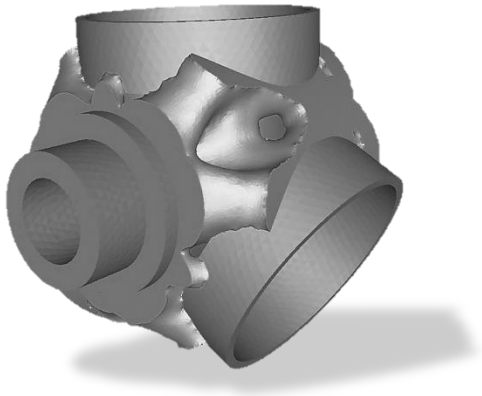
3DEXPERIENCE®

The Tosca Tuesdays

Tosca Tuesday #3

Basics: Topology optimization

Example: Topology optimization of a wind turbine hub

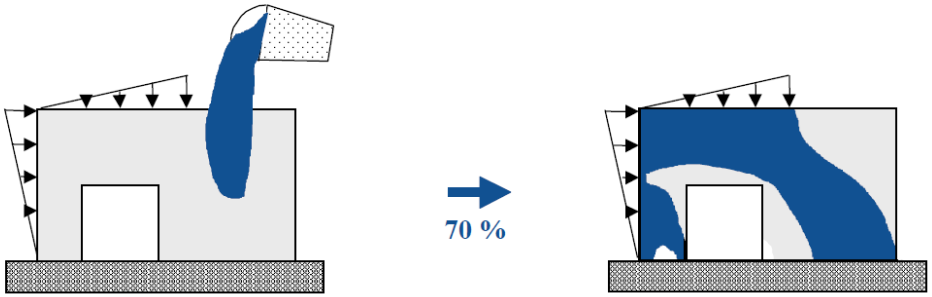


Basics | Topology optimization

TTT #1

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

TTT #1

Fundamental concept

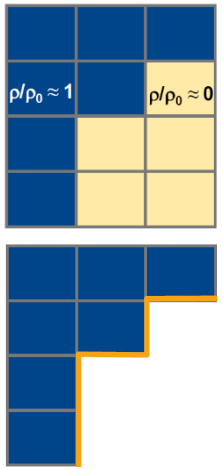
- **Design variables:** Density value (0% - 100%) of each element from a given design space
- **Goal:** Calculate an optimal design proposal in a given design space under consideration of all boundary conditions, constraints and geometric restrictions
- **Result**: Best material distribution for a given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

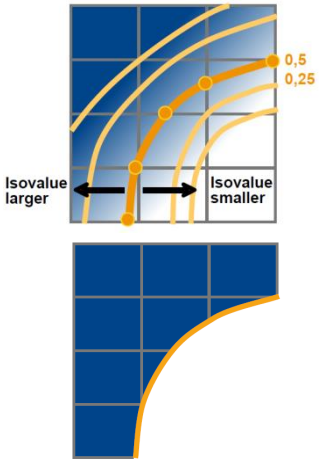
TTT #2

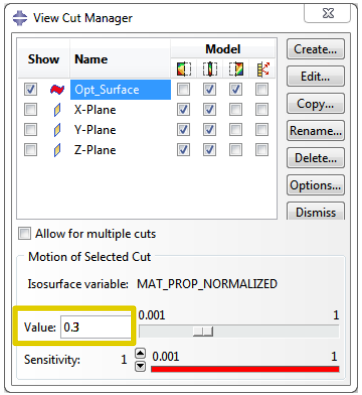
Smoothing

- **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

Basics | Topology optimization

NEW

Strain Energy (Compliance)

- One of the most common topology optimization tasks is to find a structure with maximum stiffness under a given volume or weight restriction.
- Compliance is a measure of the overall flexibility or “softness” of a structure given by the sum of elastic or strain energy in a structure. Thus, compliance can be seen as a stiffness measure or more correctly the reciprocal of stiffness.
- In order to maximize the global stiffness we therefore minimize compliance (if the loads for the model are applied as external forces or pressure). Compliance is defined in Tosca Structure by the sum of strain energy of all elements:

Strain Energy: $c = \sum u^T K u$

Basics | Topology optimization

NEW

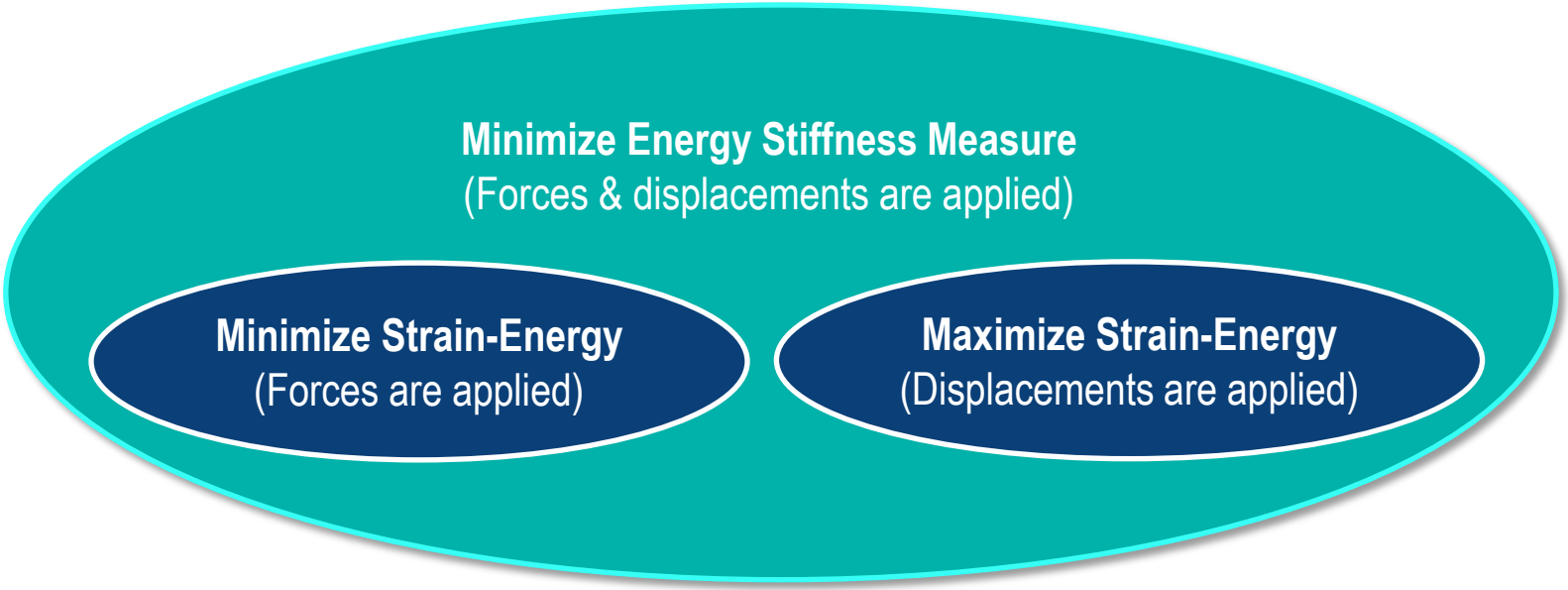
Energy stiffness measure

- It is important to note that whether to minimize or to maximize the sum of the strain energy (compliance) depends on the loading types and boundary conditions.
- If the loads in the model are applied as **external forces** or **pressure**, then the objective function (compliance) has to be minimized.
- If only **prescribed displacements** are assigned and no external forces, then the objective function (compliance) has to be maximized.
- If **simultaneously prescribed displacements and external loading** are assigned then a new design response called **energy stiffness measure** can be used.
- Please note that the energy stiffness measure has to be minimized and it is only available for the sensitivity based topology optimization.

