



**3DEXPERIENCE®**

# The Tosca Tuesdays

# Tosca Tuesday #1

**Basics:** Structural optimization

**Basics:** Topology optimization

**Example:** Topology optimization of a crane hook



# Basics | Structural optimization

## Terminology (1)

- **Design variables** are used within a structural optimization to modify a structure and its geometry.
  - e.g. radius of a hole, position of a surface node, density of an element ...
- The **design area** is the region of the structure that is modified during a structural optimization.
- A **design response** is a system response and serves as an objective function or as a constraint.
  - e.g. volume, weight, stress, strain, damage, displacement, strain-energy (compliance) ...

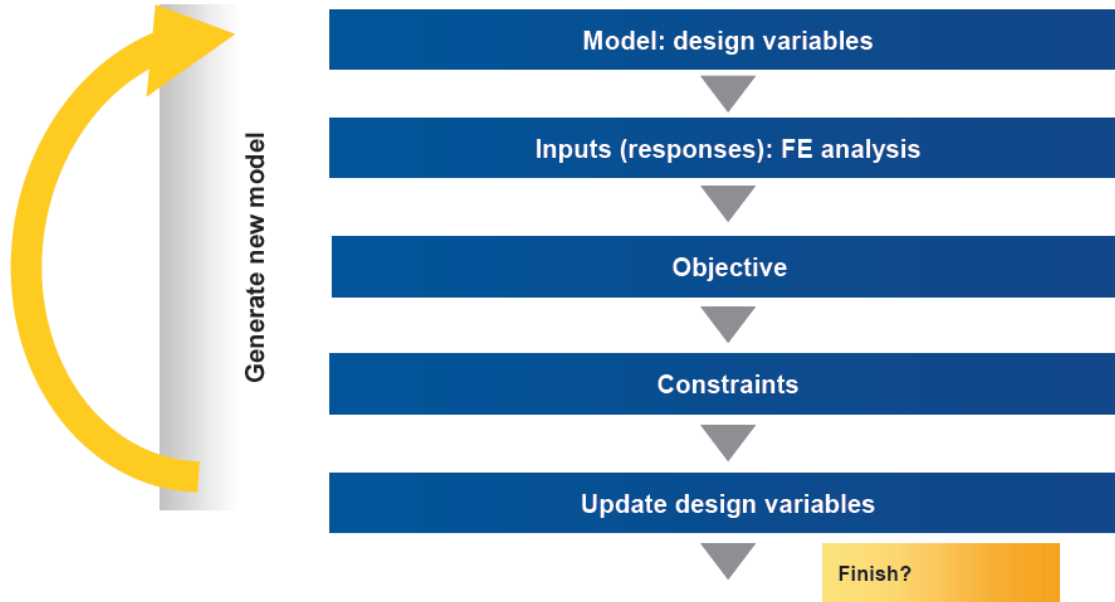
# Basics | Structural optimization

## Terminology (2)

- The **objective function** is a design response that is to be maximized or minimized.
  - It can be a single term design response or combinations of design responses.
  - e.g. minimize volume, maximize eigenfrequencies, minimize stress ...
- **Constraints** are design limitations on structural responses from a FE analysis.
  - e.g. displacement of a certain FE-node should not exceed a certain limit ...
- **Geometric restrictions** are geometrical manufacturing requirements.
  - e.g. symmetry constraints, demold constraints, minimum/maximum member size ...

# Basics | Structural optimization

## General process



# Tosca Tuesday #1

**Basics:** Structural optimization

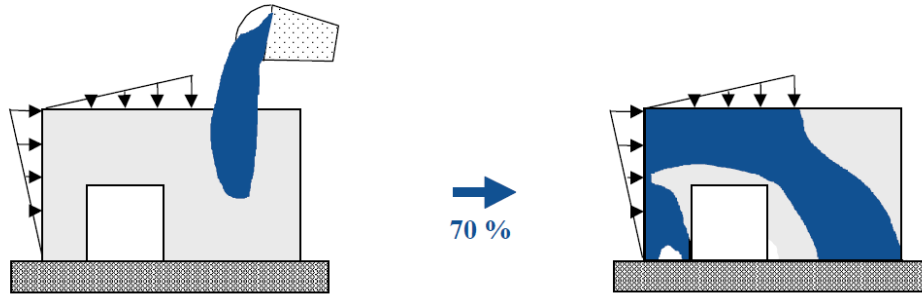
**Basics:** Topology optimization

**Example:** Topology optimization of a crane hook

# 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
  - ...



# Tosca Tuesday #1

**Basics:** Structural optimization

**Basics:** Topology optimization

**Example:** Topology optimization of a crane hook

# Example | Crane Hook

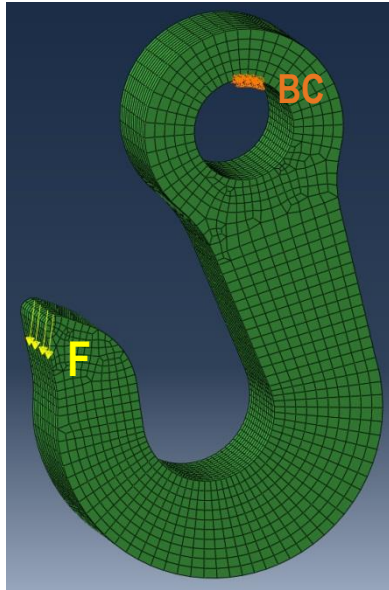
Get started ...

- ▶ Start Abaqus CAE (at least version 6.13, preferable 6.13-4)
- ▶ File → Open the file cranehook.cae
- ▶ File → Set Work Directory → Choose Directory

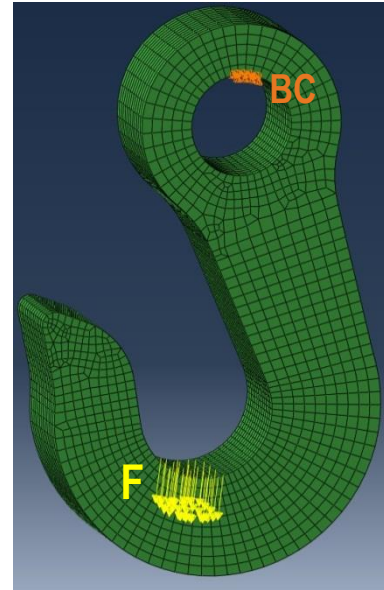


# Example | Crane Hook

**Basic model:** Loading and boundary conditions



Step 1

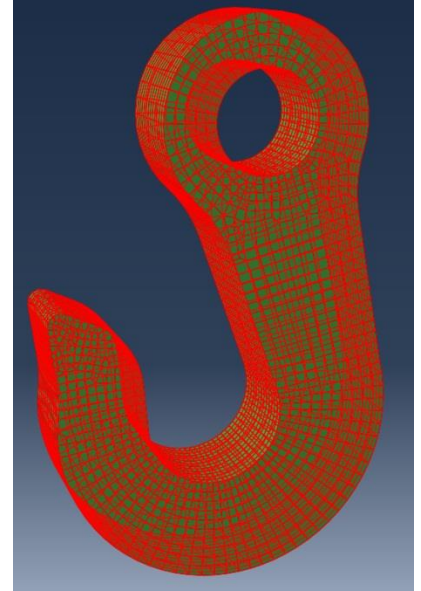


Step 2

# Example | Crane Hook

## Topology Optimization: Setup

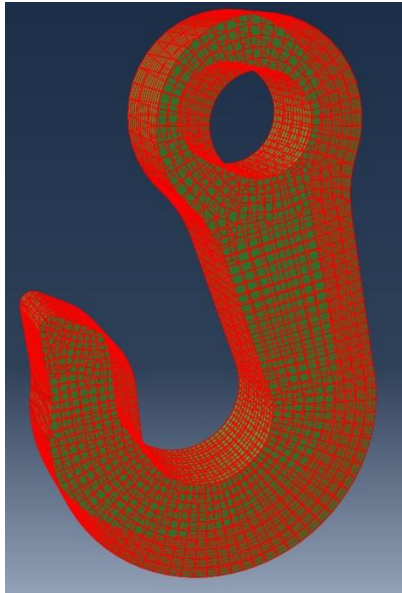
- **Objective function**
  - Minimize total strain-energy (→ maximize stiffness)
- **Constraint**
  - Volume constraint: Use less than 40% of the design space
- **Geometric restriction**
  - Demold-able design (→ manufacturing process)
  - Some frozen elements (→ element density == 100%)



