



3DEXPERIENCE®

The Tosca Tuesdays

Tosca Tuesday #2

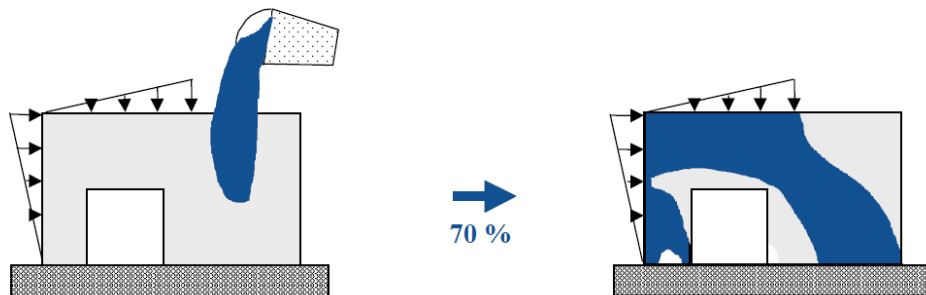
Basics: Topology optimization

Example: Topology optimization of a quadcopter

Basics | Topology optimization

Fundamental concept

- **Design variables:** Density value (0% - 100%) of each element from a given design space
- **Goal:** Calculate an optimal design proposal in a given design space under consideration of all boundary conditions, constraints and geometric restrictions
- **Result:** Best material distribution for a given optimization problem



Basics | Topology optimization

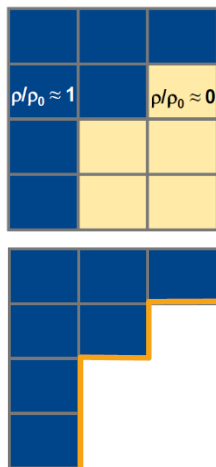
Fundamental concept

- **Design variables:** Density value (0% - 100%) of each element from a given design space
- **Goal:** Calculate an optimal design proposal in a given design space under consideration of all boundary conditions, constraints and geometric restrictions
- **Result:** Best material distribution for a given optimization problem
- **Examples of possible topology optimization tasks**
 - Maximize stiffness with volume constraint
 - Minimize volume with displacement constraint
 - Maximize stiffness with frequency constraints
 - Minimize displacement with volume constraint
 - Maximize first eigenfrequencies
 - ...

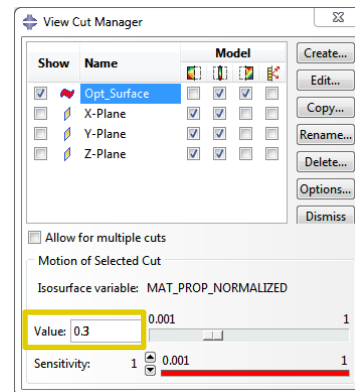
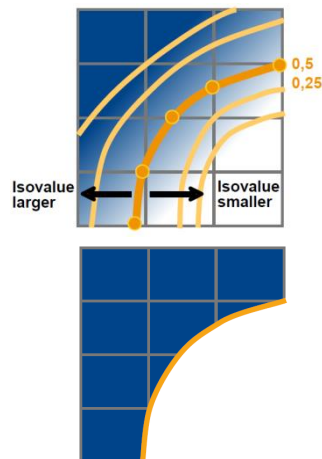
Basics | Topology optimization

Smoothing

- **Topology optimization result:**
Discrete material distribution
(density value for each design element)



- **Result smoothing:**
Calculation of an Isosurface for a defined density value (iso-value)



View Cut Manager
in Abaqus CAE

Tosca Tuesday #2

Basics: Topology optimization

Example: Topology optimization of a quadcopter

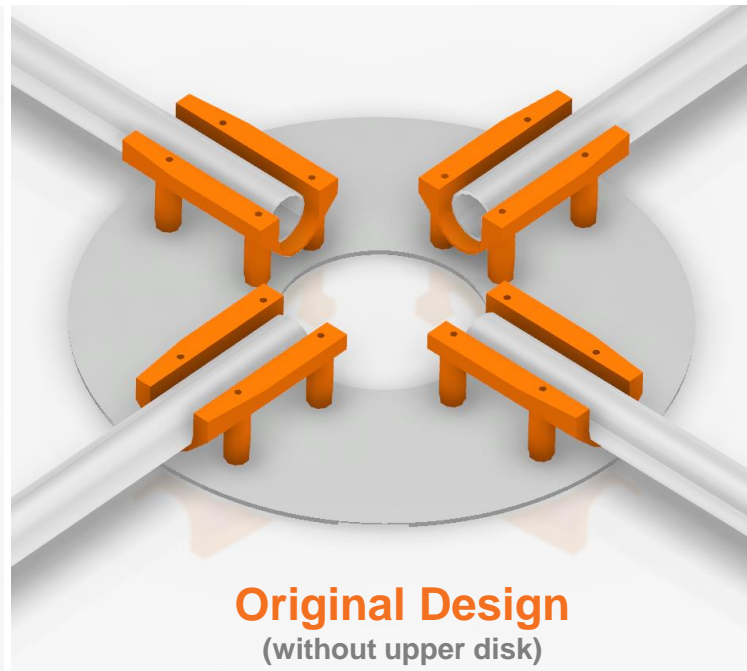
Example | Quadcopter

Virtual model



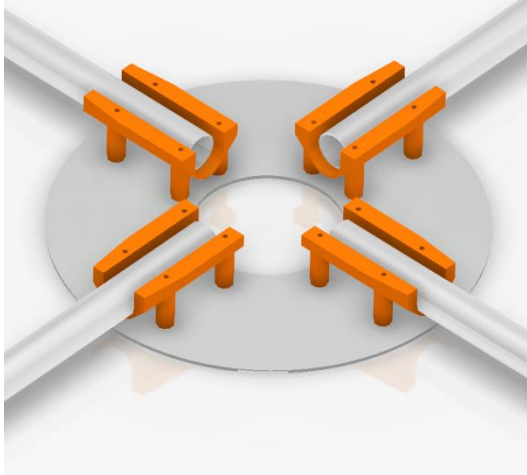
Example | Quadcopter

Virtual model



Example | Quadcopter

Original Design

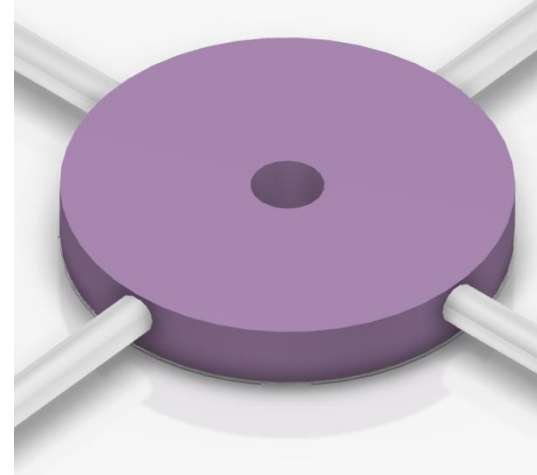


Redesign

Goals:

- Lightweight design
- Maximal stiffness
- Simplify design
(→ Include **brackets**
and upper disk
into design space)

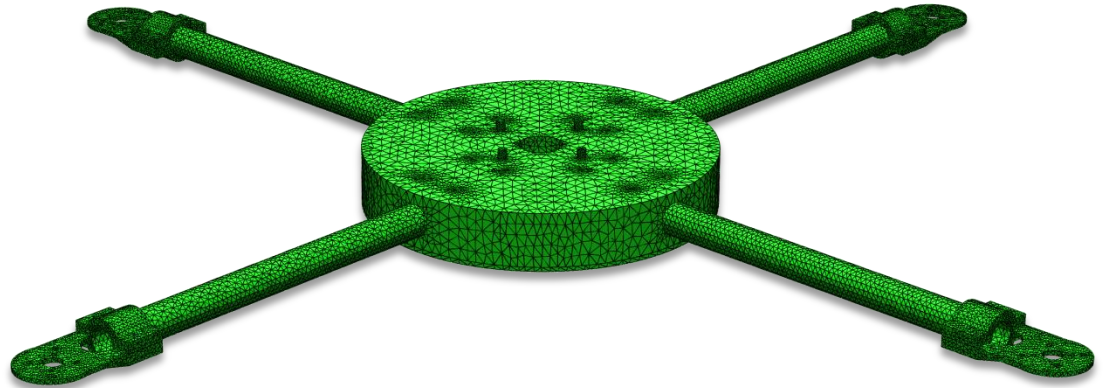
Design Space



Example | Quadcopter

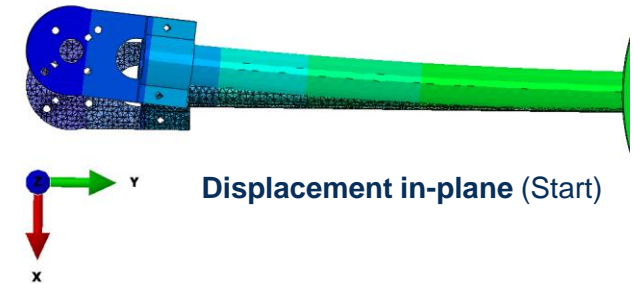
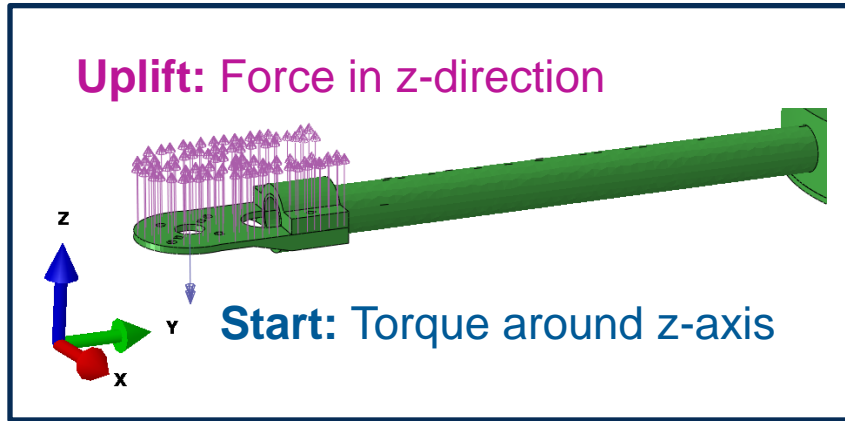
Get started ...

