3DEXPERIENCE®

The Tosca Tuesdays

Tosca Tuesday #4

Basics: Shape optimization

Example: Shape optimization of a wheel rim

Basics | Shape optimization

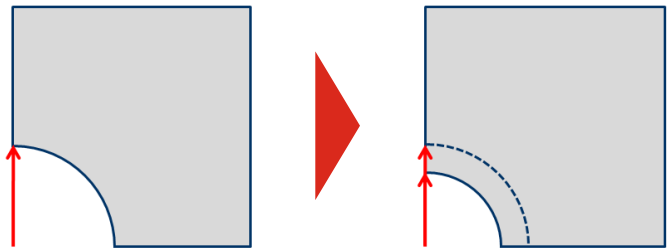
Fundamental concept

- **Design variables:** Position of each surface node from a given design area
- **Goal:** Calculate an optimal surface geometry of a given model under consideration of all boundary conditions, constraints and geometric restrictions
- **Result:** Optimization displacements for all corresponding design nodes
- **Examples of possible tasks (controller strategy):**
  - Minimize local stress /strain peaks
  - Minimize local stress / strain peaks under a volume equality constraint
  - Minimize local fatigue hotspots / nodal damage peaks
  - Minimize local fatigue hotspots / nodal damage peaks under a volume equality constraint
  - …

Basics | Shape optimization

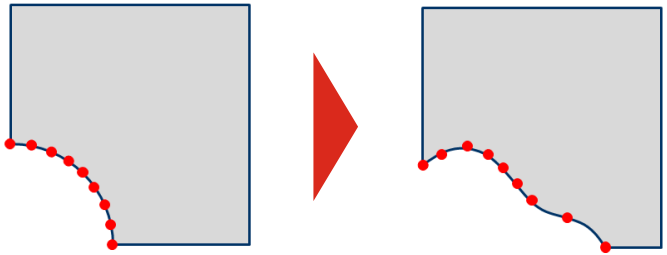
Different approaches

Parametric concept (→ Isight)



e.g. Variation of a radius

Non-parametric concept (→ Tosca)

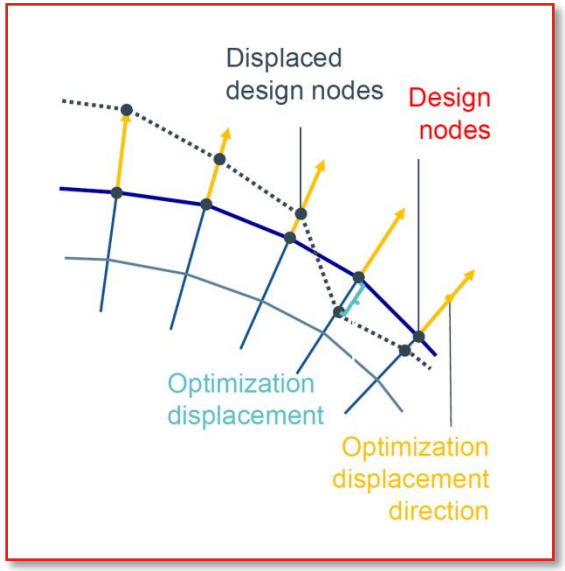


Modification of each surface node

→ Flexibility of possible shapes

Basics | Shape optimization

Non-parametric concept



Terminology

- **"Growth":** Design node is moved outwards in normal direction (positive displacement)
- **"Shrinkage":** Design node is moved against normal direction (negative displacement)
- The **design variables** are more specifically the optimization displacement values of the corresponding design nodes.

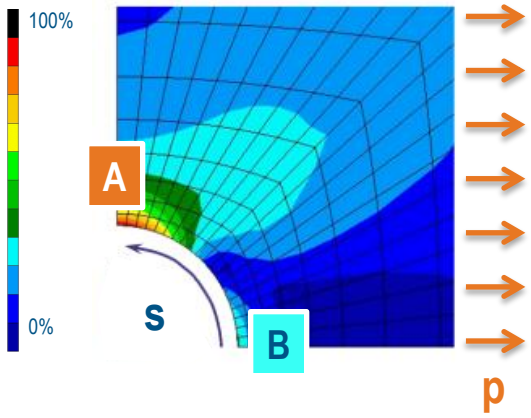
Basics | Shape optimization

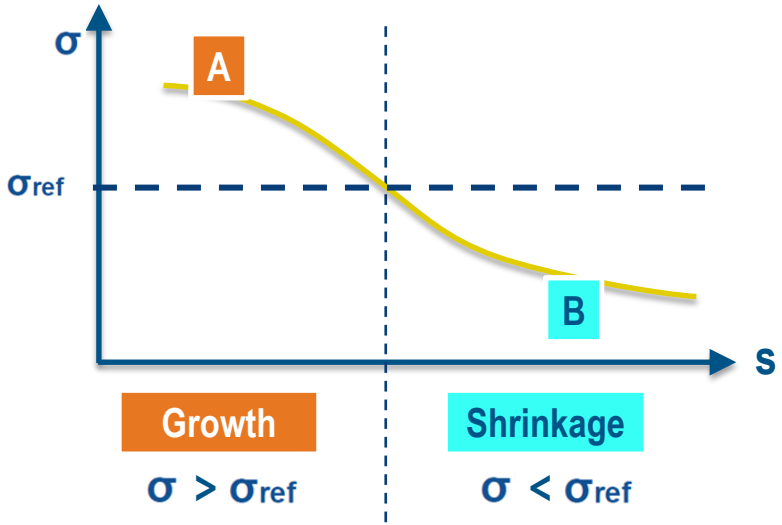
Controller strategy

- **Goal:** Minimize local stress peaks on the surface of a structure
- **Controller strategy:**
  - Homogenization of the surface stress distribution
  - “Growth” in regions of high stress → leads to local stress decrease
  - “Shrinkage” in regions of low stress → leads to local stress increase
  - Characterization of a certain region by using a reference stress (~ average stress of all design nodes)
- **Result:** Homogeneous (uniform) stress distribution without any stress peaks
- The concept is in a similar manner applicable to strain or damage peaks (fatigue analysis).

Basics | Shape optimization

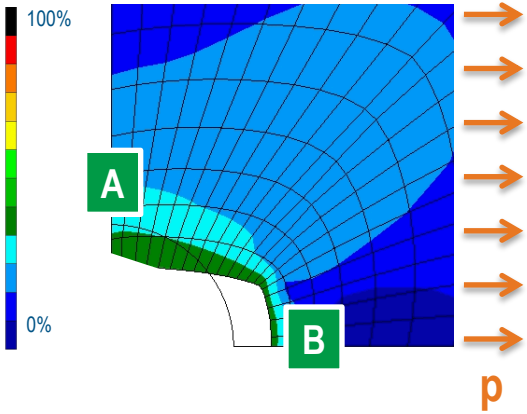
Controller strategy – Example of a hole plate

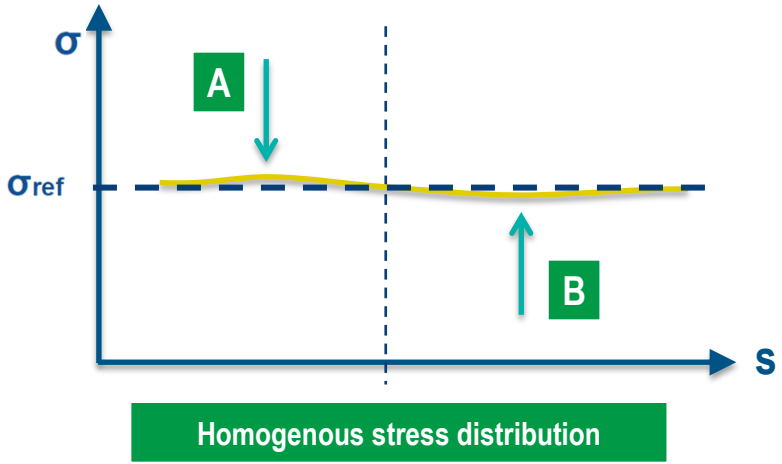




Basics | Shape optimization

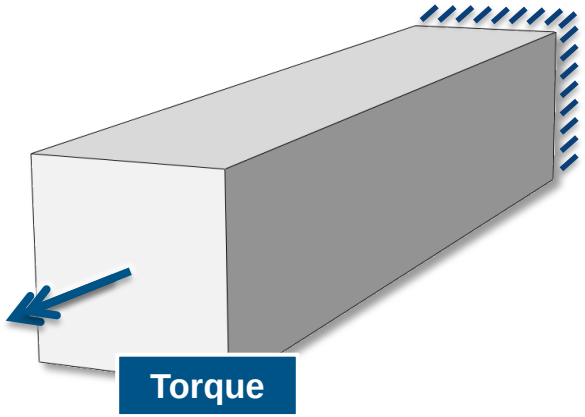
Controller strategy – Example of a hole plate