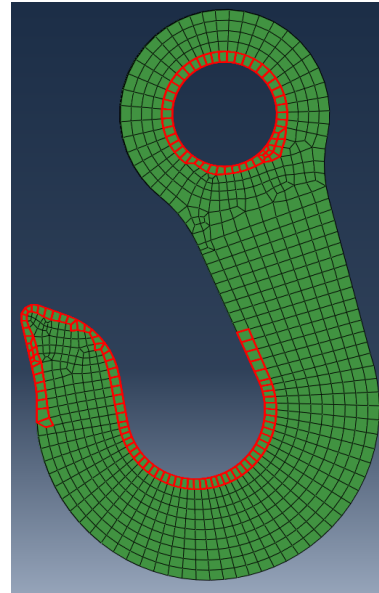
Design space

# Example | Crane Hook

Topology Optimization: Used element sets



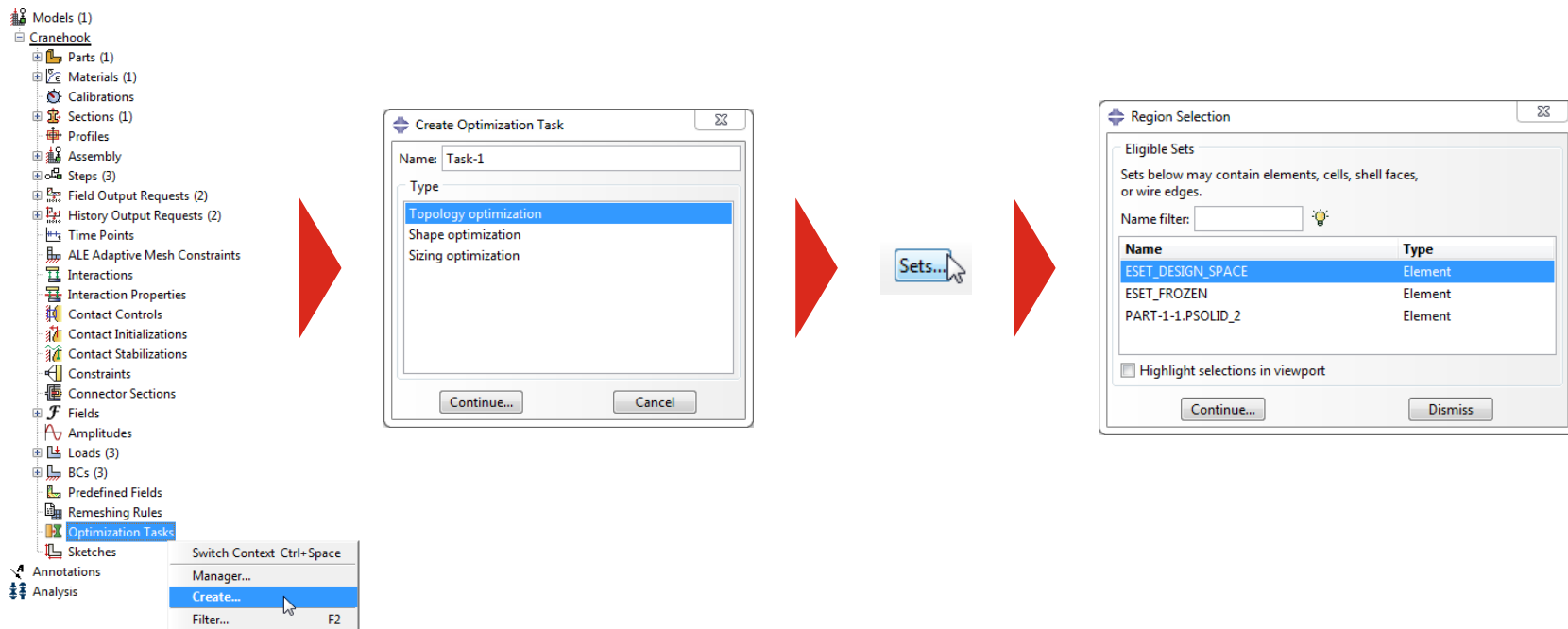
Design space



Frozen elements

# Example | Crane Hook

## Step 1: Topology optimization task



# Example | Crane Hook

## Step 1: Topology optimization task

**Edit Optimization Task**

Name: Task-1  
Type: Topology  
Region: ESET\_DESIGN\_SPACE

Basic Density Perturbation Convergence Advanced

☐ Freeze load regions  
☐ Freeze boundary condition regions

OK Cancel

**Edit Optimization Task**

Name: Task-1  
Type: Topology  
Region: ESET\_DESIGN\_SPACE

Basic Density Perturbation Convergence Advanced

Density update strategy: Normal

Initial density: ☒ Optimization product default ☐ Specify: 0.5

Minimum density: 0.001

Maximum density: 1

Maximum change per design cycle: 0.25

OK Cancel

**Edit Optimization Task**

Name: Task-1  
Type: Topology  
Region: ESET\_DESIGN\_SPACE

Basic Density Perturbation Convergence Advanced

Algorithm: ☒ General optimization (sensitivity-based) ☐ Condition-based optimization

☐ Delete soft elements in region: (Not Picked)

Method: Favor continuity (Standard)

Relative material density threshold: 0.05

☐ Delete only if neighbors are soft within a radius:  
☒ Average edge length ☐ Specify:

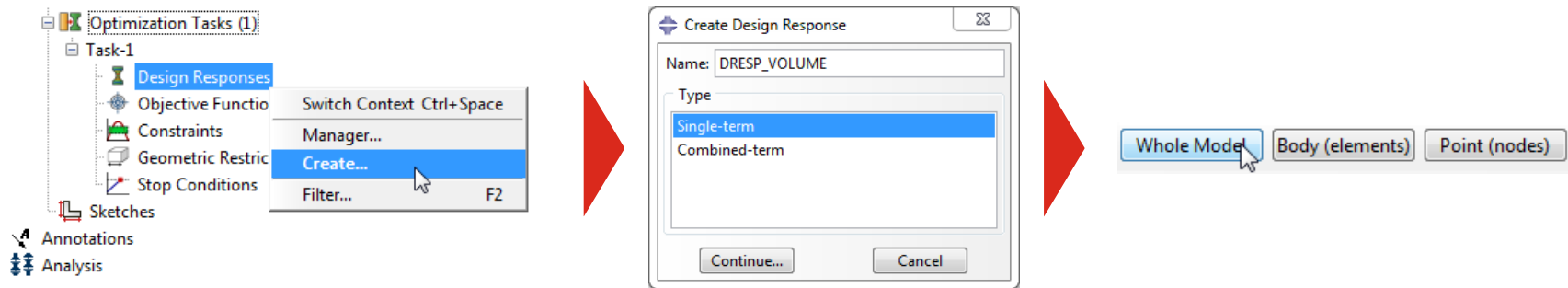
Material interpolation technique:  
☒ Optimization product default ☐ SIMP ☐ RAMP