Basics | Topology optimization

NEW

Energy stiffness measure



Tosca Tuesday #3

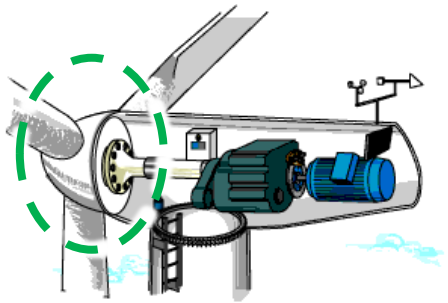
Basics: Topology optimization

Example: Topology optimization of a wind turbine hub

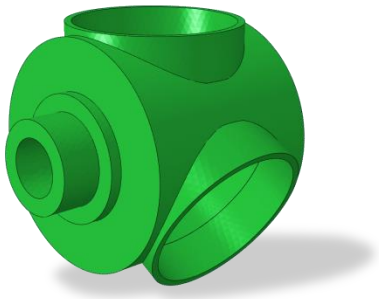
Example | Wind turbine hub

Get started …

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

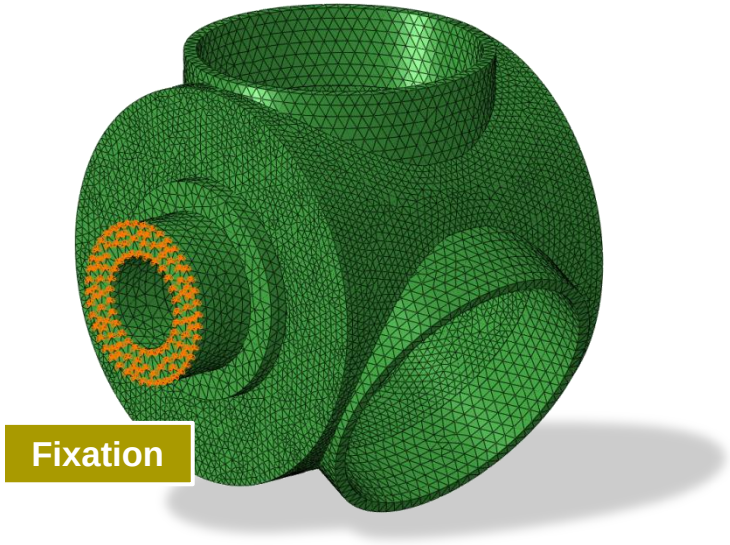


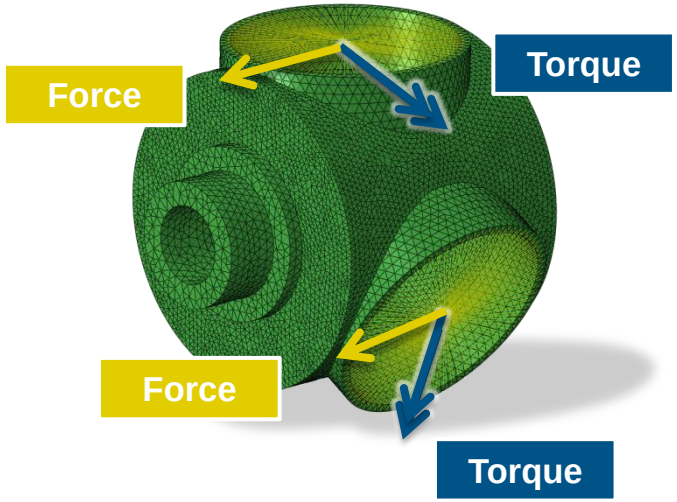
Courtesy of www.talentfactory.dk



Example | Wind turbine hub

Basic model: Loading and boundary conditions

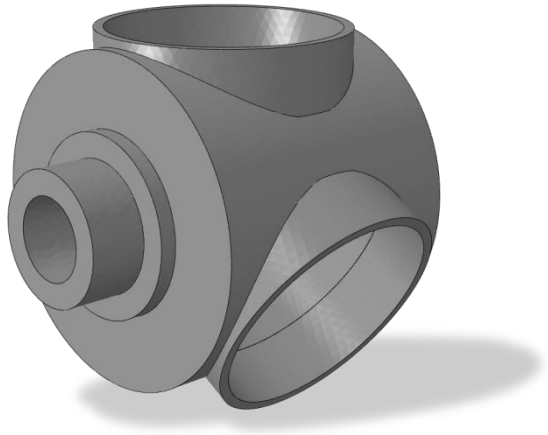




Example | Wind turbine hub

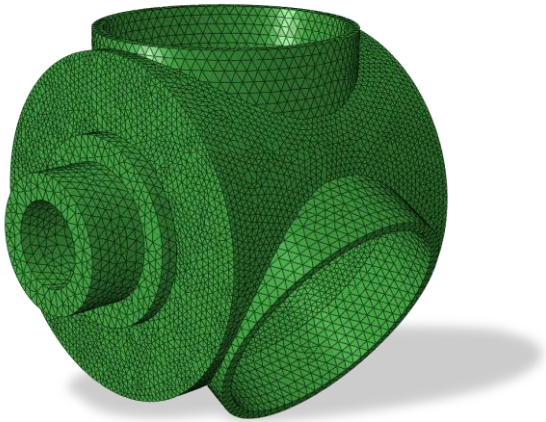
Topology Optimization: Setup

- **Objective function**
  - Minimize total strain-energy (→ maximize stiffness)
- **Constraint**
  - Volume constraint: Use less than 60% of the design space
- **Geometric restrictions**
  - Rotational symmetry
  - Planar symmetry
  - Minimum member size
  - Demold restriction
  - Frozen elements

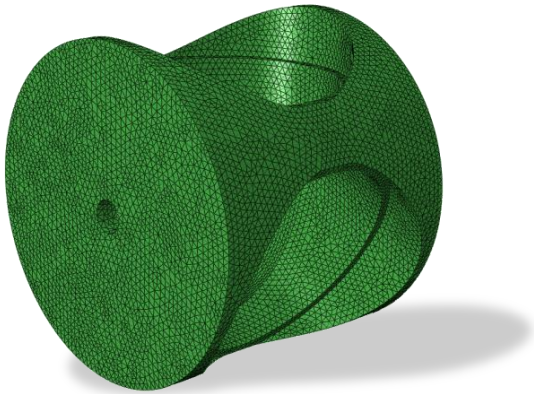


Example | Wind turbine hub

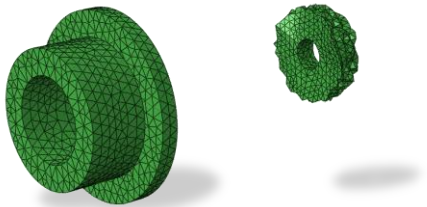
Topology Optimization: Used element sets



Complete model



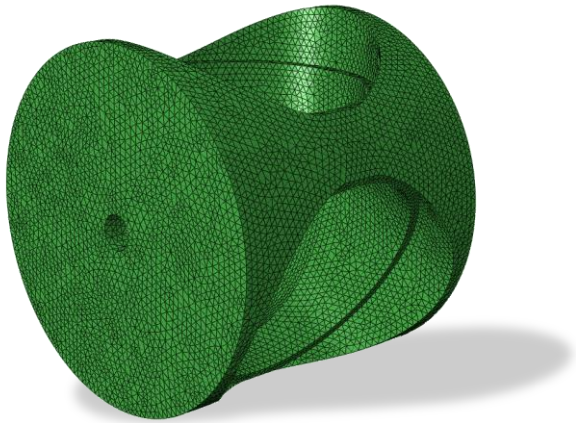
Design elements



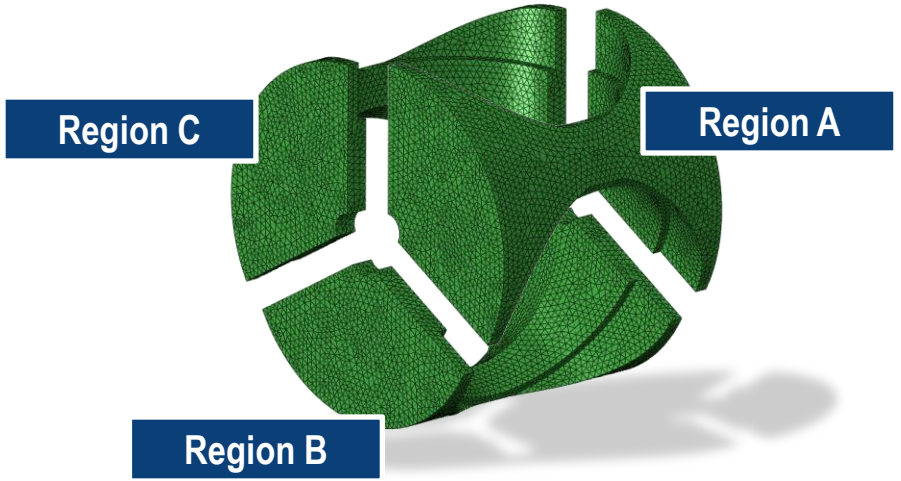
Frozen elements

Example | Wind turbine hub

Topology Optimization: Used element sets

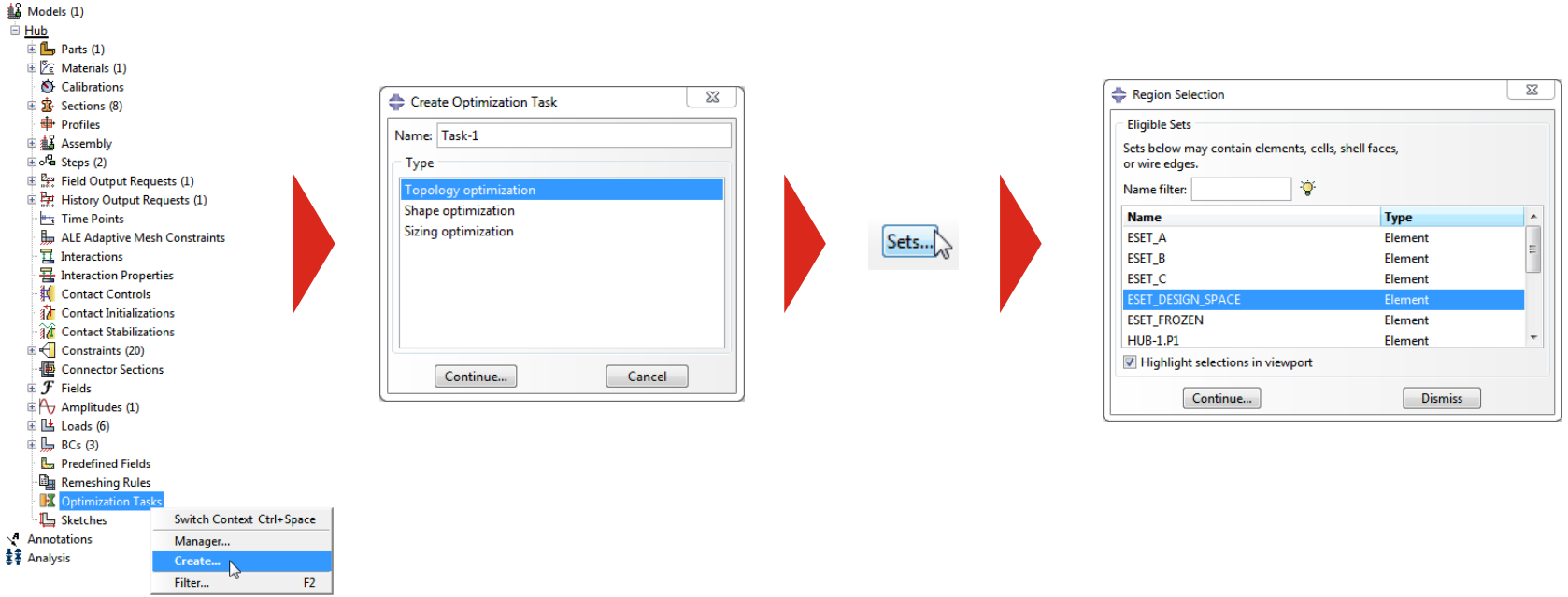


Design elements



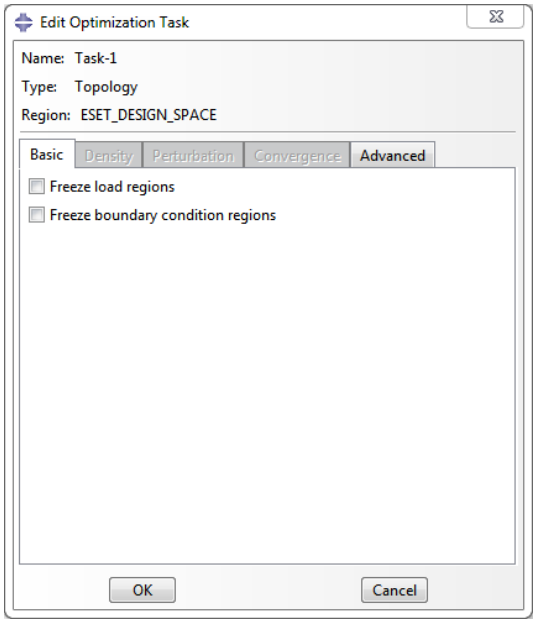
Example | Wind turbine hub

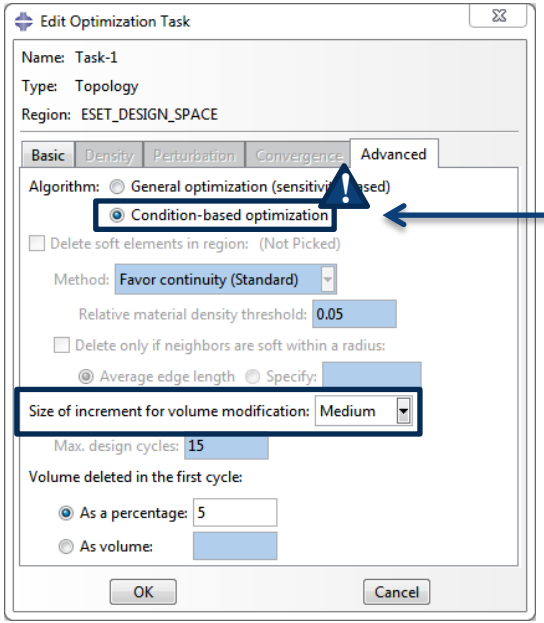
Step 1: Topology optimization task



Example | Wind turbine hub

Step 1: Topology optimization task

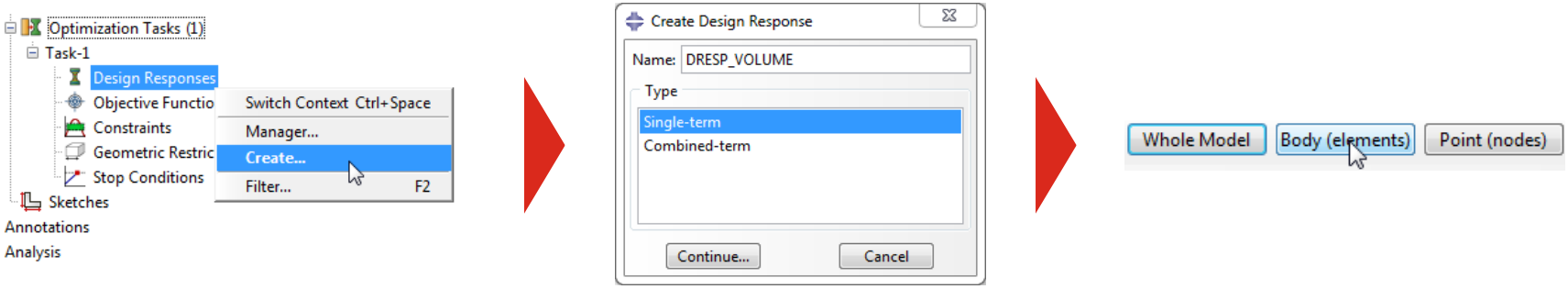




In this example the condition-based or controller-based strategy is used!