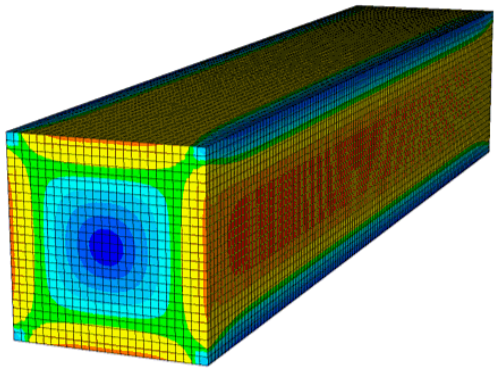




Basics | Shape optimization

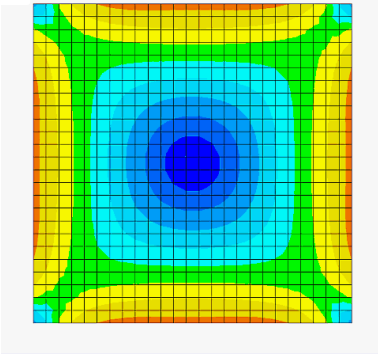
Controller strategy – Example of a rectangular beam under torsional loading





Shrinkage

Growth



Homogenous stress distribution

Tosca Tuesday #4

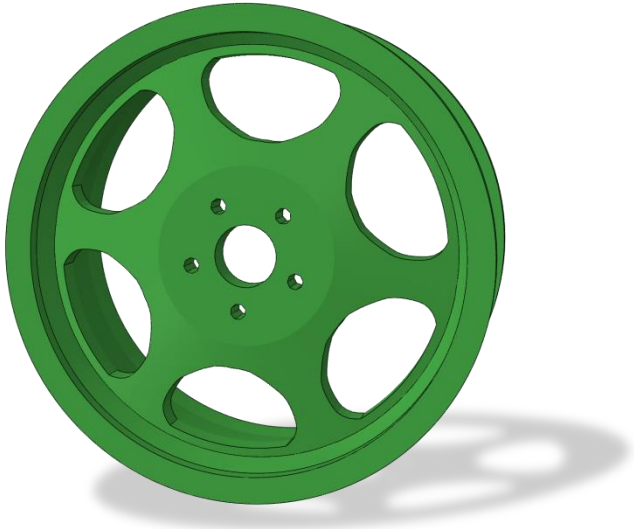
Basics: Shape optimization

Example: Shape optimization of a wheel rim

Example | Wheel rim

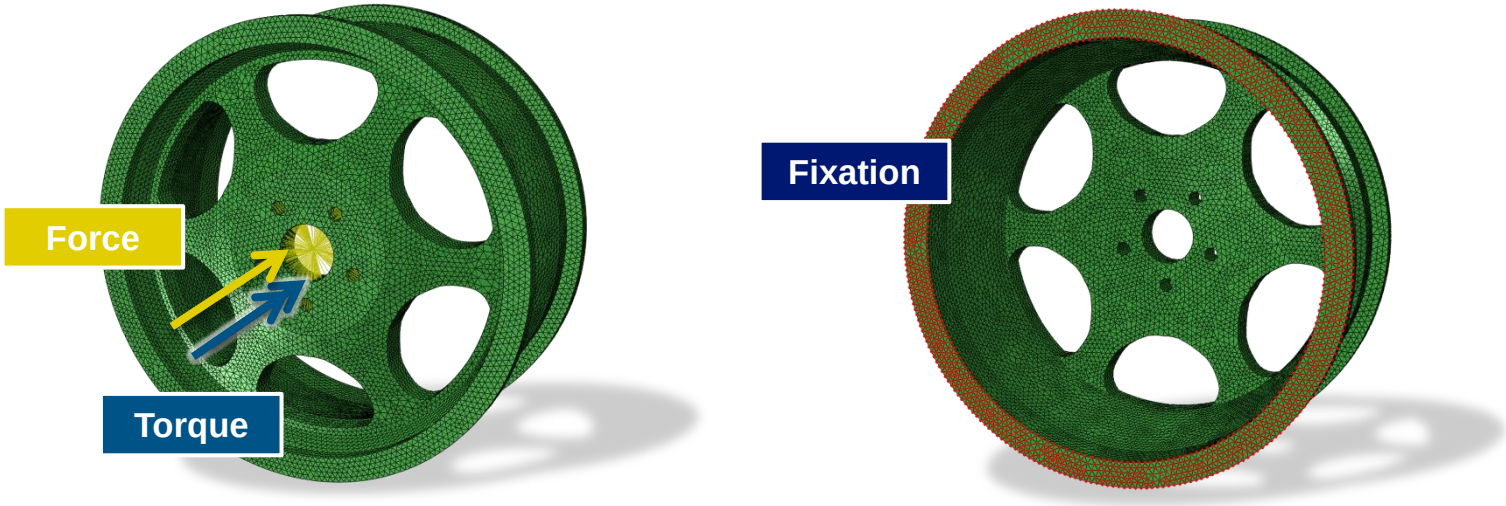
Get started …

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



Example | Wheel rim

Basic model: Loading and boundary conditions

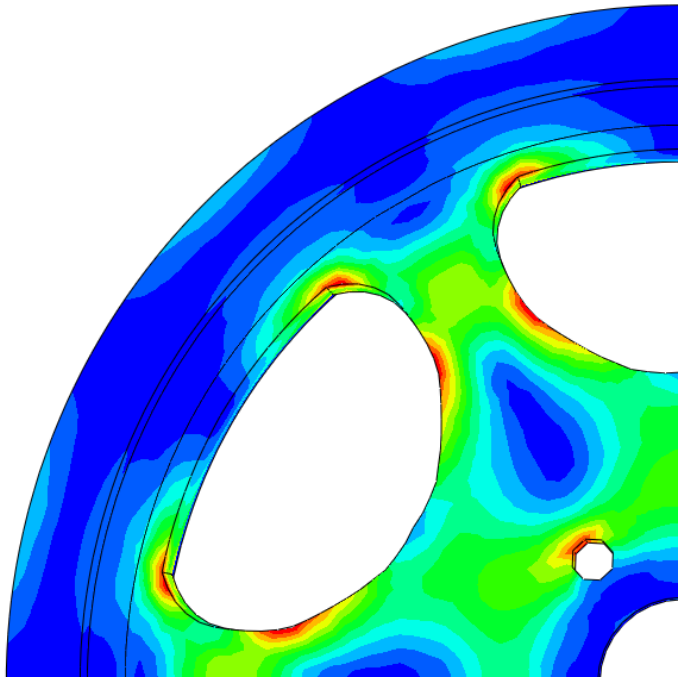


Example | Wheel rim

Shape Optimization: Setup

- **Objective function**
  - Minimize maximal stress peaks (v. Mises)

  → Controller strategy
- **Geometric restrictions**
  - Rotational symmetry
  - Planar symmetry for each segment
  - Stamp restriction (manufacturing)