- ▶ Start Abaqus CAE (at least version 6.13, preferable 6.13-4)
- ▶ File → Import → Model → “quadcopter.inp”
- ▶ File → Set Work Directory → Choose Directory



Example | Quadcopter

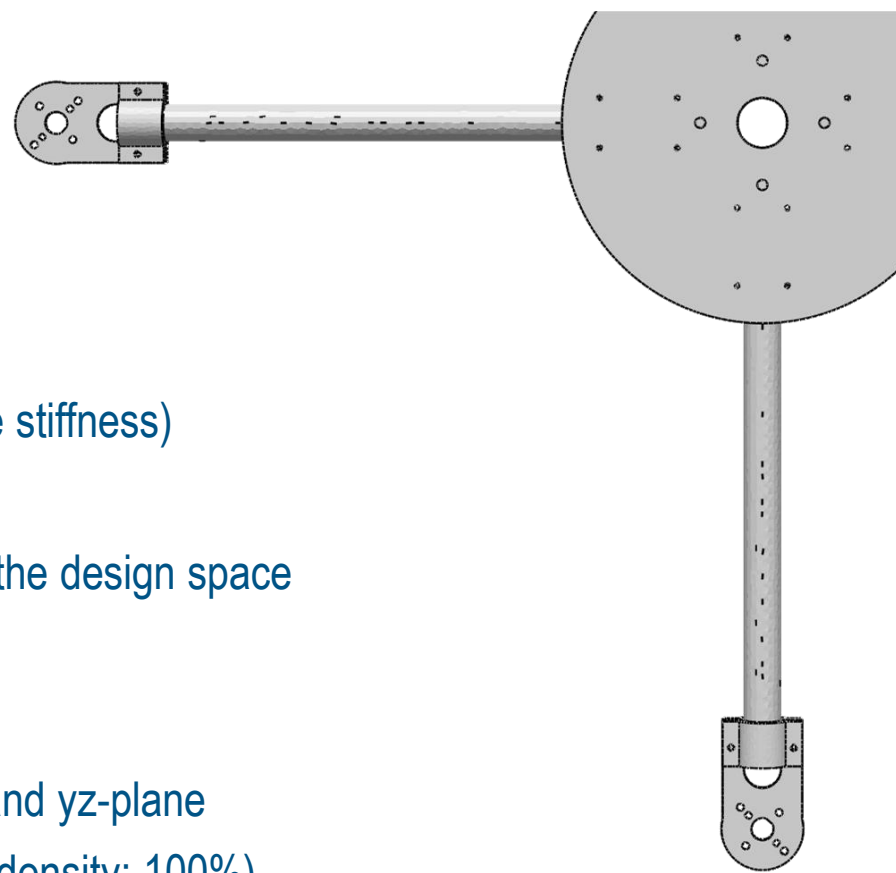
Basic model: Loading conditions and displacements



Example | Quadcopter

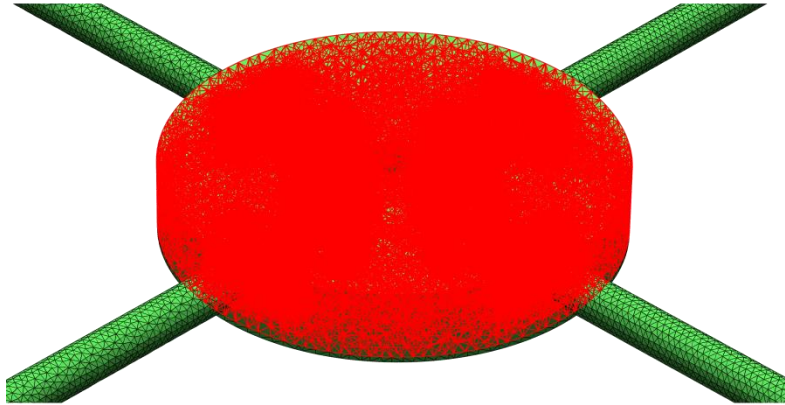
Topology Optimization: Setup

- **Objective function**
 - Minimize total strain-energy (→ maximize stiffness)
- **Constraint**
 - Volume constraint: Use less than 30% of the design space
- **Geometric restriction**
 - Rotational symmetry around the z-axis
 - Planar symmetry with regards to the xz- and yz-plane
 - Frozen elements for bore holes (element density: 100%)

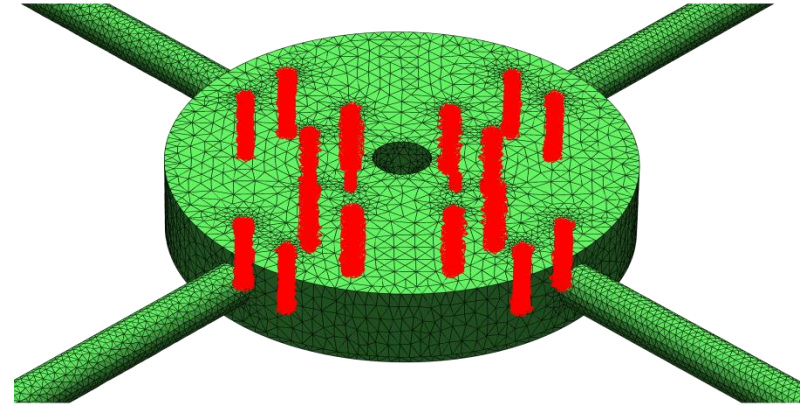


Example | Quadcopter

Topology Optimization: Used element sets



Design elements



Frozen elements
(bore holes)

Example | Quadcopter

Step 1: Topology optimization task

3DS.COM © Dassault Systèmes

Models (1)
quadcopter

- Parts (1)
- Materials (2)
- Calibrations
- Sections (14)
- Profiles
- Assembly
- Steps (3)
- Field Output Requests (18)
- History Output Requests (32)
- Time Points
- ALE Adaptive Mesh Constraints
- Interactions (1)
- Interaction Properties (2)
- Contact Controls
- Contact Initializations
- Contact Stabilizations
- Constraints (25)
- Connector Sections (8)
- Fields
- Amplitudes
- Loads (16)
- BCs (20)
- Predefined Fields
- Remeshing Rules
- Optimization Tasks**
- Sketches
- Annotations
- Analysis

Switch Context Ctrl+Space
Manager...
Create...
Filter... F2

Create Optimization Task

Name: Task-1

Type

- Topology optimization**
- Shape optimization
- Sizing optimization

Continue... Cancel

Sets...

Region Selection

Eligible Sets
Sets below may contain elements, cells, shell faces, or wire edges.

Name filter:

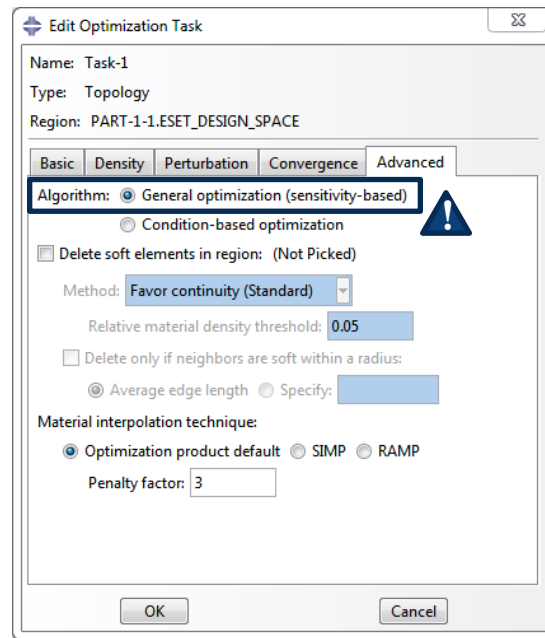
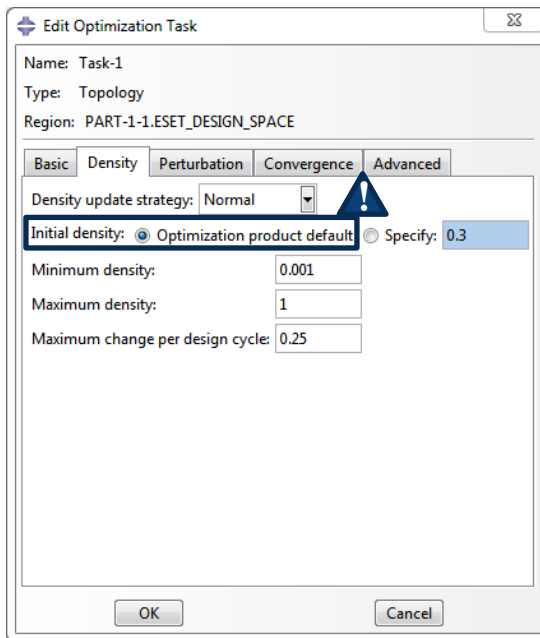
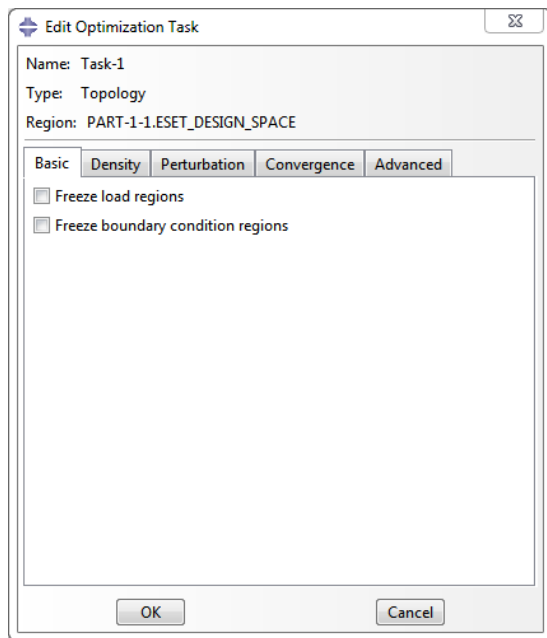
Name	Type
ESET_SCREWS	Element
PART-1-1.Bottom Plate-Elements-1-1	Element
PART-1-1.ESET_DESIGN_SPACE	Element
PART-1-1.Solid Section1-1-1-1	Element
PART-1-1.Solid Section1-1-1-2	Element
PART-1-1.Solid Section1-1-1-3	Element
PART-1-1.Solid Section1-1-1-4	Element
PART-1-1.Solid Section2-1-1-1	Element
PART-1-1.Solid Section2-1-1-2	Element

