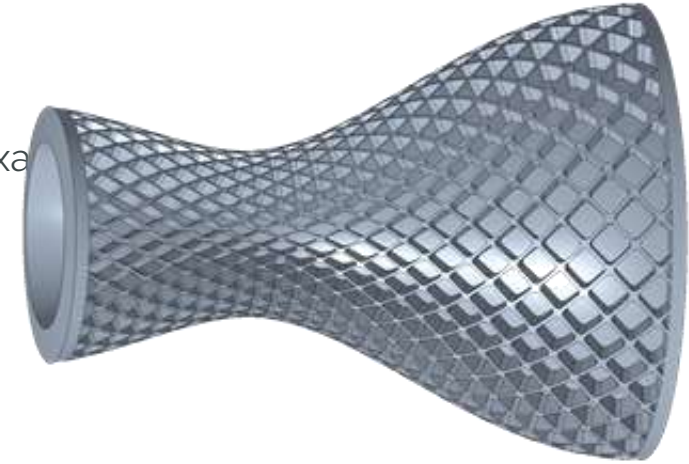


Surface Delaunay

Triangulation

2 1/2 D Lattice

- Periodic
 - Cartesian Trimmed
 - Triangle, Square, Hexagon, Octagon, etc.
 - Cartesian Conformal Edge
- Polar
- Herringbone



Rocket Nozzle with Ribs

3D Beam Lattice

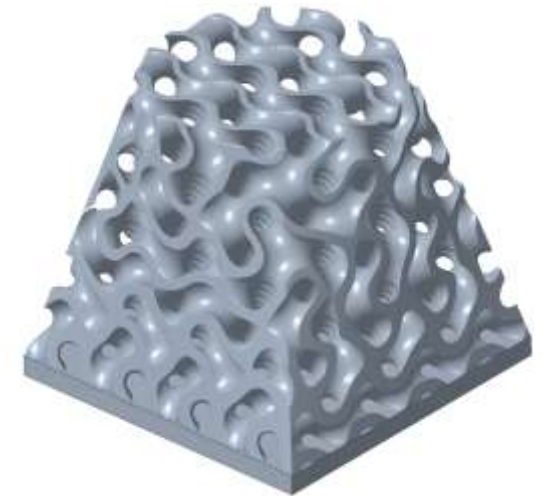
- Periodic
 - Cartesian,
 - Triangle, Square, Hexagon, Octagon, etc.
 - Polar
- Stochastic
 - Voronoi Tessellation
 - Delaunay Triangulation
 - Uniform
 - Spatially Varied



High Performance Heat Exchanger

3D Surface Lattice TPMS

- Periodic
 - Uniform thickness
 - Variable thickness
 - Variable cell size
 - Spatially Varied
- Examples:
 - Gyroids, Diamonds, Octets, Lidinoid, Schwarz D, Schwarz P, Neovius, ...

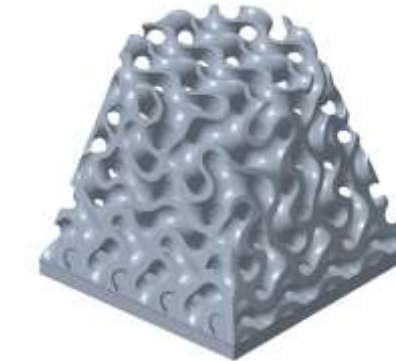
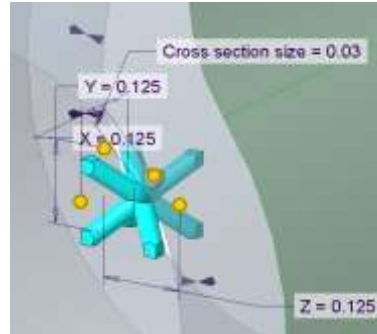


TPMS High Performance Heat Exchanger

WHAT ARE THE CHALLENGES IN SIMULATING LATTICE GEOMETRIES?

Challenges

- Massive tet element size
 - Required to capture the small geometry details
- Interoperability
 - TPMS are using explicit or voxel-based kernels not (B-rep) without neutral file format (STEP, Parasolid) exports
- Integration with Generative Design
 - GD tools can't use a TPMS geometry as a design space

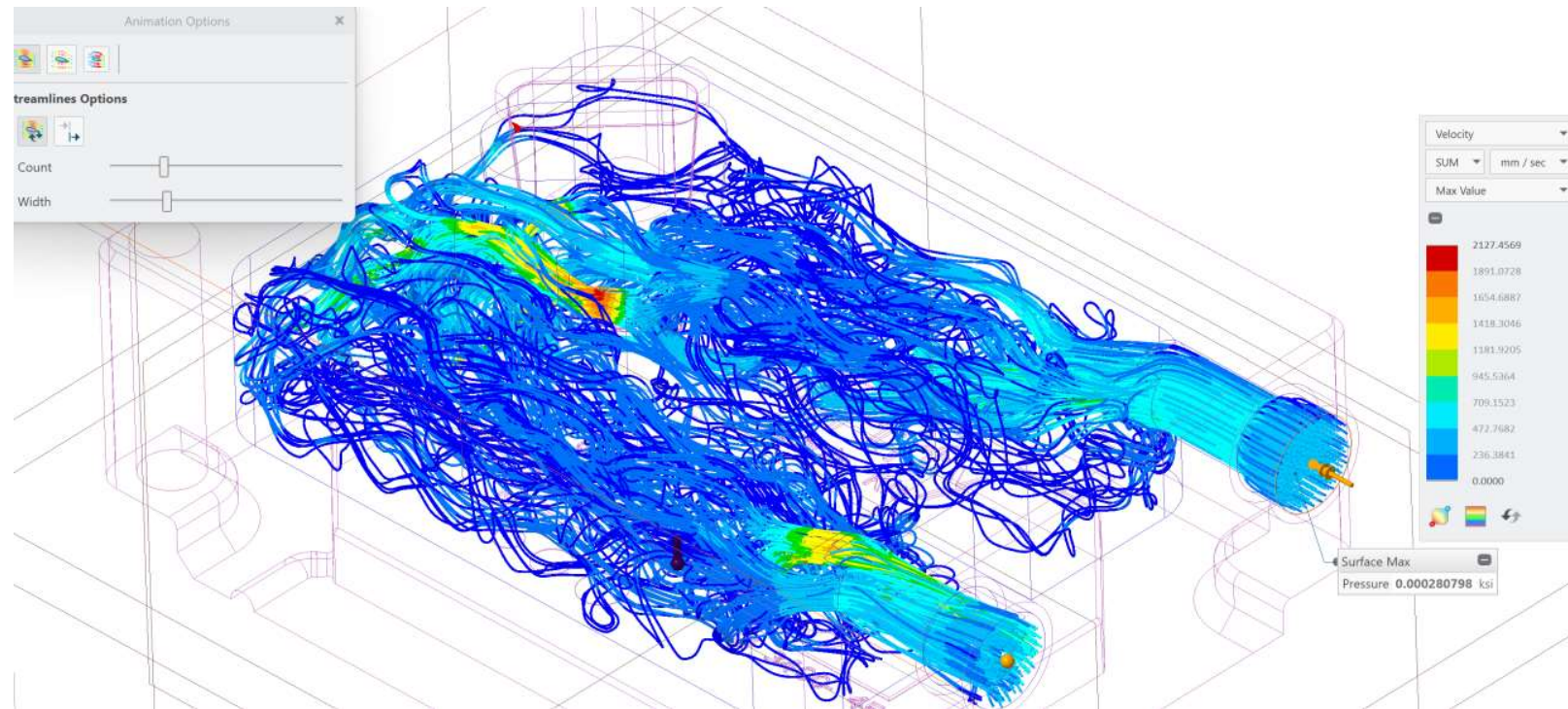


Solutions

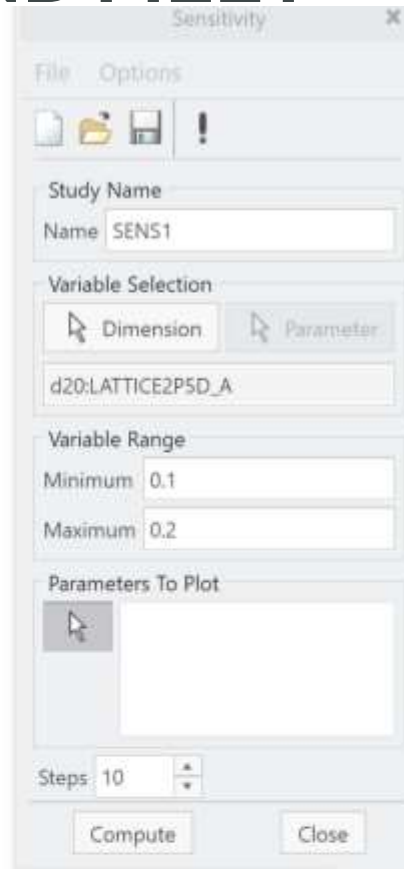
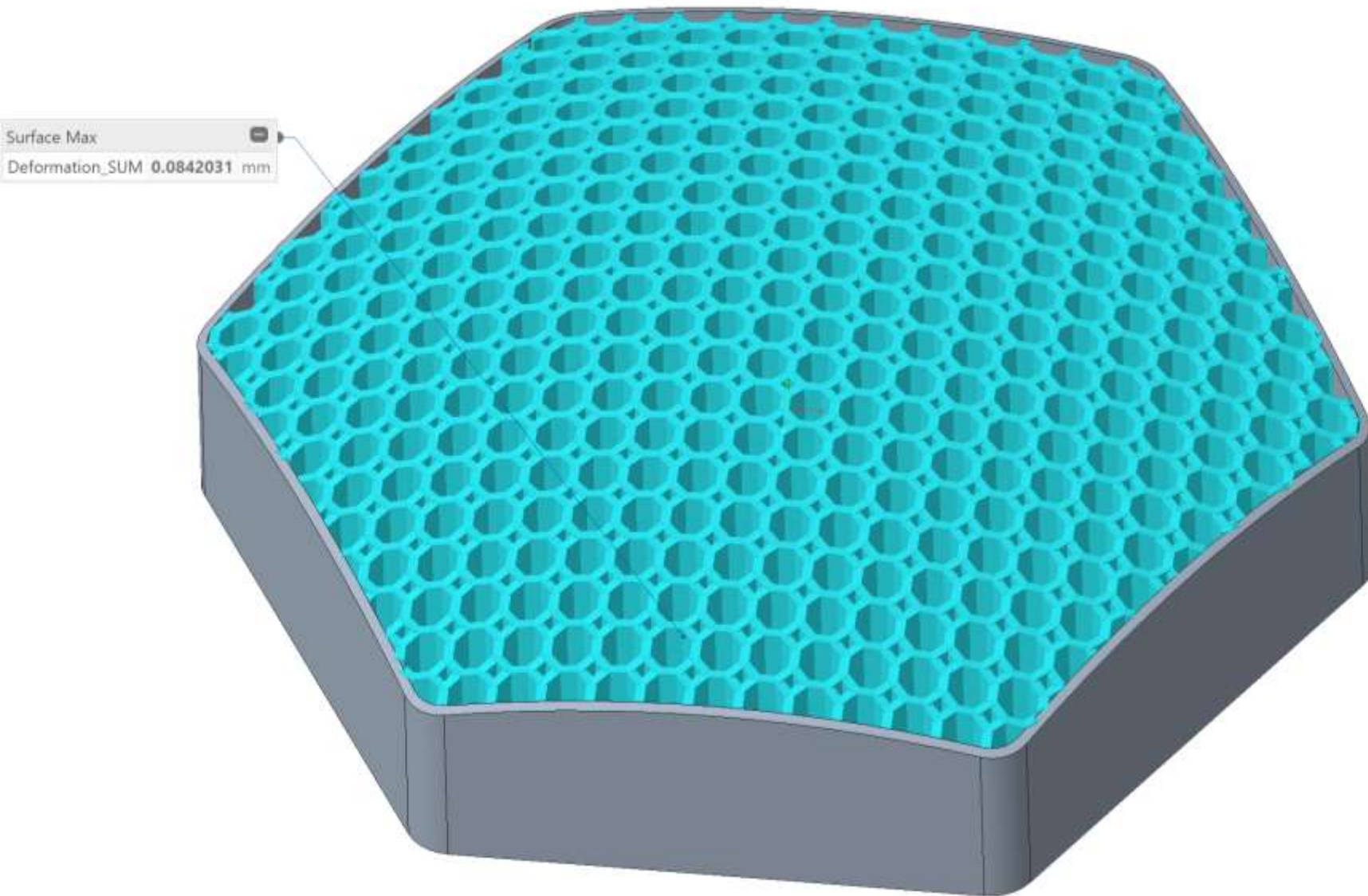
- Geometric Representation
 - Full Geometry
 - Simplified
 - Homogenized
- Real Time Simulation
 - Use & Understand Voxel geometry
- Generative Design
 - Use Homogenized Material properties,
 - Simulation Driven lattice sizing

ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES

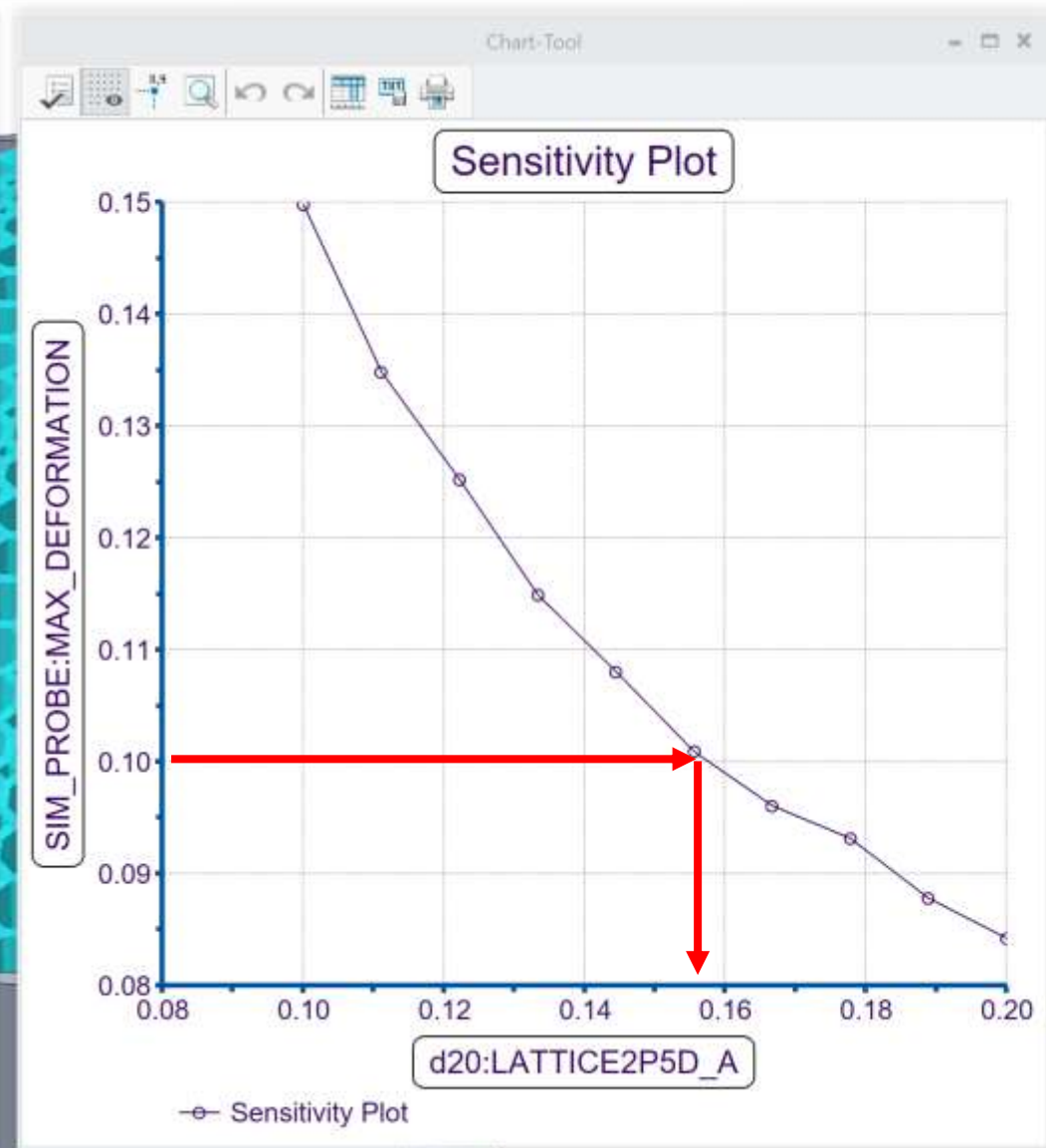
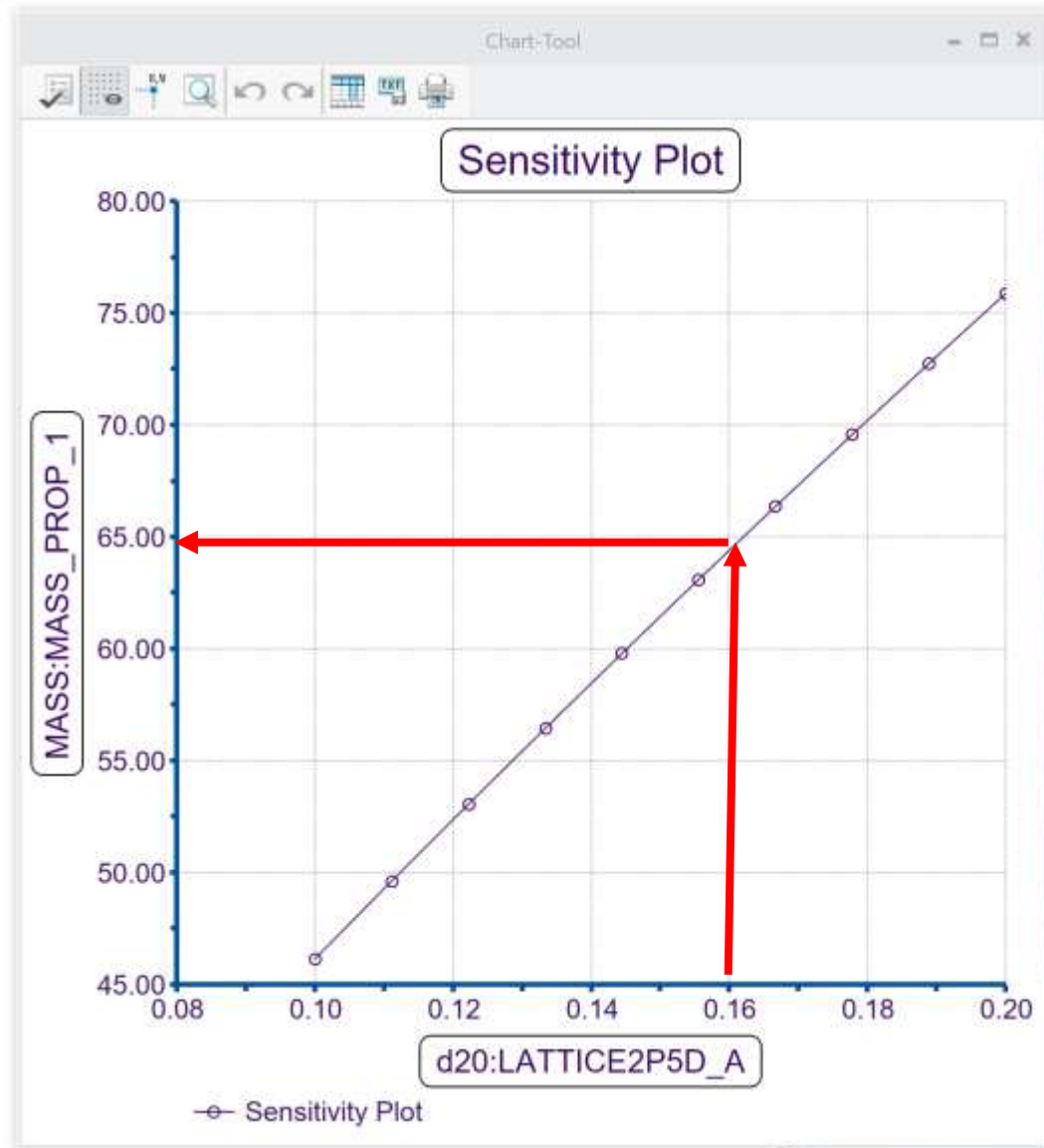
- Taxonomy of Lattice Structures
- **Optimization Workflow**
- Simulation-driven lattices in Creo
- Special cases



OPTIMIZATION WORKFLOW TO MINIMIZE WEIGHT AND MEET PERFORMANCE REQUIREMENTS



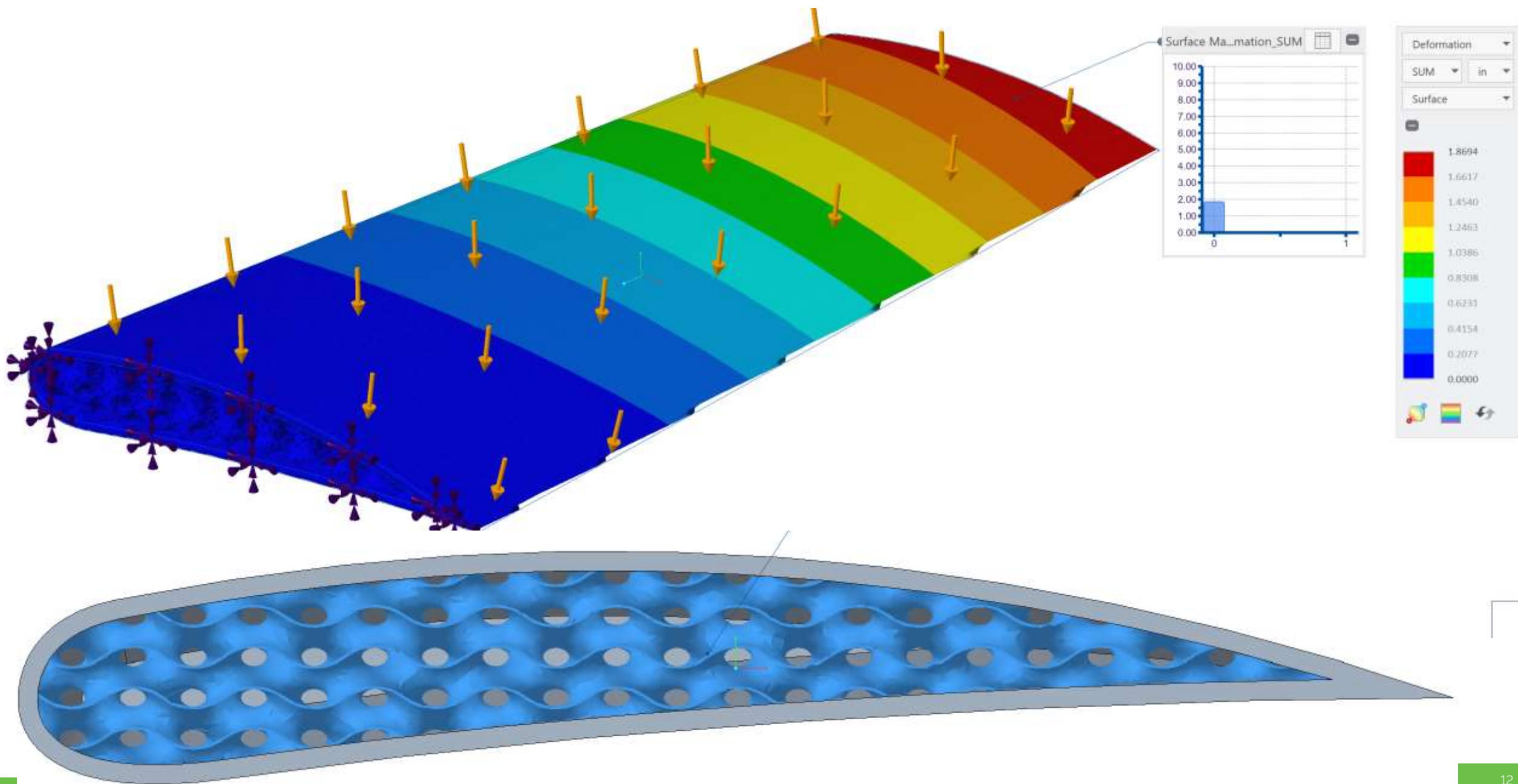
PERFORM A SENSITIVITY ANALYSIS TO DETERMINE THE REQUIRED CELL THICKNESS TO MINIMIZE THE DEFLECTION TO 0.1 MM



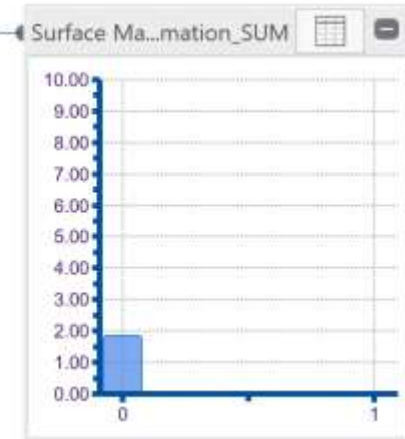
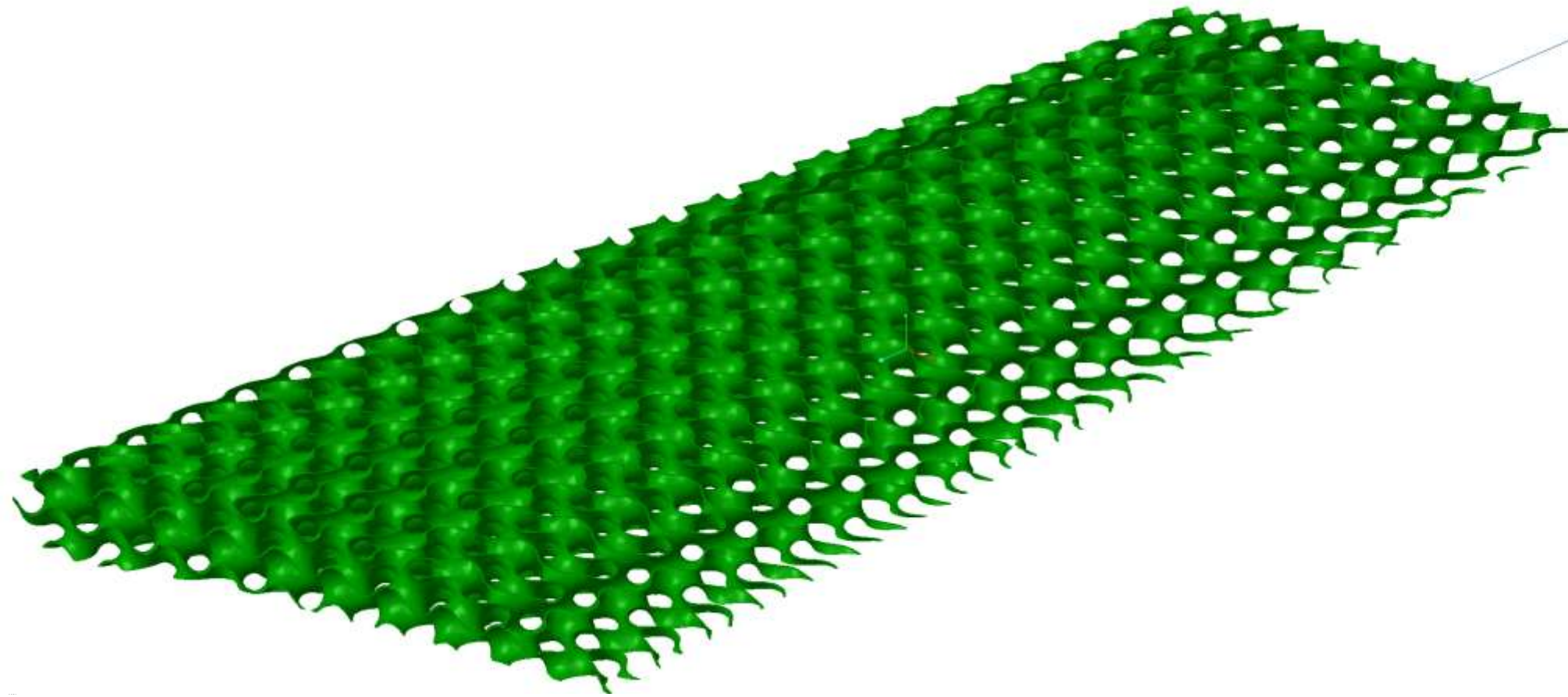
The "Sensitivity" settings panel shows the following configuration:

- Study Name: SENS1
- Variable Selection: Dimension (selected), Parameter
- Variable: d20:LATTICE2P5D_A
- Variable Range: Minimum 0.100000, Maximum 0.200000
- Parameters To Plot: MASS:MASS_PROP_1, SIM_PROBE:MAX_DEFORMA
- Steps: 10
- Buttons: Compute, Close

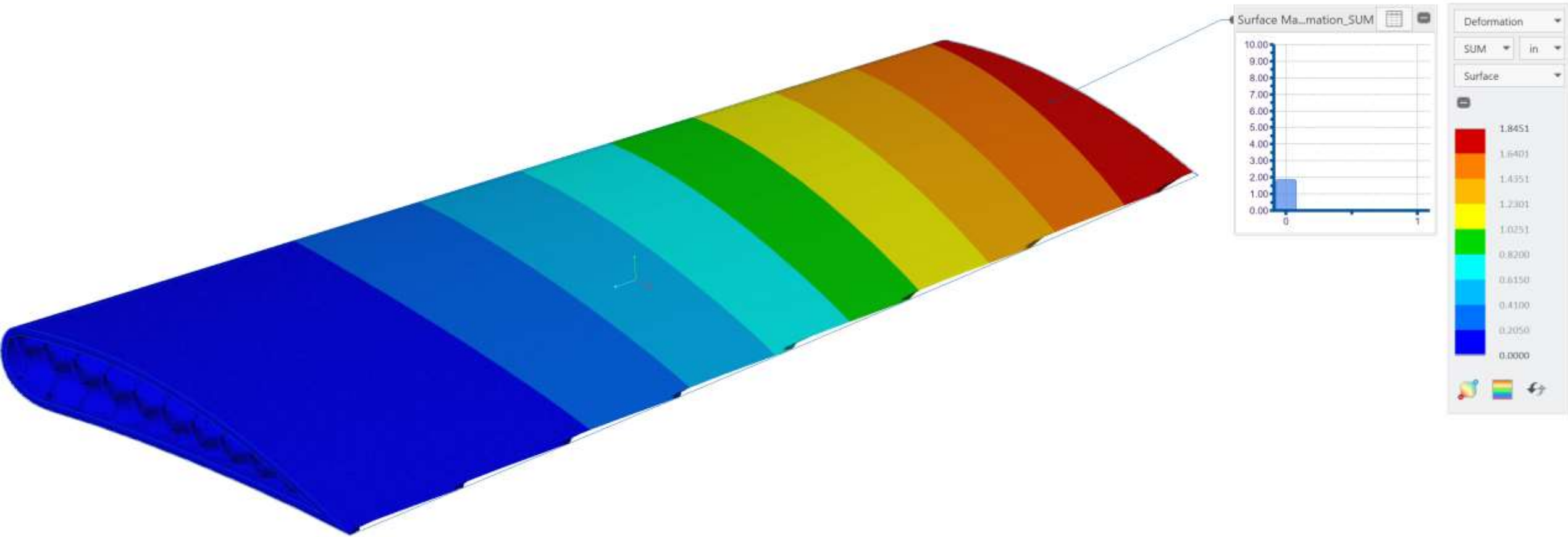
COMPARE DISPLACEMENTS FOR VARIOUS LATTICES - GYROID