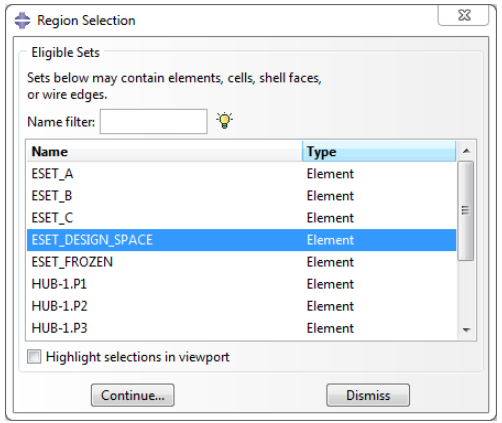
Example | Wind turbine hub

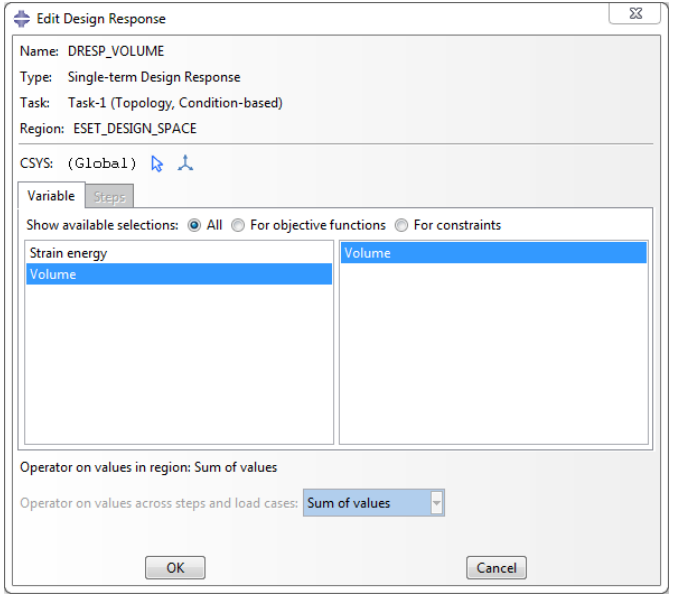
Step 2: Design response for volume



Example | Wind turbine hub

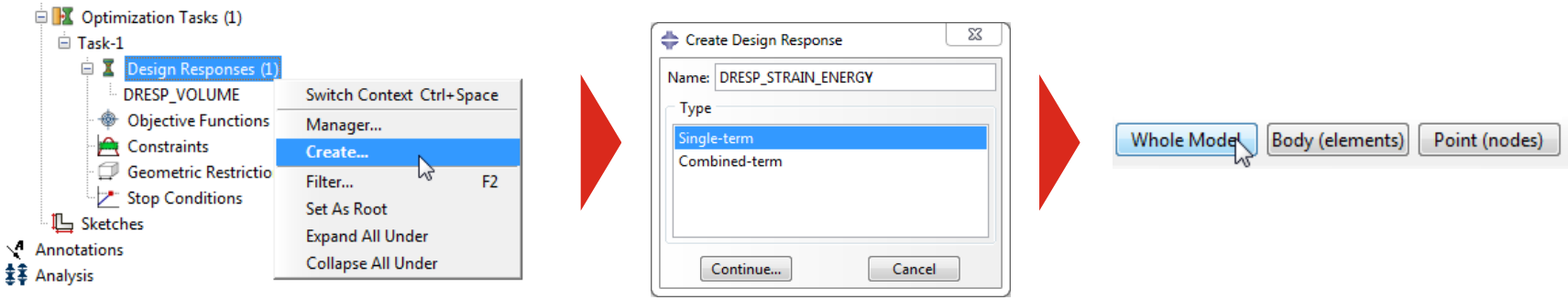
Step 2: Design response for volume





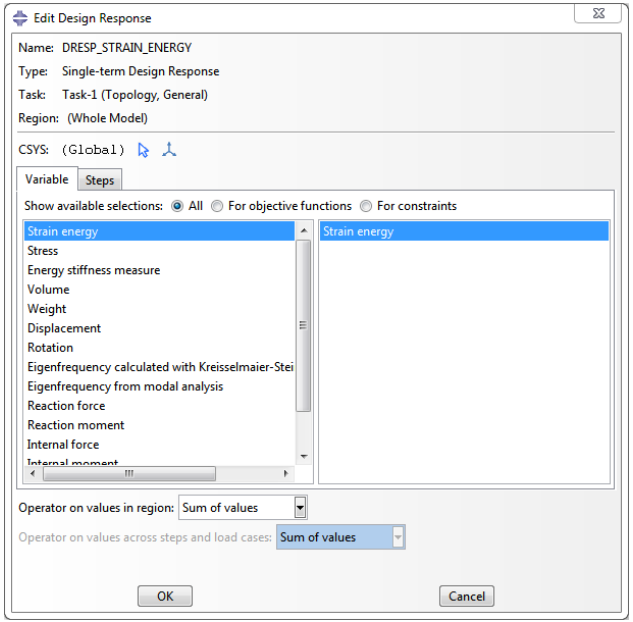
Example | Wind turbine hub

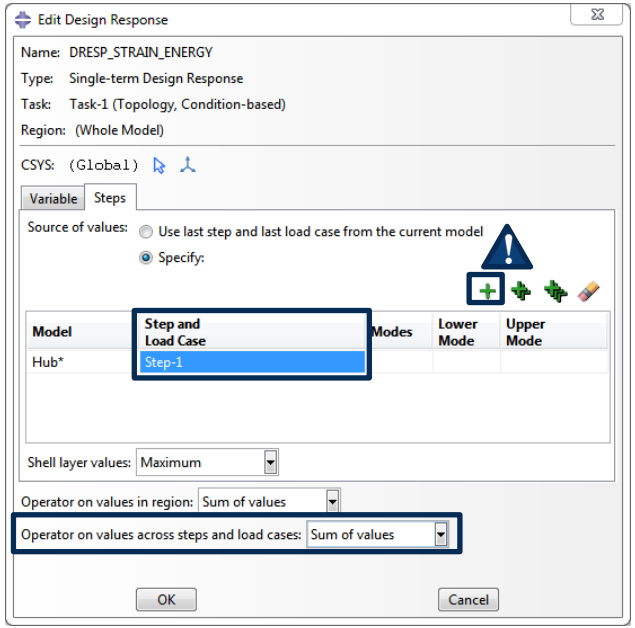
Step 3: Design response for total strain-energy



Example | Wind turbine hub

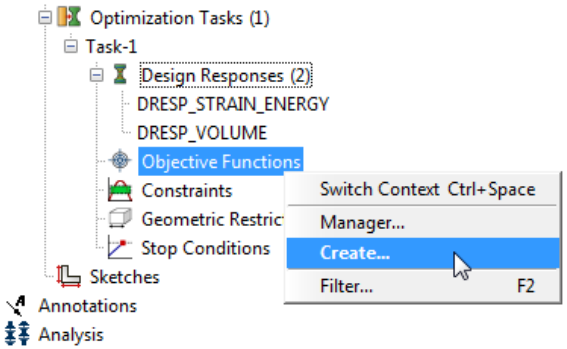
Step 3: Design response for total strain-energy