☒ Highlight selections in viewport

Continue... Dismiss

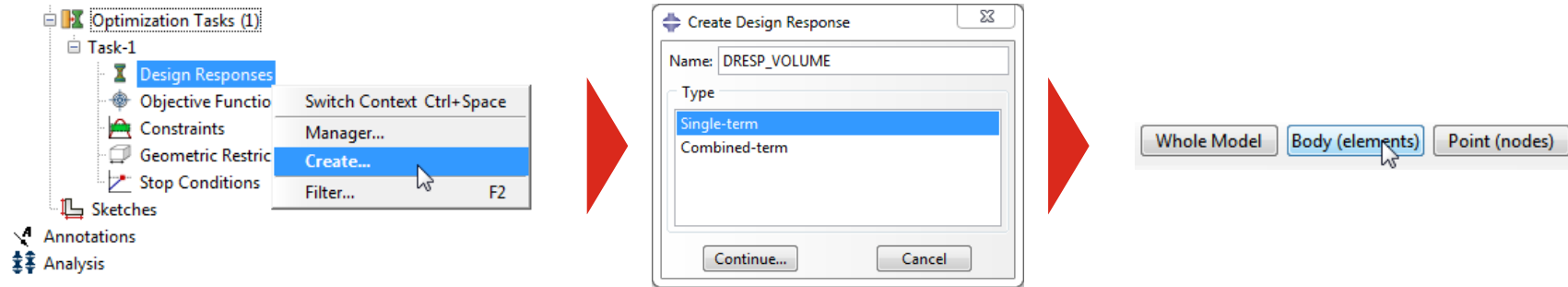
Example | Quadcopter

Step 1: Topology optimization task



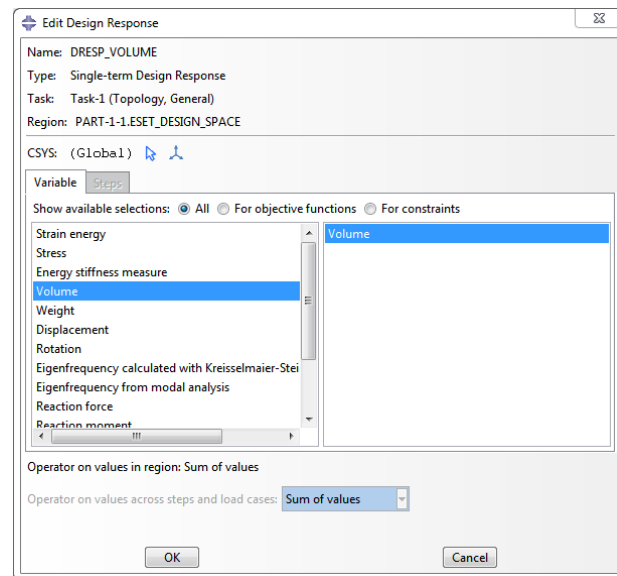
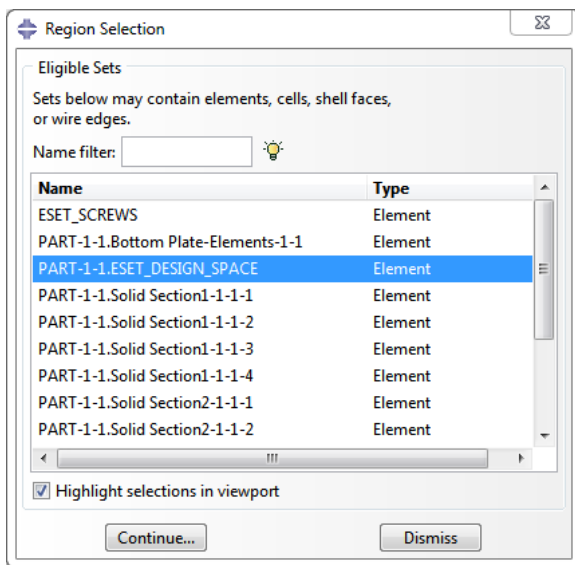
Example | Quadcopter

Step 2: Design response for volume



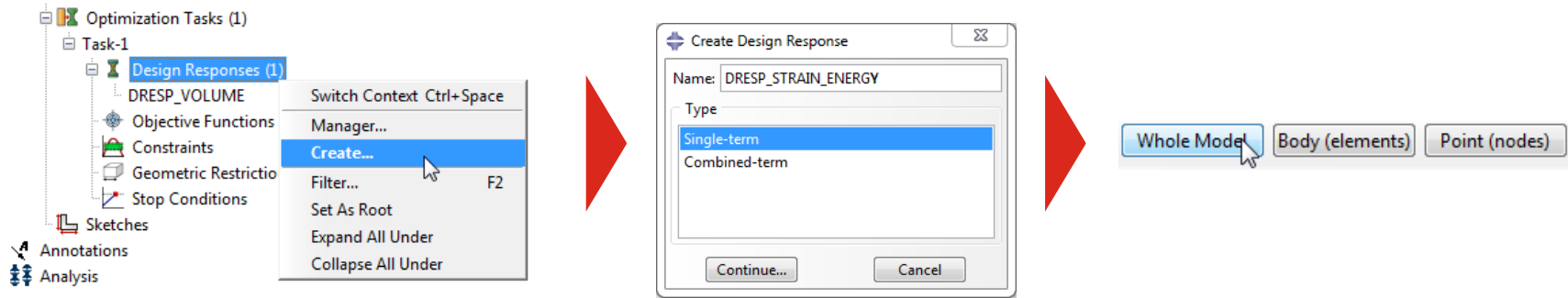
Example | Quadcopter

Step 2: Design response for volume



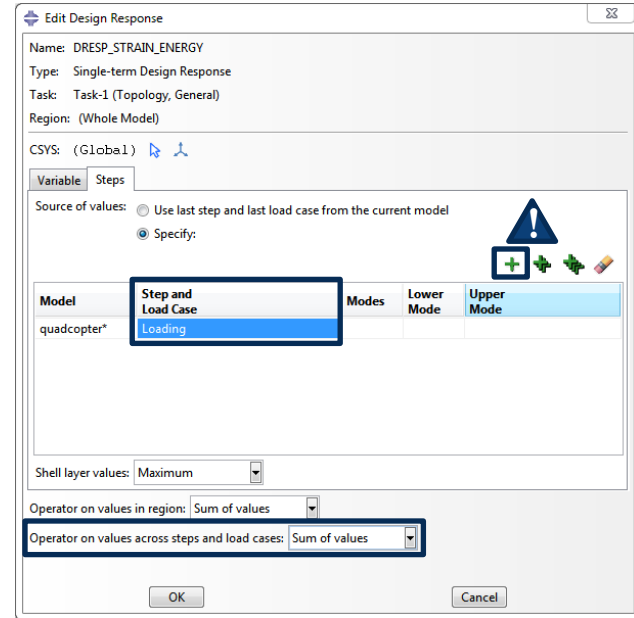
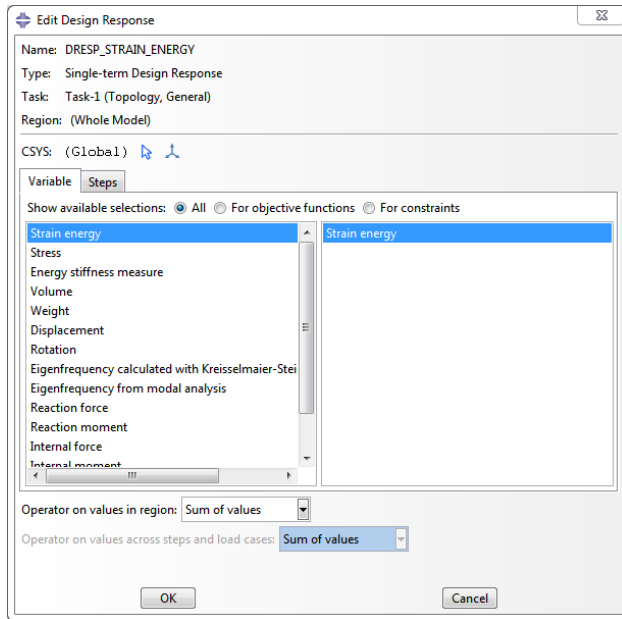
Example | Quadcopter