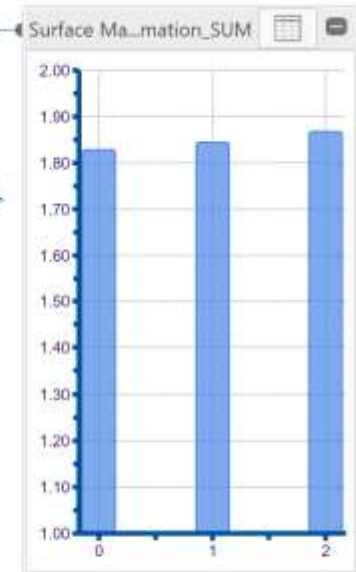
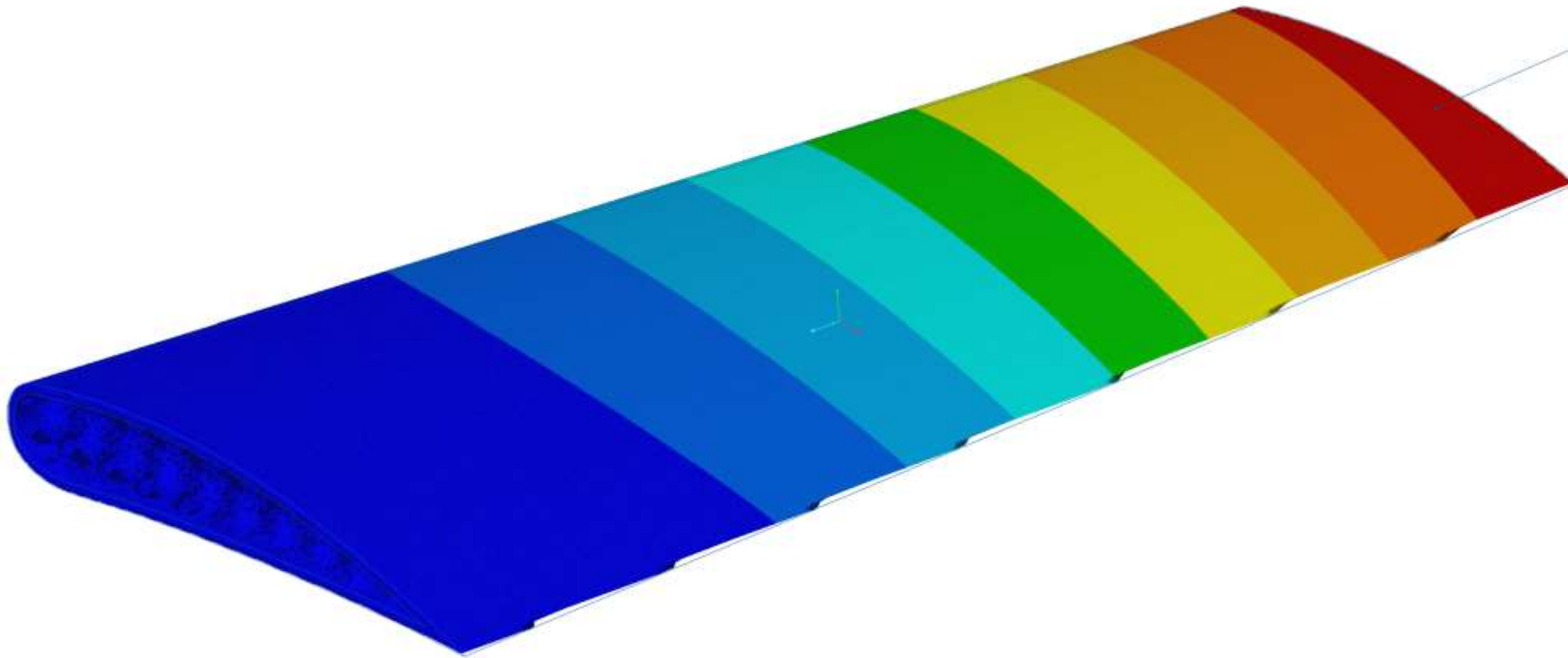
THE GYROID INFILL



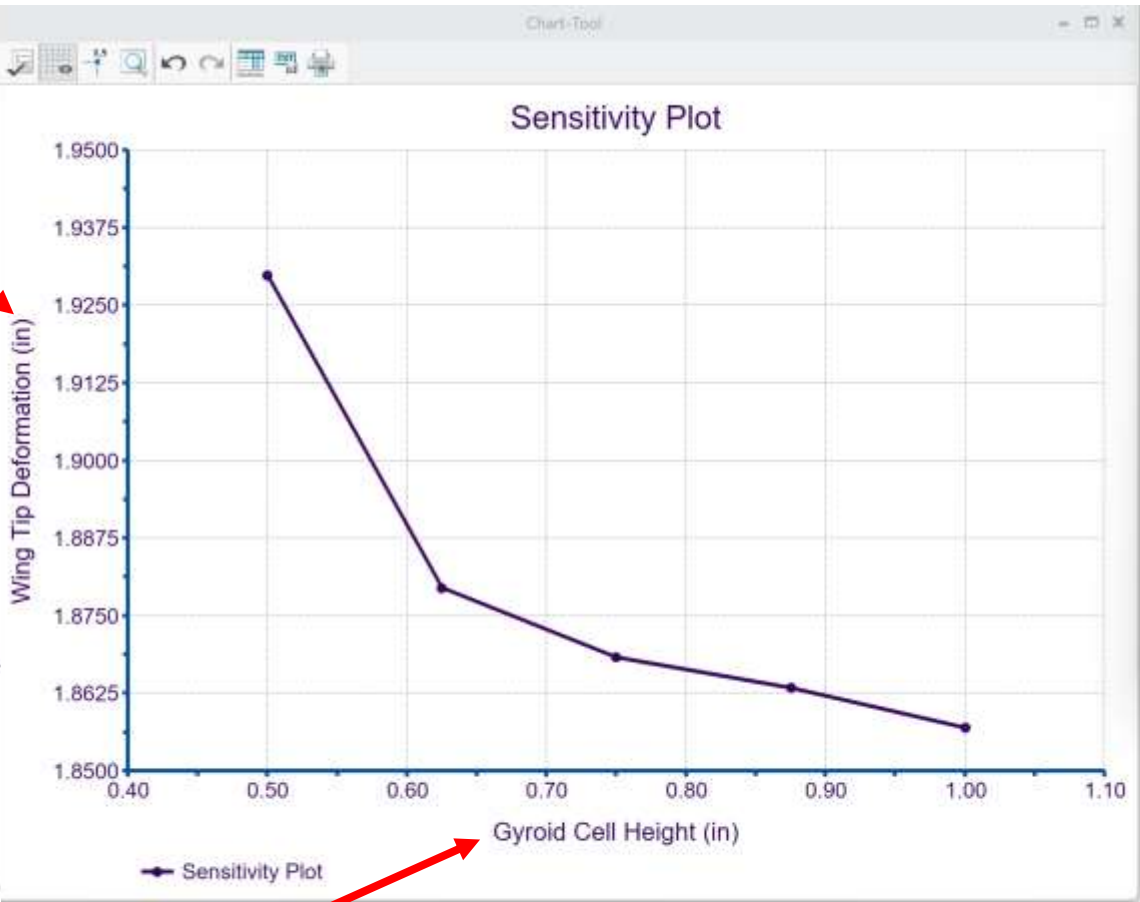
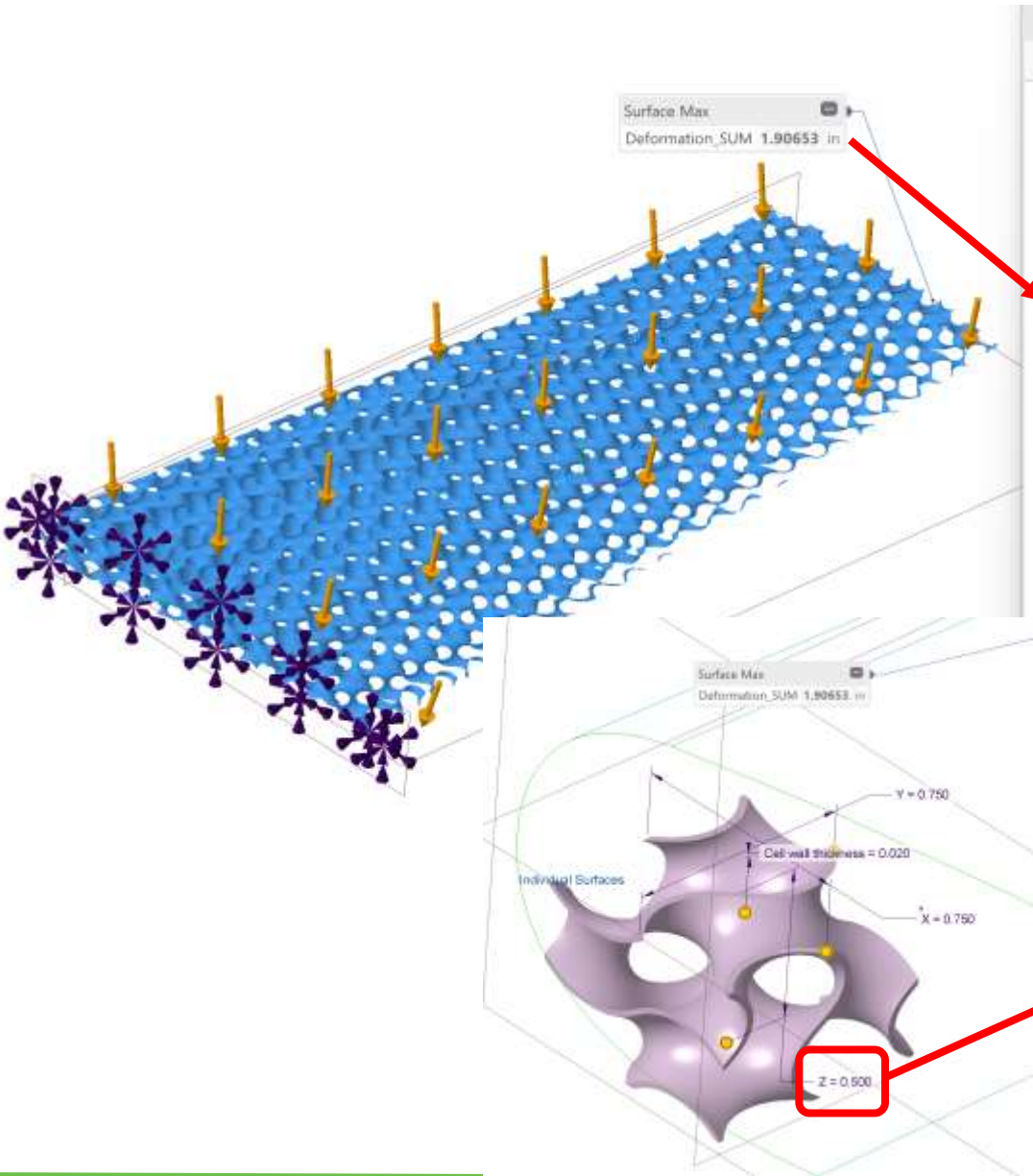
COMPARE DISPLACEMENTS – PRIMITIVE LATTICE



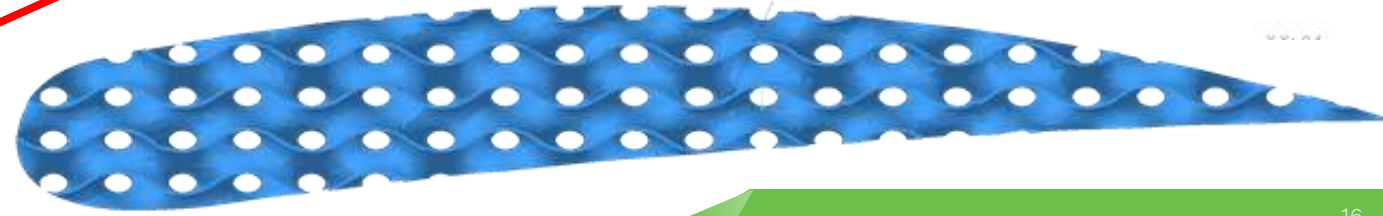
COMPARE DISPLACEMENTS - DIAMOND LATTICE



SENSITIVITY OF WING TIP DEFLECTION TO VERTICAL GYROID CELL HEIGHT



The image shows the 'Sensitivity' analysis software interface. The 'Study Name' is 'SENS1'. The 'Variable Selection' is 'd40:LATTICE_SELECTION'. The 'Variable Range' is set from 'Minimum 0.500000' to 'Maximum 1.000000'. The 'Parameters To Plot' list includes 'SIM_PROBE:STRUCTU_DEFC'. The 'Steps' are set to 5. The interface includes 'Compute' and 'Close' buttons.