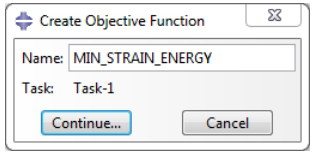


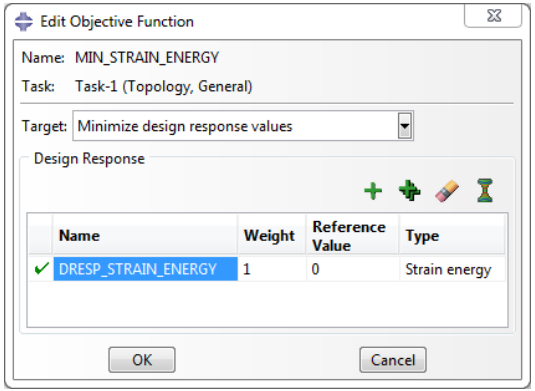


Example | Wind turbine hub

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

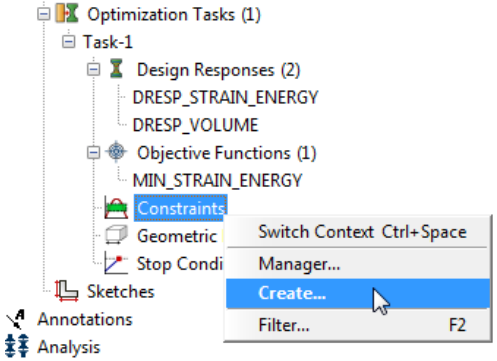


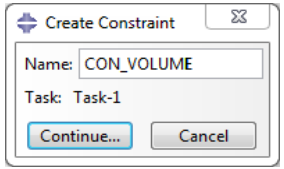


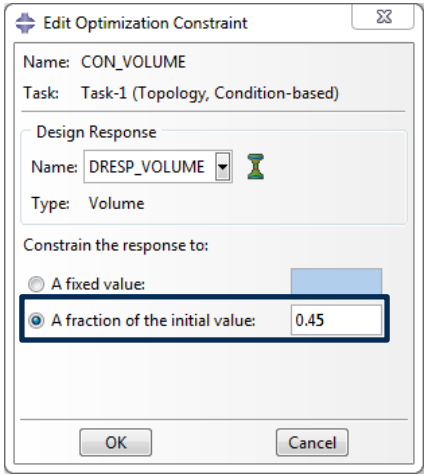


Example | Wind turbine hub

Step 5: Volume constraint

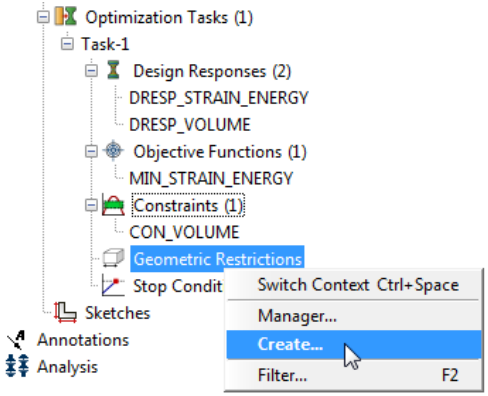


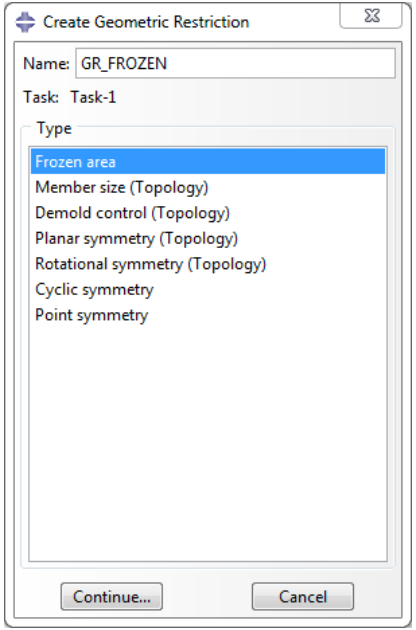


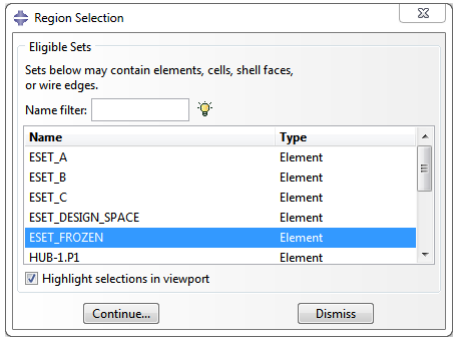


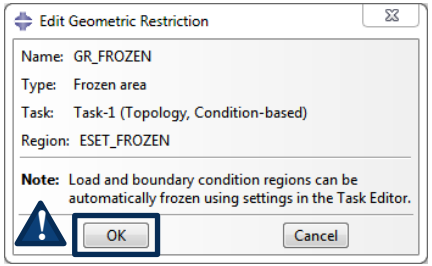
Example | Wind turbine hub

Step 6: Geometric restriction for frozen elements



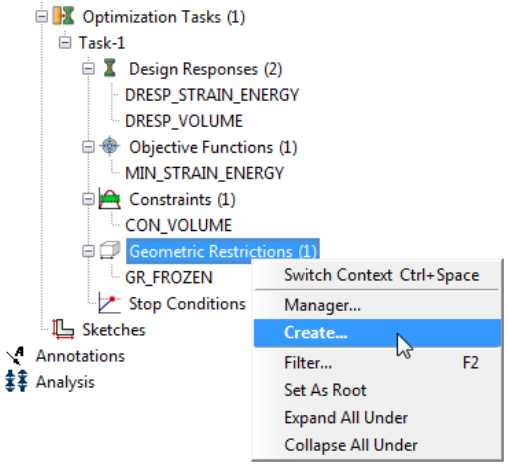


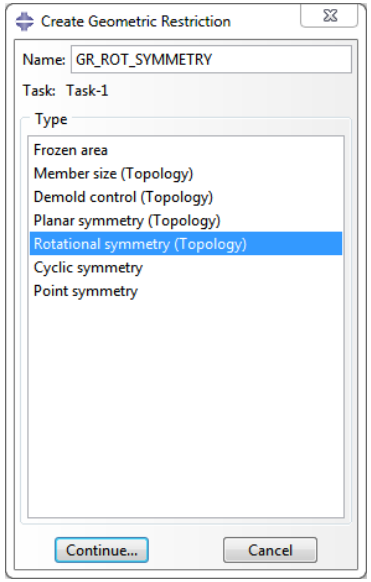


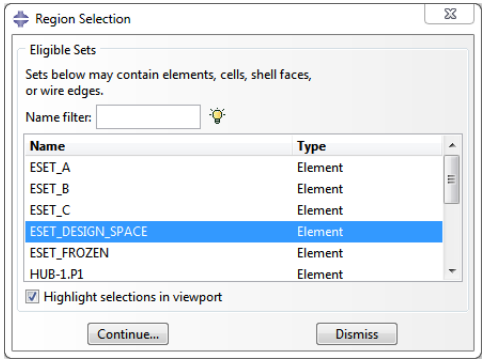


Example | Wind turbine hub

Step 7: Geometric restriction for rotational symmetry

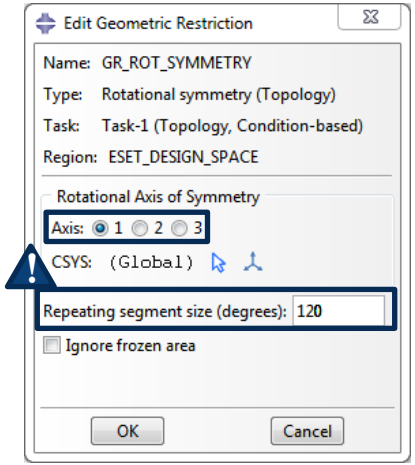


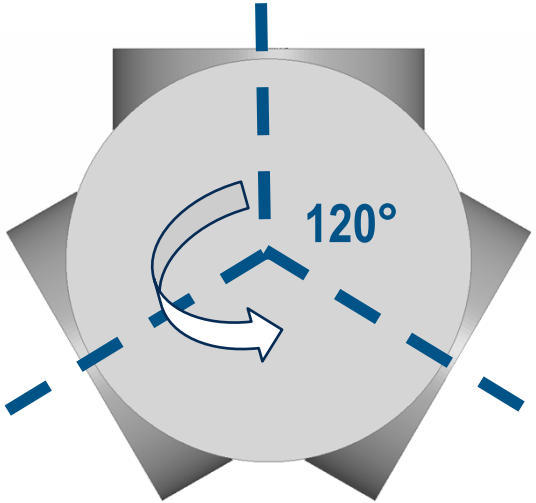




Example | Wind turbine hub

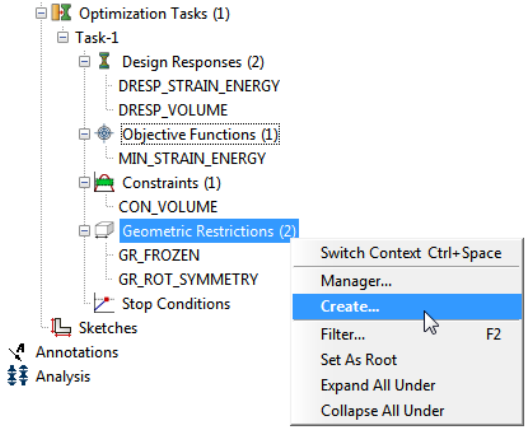
Step 7: Geometric restriction for rotational symmetry

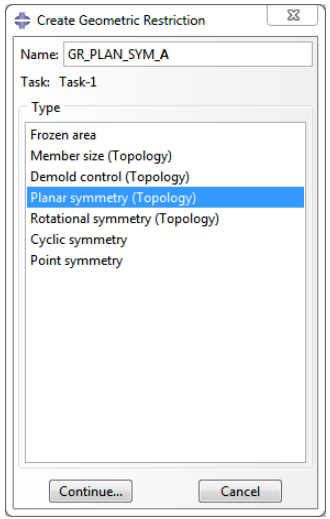


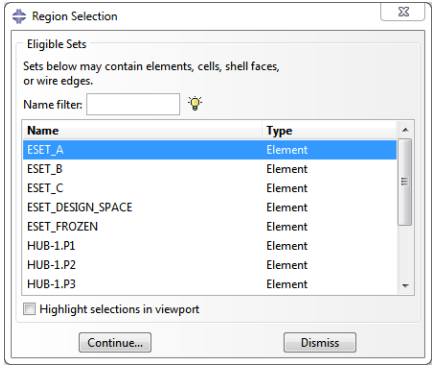


Example | Wind turbine hub

Step 8: Geometric restriction for planar symmetry (region A)

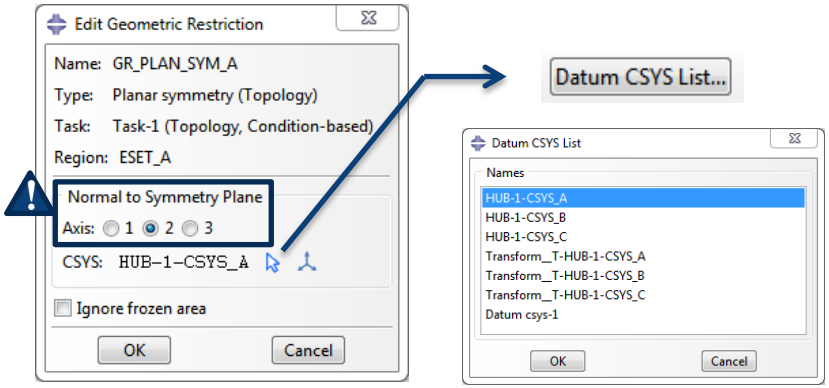


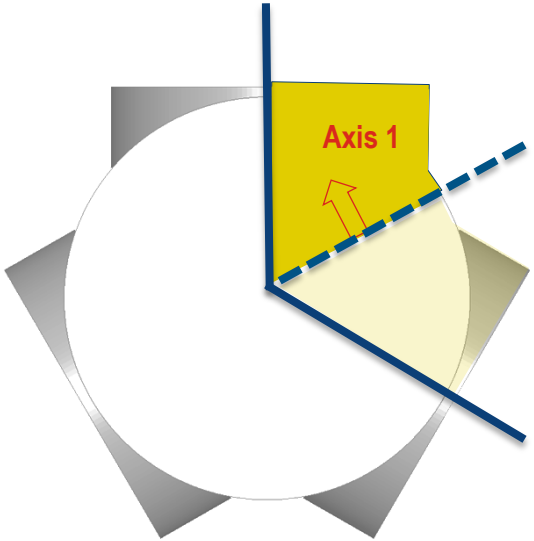




Example | Wind turbine hub

Step 8: Geometric restriction for planar symmetry (region A)