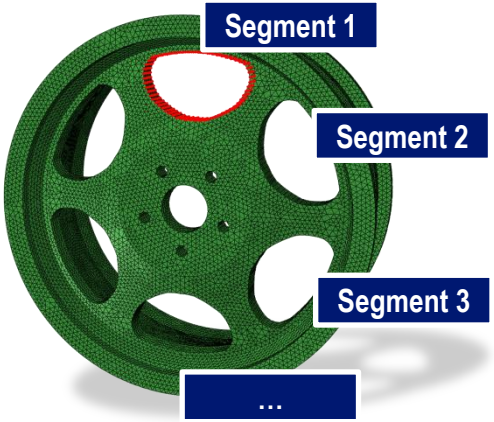


Example | Wheel rim

Shape Optimization: Used node sets

Complete model

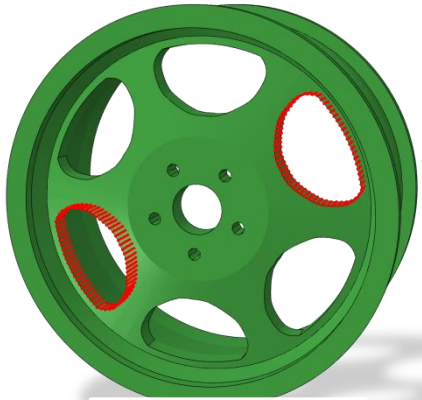
Design nodes



Example | Wheel rim

Shape Optimization: Used node sets

Pair A

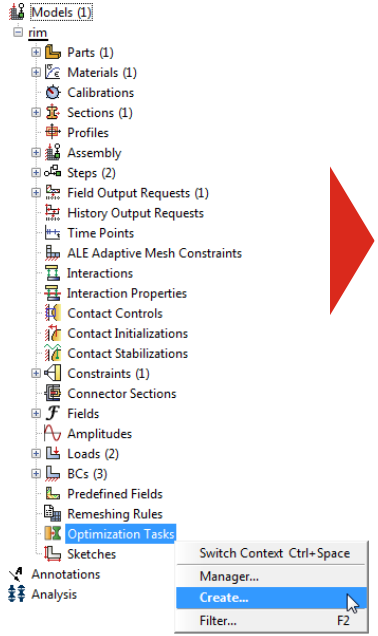


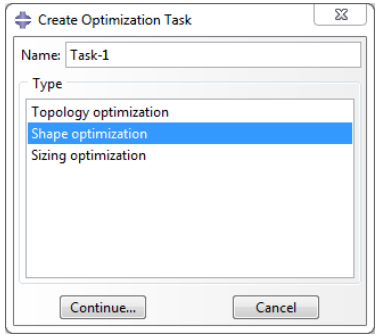
Pair B

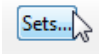
Pair C

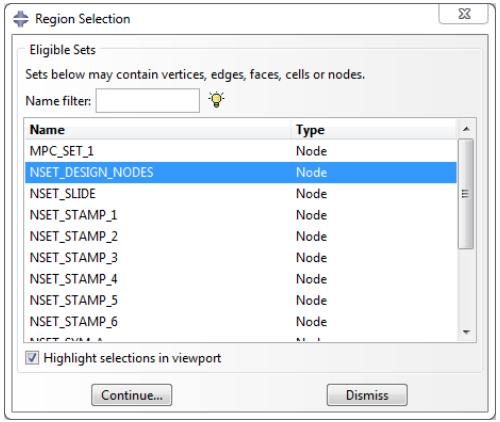
Example | Wheel rim

Step 1: Shape optimization task



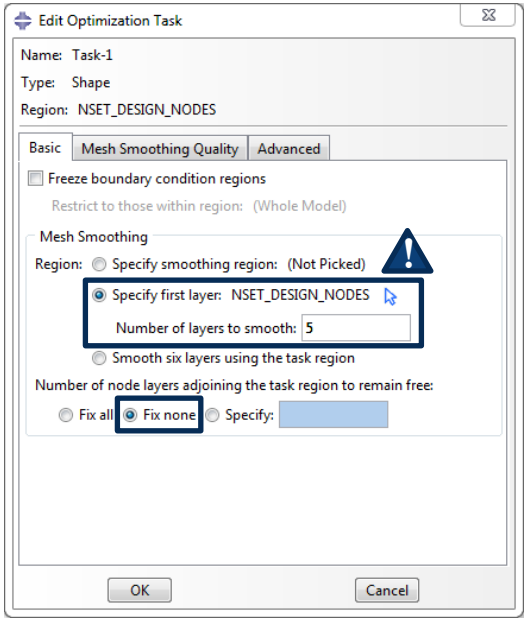


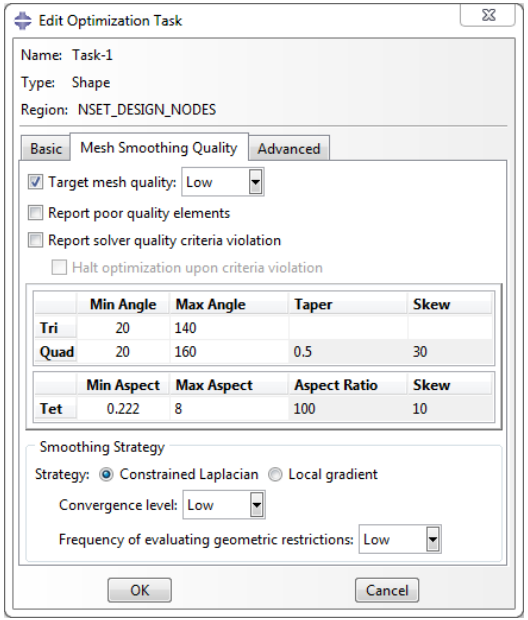


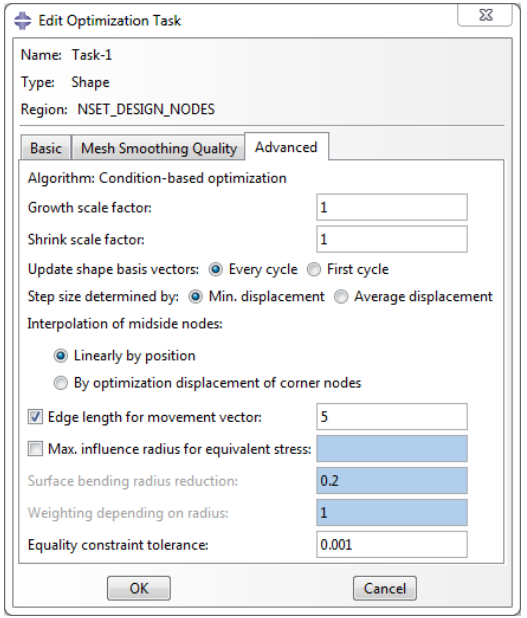


Example | Wheel rim

Step 1: Shape optimization task

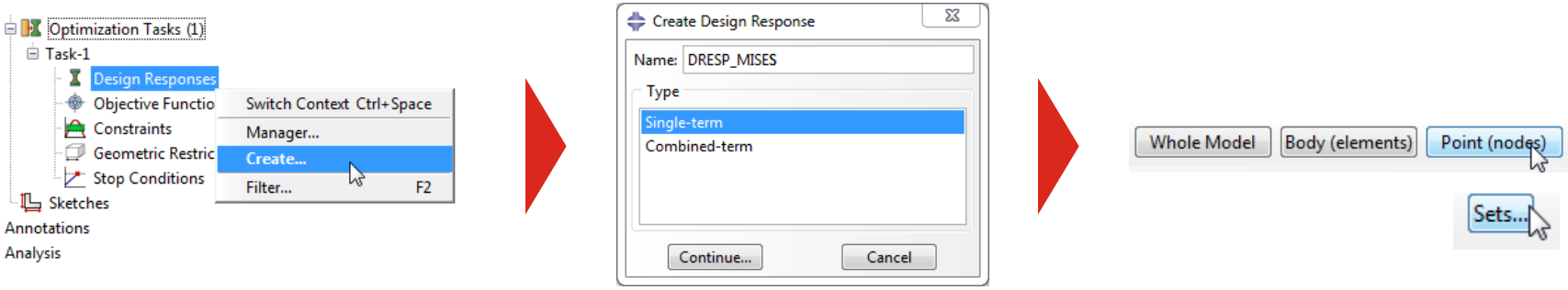






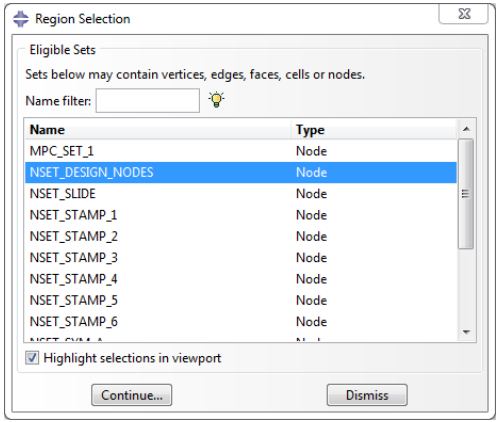
Example | Wheel rim

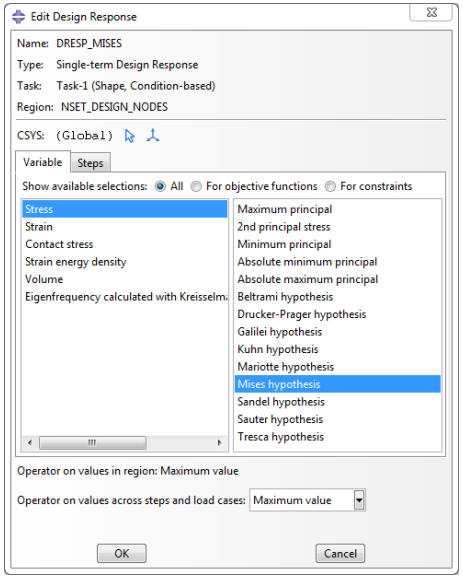
Step 2: Design response for maximal v. Mises stress