Penalty factor: 3

OK Cancel

# Example | Crane Hook

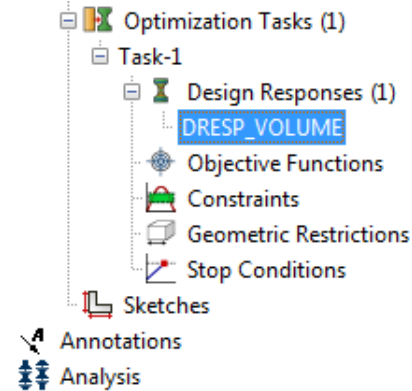
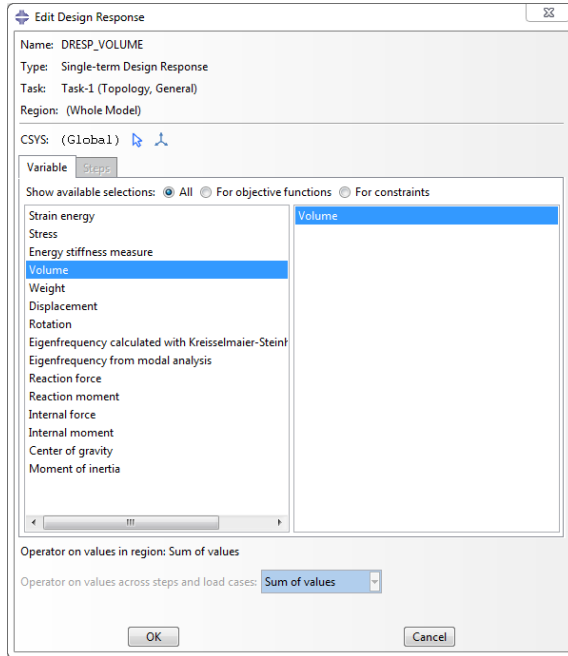
## Step 2: Design response for volume





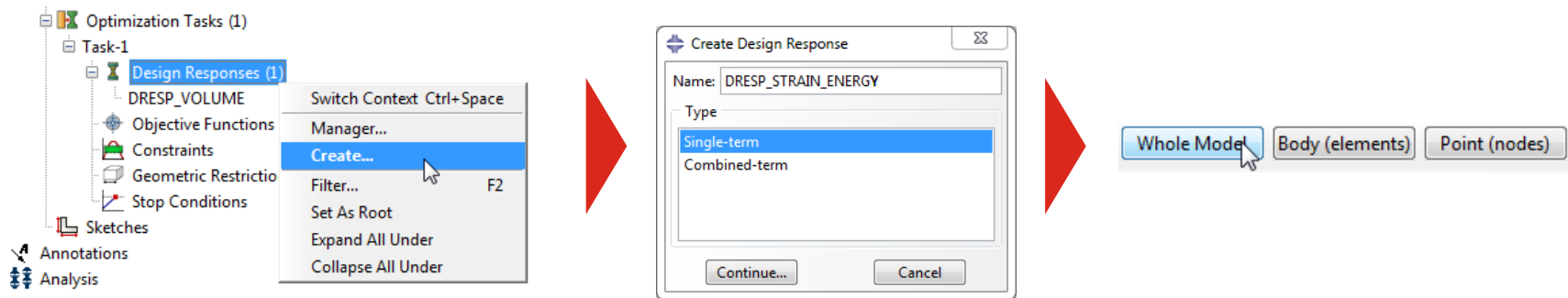
# Example | Crane Hook

## Step 2: Design response for volume



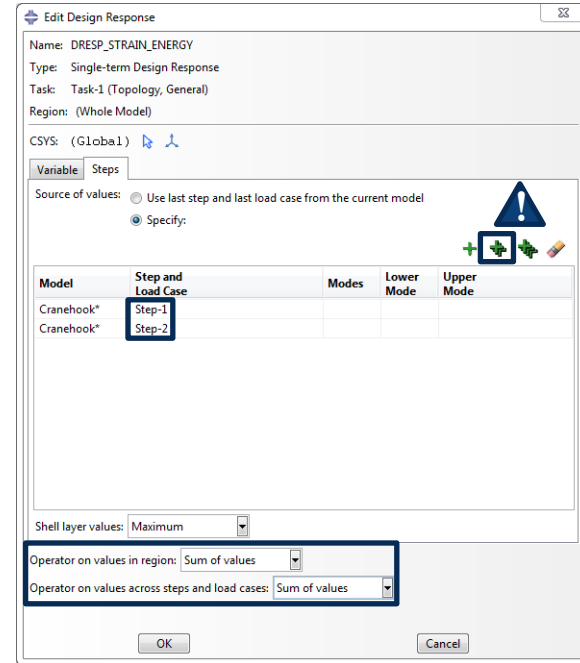
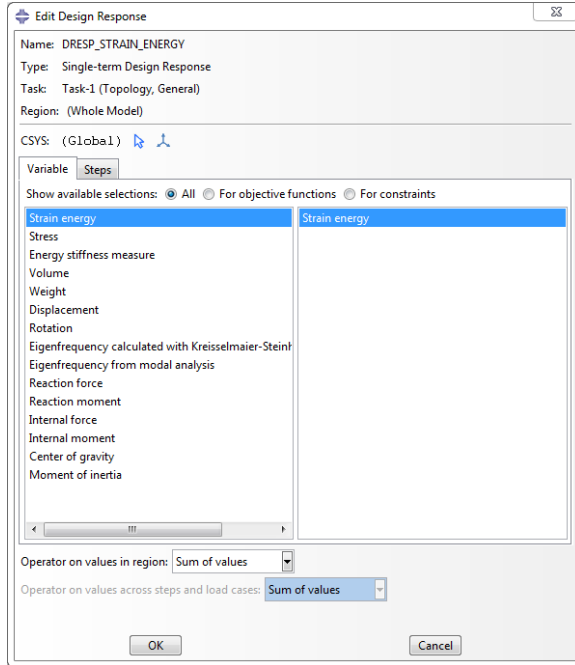
# Example | Crane Hook

## Step 3: Design response for total strain-energy



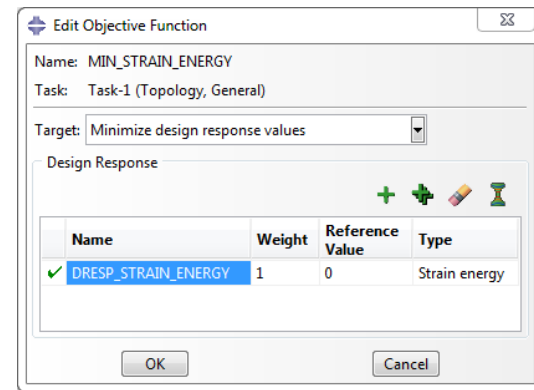
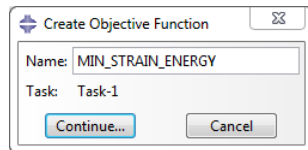
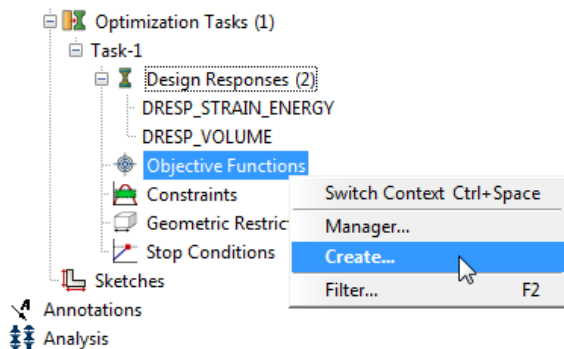
# Example | Crane Hook