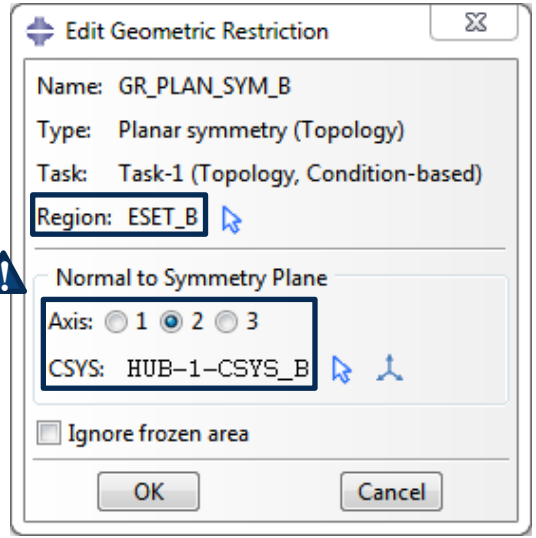


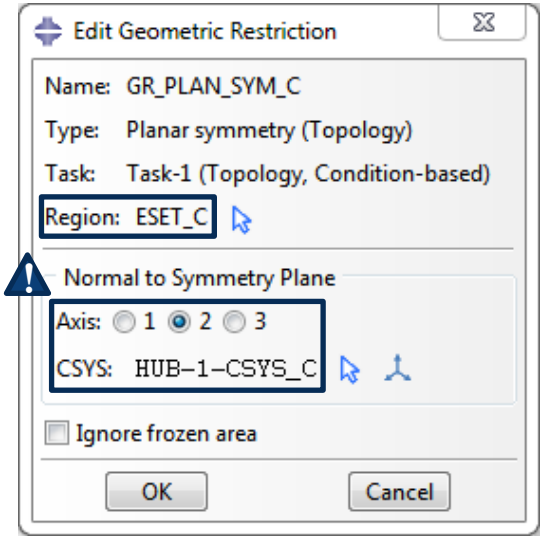


Example | Wind turbine hub

Step 8: Geometric restriction for planar symmetry (region B & C)

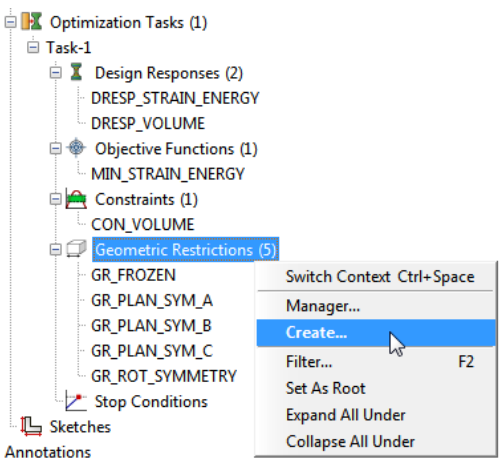
Repeat for region B and region C

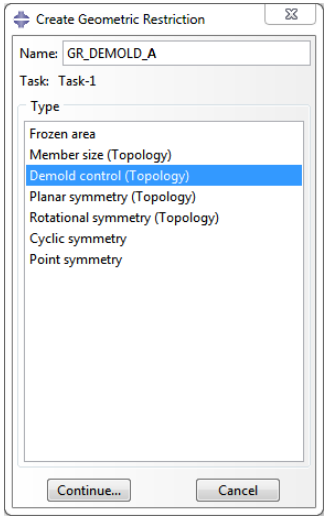


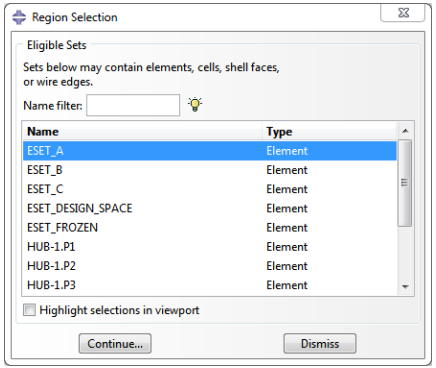


Example | Wind turbine hub

Step 9: Geometric restriction for demold-able design (region A)

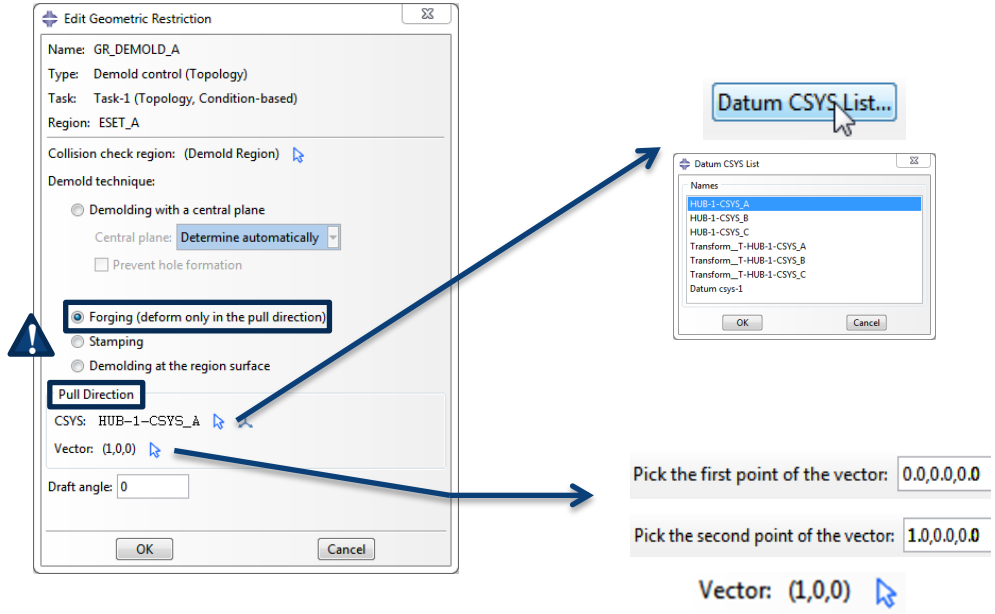


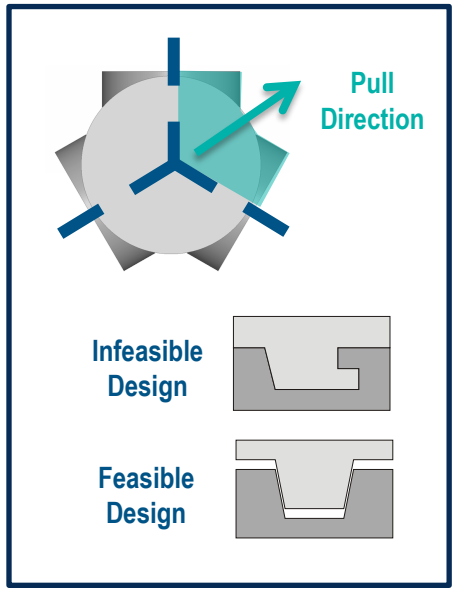




Example | Wind turbine hub

Step 9: Geometric restriction for demold-able design (region A)

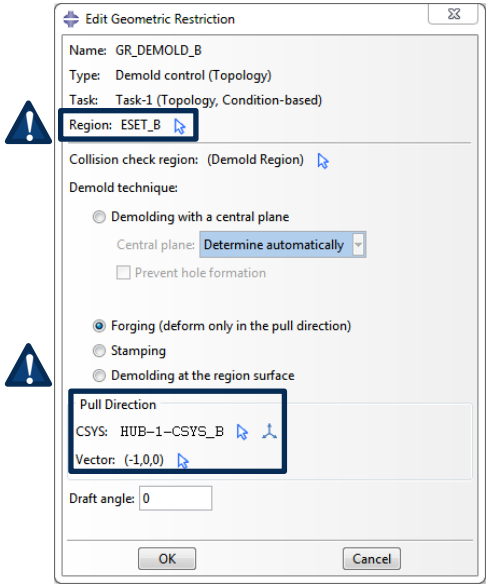


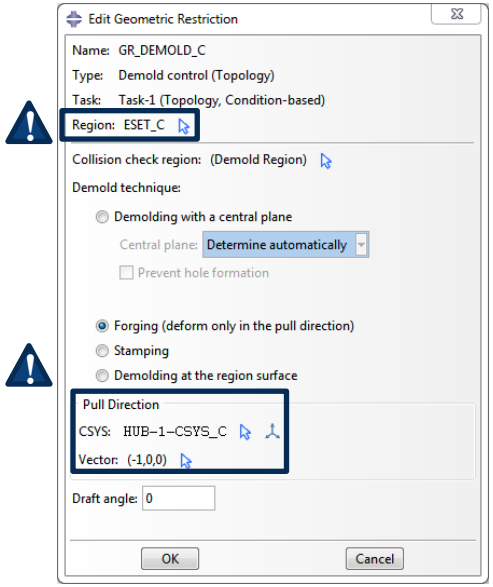


Example | Wind turbine hub

Step 9: Geometric restriction for demold-able design (region B & C)