OPTIMIZATION SETUP MINIMIZE WEIGHT WITH DEFLECTION CONSTRAINT

Optimization/Feasibility

File Run Options

Study Type/Name
 Optimization Feasibility

Name OPTIM1

Goal
Minimize MASS:MASS_PROP_1

Design Constraints

Parameter	Op	Value
SIM_PROBE:STRUCTU_DEFORMATI	<	1.500000

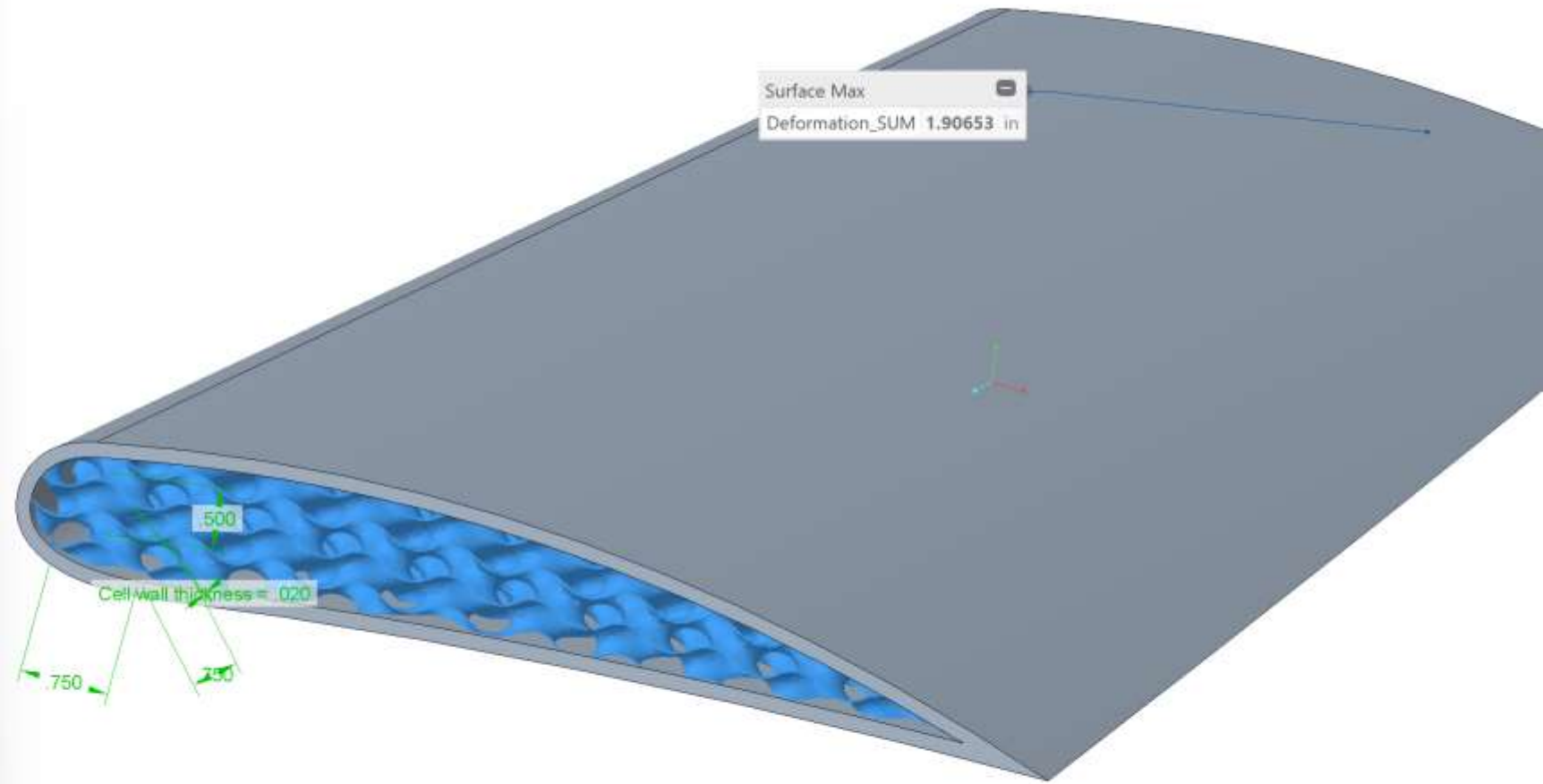
Add... Delete

Design Variables

Variable	Min	Max
Cell_vertical:LATTICE_SELECTION	0.450000	0.550000
Cell_lateral:LATTICE_SELECTION	0.675000	0.825000
Cell_longitudinal:LATTICE_SELECTION	0.675000	0.825000
d47:LATTICE_SELECTION	0.018000	0.022000

Add Dimension... Add Parameter... Delete

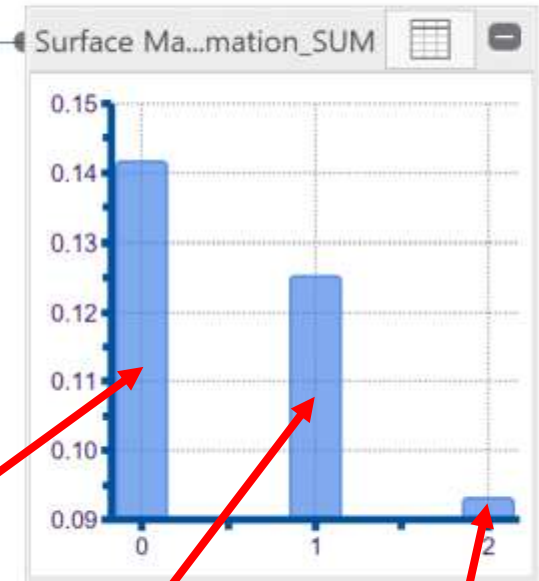
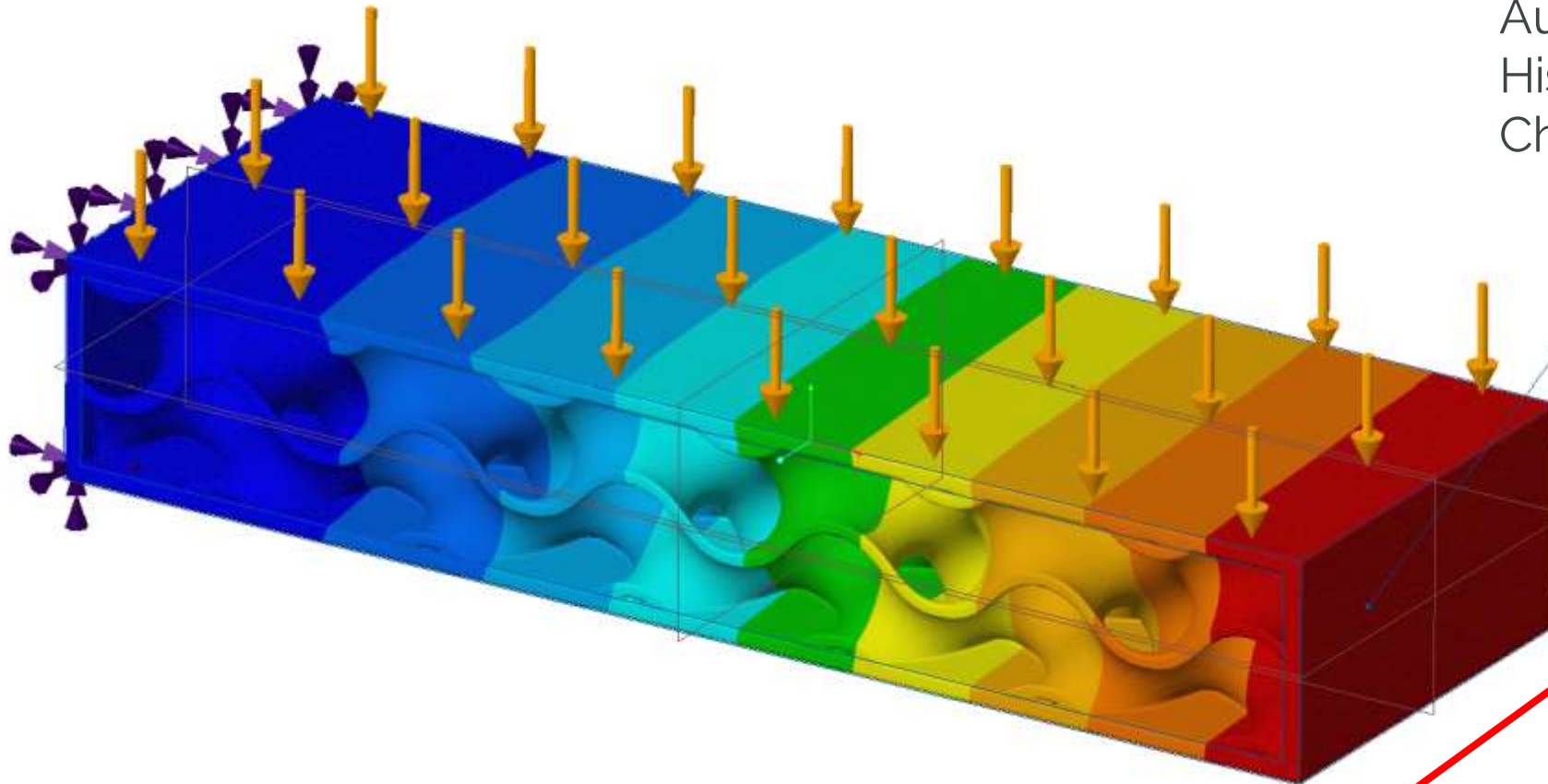
Restore Compute Close



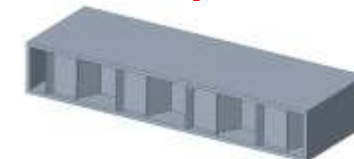
Design Variables are the 4 dimensions of the unit cell

LIVE DEMONSTRATION – DESIGN EXPLORATION

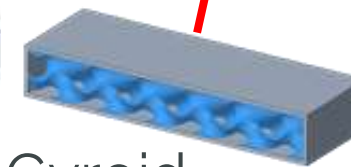
Capturing
Automatically
Historical Data in a Bar
Chart