## Step 3: Design response for total strain-energy



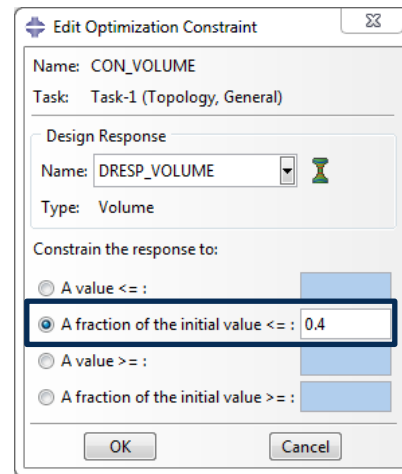
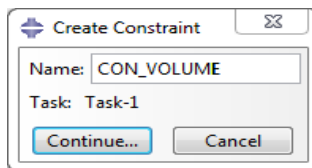
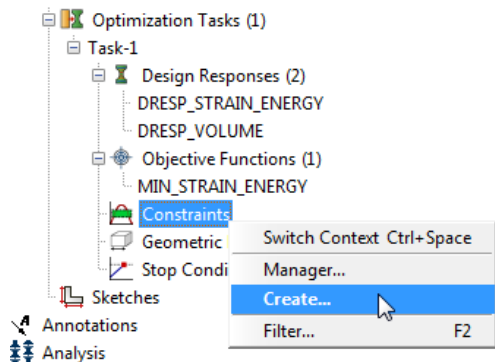
# Example | Crane Hook

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



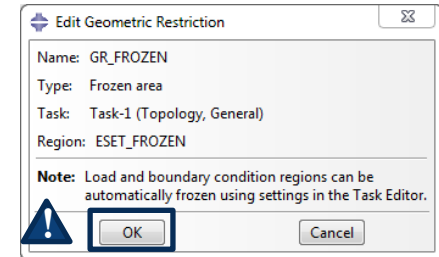
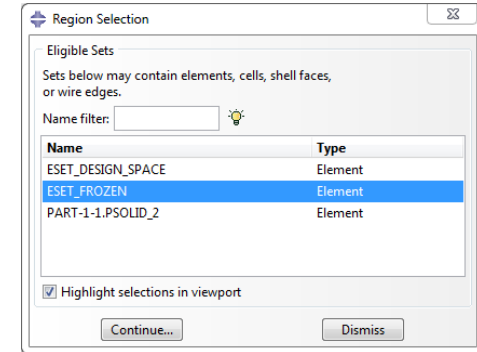
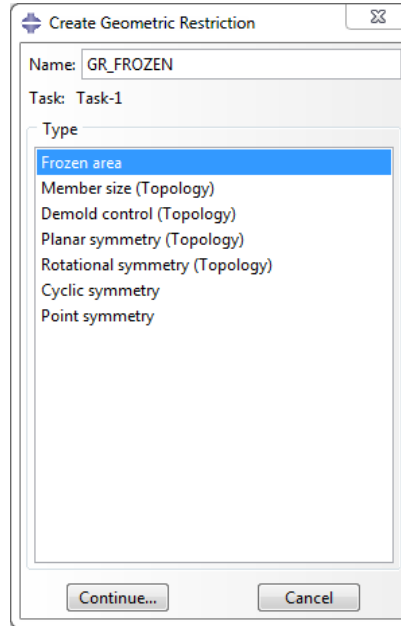
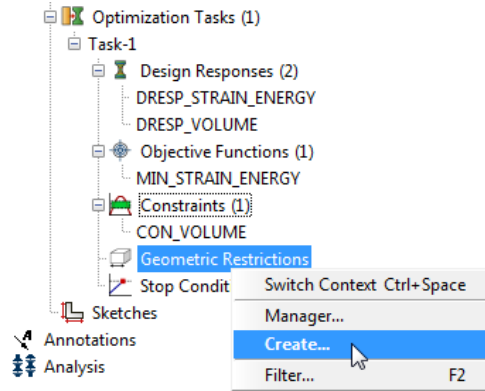
# Example | Crane Hook

## Step 5: Volume constraint



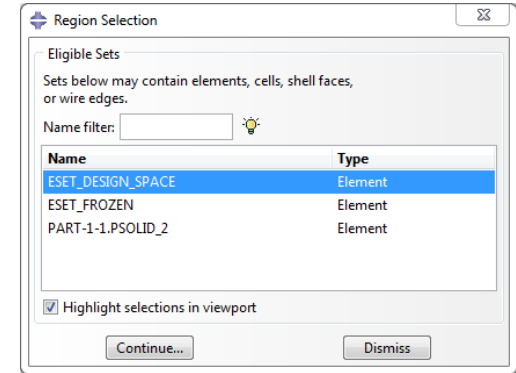
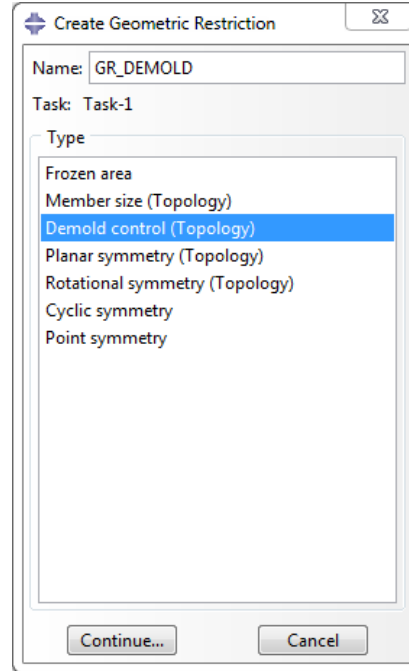
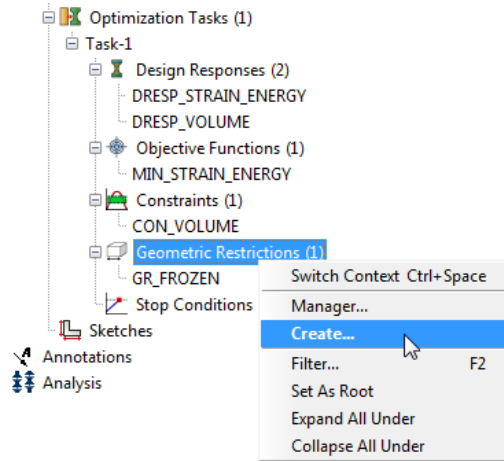
# Example | Crane Hook