Step 3: Design response for total strain-energy



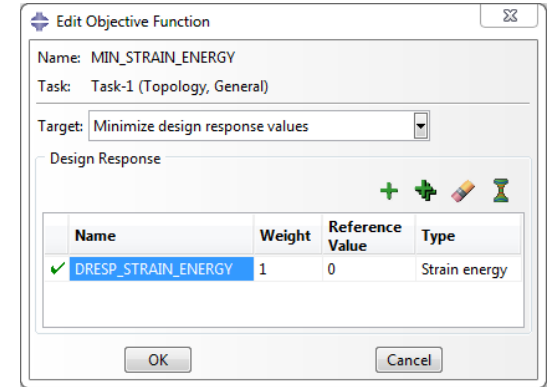
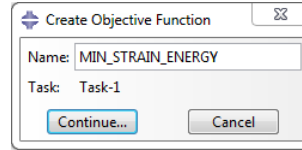
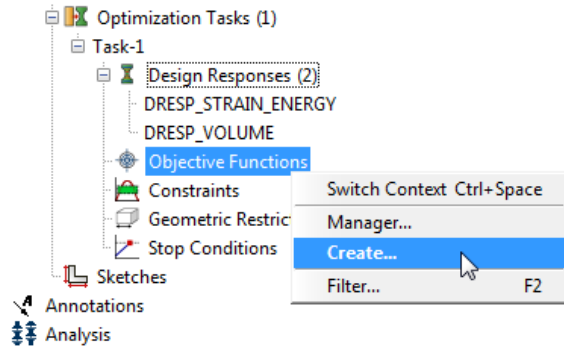
Example | Quadcopter

Step 3: Design response for total strain-energy



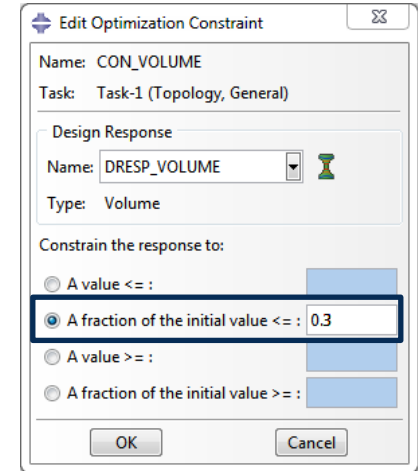
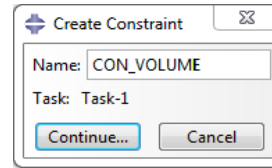
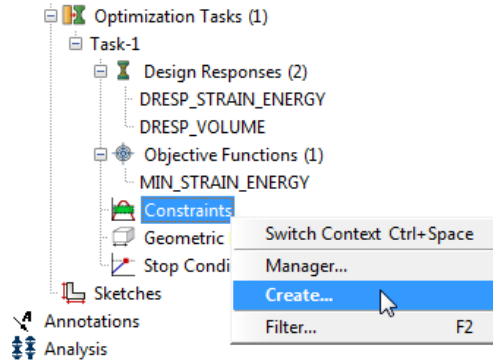
Example | Quadcopter

Step 4: Objective function (→ minimize total strain-energy)



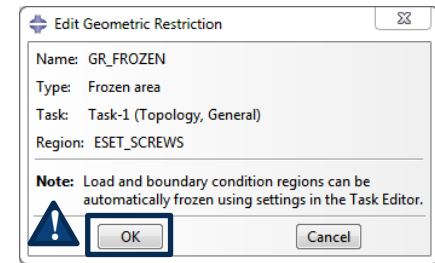
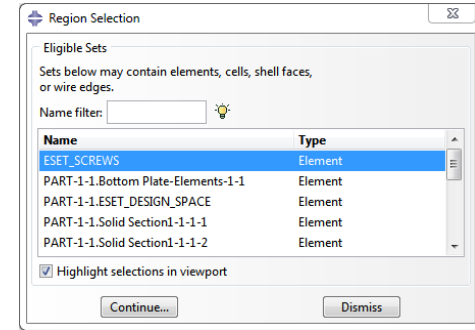
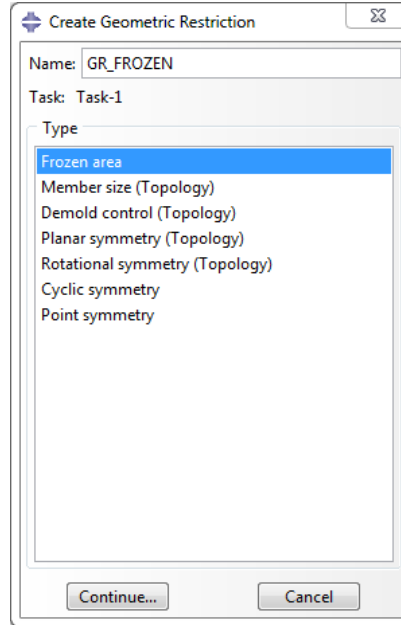
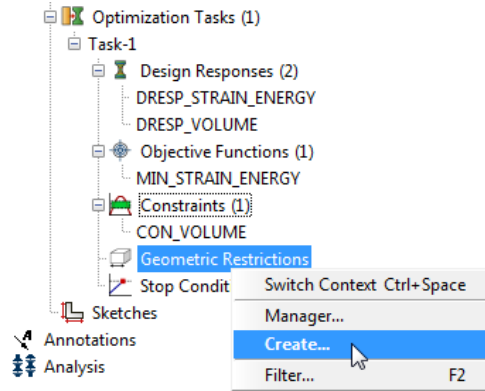
Example | Quadcopter

Step 5: Volume constraint



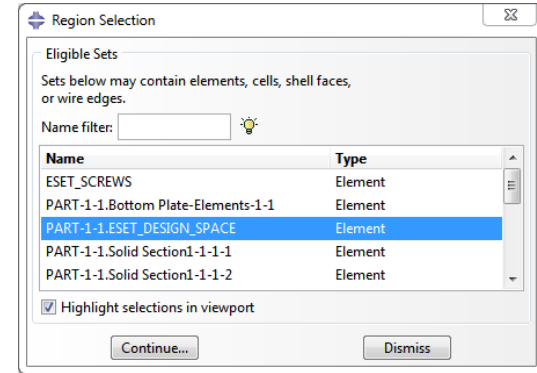
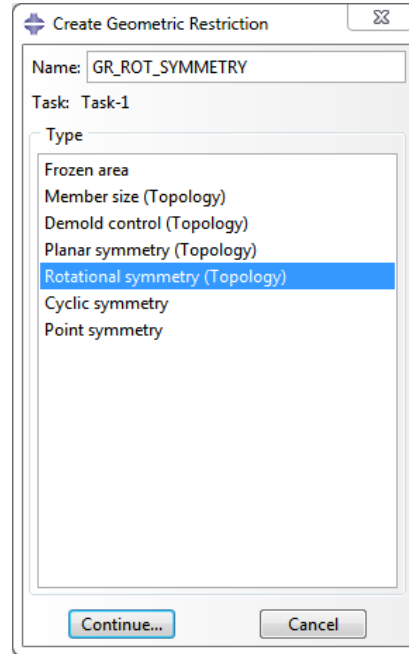
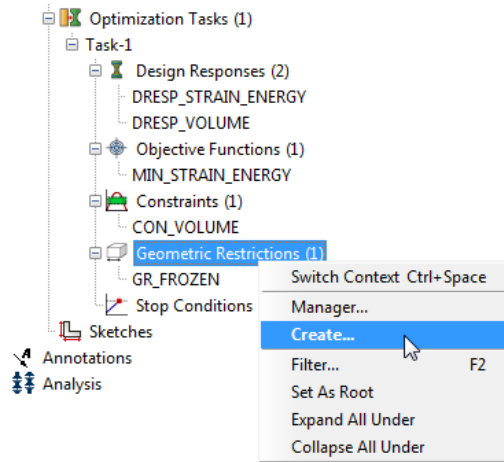
Example | Quadcopter

Step 6: Geometric restriction for frozen elements



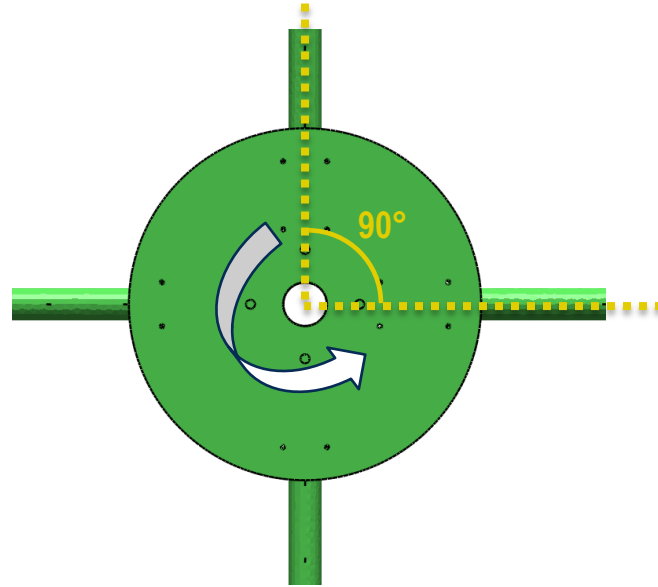
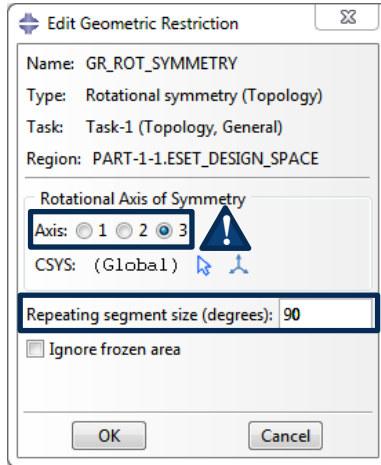
Example | Quadcopter