Star

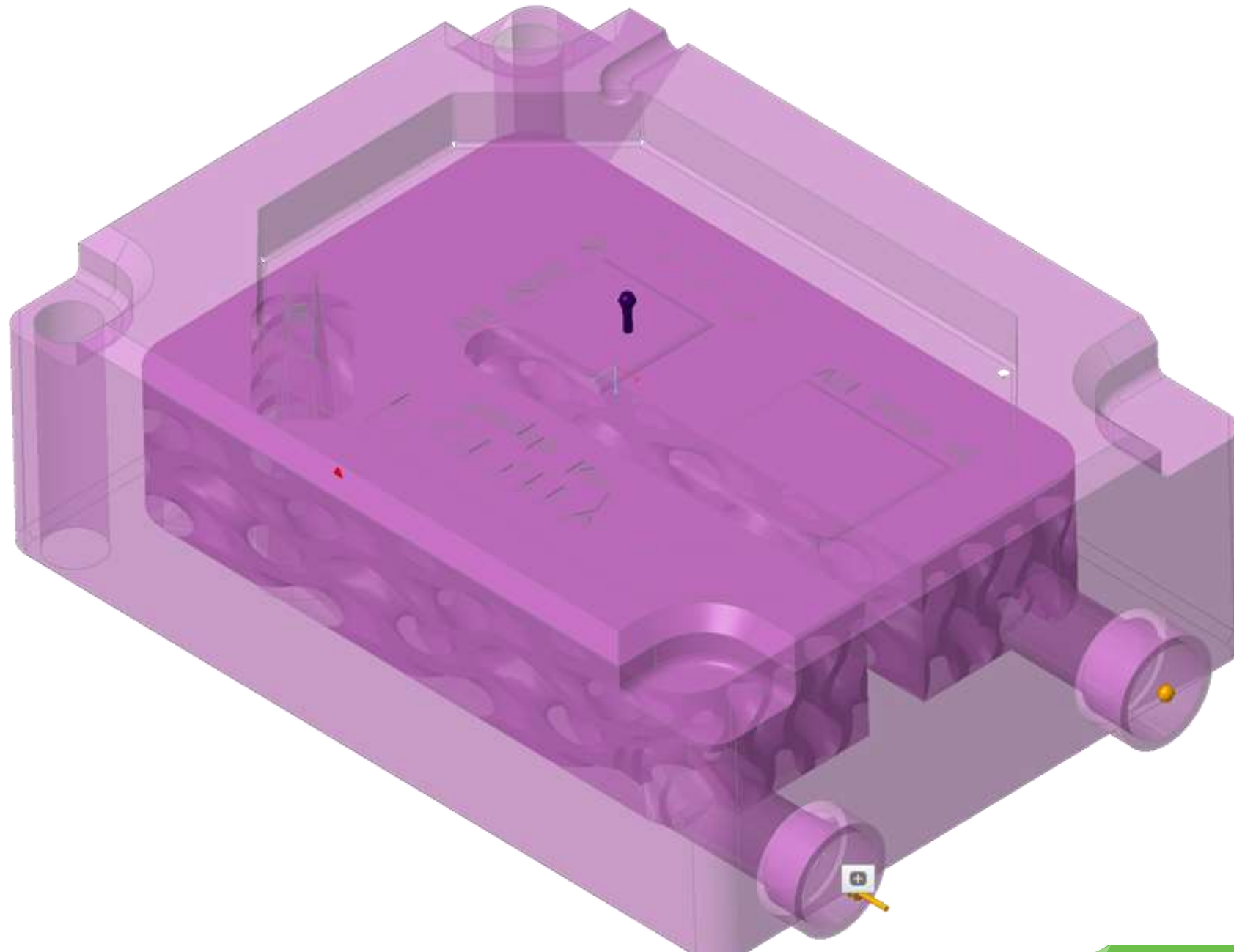


Honeycomb



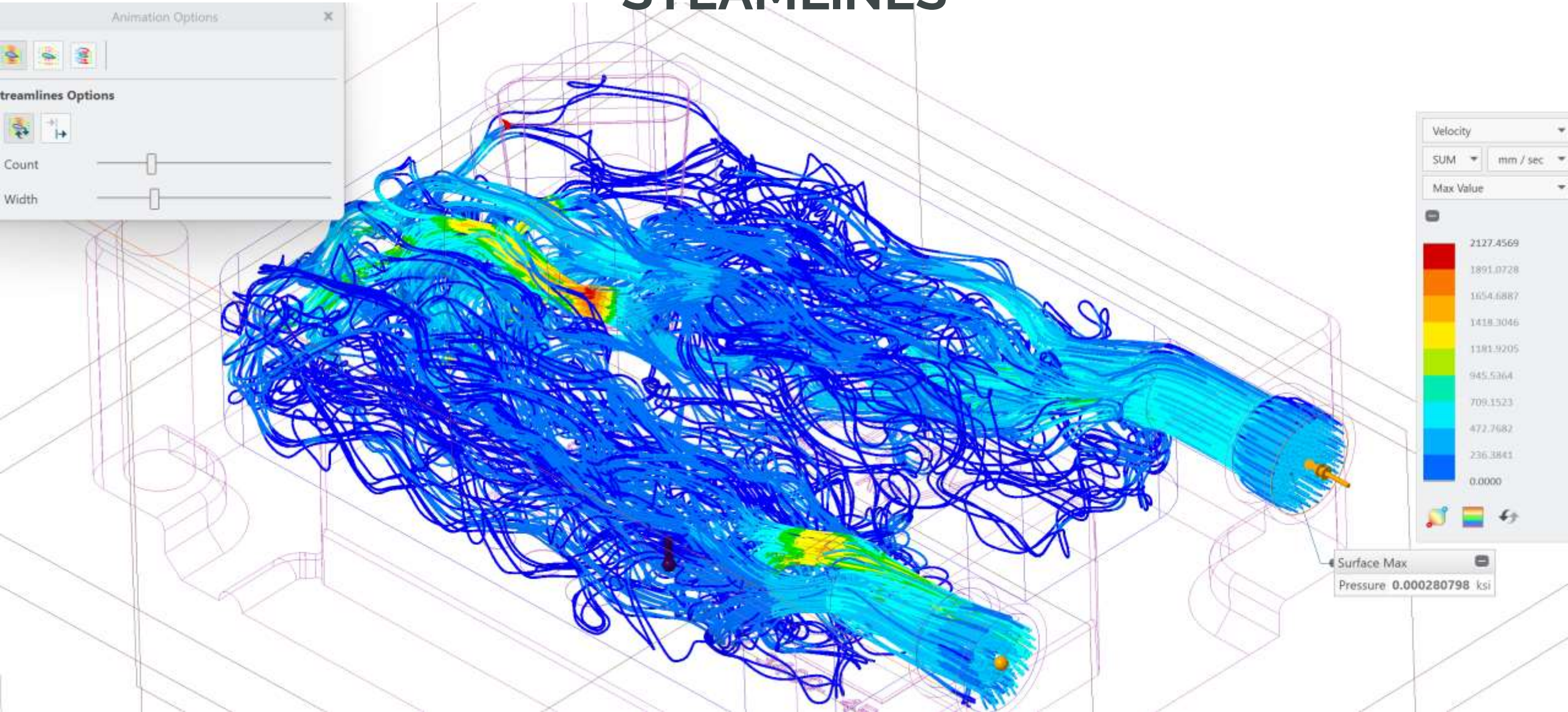
Gyroid

PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY



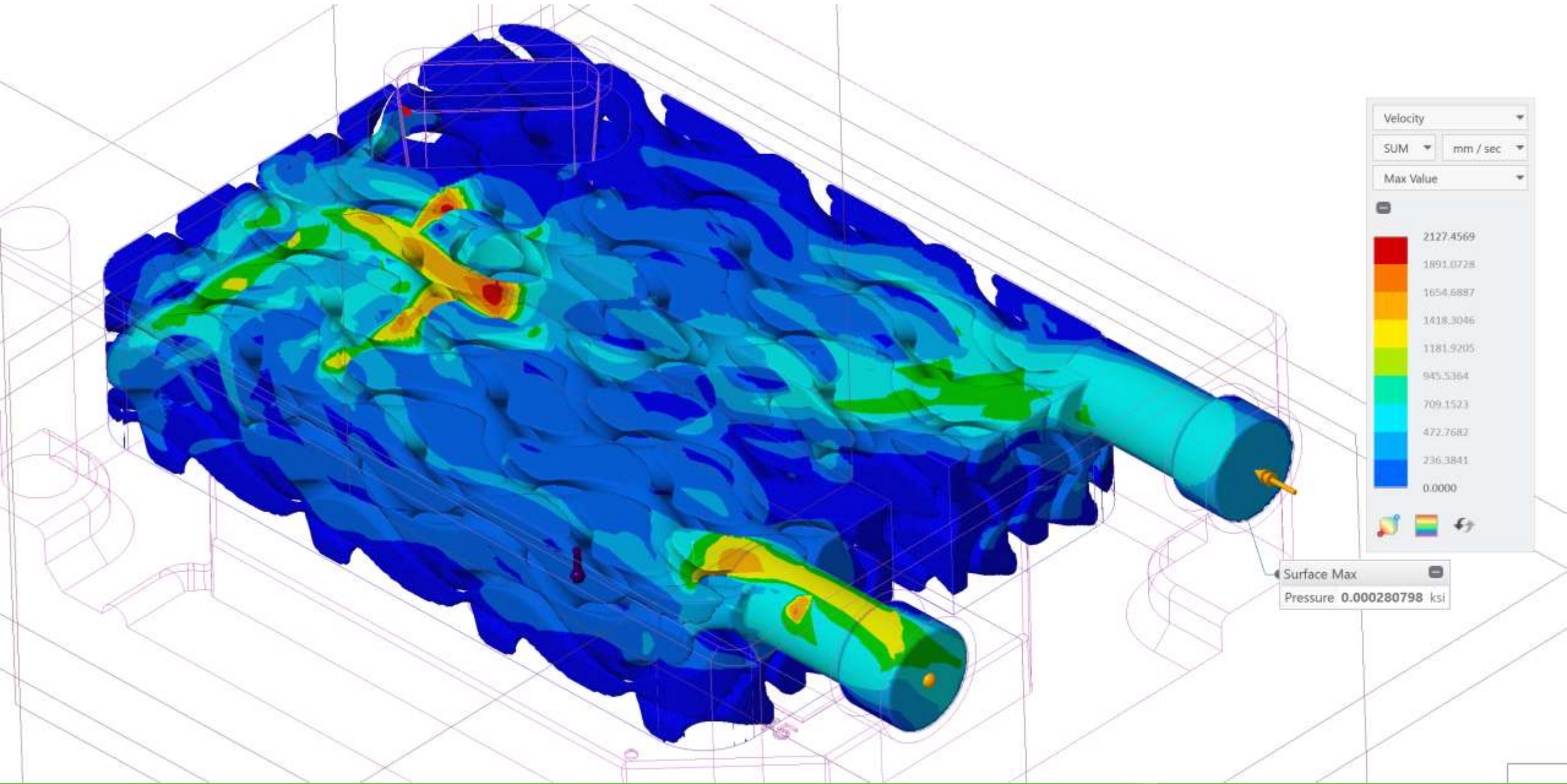
PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY

STREAMLINES



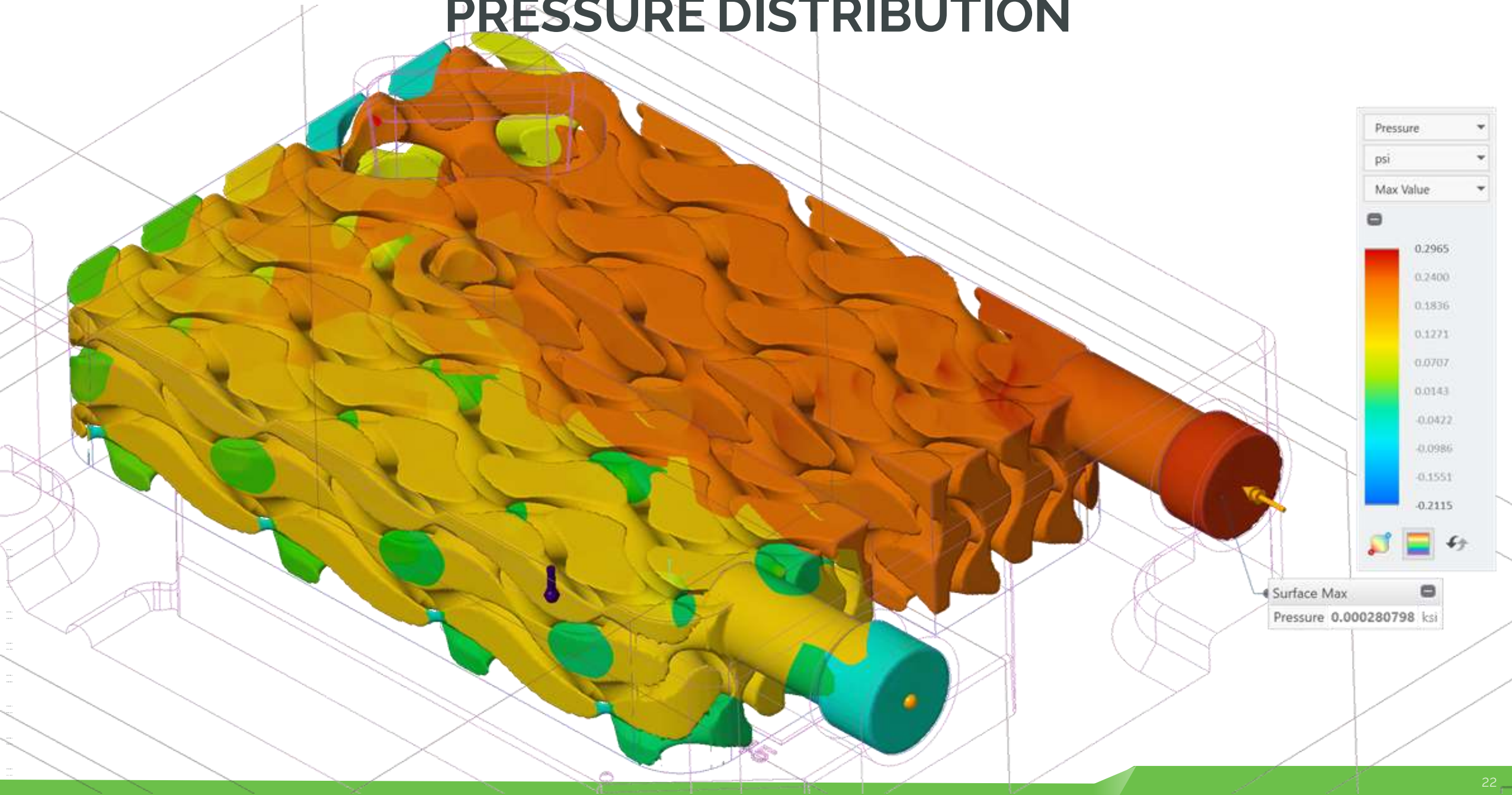
PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY

VELOCITY DISTRIBUTION

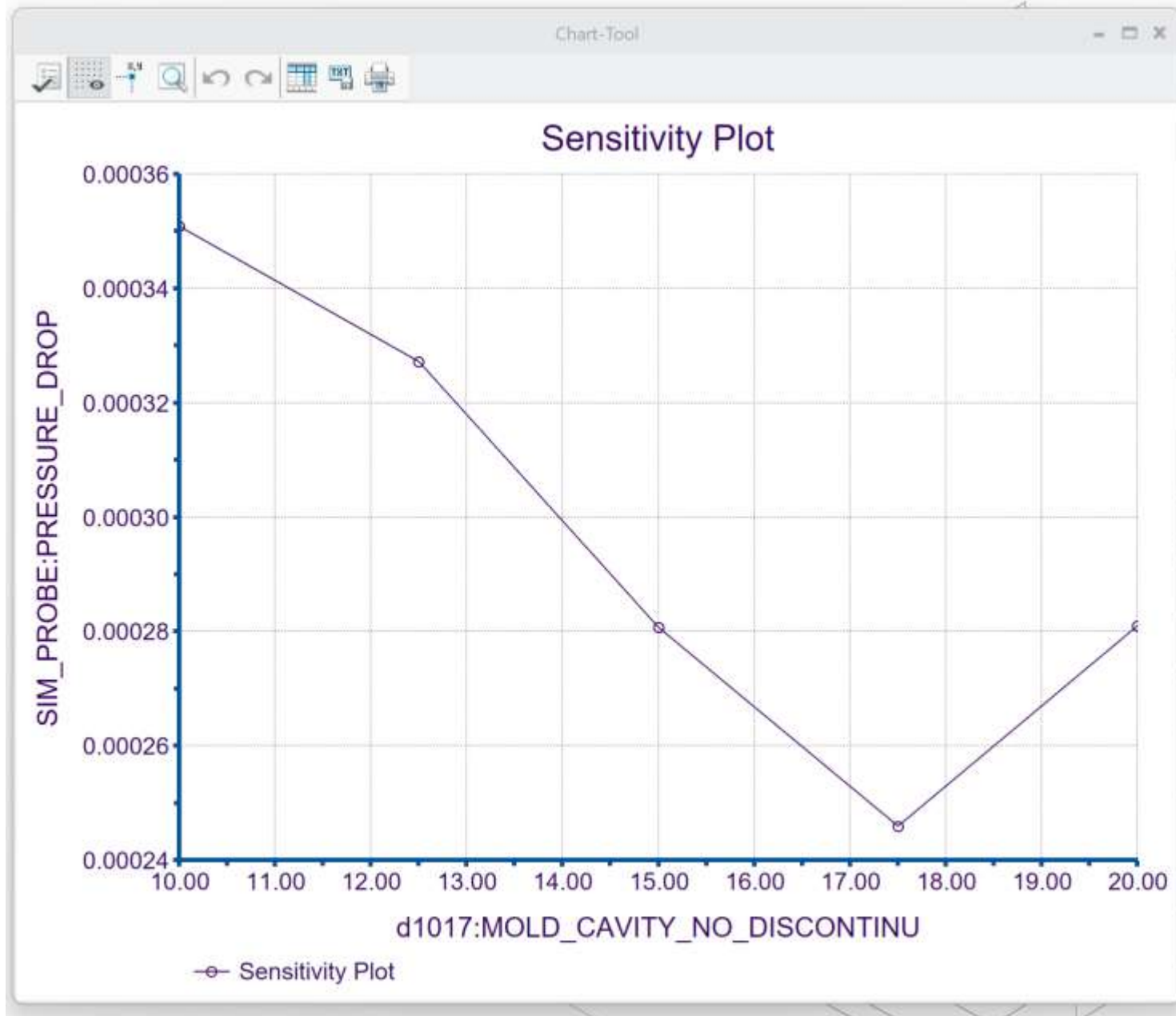


PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY

PRESSURE DISTRIBUTION



PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY

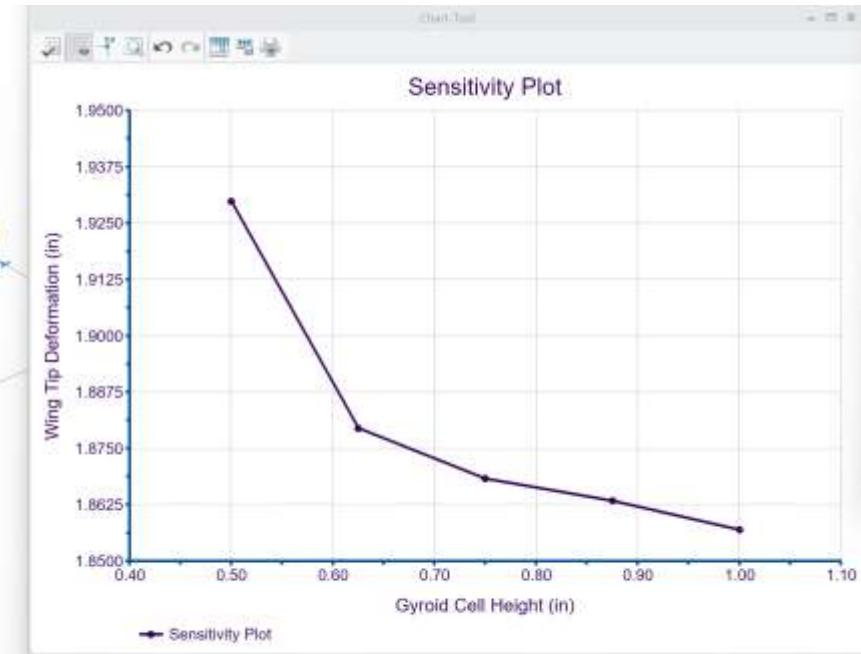
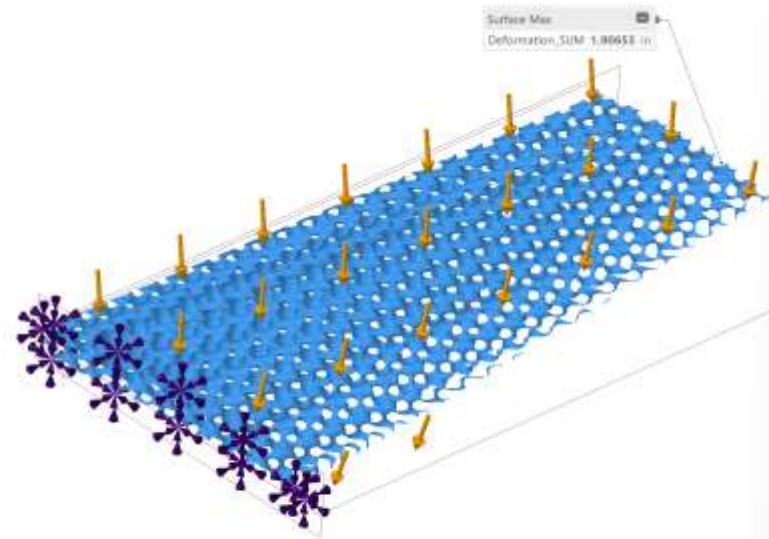


The "Sensitivity" dialog box is open, showing the following settings:

- Study Name: SENS1
- Variable Selection: Dimension (selected), Parameter
- Variable: MOLD_CAVITY_NO_DISCONTINUITY
- Variable Range: Minimum 10.000000, Maximum 20.000000
- Parameters To Plot: SIM_PROBE:PRESSURE_DROP
- Steps: 5
- Buttons: Compute, Close

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LATTICE VARIABILITY USING GEOMETRIC REFERENCES

Variability based on:
 Uniform References Simulation

Variable Beams
 Cross section cutoff: 0.00
 Continuous variability

Set Settings
 Set 1
 *New set
 Distance: 20.00
 Target cross section size: 10.00
 Size change rate: 1.00

References:
 Curve:F23(SKETCH_4)

Cross section size = 2.00
 Ball diameter = \varnothing 2.50
 X = 17.50
 Y = 17.50
 Z = 17.50
 0.0

Size change rate: 0.10

Set the rate of change between the reference cross section size and the global cross section size.
 When the rate=1, the rate of the change is linear.
 When the rate<1, the rate is slower than linear.
 When the rate>1, the rate is faster than linear.