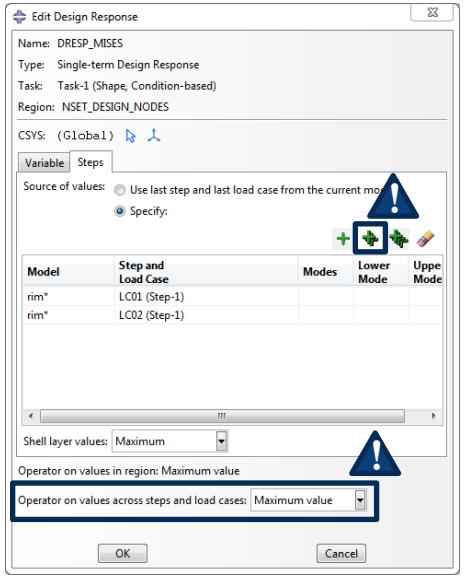


Example | Wheel rim

Step 2: Design response for maximal v. Mises stress

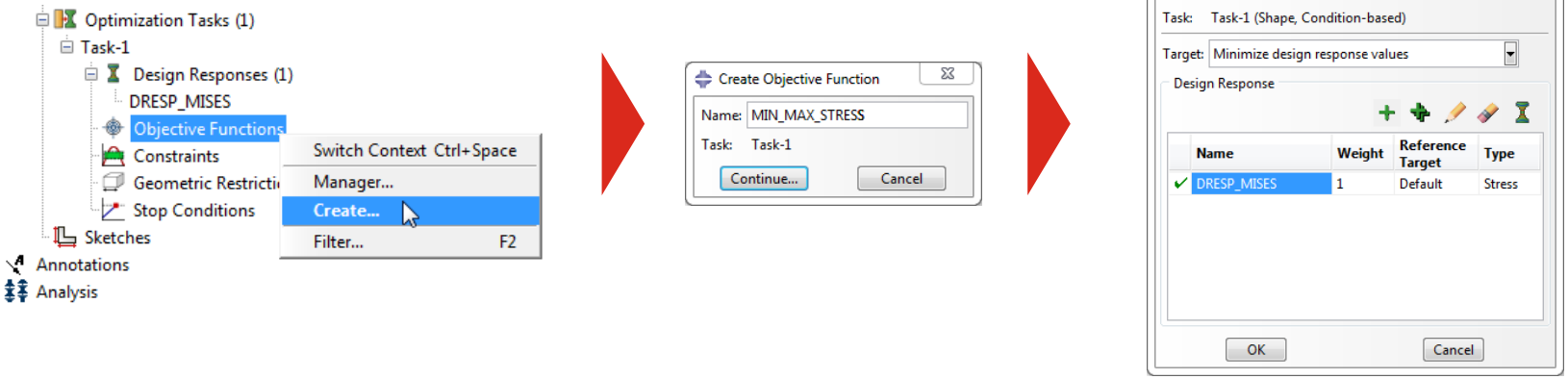






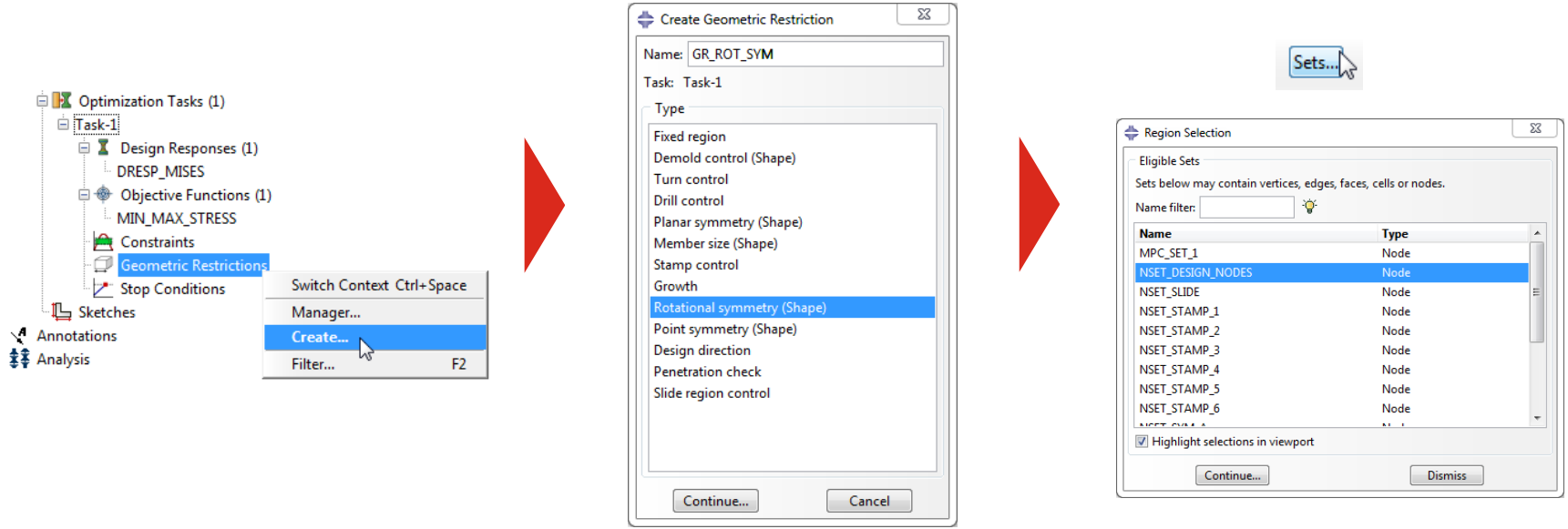
Example | Wheel rim

Step 3: Objective function (→ minimize maximal v. Mises stress peak)



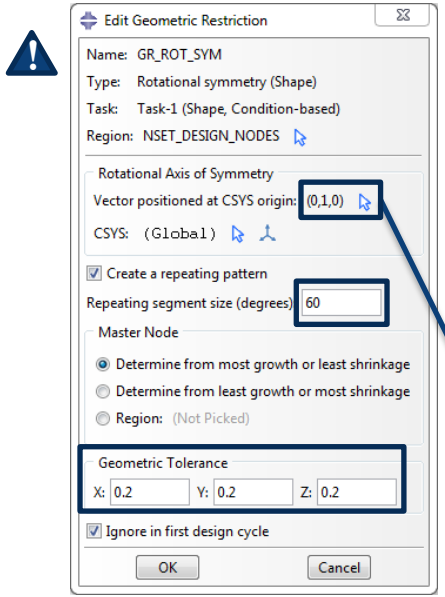
Example | Wheel rim

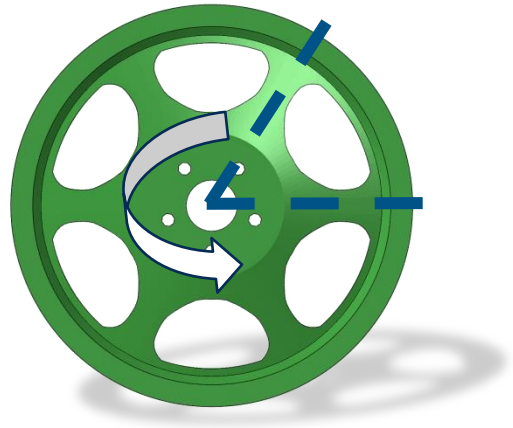
Step 4: Geometric restriction for rotational symmetry