## Step 6: Geometric restriction for frozen elements



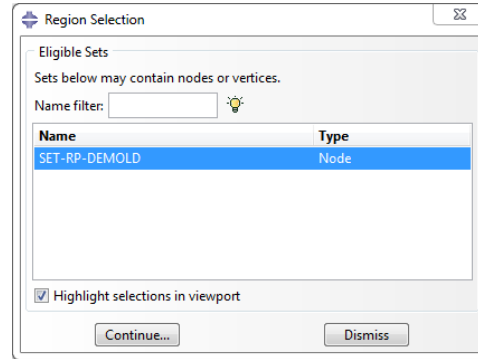
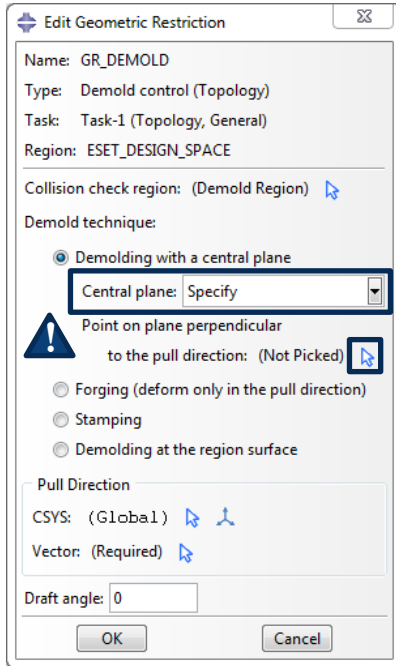
# Example | Crane Hook

## Step 7: Geometric restriction for demold-able design



# Example | Crane Hook

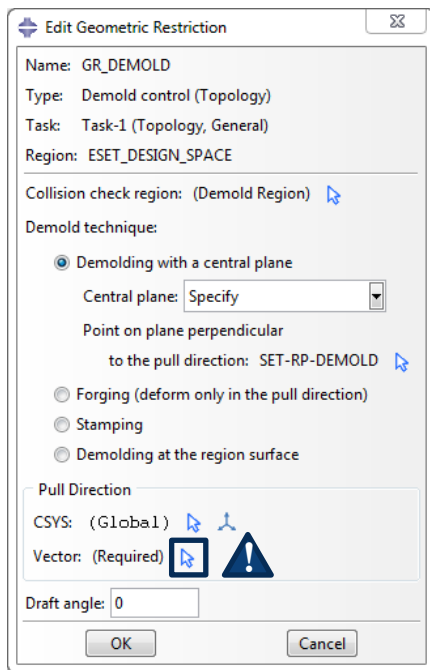

## Step 7: Geometric restriction for demold-able design





# Example | Crane Hook

## Step 7: Geometric restriction for demold-able design



**Edit Geometric Restriction**

Name: GR\_DEMOLD  
Type: Demold control (Topology)  
Task: Task-1 (Topology, General)  
Region: ESET\_DESIGN\_SPACE

Collision check region: (Demold Region)

Demold technique:

- ☒ Demolding with a central plane
  - Central plane: Specify
  - Point on plane perpendicular to the pull direction: SET-RP-DEMOLD
- ☐ Forging (deform only in the pull direction)
- ☐ Stamping
- ☐ Demolding at the region surface


Pull Direction

CSYS: (Global)

Vector: (Required)

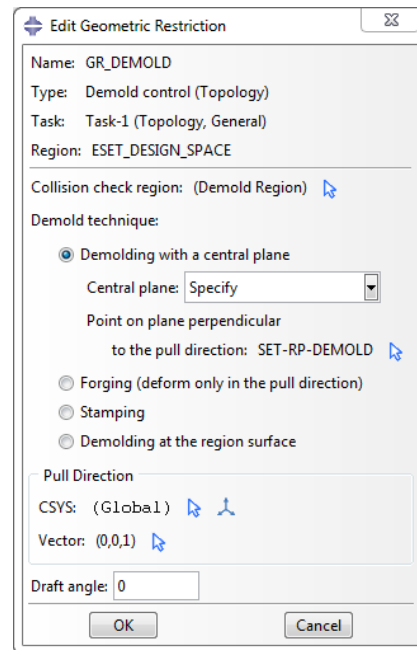

Draft angle: 0

OK Cancel



Pick the first point of the vector: 0,0,0,0,0

Pick the second point of the vector: 0,0,0,1,0



**Edit Geometric Restriction**

Name: GR\_DEMOLD  
Type: Demold control (Topology)  
Task: Task-1 (Topology, General)  
Region: ESET\_DESIGN\_SPACE

Collision check region: (Demold Region)

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Pull Direction

CSYS: (Global)

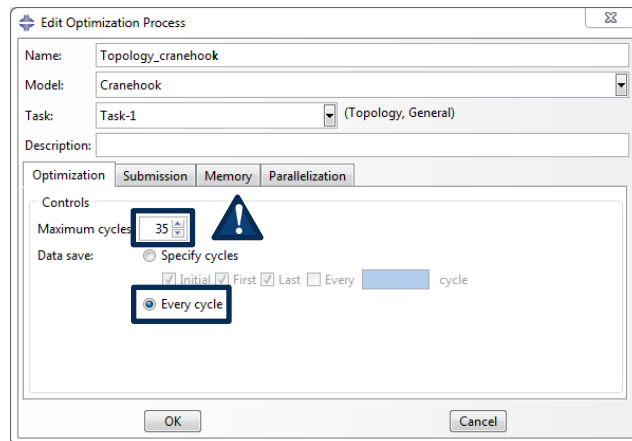
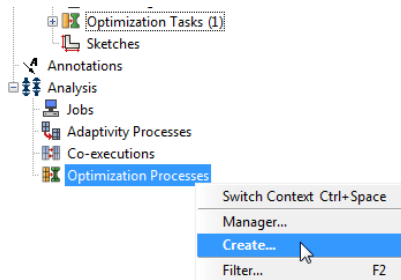
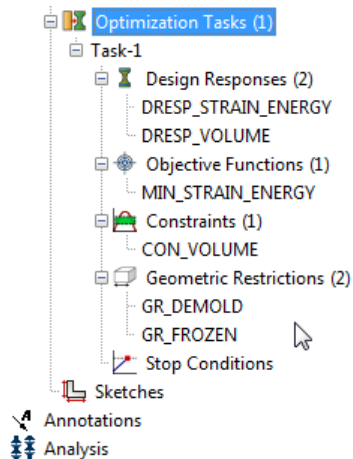
Vector: (0,0,1)

Draft angle: 0

OK Cancel

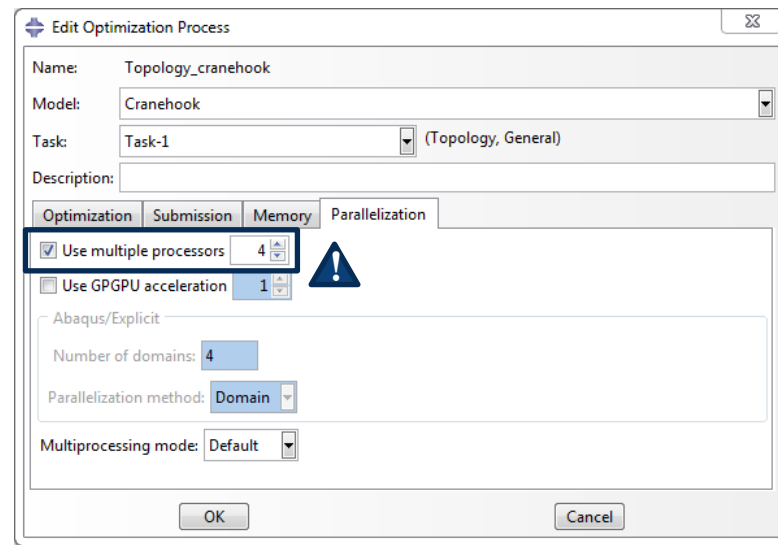
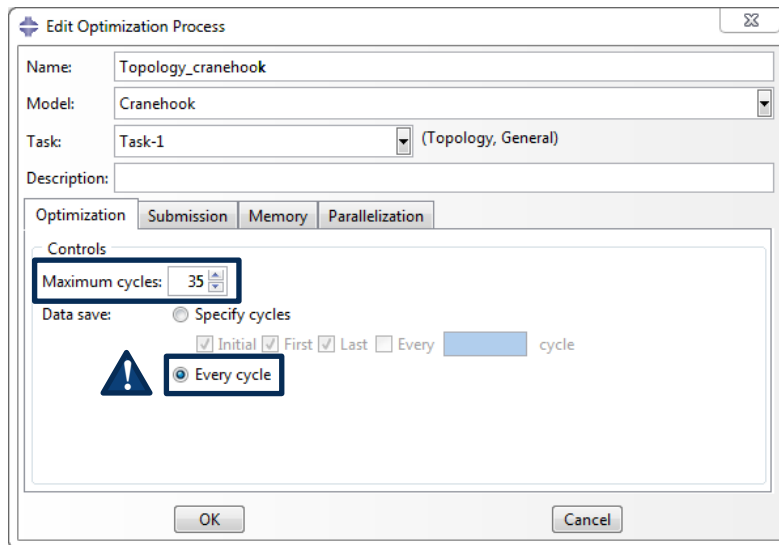
# Example | Crane Hook