Continuous variability

Set Settings:
 Set 1
 *New set
 Distance: 20.00
 Target cross section size: 10.00
 Size change rate: 1.00

References:
 Curve:F23(SKETCH_4)

Transitioning with conical beams

Continuous variability

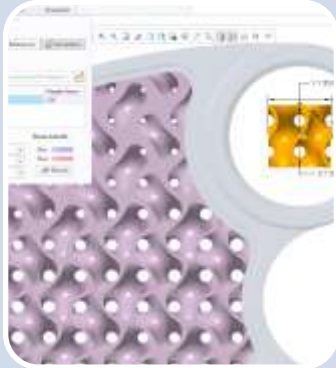
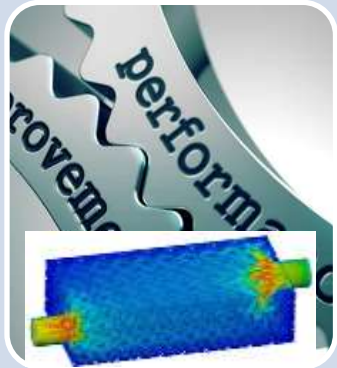
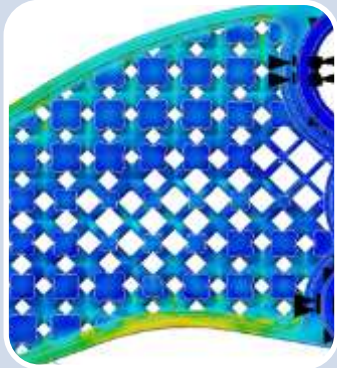
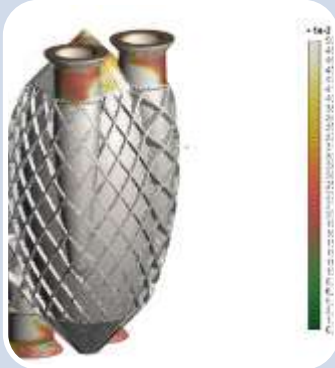
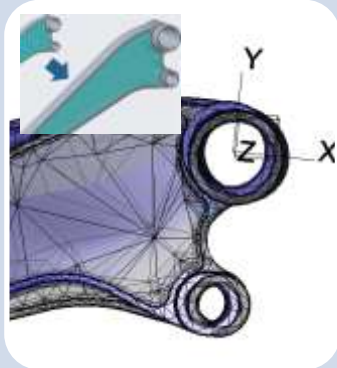
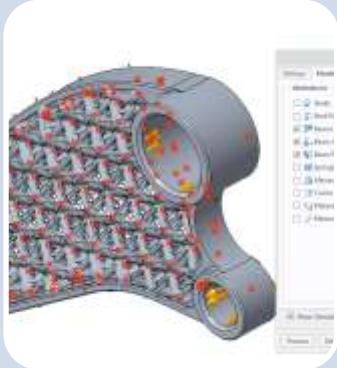
Set Settings:
 Set 1
 *New set
 Distance: 20.00
 Target cross section size: 10.00
 Size change rate: 1.00

References:
 Curve:F23(SKETCH_4)

Transitioning with cylindrical beams

EVOLUTION OF SIMULATION-DRIVEN LATTICE MODELLING

CREO CONTINUES TO FOCUS ON INNOVATING LATTICE MODELLING



Creo 5

Simulation and optimization of lattices using idealizations in Creo Simulate

- Beams, Shells and Masses

Creo 6

Material homogenization

- For uniform lattices, uniformly propagated
- Creo Simulate solver only...

Real-time simulation

- Using Creo Simulation Live

Creo 7

Additive process simulation (3rd party)

- Simulation of parts, lattices and supports
- Creation of compensated models

Creo 8

Automatic Lattice variability based on simulation results

- for beam-based lattices

Creo 9

Real-time simulation

- FDL Lattice support for CSL Fluids

Regular performance improvements projects

Creo 10

Automatic Lattice variability based on simulation results

- for formula-driven lattices

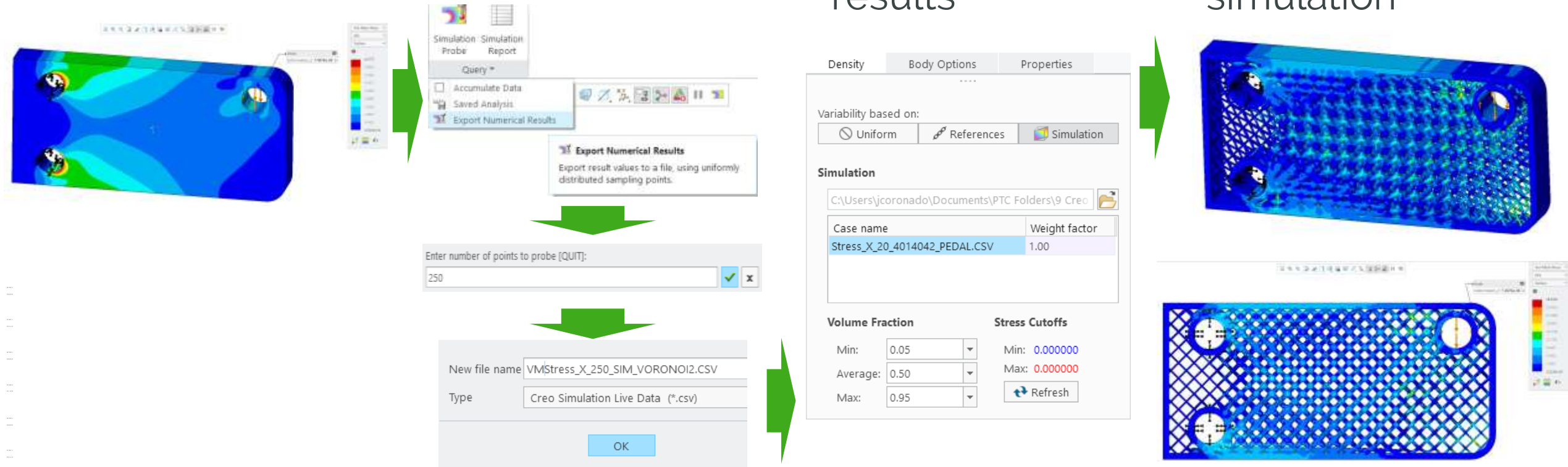
LATTICE VARIABILITY BASED ON SIMULATION RESULTS. - PROCESS -

- Simulate a part

- Export simulation results

- Add lattice with variability based on simulation results

- Get a smart infill and validate results using simulation

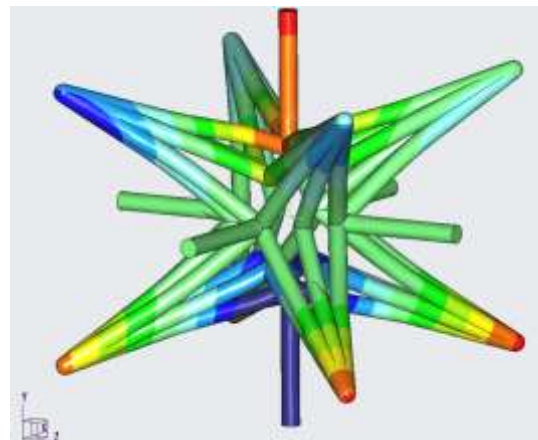
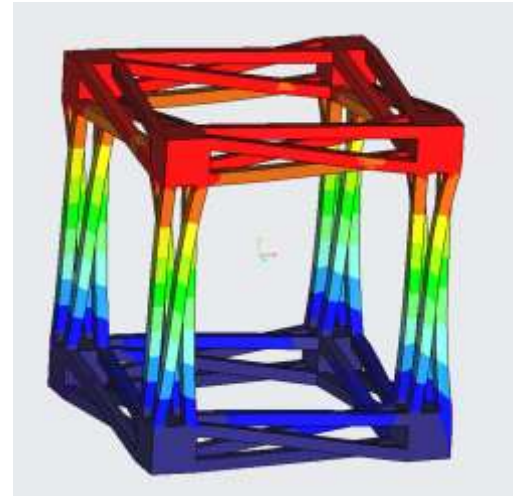


SIMULATION SUPPORT FOR LATTICE

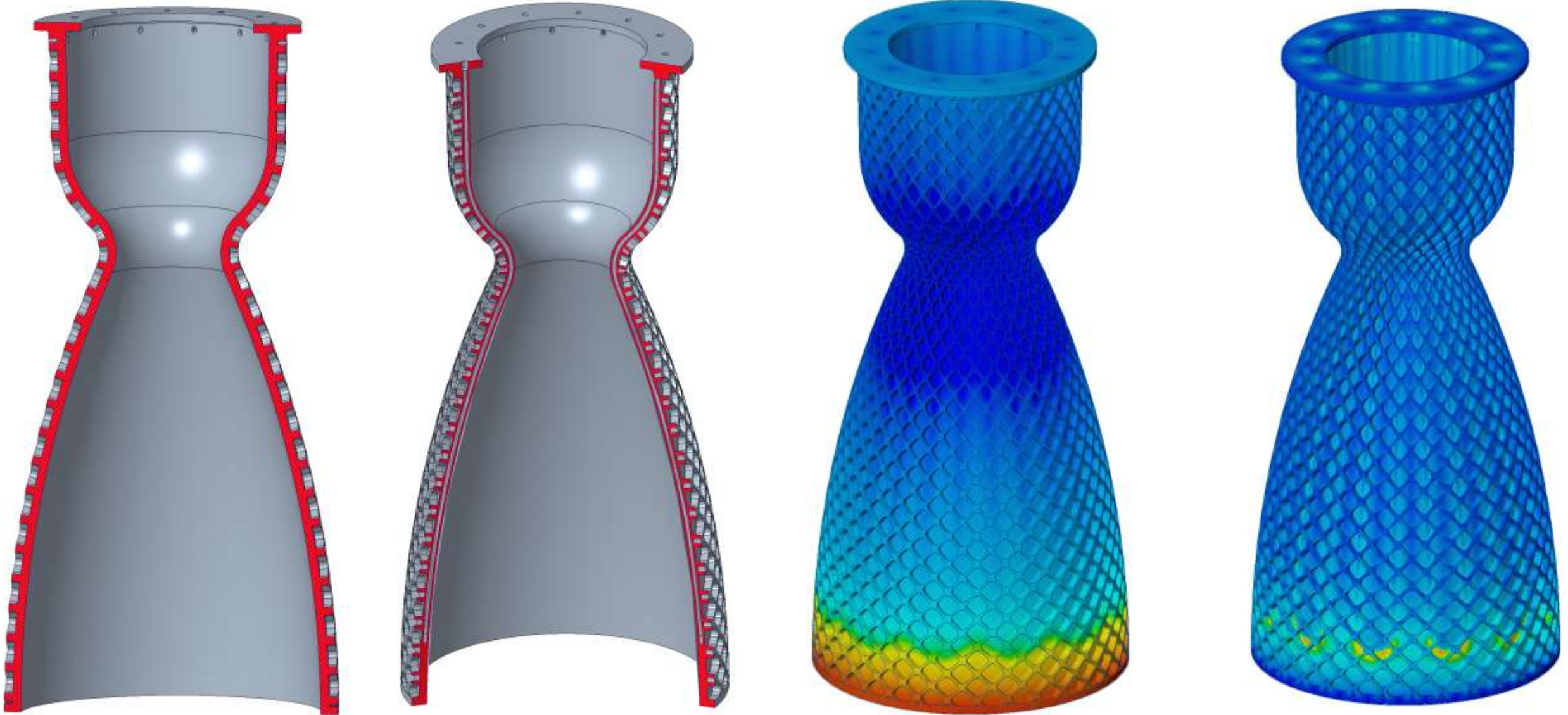
Lattice type	Lattice representation	Creo Simulate	CSL	Ansys Simulation	Creo Flow Analysis
 Beams 	Full geometry	✓	✓	✓	✓
	Simplified	✓	✓	X	✓
 Beams 	Homogenized	✓ (static and modal analysis)	X	X	X
 2.5D	Full geometry	✓	✓	✓	✓
	Simplified	✓	✓	X	✓
 Formula Driven	Voxelized	X	✓	X	✓
 Custom	Full geometry	✓	✓	✓	✓
	Simplified	X	✓	X	✓

ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES

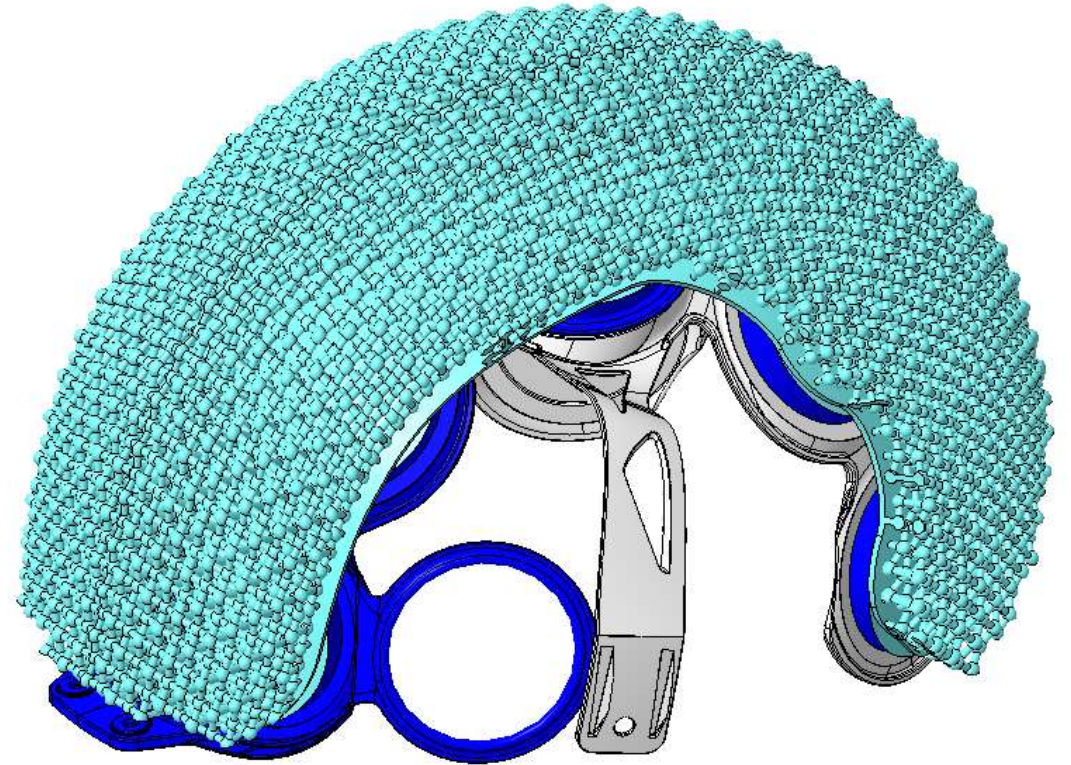
- Taxonomy of Lattice Structures
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ROCKET NOZZLE WITH COOLING CHANNELS