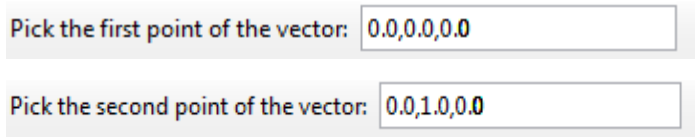


Example | Wheel rim

Step 4: Geometric restriction for rotational symmetry

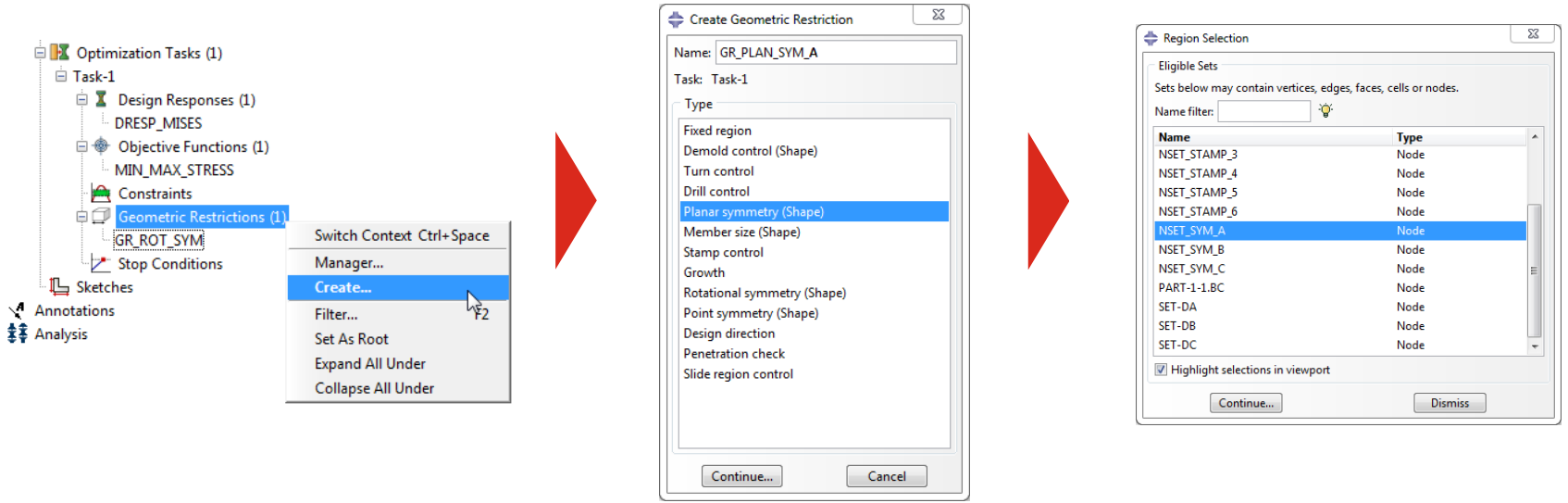






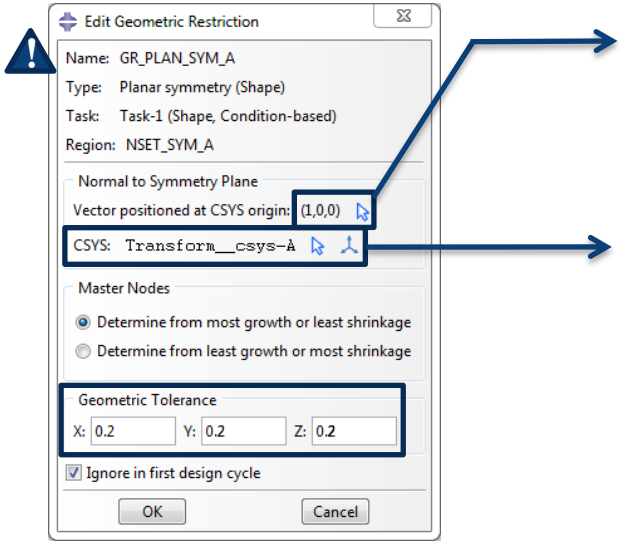
Example | Wheel rim

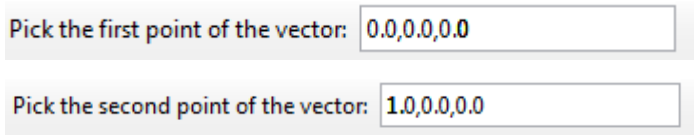
Step 5: Geometric restriction for planar symmetry (pair A)

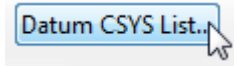


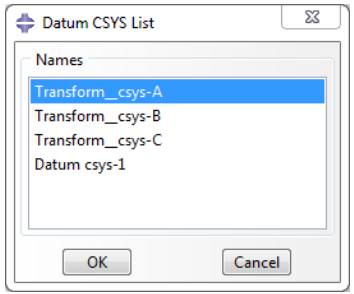
Example | Wheel rim

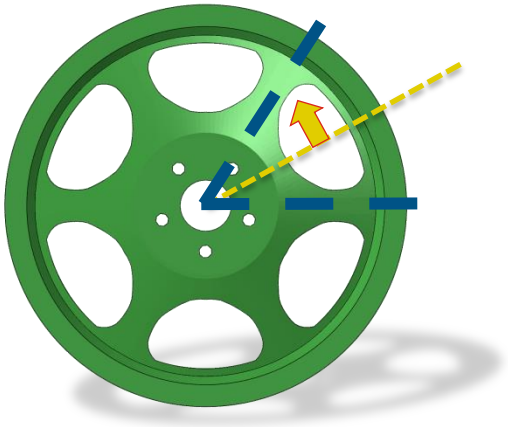
Step 5: Geometric restriction for planar symmetry (pair A)







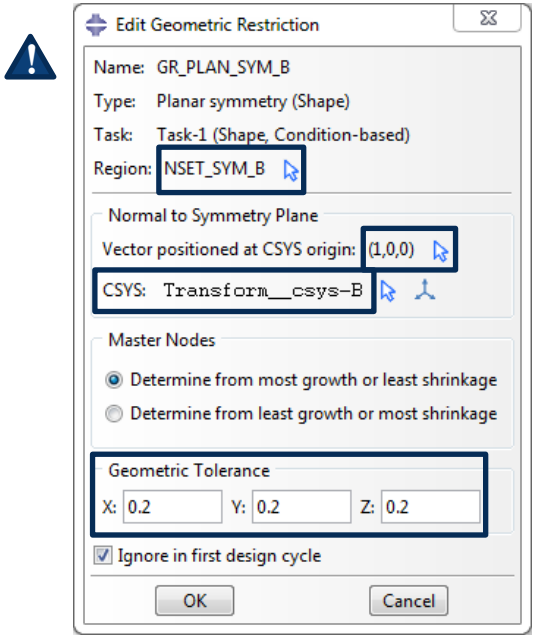


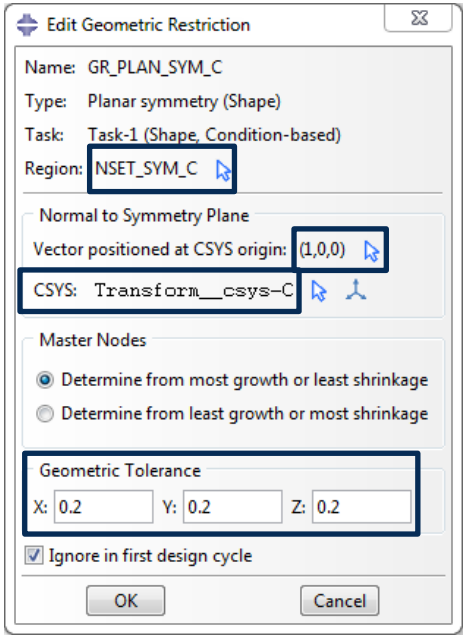


Example | Wheel rim

Step 5: Geometric restriction for planar symmetry (pair B & C)

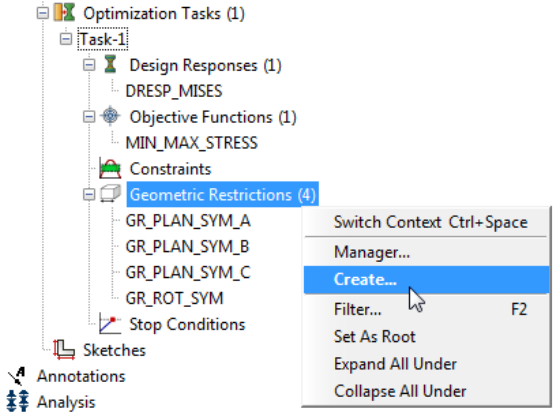
Repeat for pair B and pair C

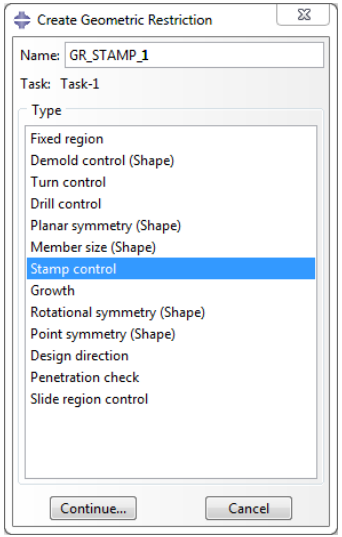


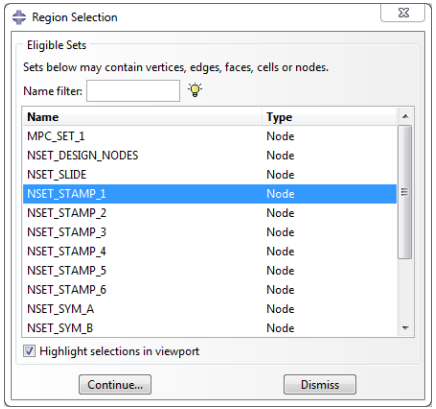


Example | Wheel rim

Step 6: Geometric restriction for stamping process (segment 1)

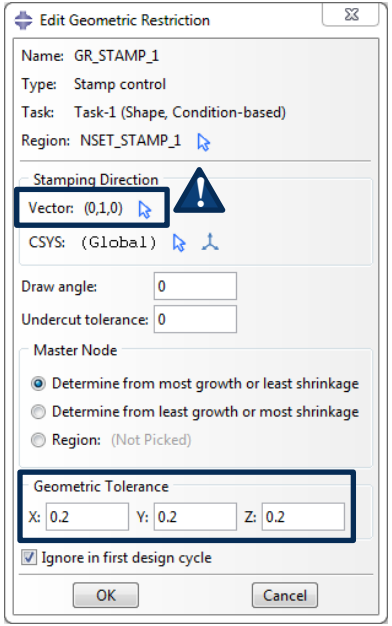


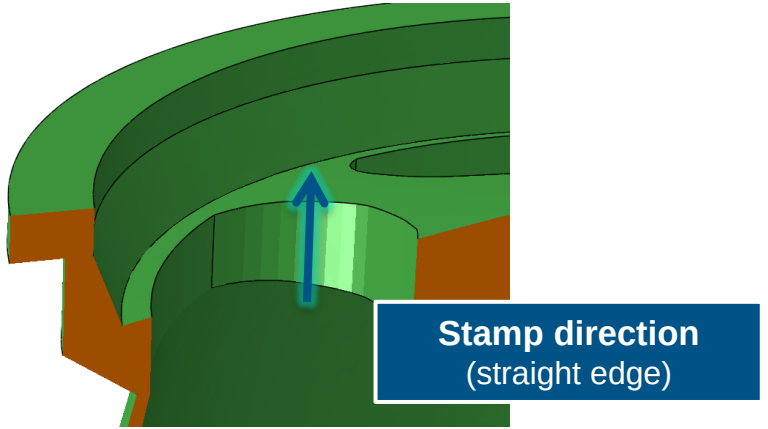




Example | Wheel rim

Step 6: Geometric restriction for stamping process (segment 1)