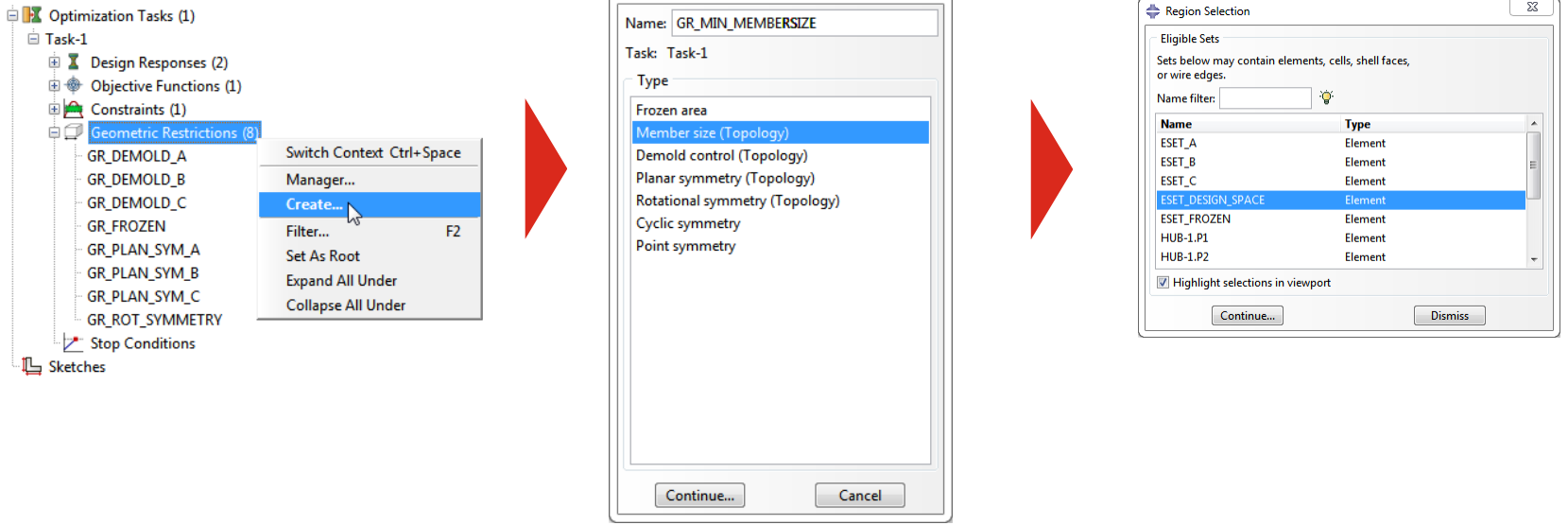
Repeat for region B and region C





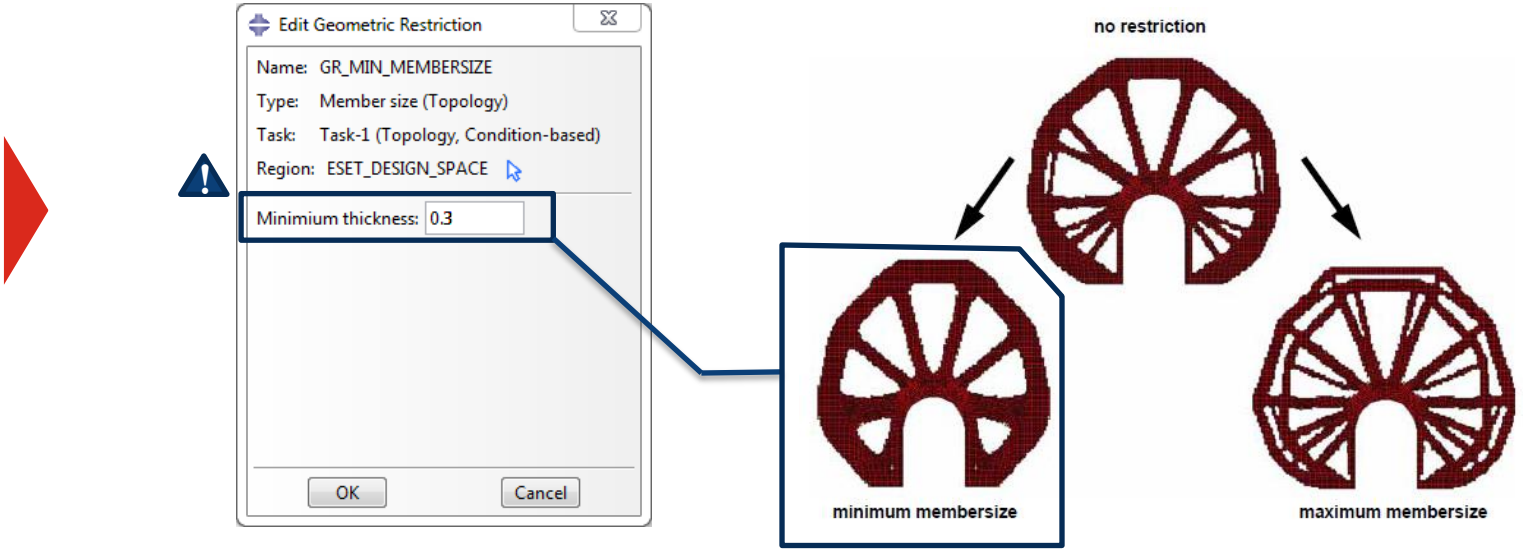
Example | Wind turbine hub

Step 10: Geometric restriction for minimal member size



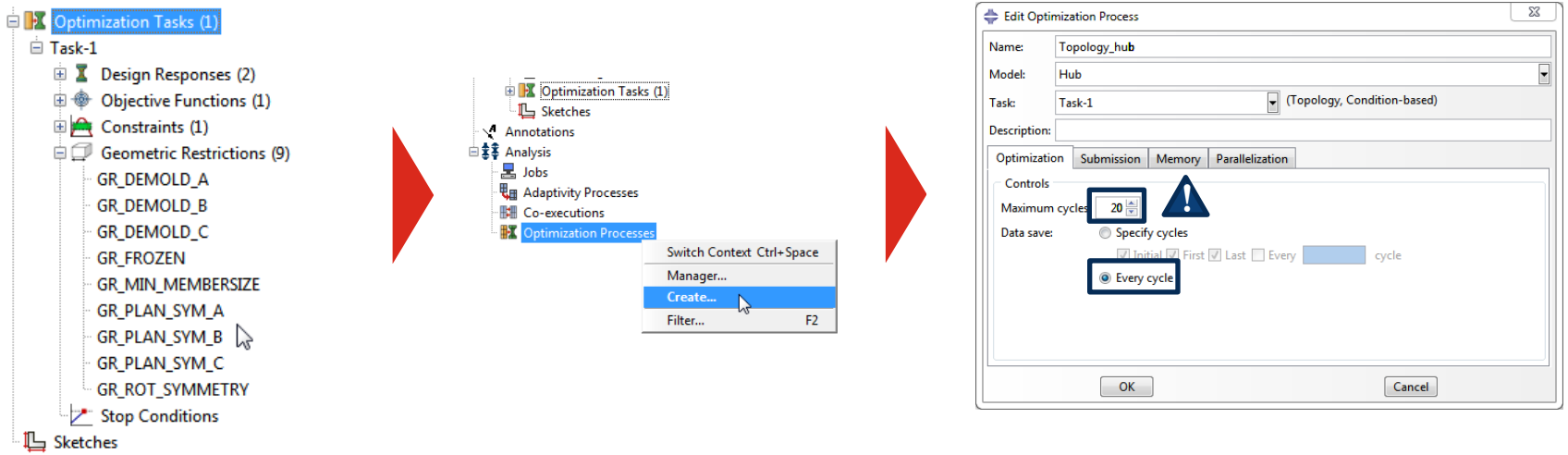
Example | Wind turbine hub

Step 10: Geometric restriction for minimal member size



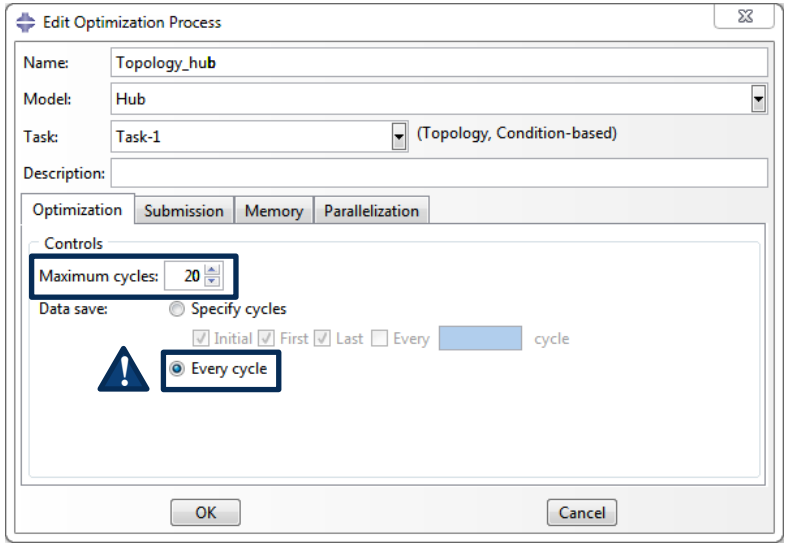
Example | Wind turbine hub

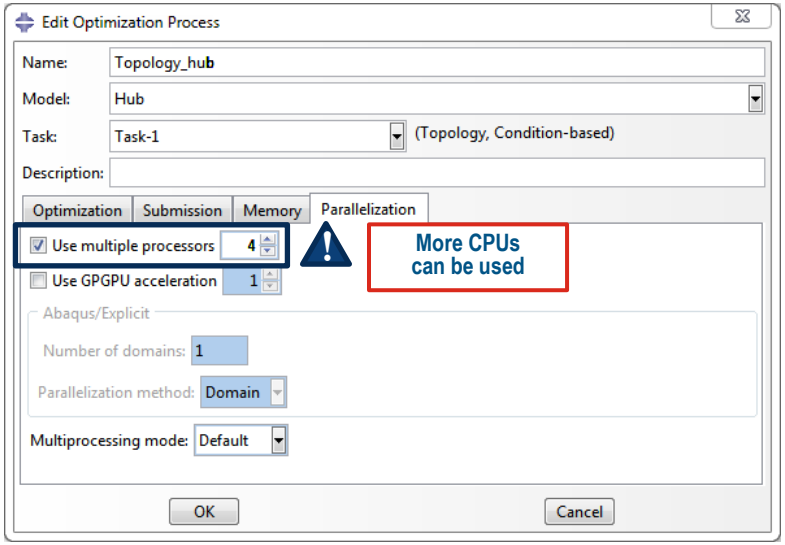
Step 11: Submission of the optimization task



Example | Wind turbine hub

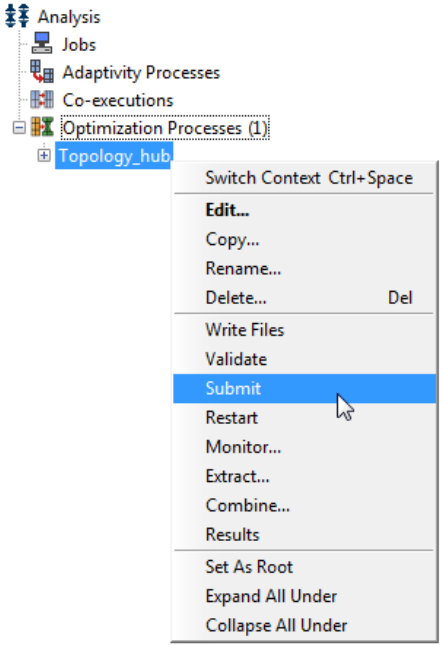
Step 11: Submission of the optimization task