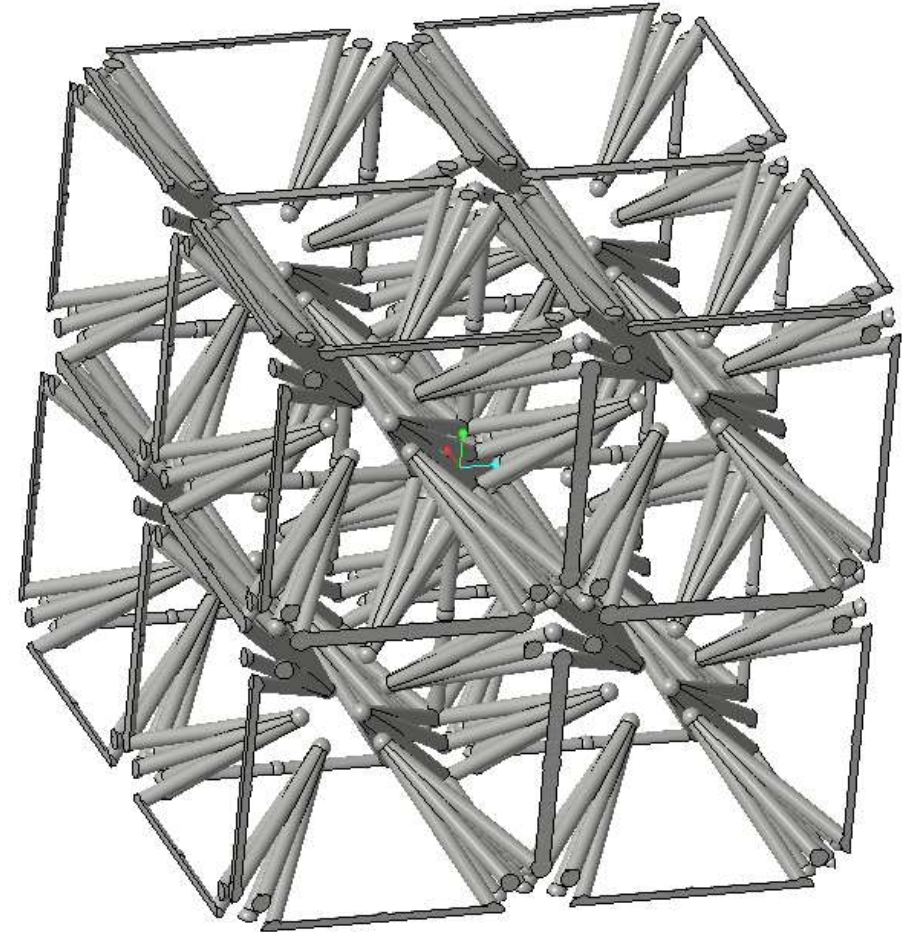
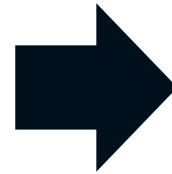
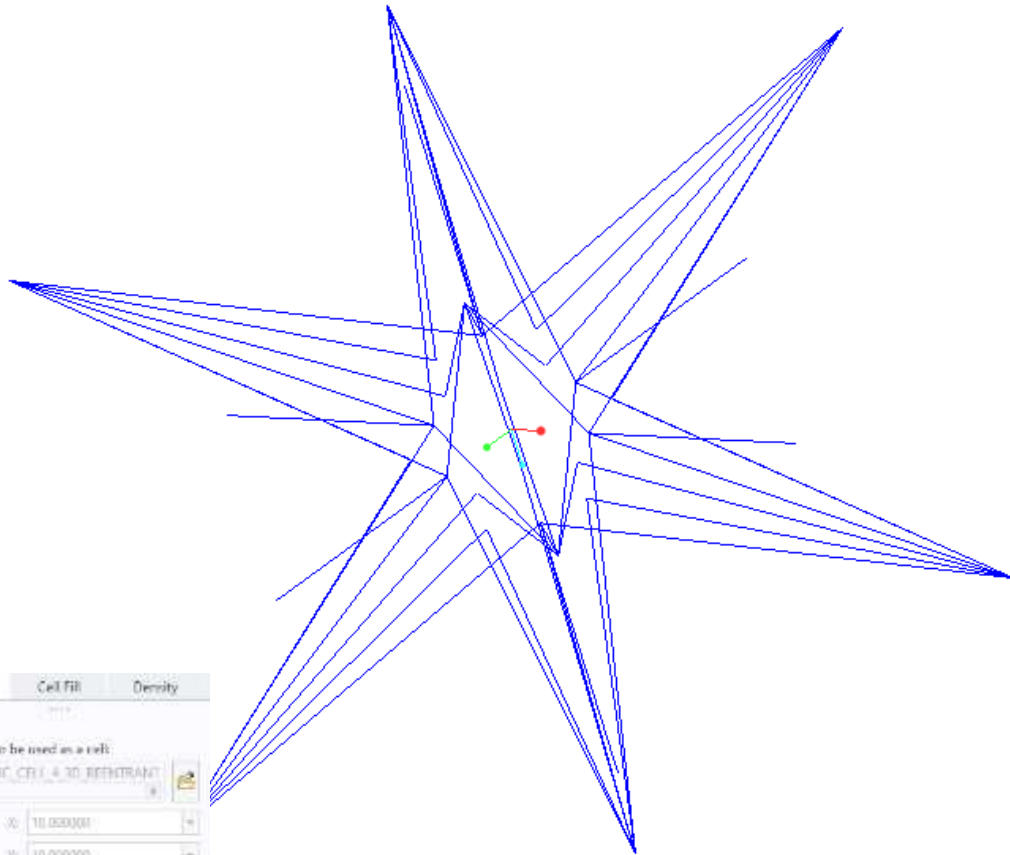


THE NEW AUXETIC LATTICE, NORMAL TO THE SURFACE



CUSTOM CELL

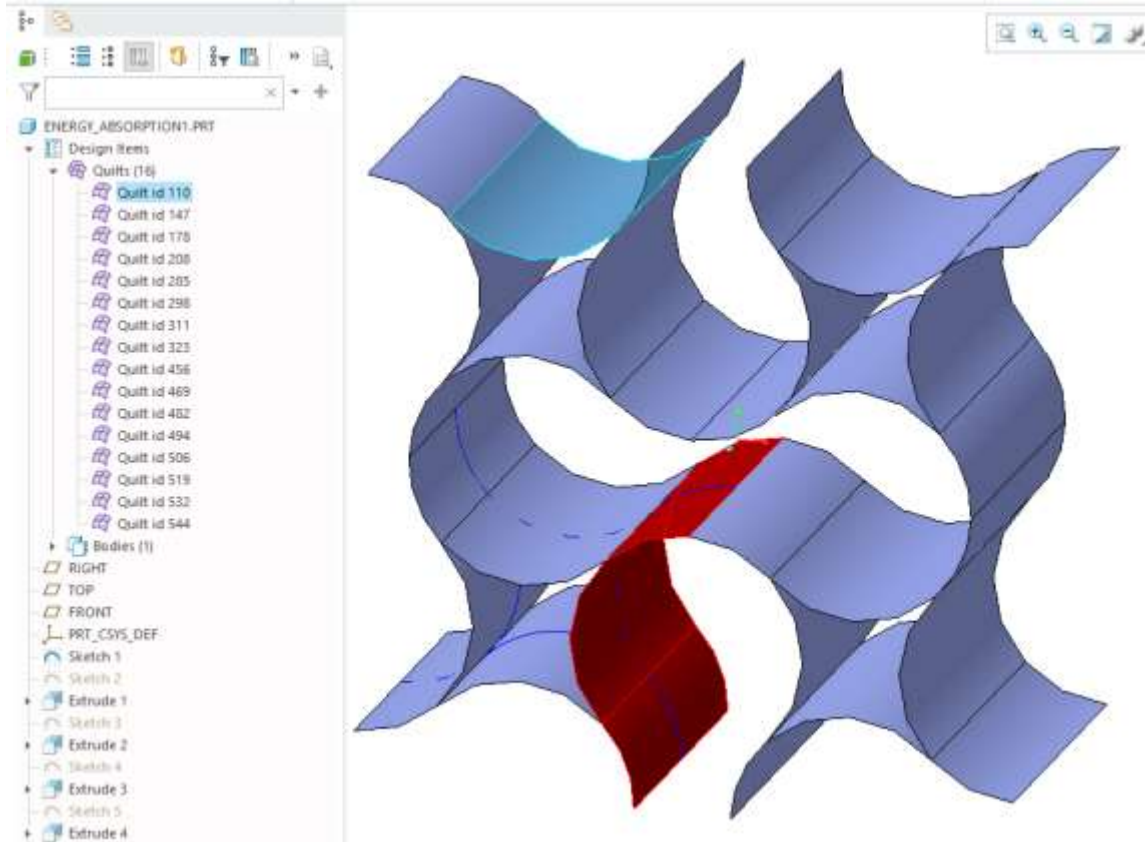
A Creo model with only straight lines



Cell Type	Cell Fill	Density
Open a part to be used as a cell:		
ALUMINUM_CELL_4_3D_RESTRAINT		
Cell size:	10.000001	
X:	10.000000	
Y:	10.000000	
Z:	10.000000	
Fixed scale:	1.00	

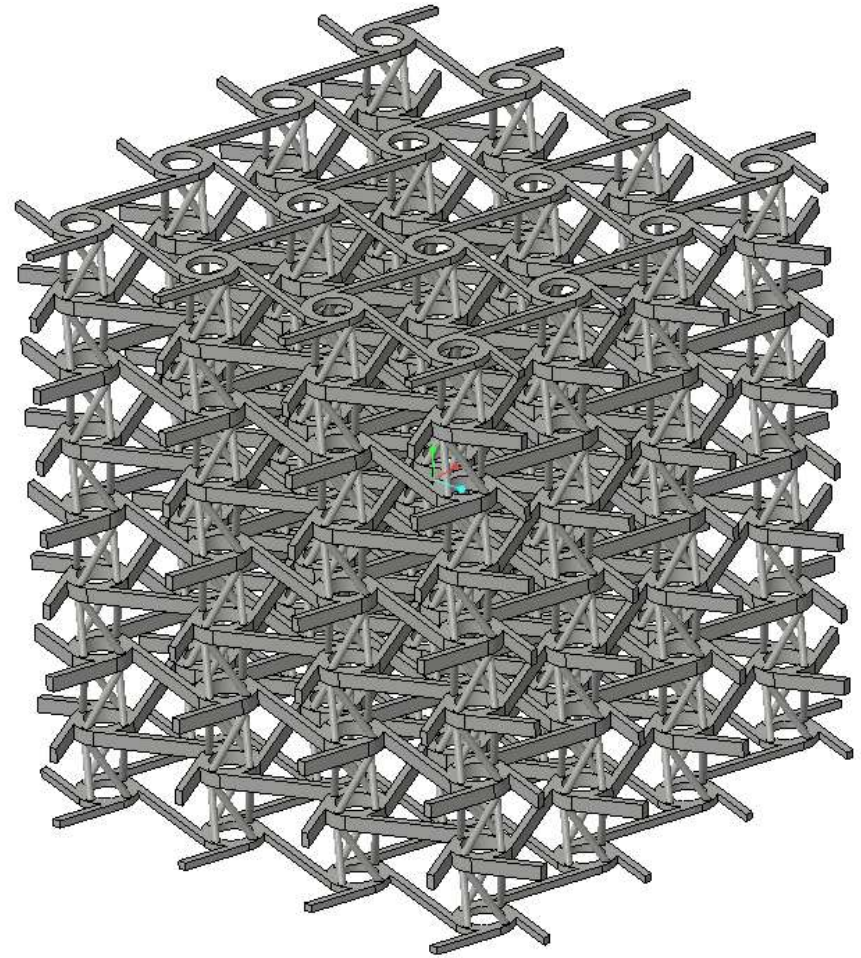
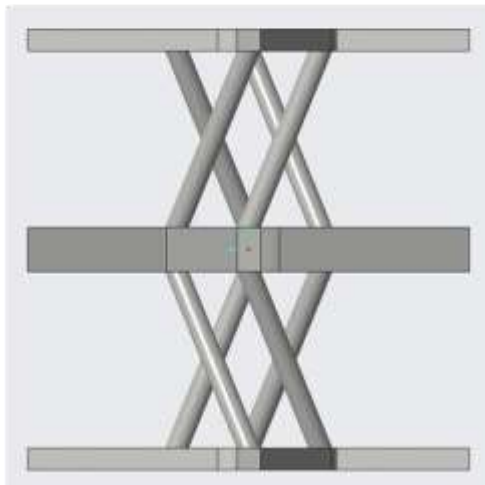
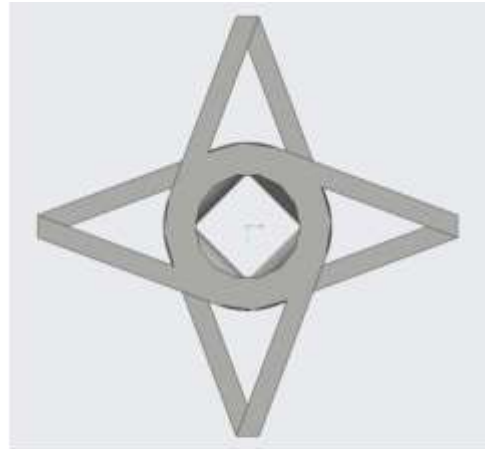
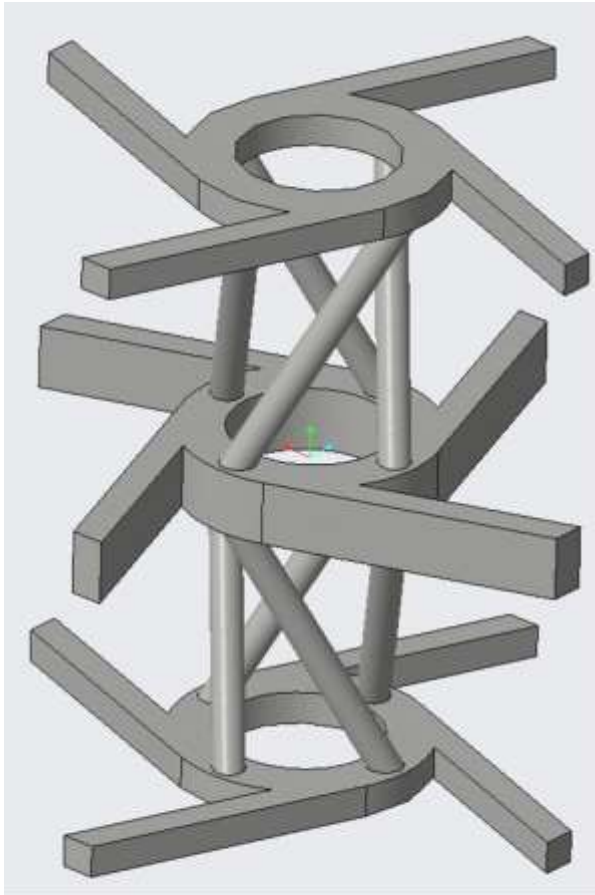
CUSTOM CELL