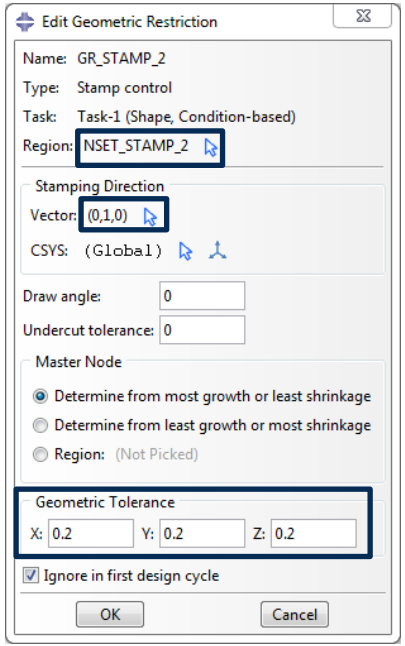


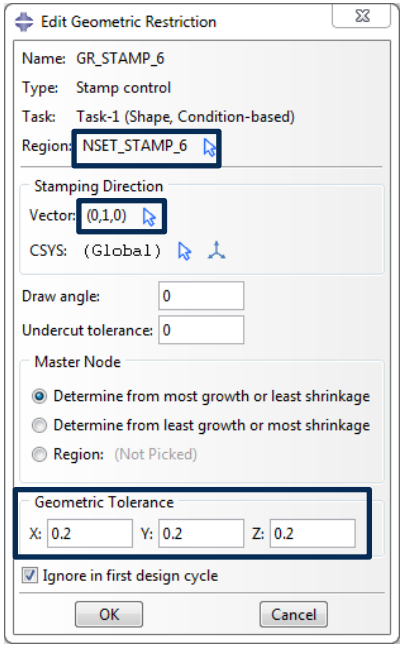


Example | Wheel rim

Step 6: Geometric restriction for stamping process (segments 2-6)

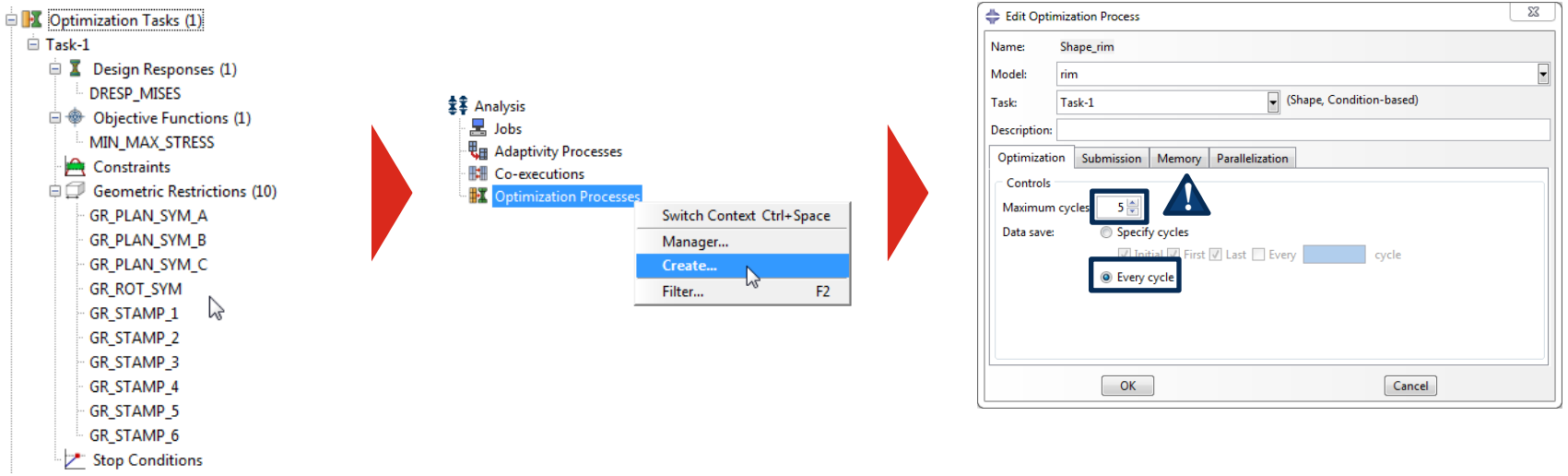
Repeat for segments 2-6





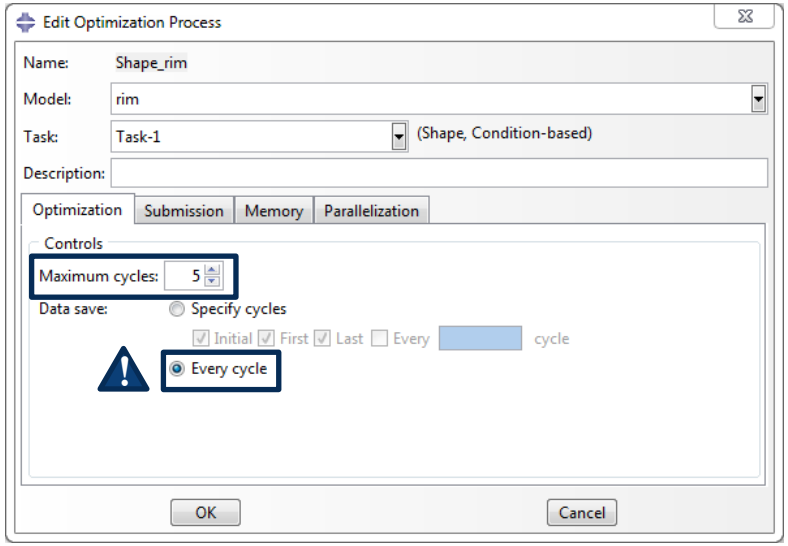
Example | Wheel rim

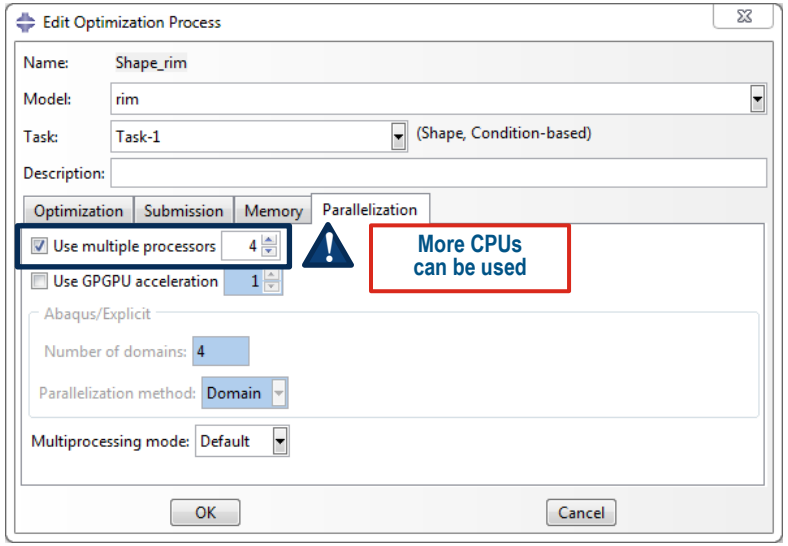
Step 7: Submission of the optimization task



Example | Wheel rim

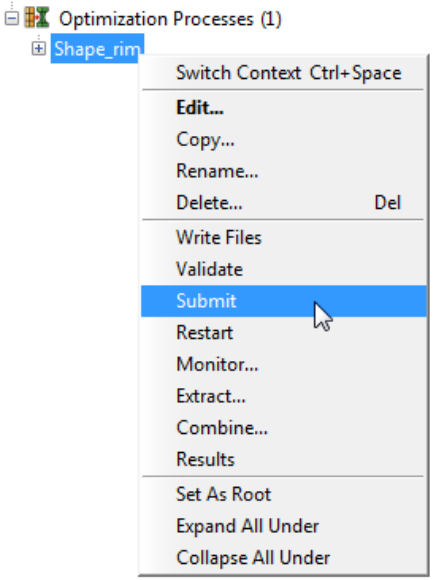
Step 7: Submission of the optimization task