Step 7: Geometric restriction for rotational symmetry



Example | Quadcopter

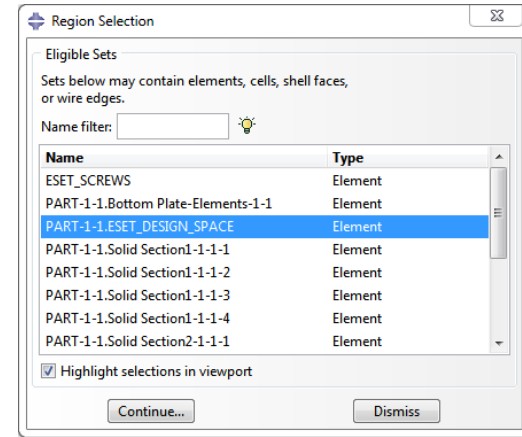
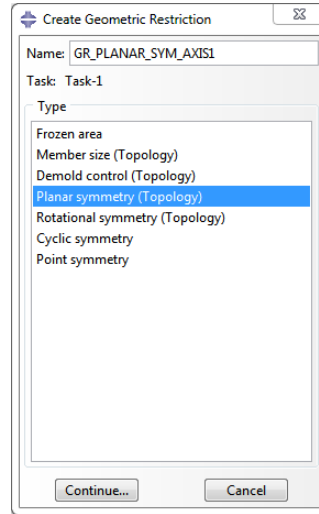
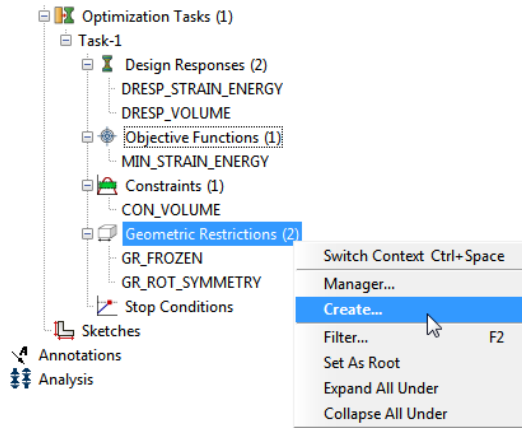
Step 7: Geometric restriction for rotational symmetry



Rotational symmetry around z-axis (Axis 3)

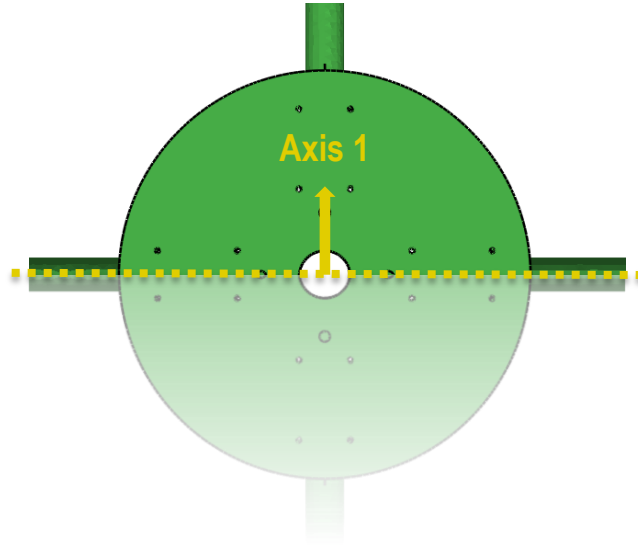
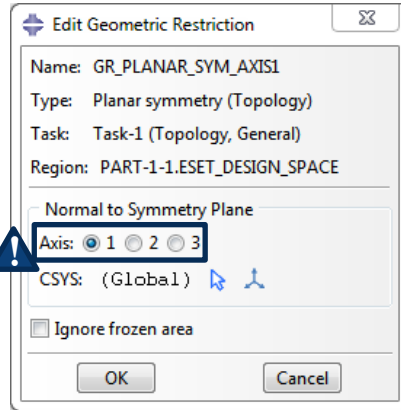
Example | Quadcopter

Step 8: Geometric restriction for planar symmetry (yz-plane)



Example | Quadcopter

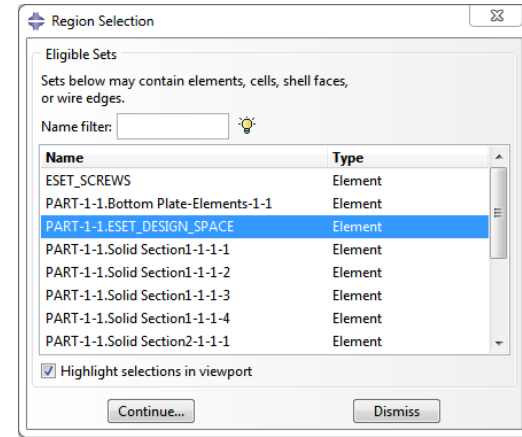
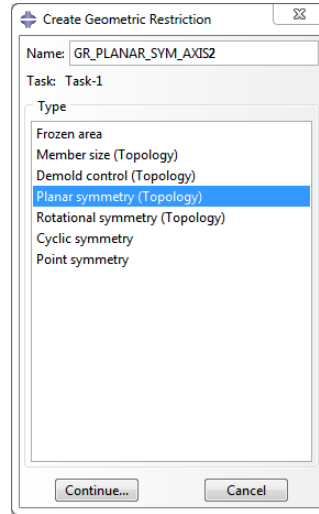
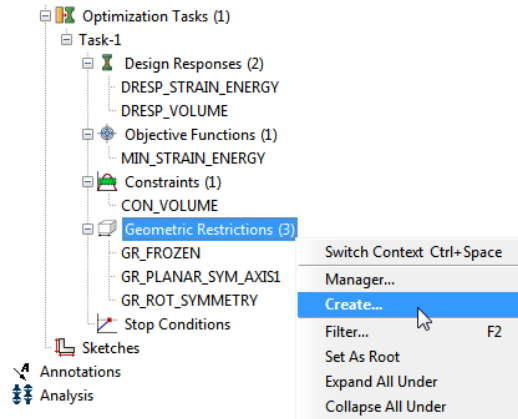
Step 8: Geometric restriction for planar symmetry (yz-plane)



Planar symmetry with respect to yz-plane (Axis 1)

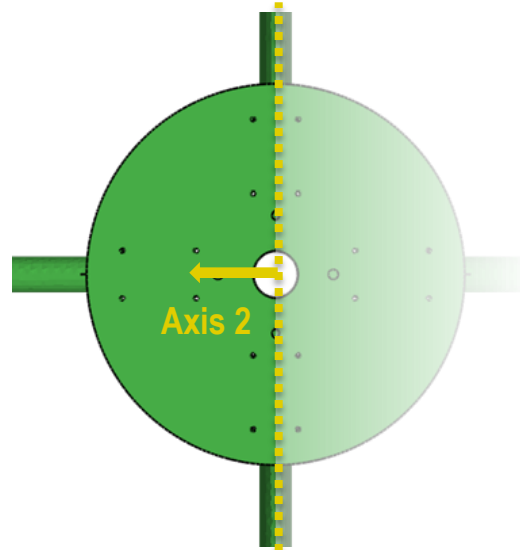
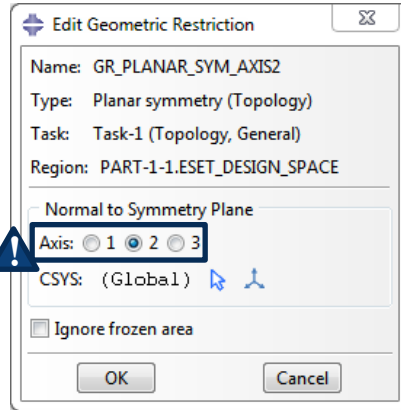
Example | Quadcopter

Step 9: Geometric restriction for planar symmetry (xz-plane)



Example | Quadcopter

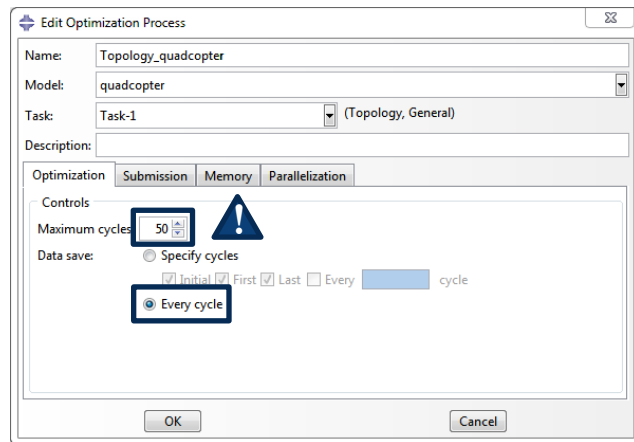
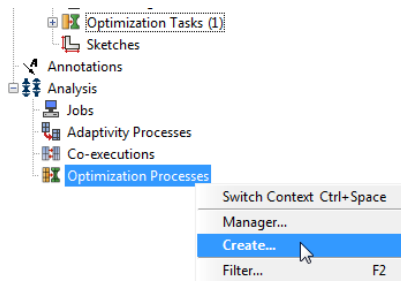
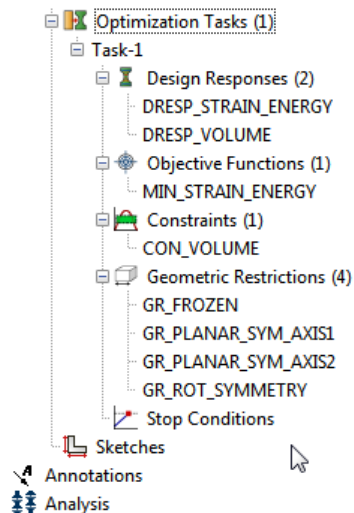
Step 9: Geometric restriction for planar symmetry (xz-plane)



Planar symmetry with respect to xz-plane (Axis 2)