## Step 8: Submission of the optimization task



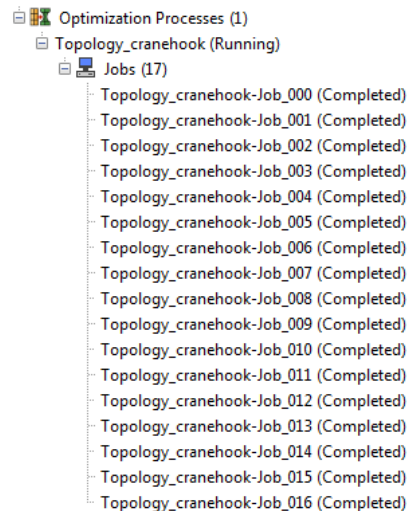
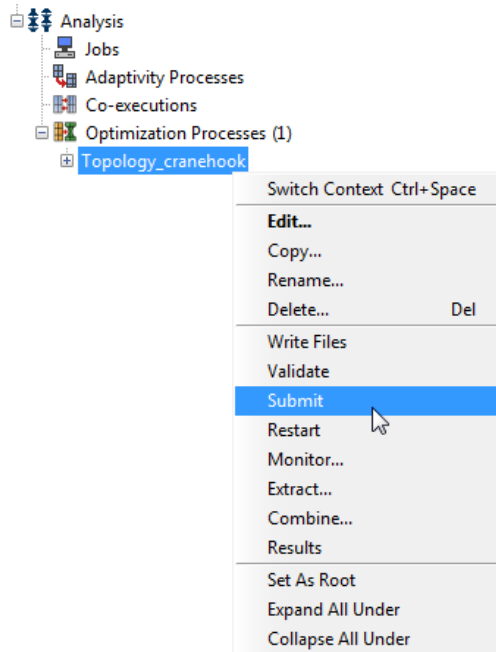
# Example | Crane Hook

## Step 8: Submission of the optimization task



# Example | Crane Hook

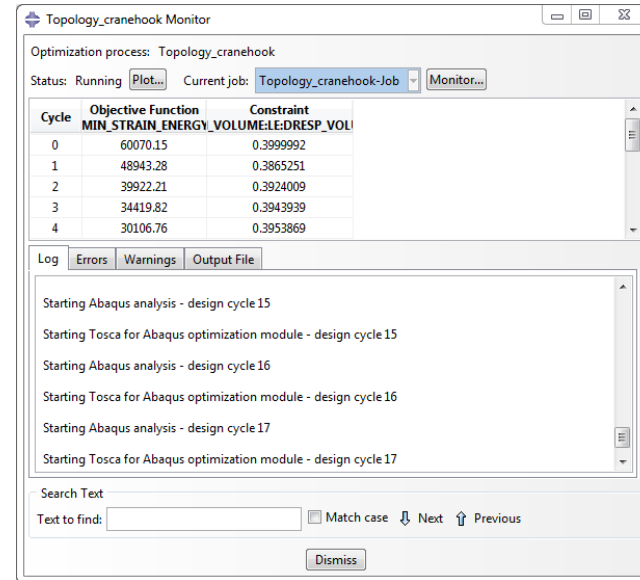
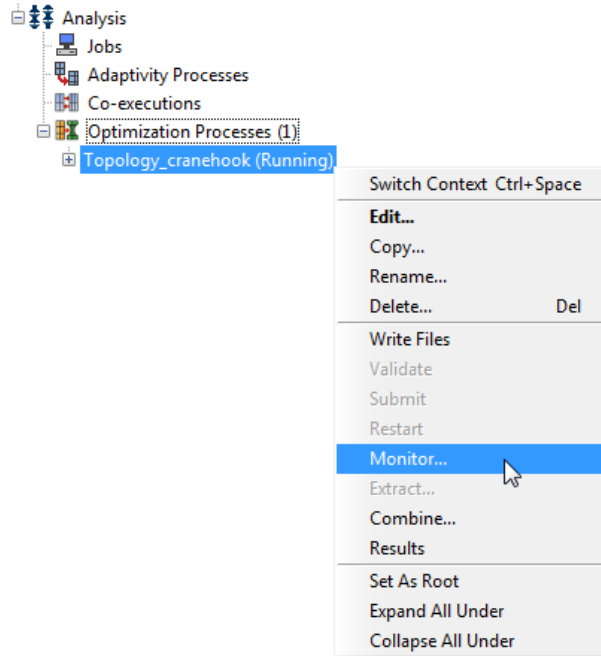
## Step 8: Submission of the optimization task