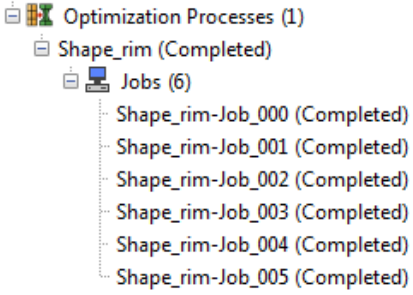




Example | Wheel rim

Step 7: Submission of the optimization task

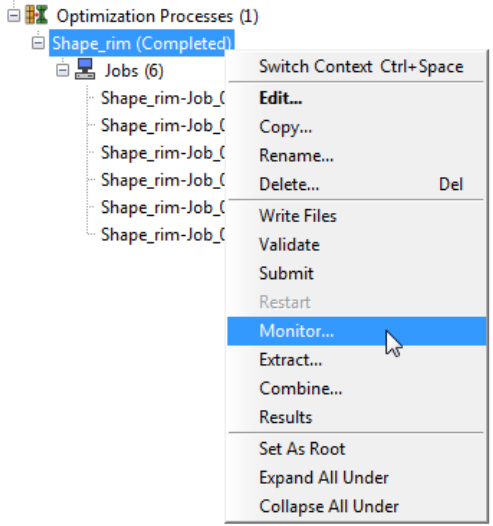


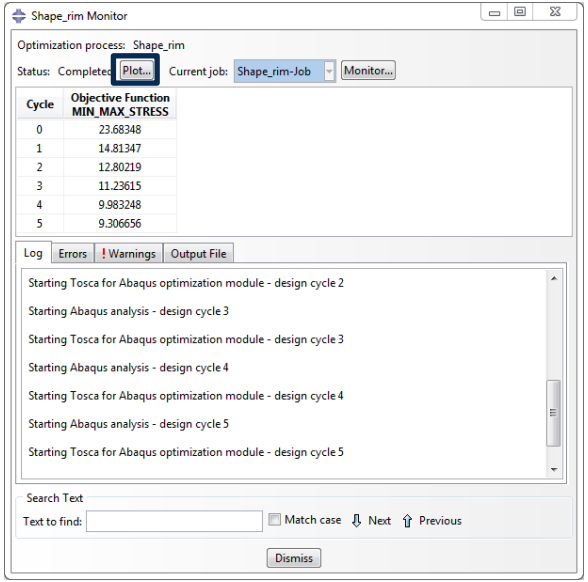


Computational time:
~ 15min with 4 CPUs

Example | Wheel rim

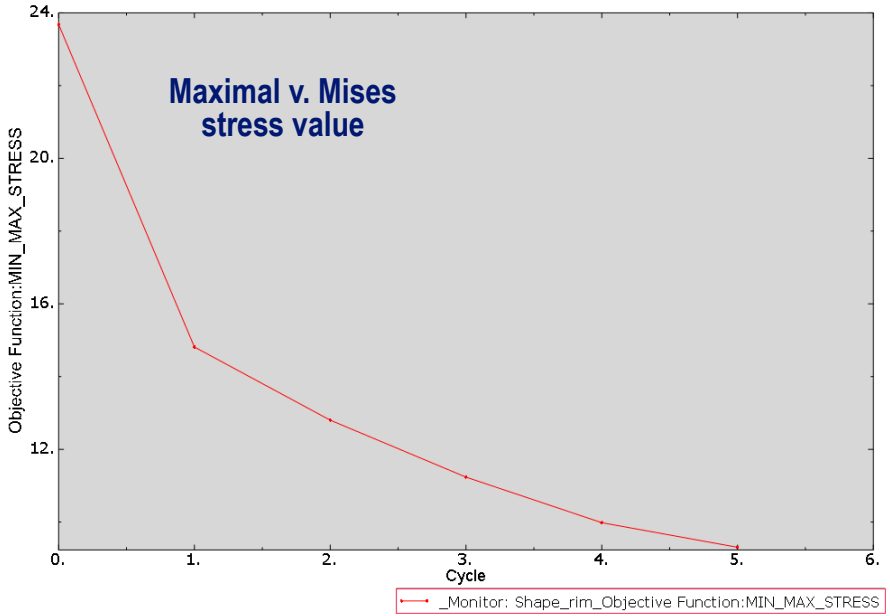
Step 8: Submission of the optimization task





Example | Wheel rim

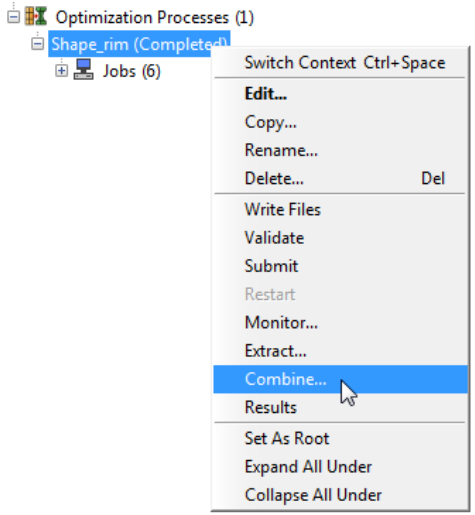
Step 8: Submission of the optimization task

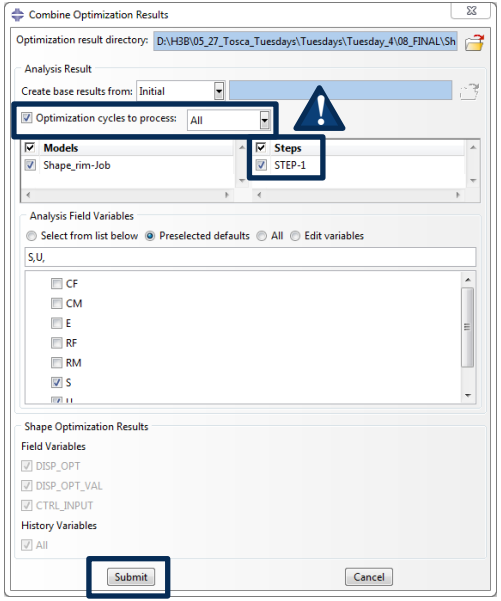


Modify axis display options (font, size, color) by double-clicking

Example | Wheel rim

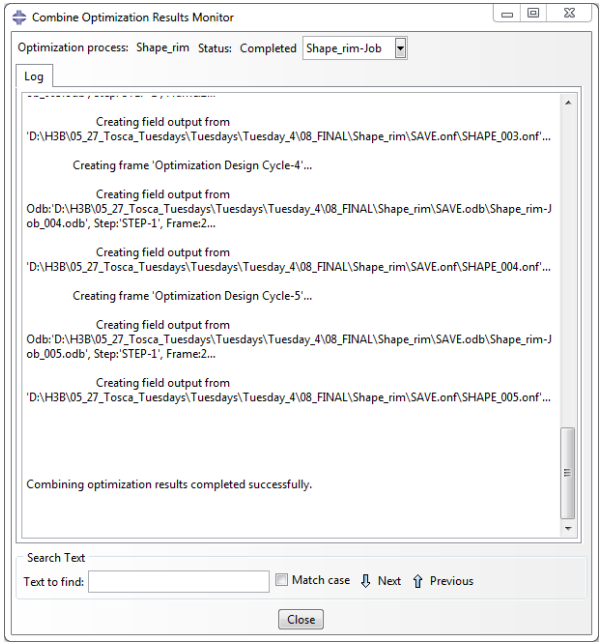
Step 9: Visualization (⚠ Optimization has to be completed)