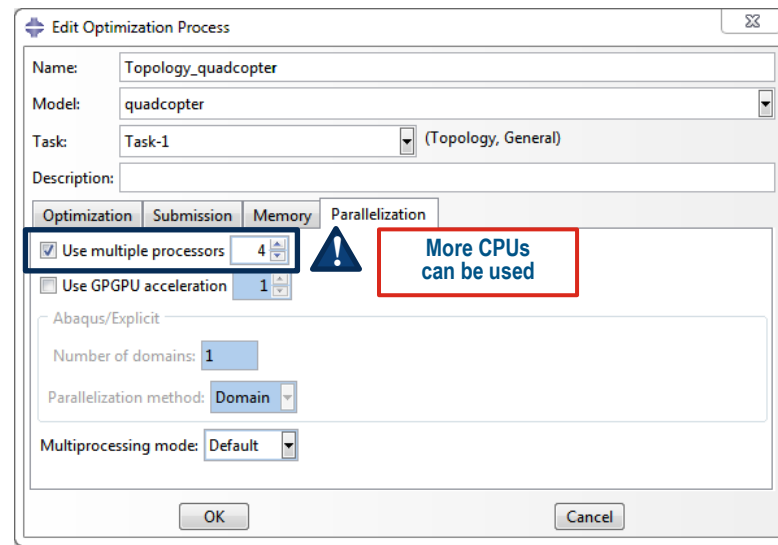
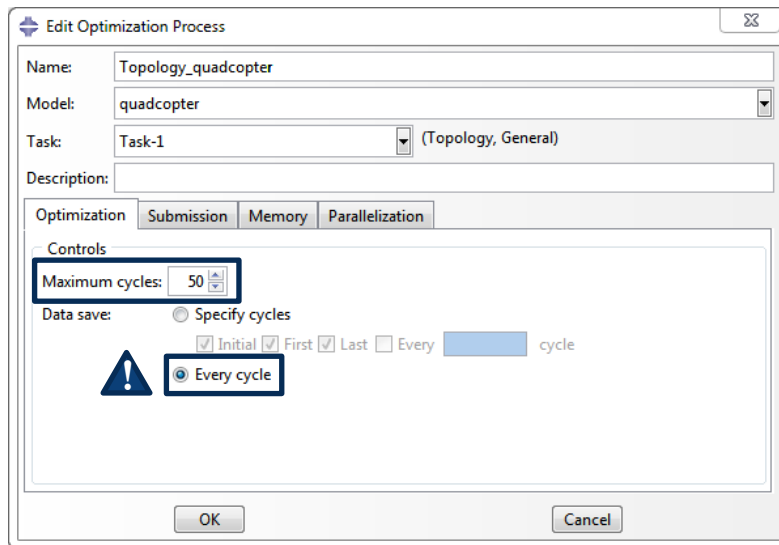
Example | Quadcopter

Step 10: Submission of the optimization task



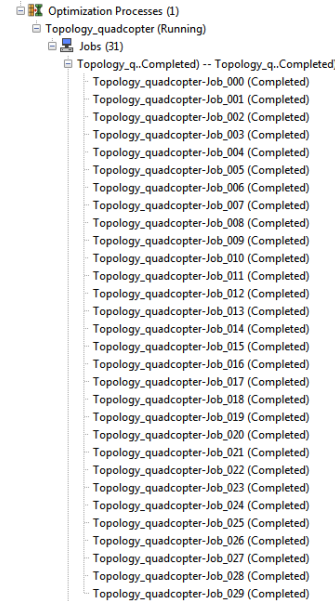
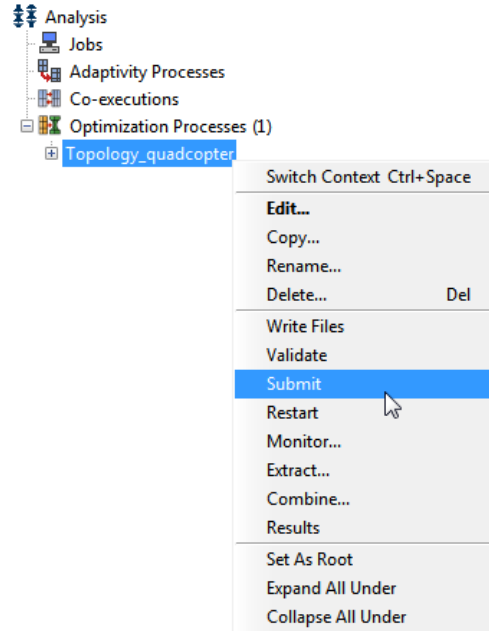
Example | Quadcopter

Step 10: Submission of the optimization task



Example | Quadcopter

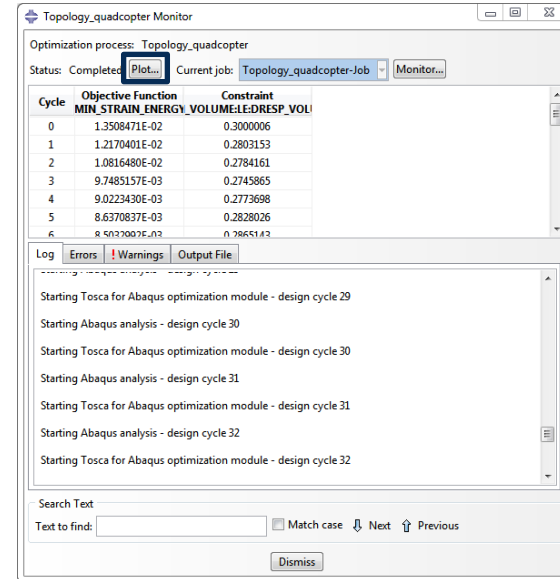
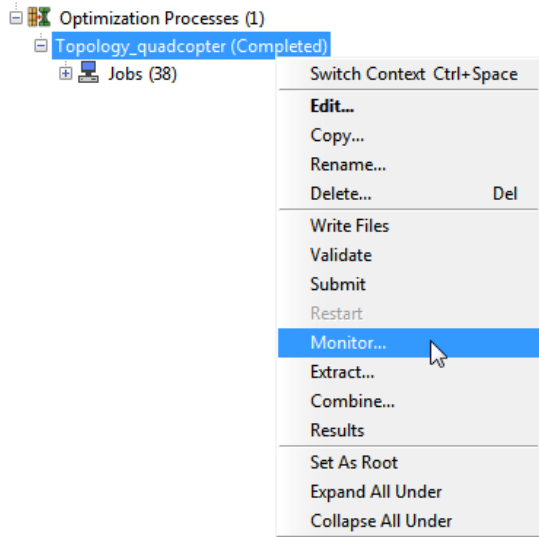
Step 10: Submission of the optimization task



Computational time:
~ 17h with 4 CPUs

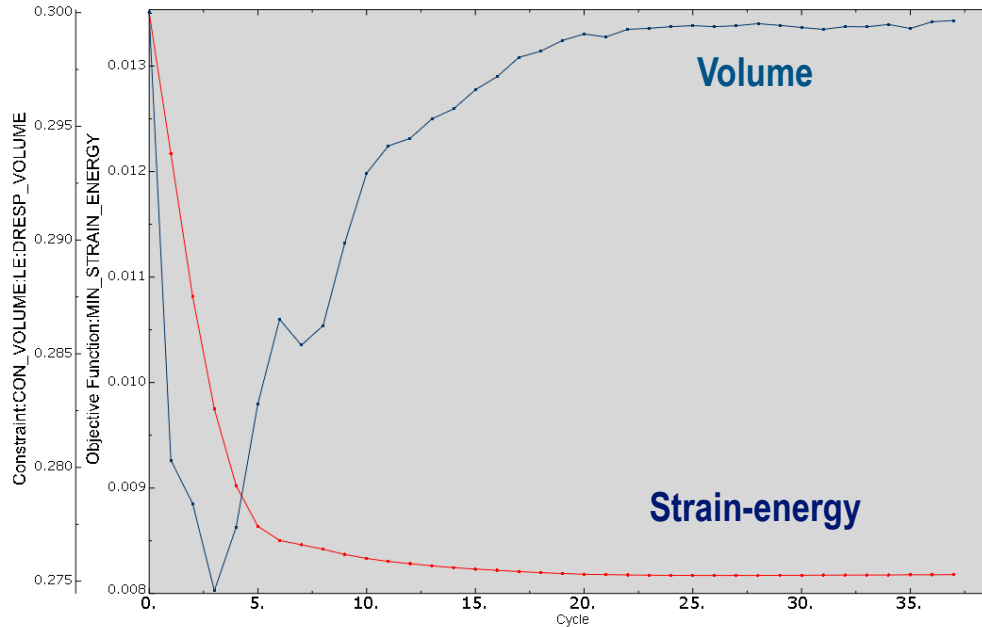
Example | Quadcopter

Step 10: Submission of the optimization task



Example | Quadcopter

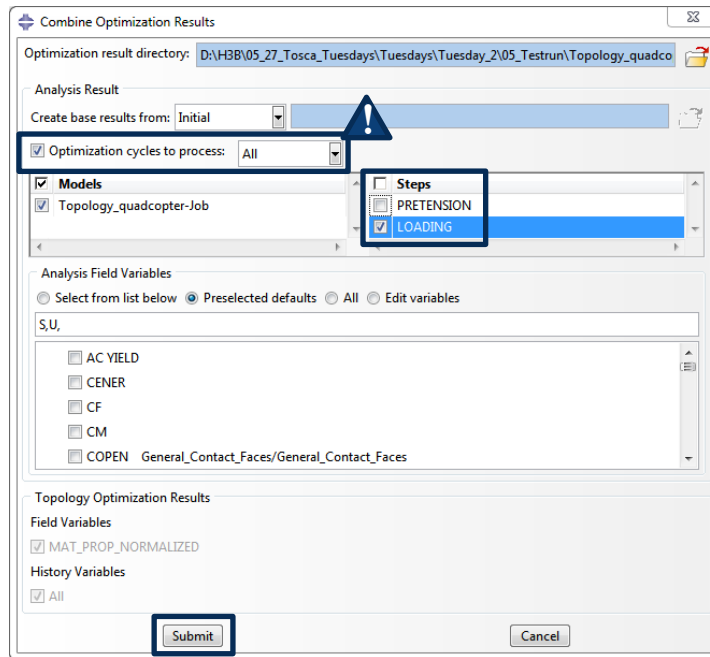
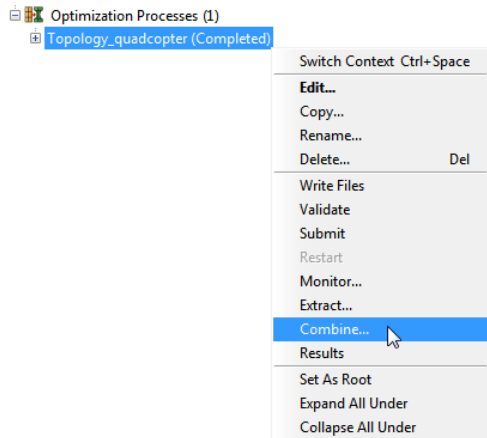
Step 10: Submission of the optimization task