**Computational time: ~ 35min with 4 CPUs**

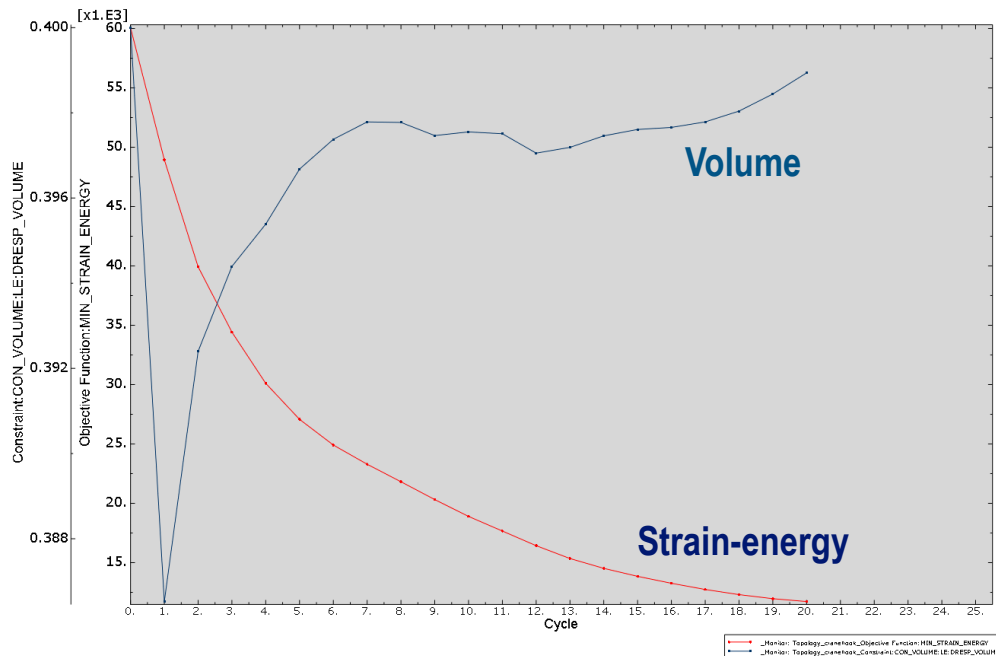
# Example | Crane Hook

## Step 8: Submission of the optimization task



# Example | Crane Hook

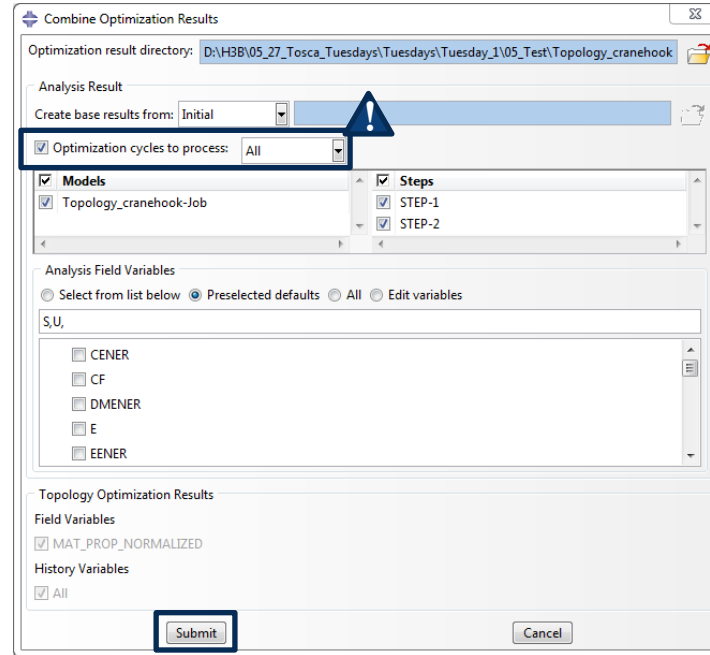
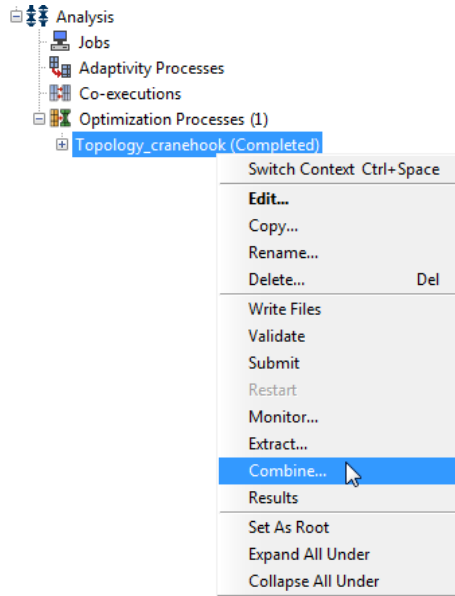
## Step 8: Submission of the optimization task



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

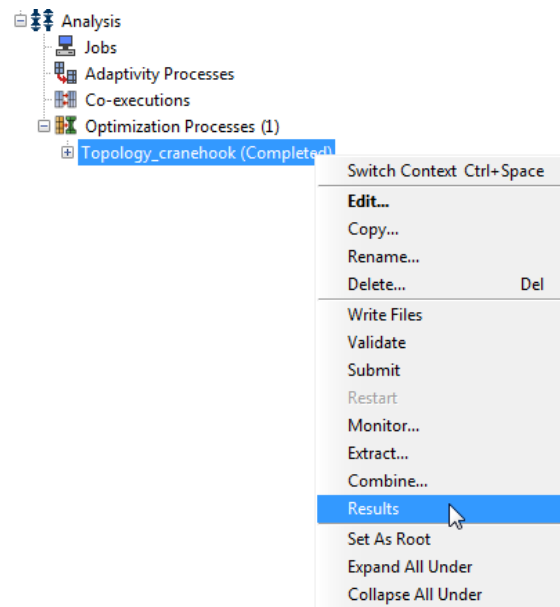
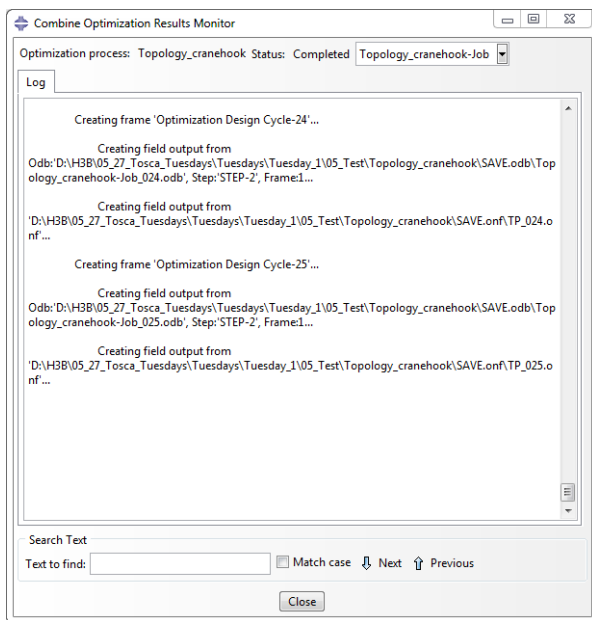
# Example | Crane Hook

## Step 9: Visualization ( ⚠ Optimization has to be completed)



# Example | Crane Hook

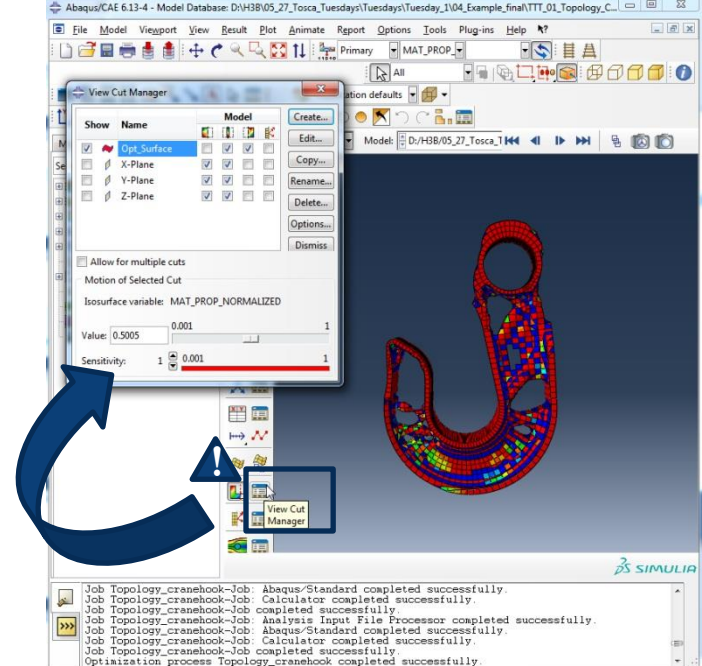
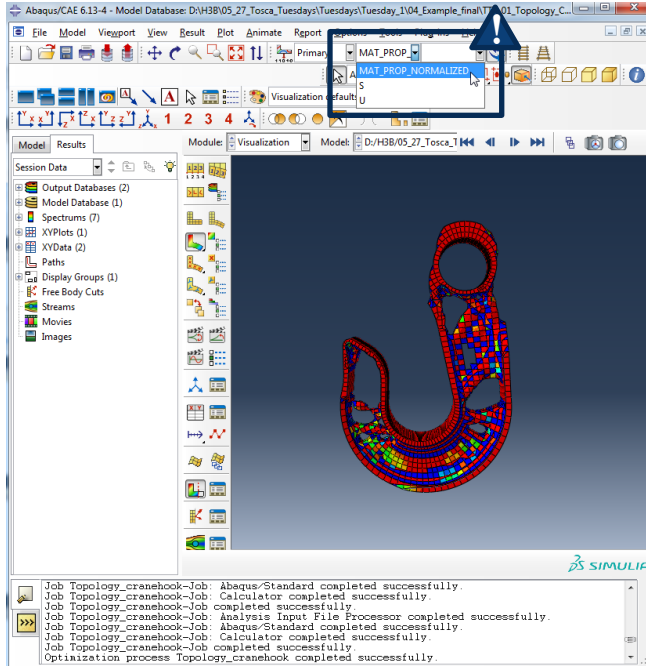
## Step 9: Visualization