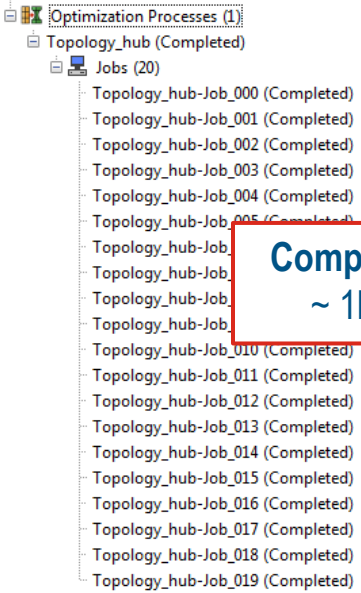




Example | Wind turbine hub

Step 11: Submission of the optimization task

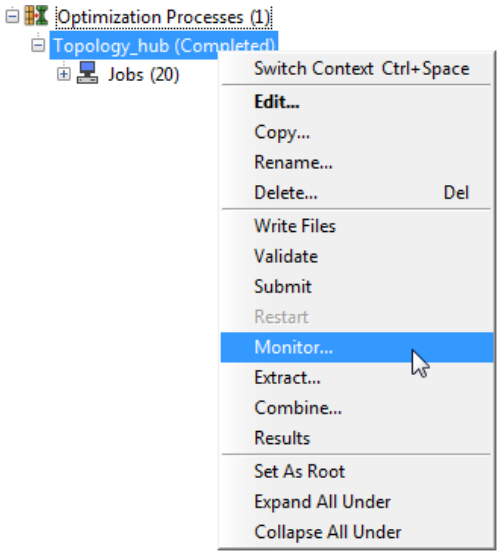


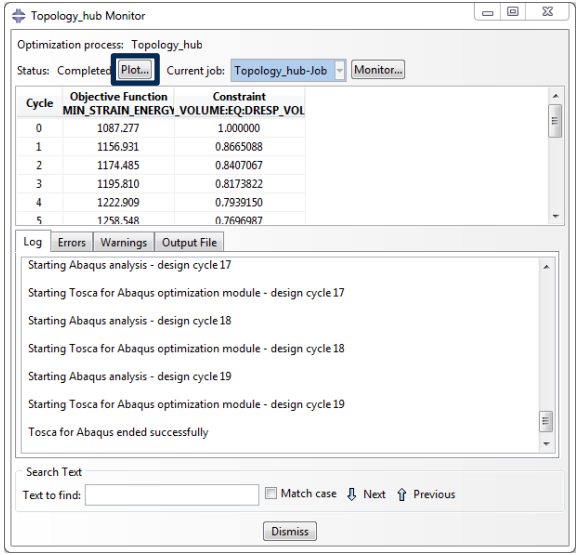


Computational time:
~ 1h with 4 CPUs

Example | Wind turbine hub

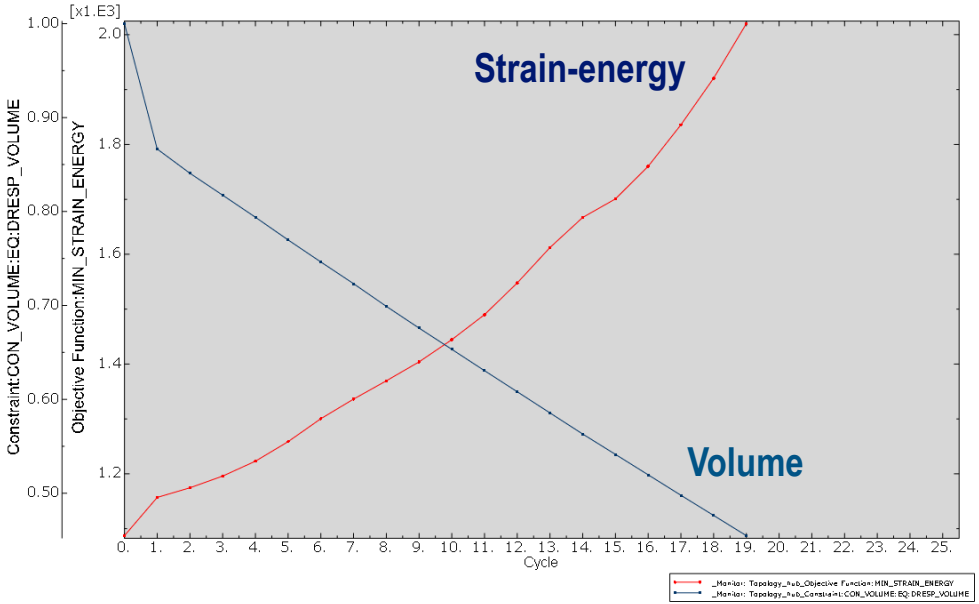
Step 11: Submission of the optimization task





Example | Wind turbine hub

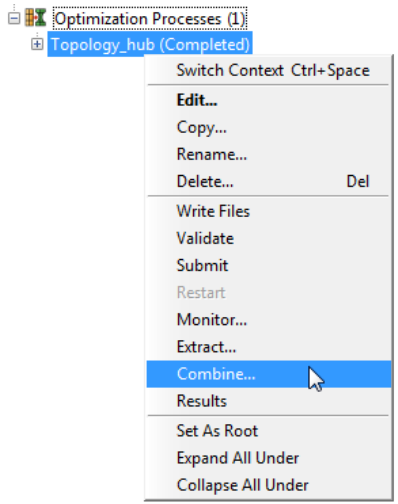
Step 11: Submission of the optimization task

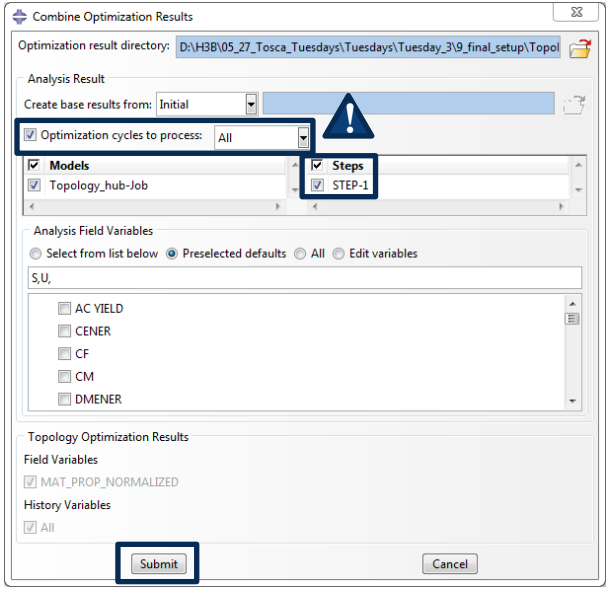


Modify axis display options (font, size, color) by double-clicking

Example | Wind turbine hub

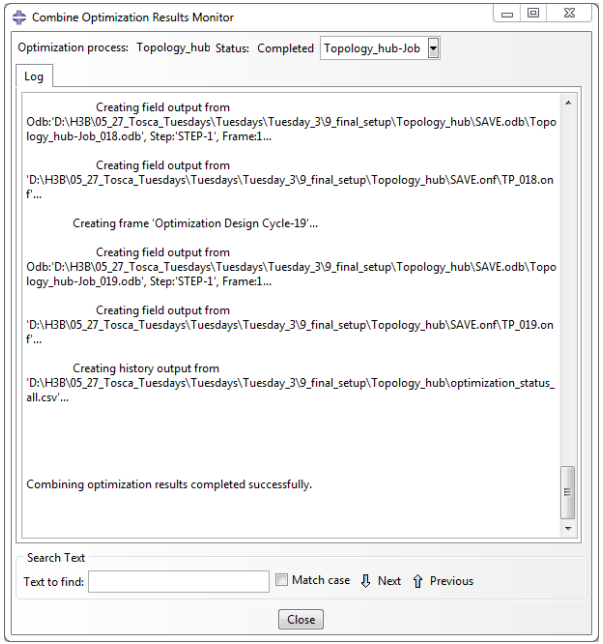
Step 12: Visualization (⚠ Optimization has to be completed)