Modify axis display options (font, size, color) by double-clicking

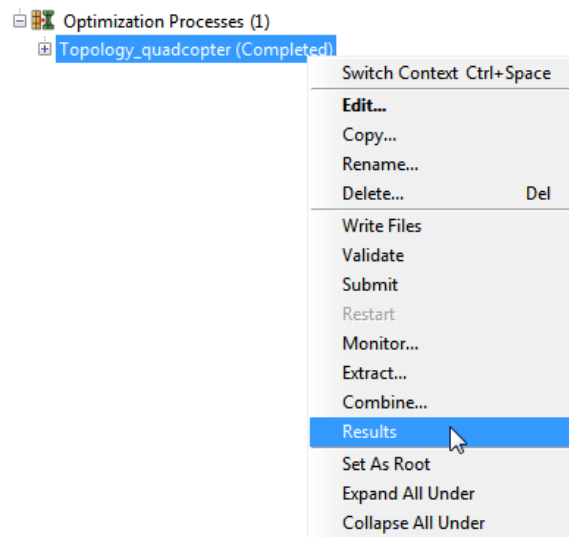
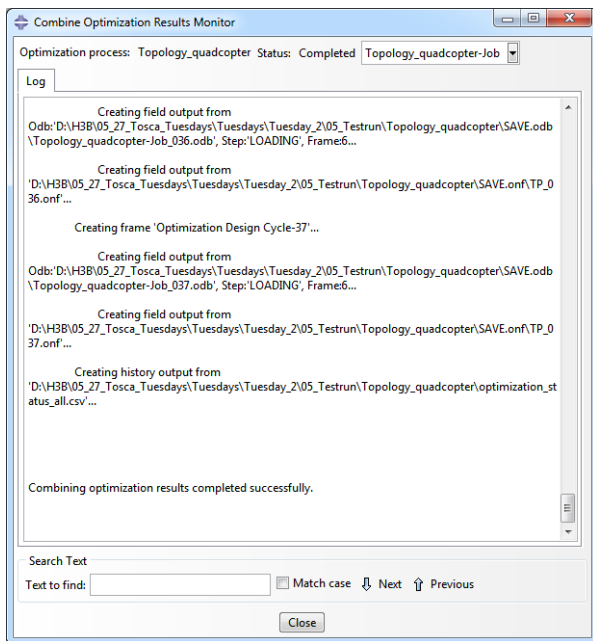
Example | Quadcopter

Step 11: Visualization (⚠ Optimization has to be completed)



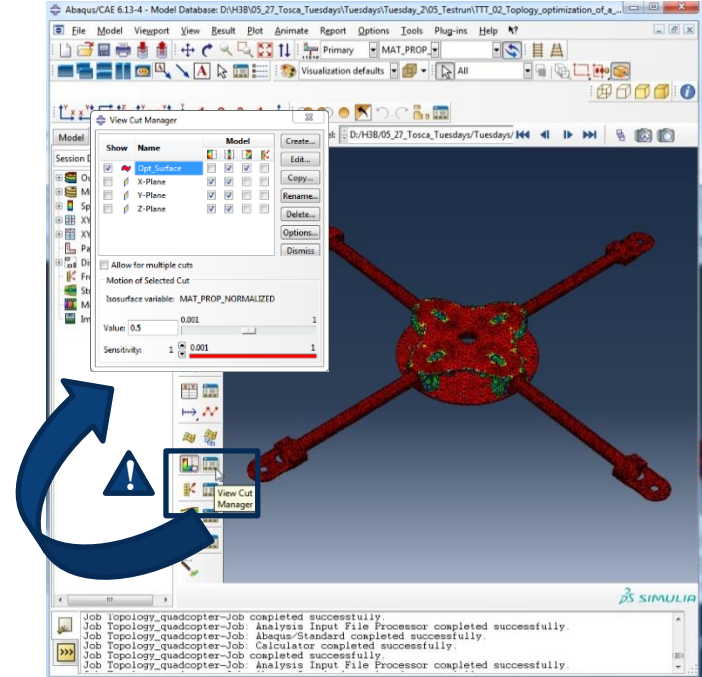
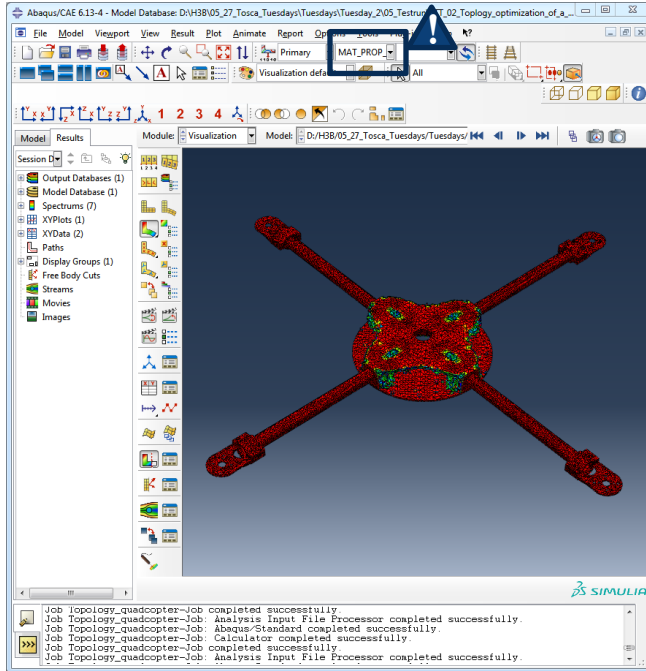
Example | Quadcopter

Step 11: Visualization



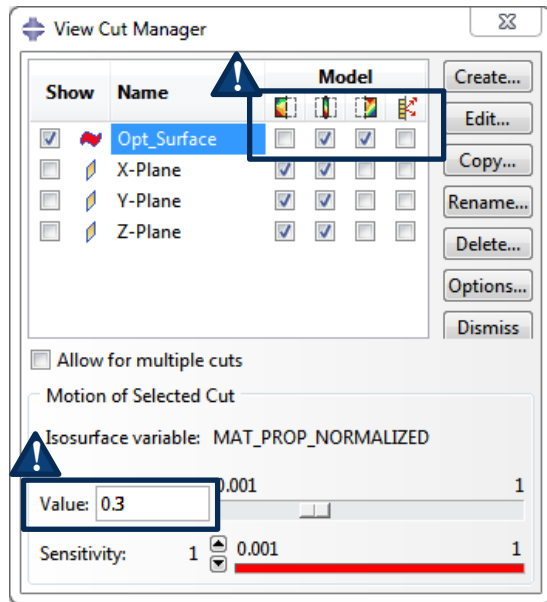
Example | Quadcopter

Step 11: Visualization

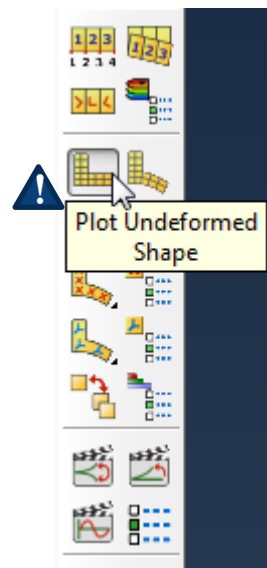


Example | Quadcopter

Step 11: Visualization

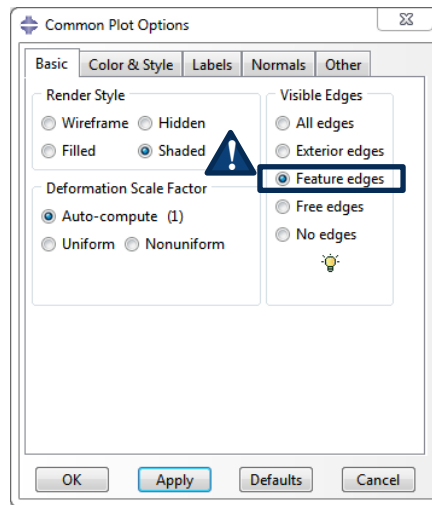
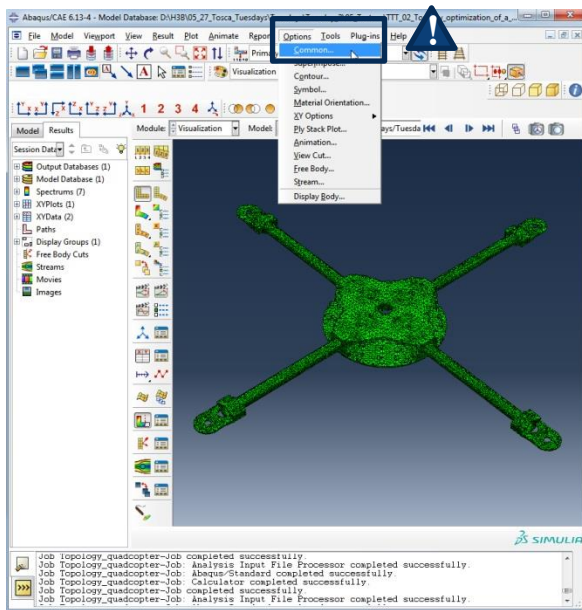