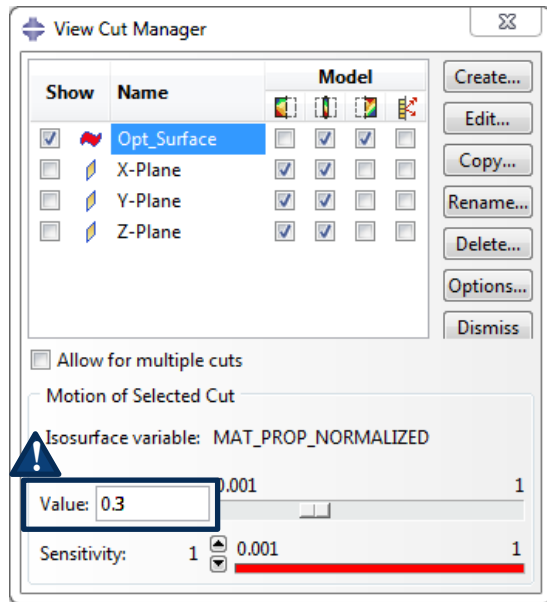
# Example | Crane Hook

## Step 9: Visualization

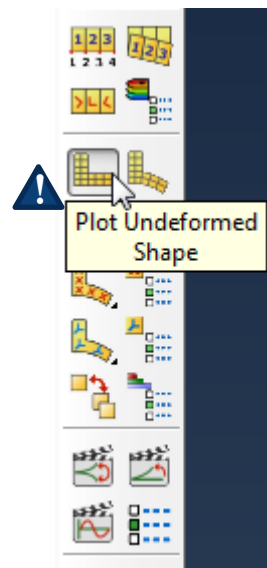


# Example | Crane Hook

## Step 9: Visualization

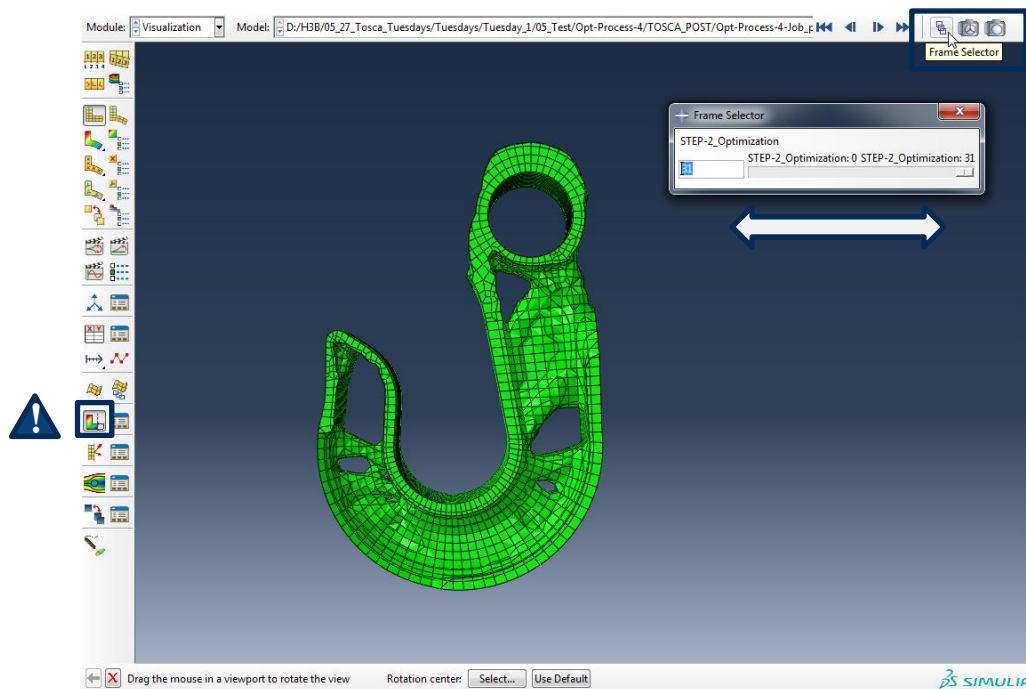


Set iso-value to 0.3



# Example | Crane Hook

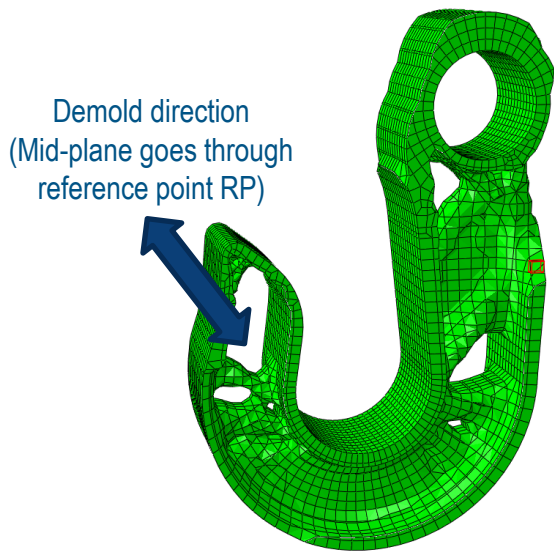
## Step 9: Visualization



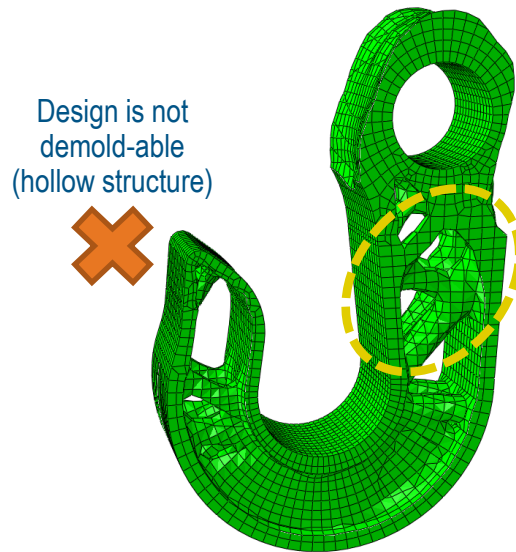
Scroll through each  
optimization cycle  
(Step 1 & Step 2)

# Example | Crane Hook

## Topology Optimization: Demold control as a geometric restriction



With demold control



Without demold control

# Example | Crane Hook

## Step 10: Extract smoothed geometry