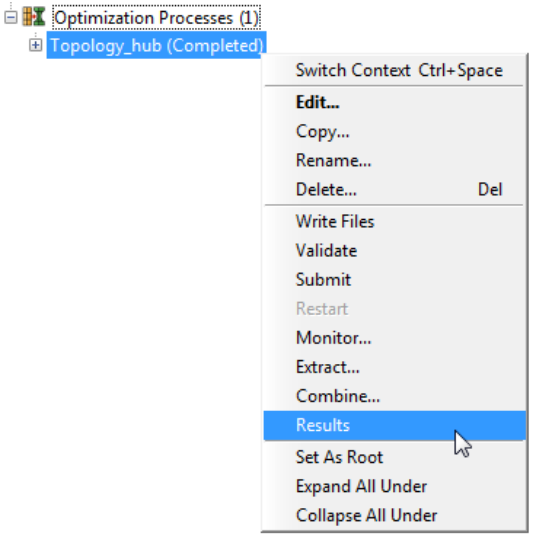




Example | Wind turbine hub

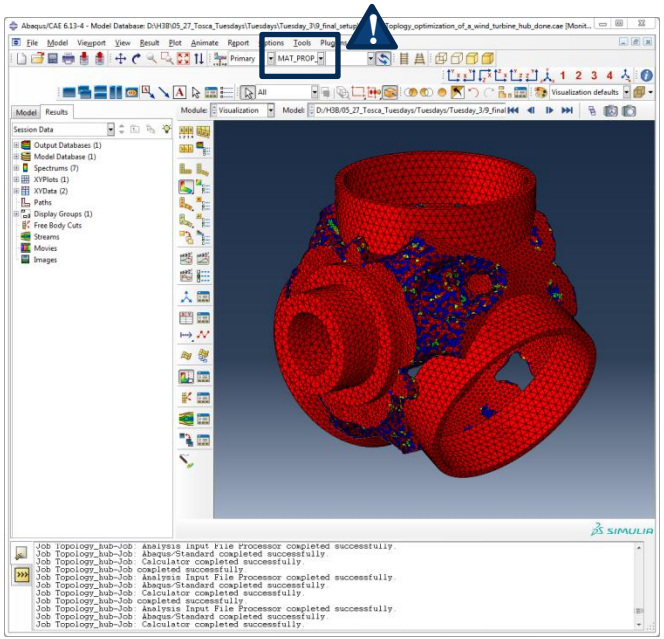
Step 12: Visualization

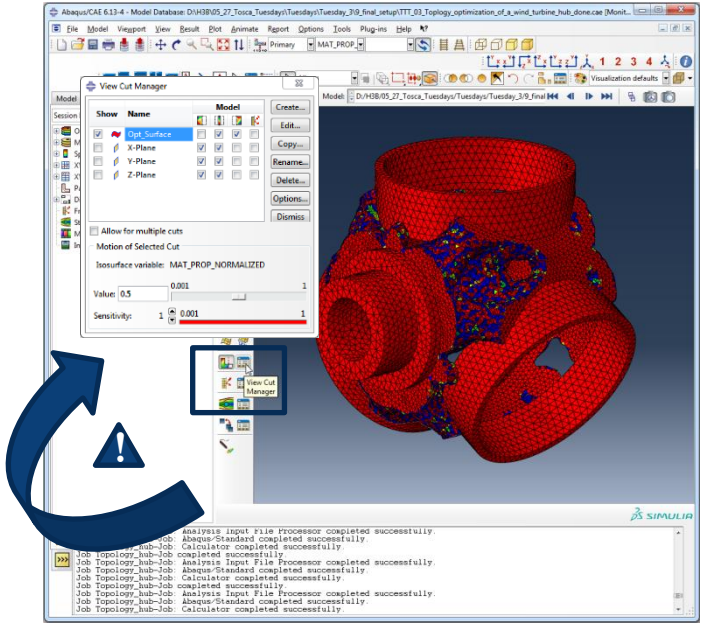




Example | Wind turbine hub

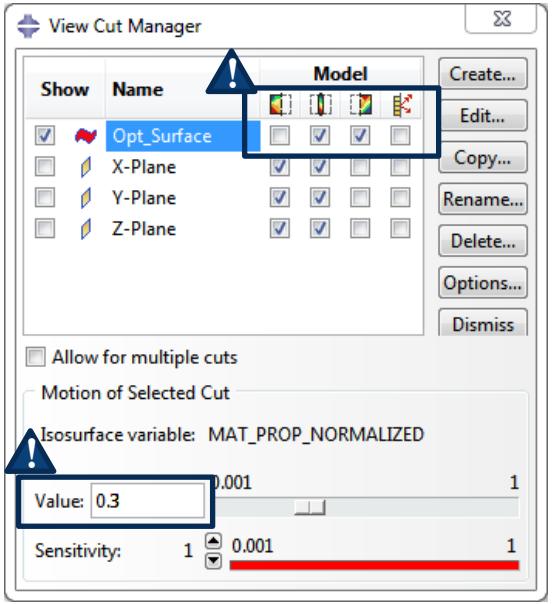
Step 12: Visualization

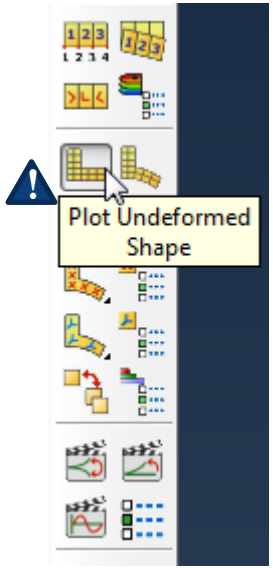




Example | Wind turbine hub

Step 12: Visualization

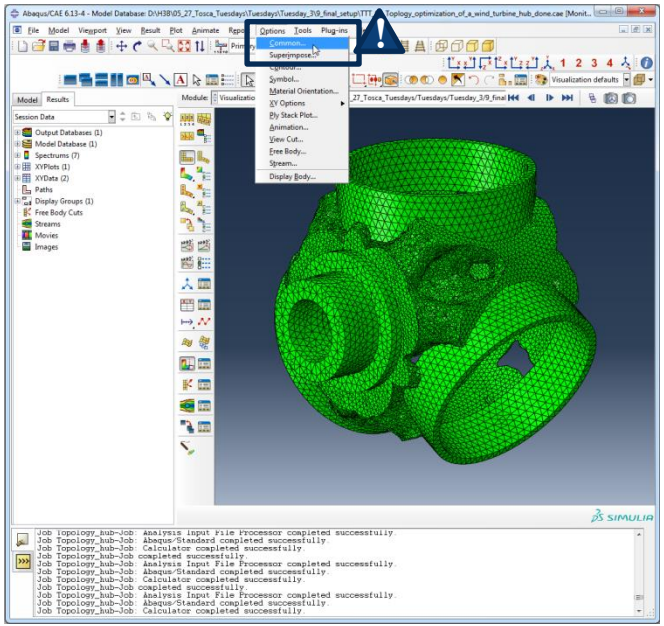


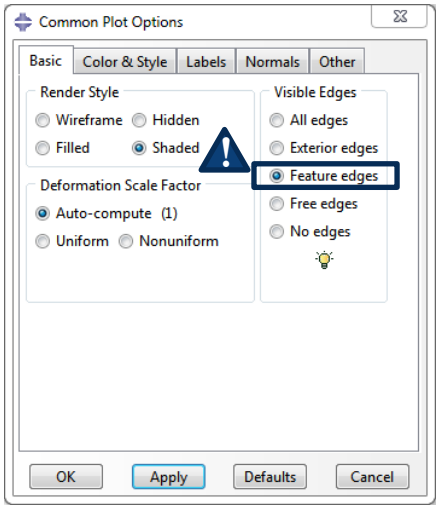


Set iso-value to 0.3

Example | Wind turbine hub

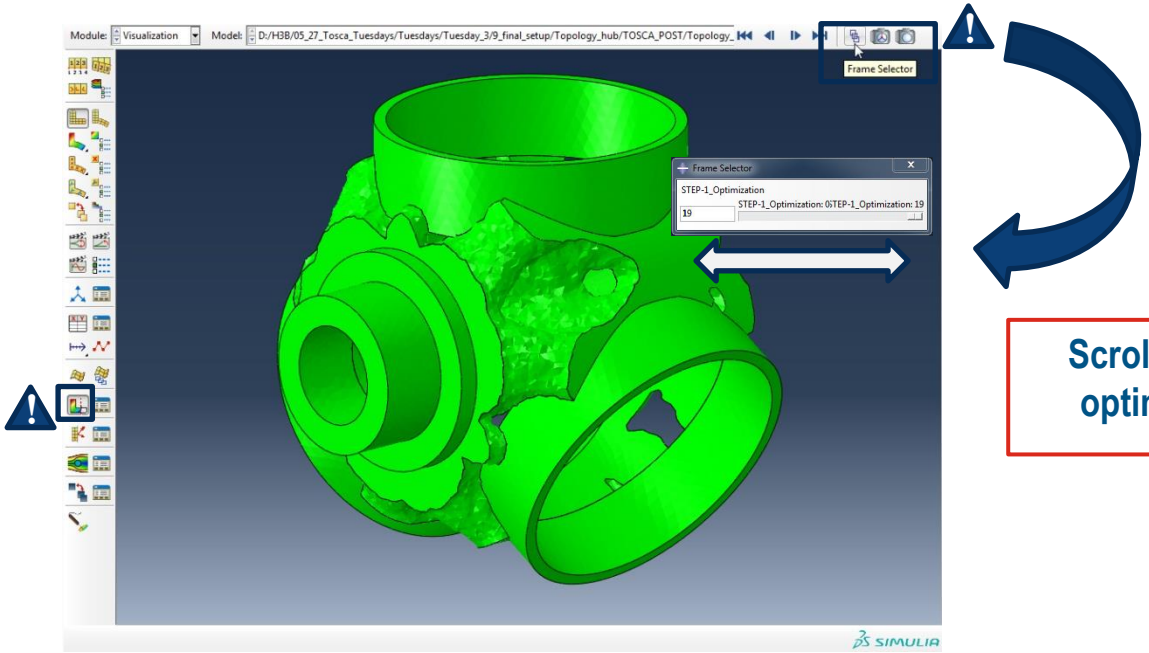
Step 12: Visualization





Example | Wind turbine hub

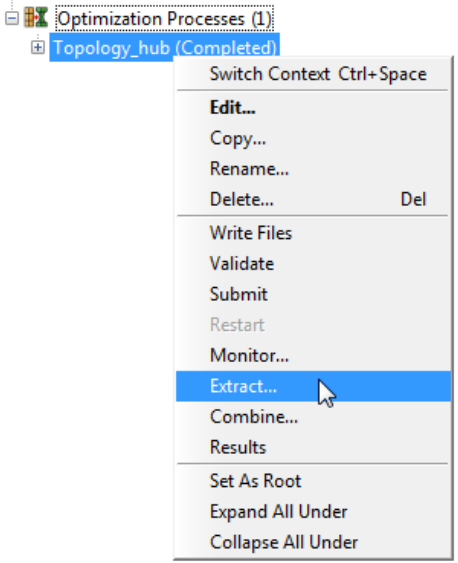
Step 12: Visualization

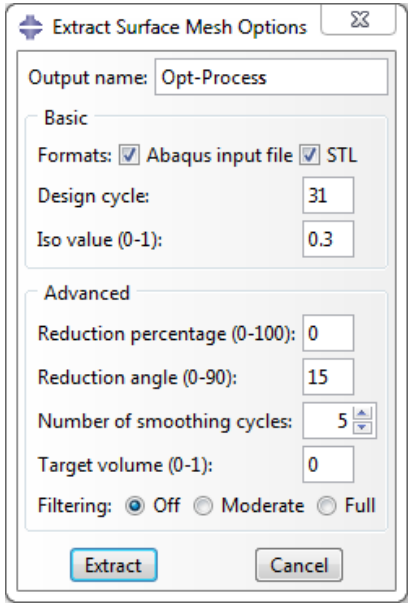


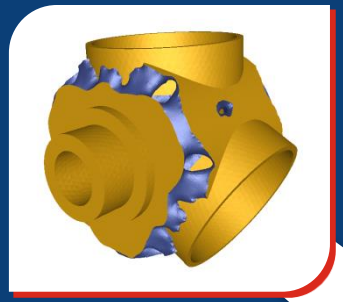
Scroll through each optimization cycle

Example | Wind turbine hub

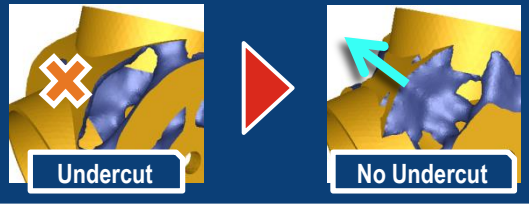
Step 13: Extract smoothed geometry



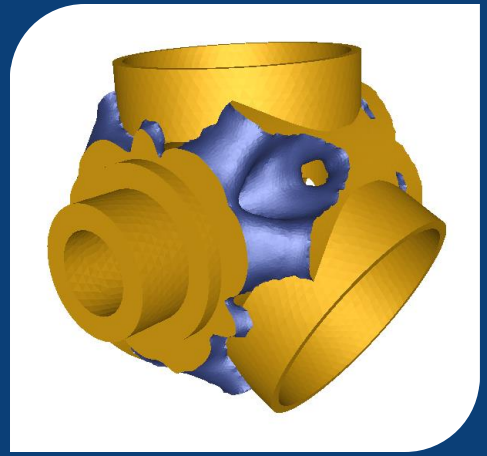


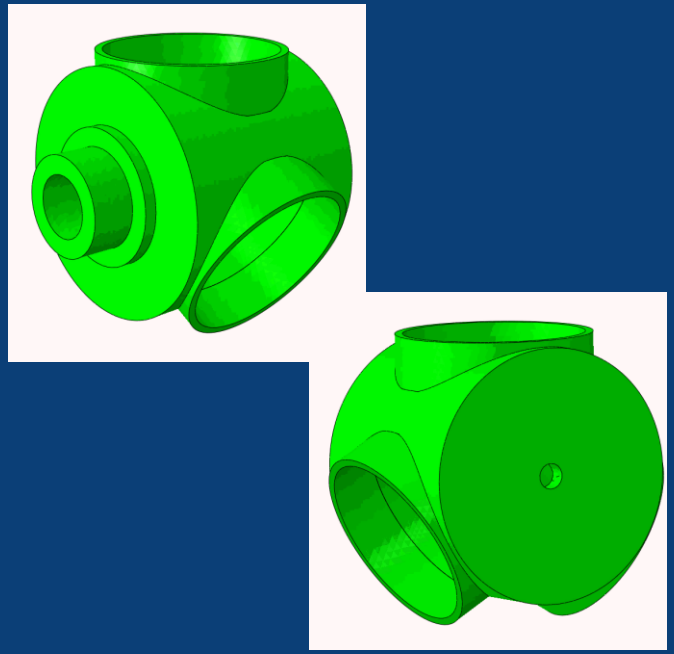


Demold/cast restriction

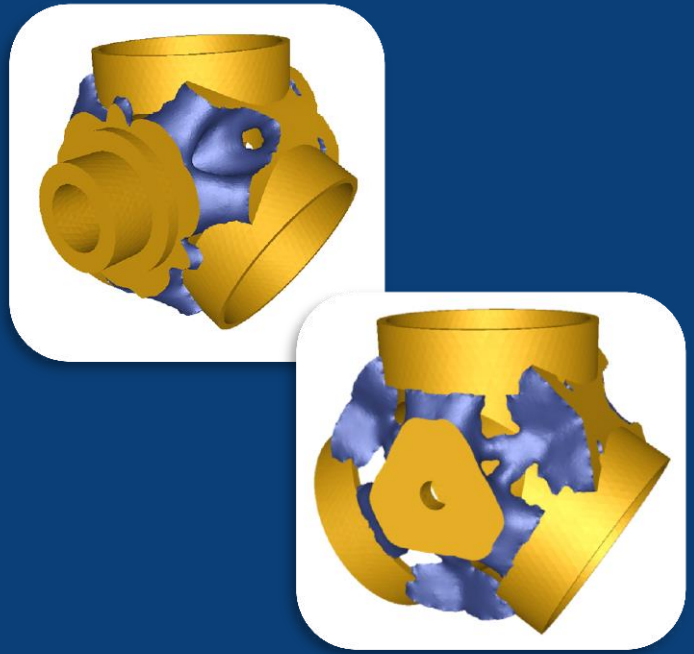


Minimum member size





Topology Optimization



Smoothed Results