Set iso-value to 0.3



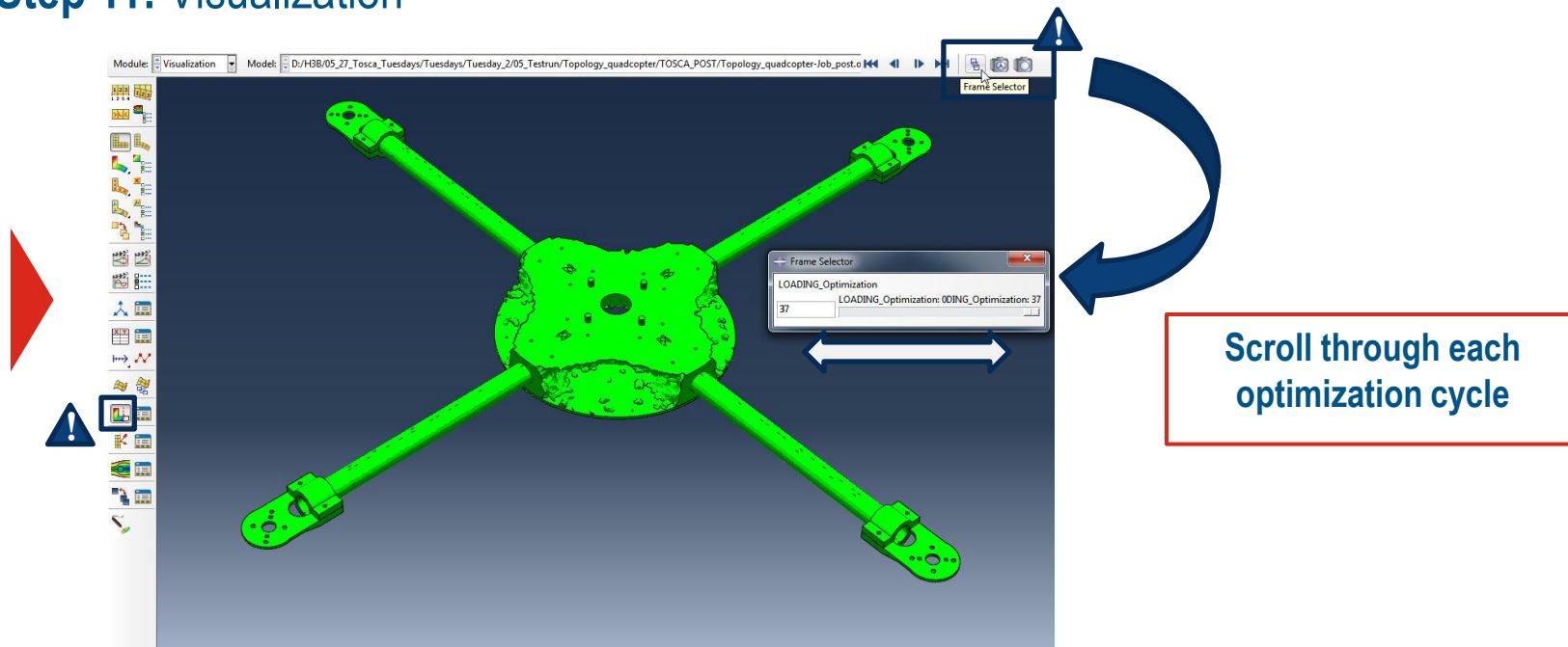
Example | Quadcopter

Step 11: Visualization



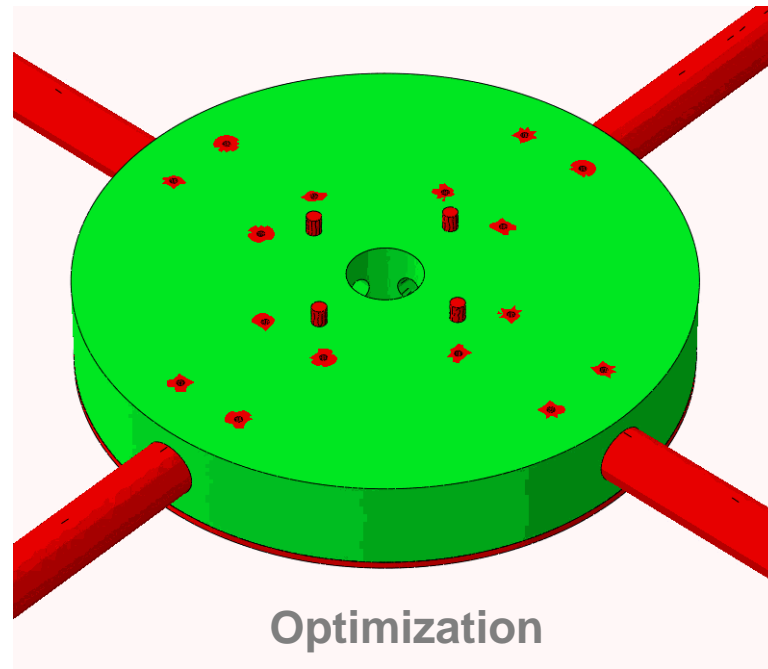
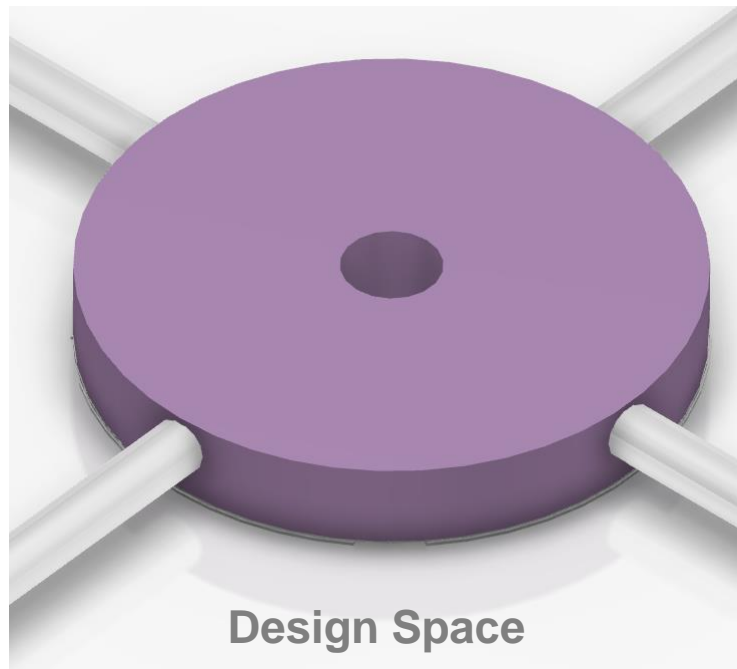
Example | Quadcopter

Step 11: Visualization



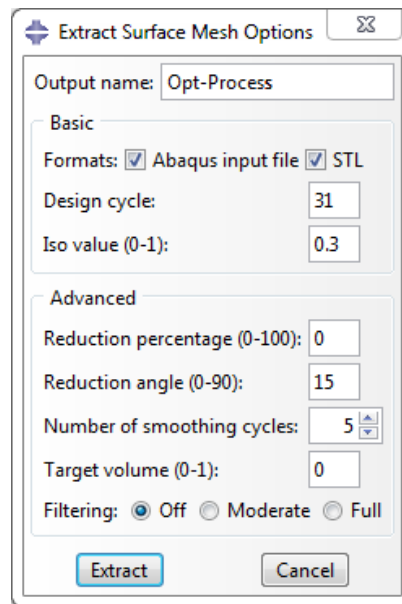
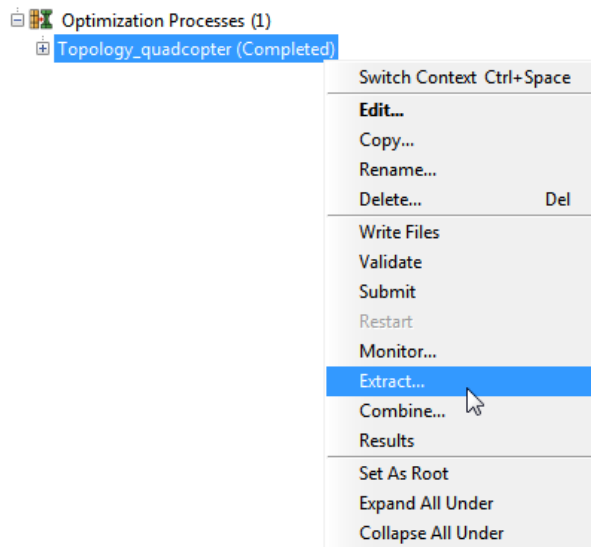
Example | Quadcopter

Step 11: Visualization



Example | Quadcopter

Step 12: Extract smoothed geometry

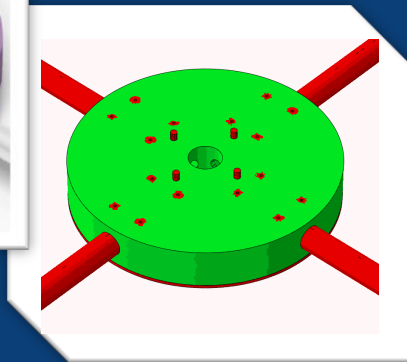




Original Design



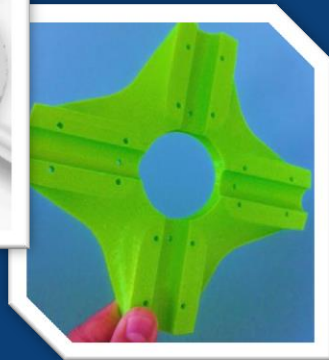
Design Space



**Topology
Optimization**



New Design



3D Printing