A model with quilts



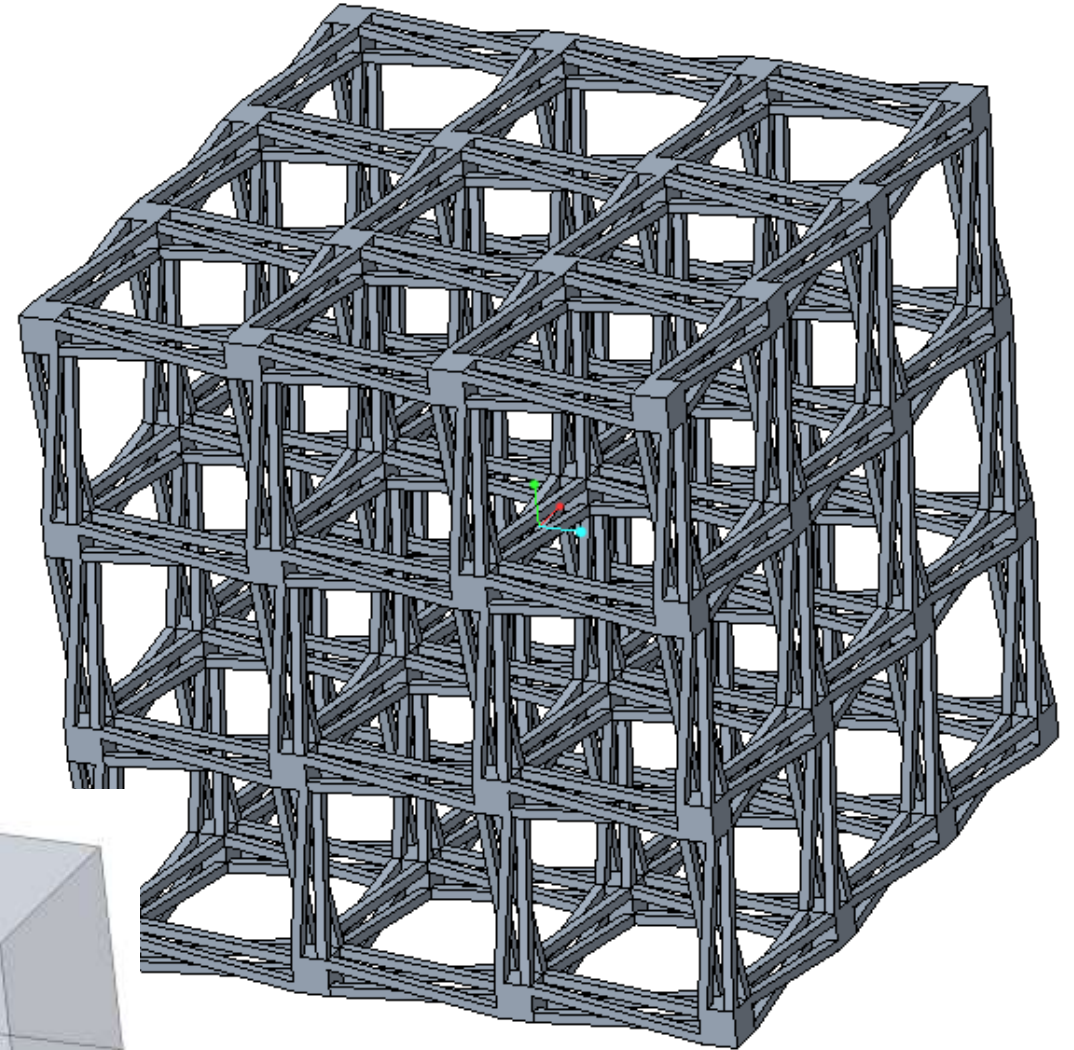
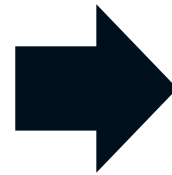
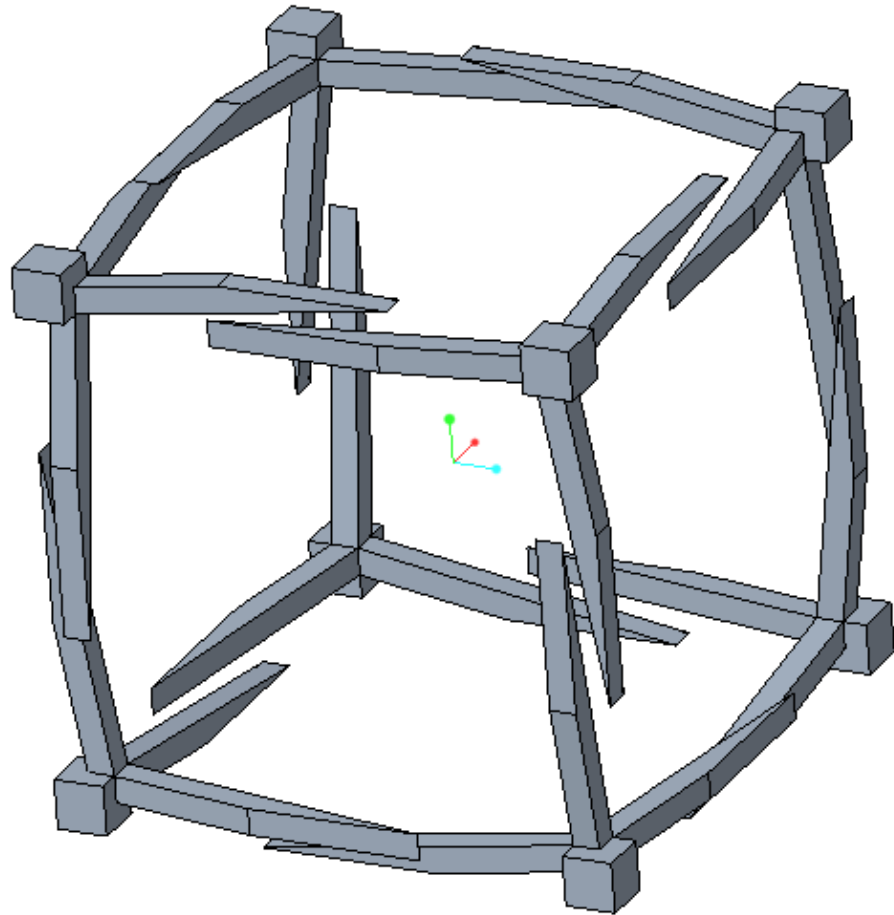
CHIRAL. LOOP-LIKE CELL

A Creo Solid Model



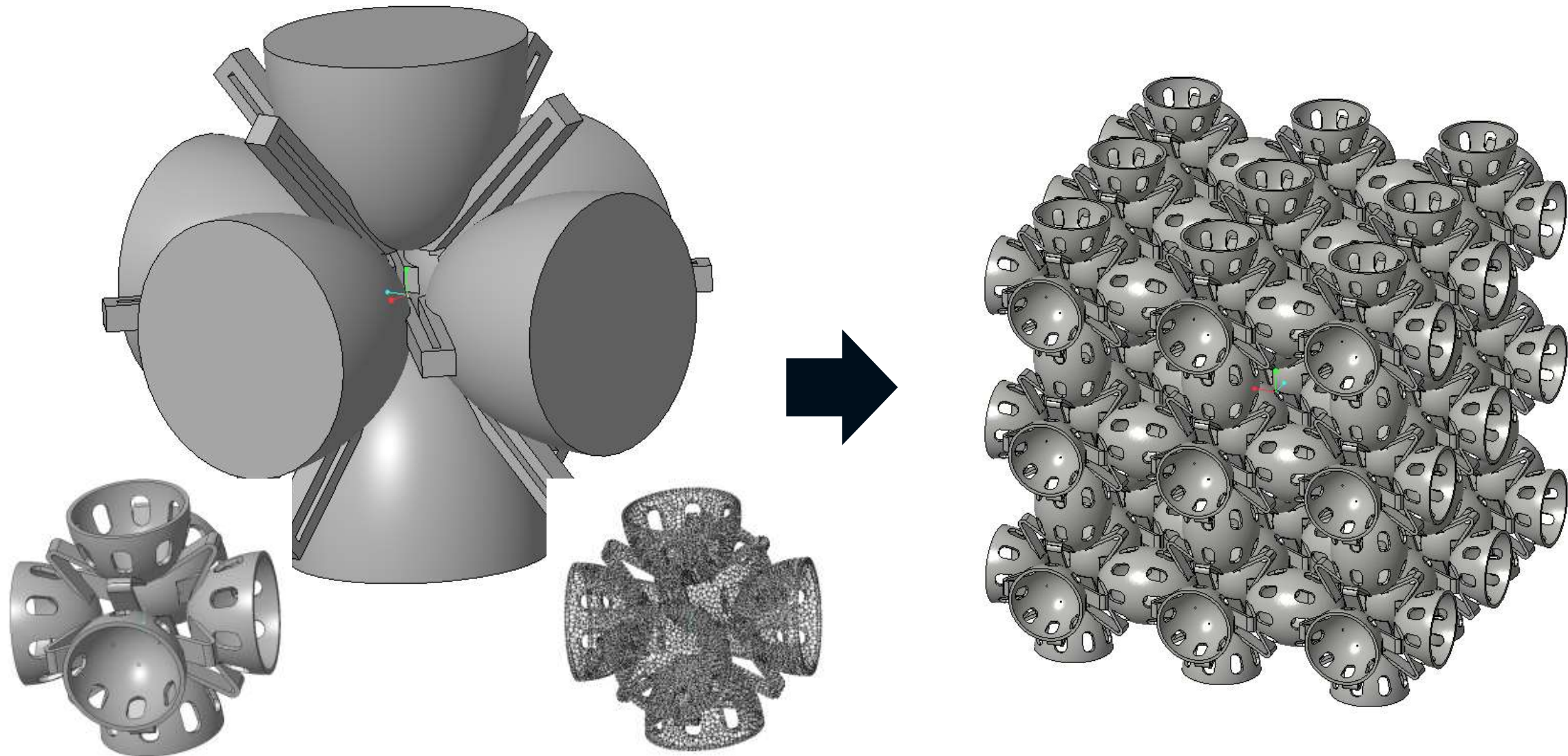
CUSTOM CELL

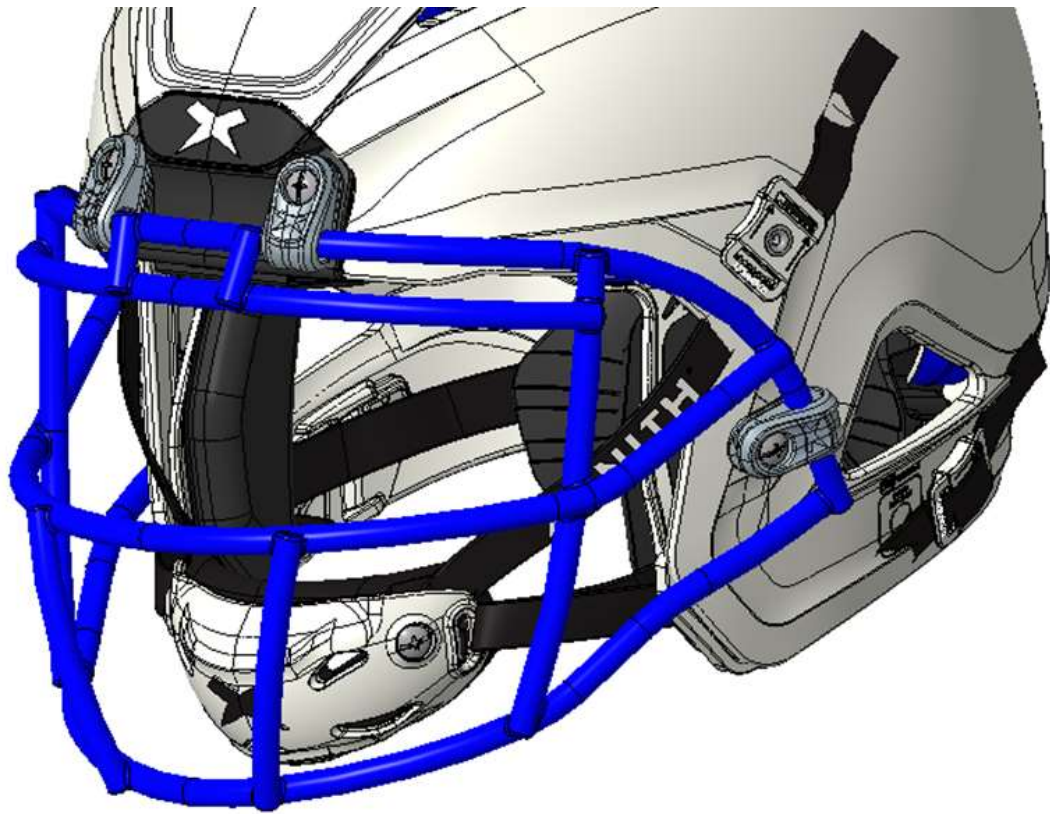
A Creo Solid Model



CUSTOM CELL

A Creo Solid Model

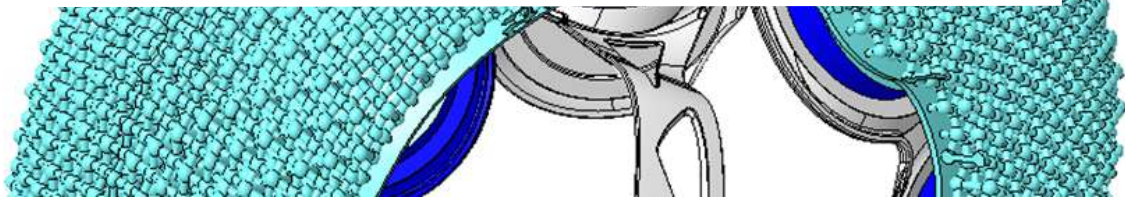




METAMATERIALS WITH CREO LATTICE MODELLING

- A metamaterial (from the Greek word μετά meta, meaning "beyond" or "after", and the Latin word materia, meaning "matter" or "material") is any material engineered to have a property that is not found in naturally occurring materials.

Art of Possible





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