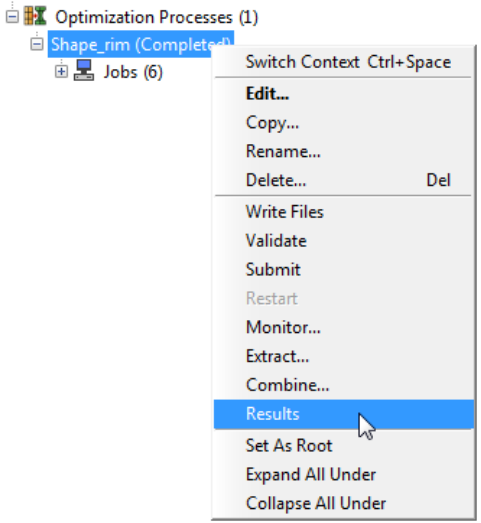




Example | Wheel rim

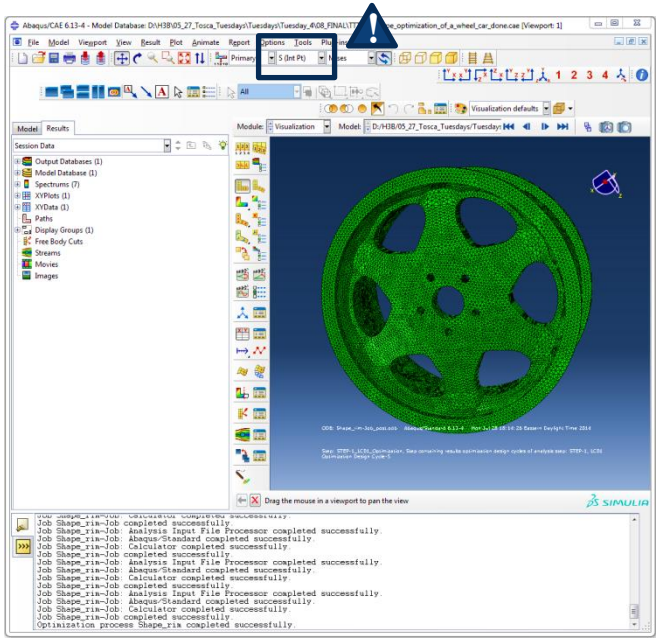
Step 9: Visualization

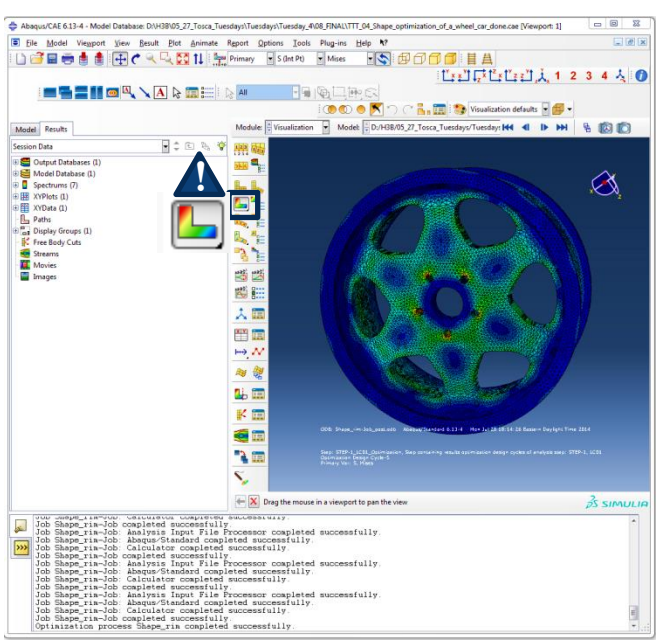




Example | Wheel rim

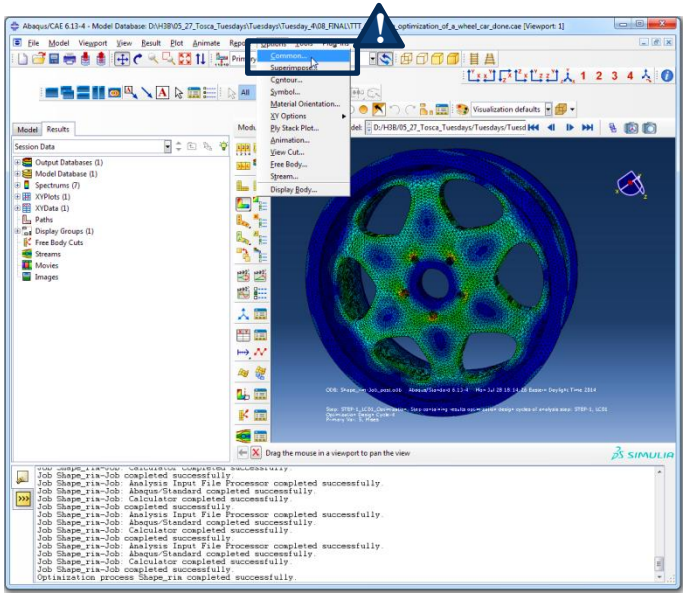
Step 9: Visualization

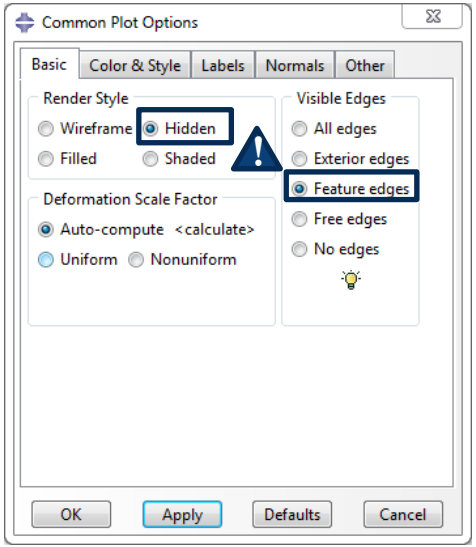




Example | Wheel rim

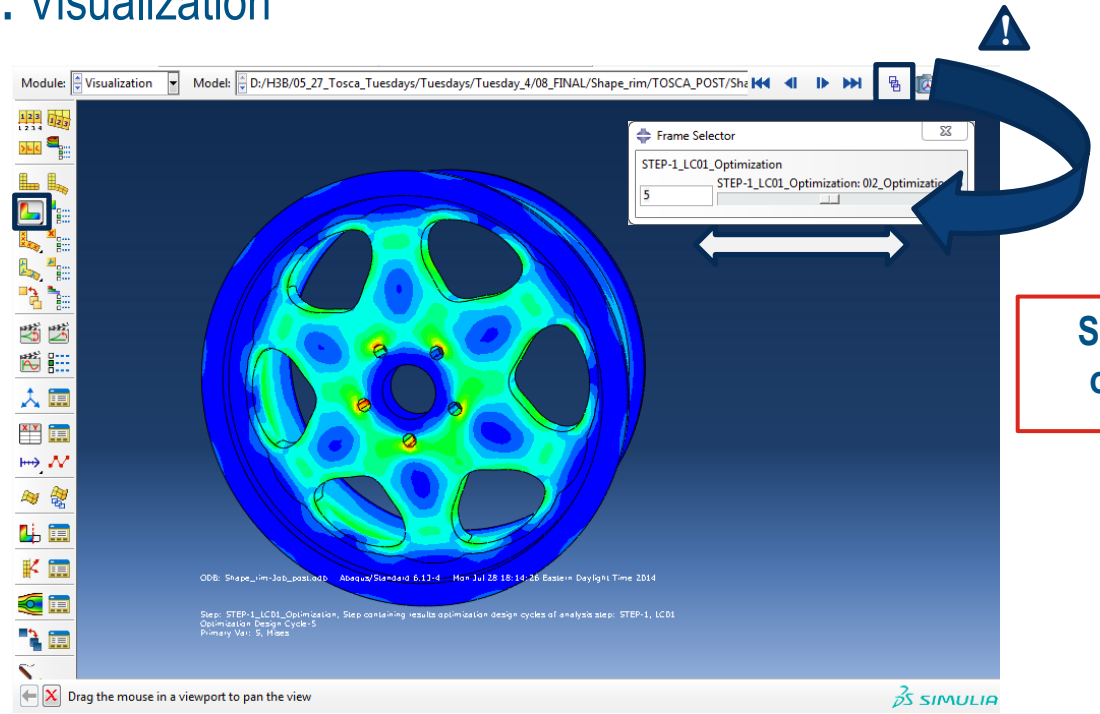
Step 9: Visualization



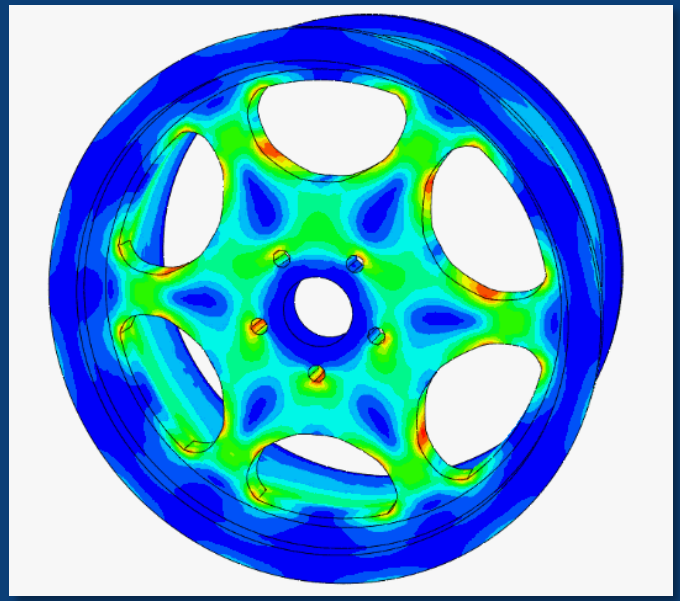


Example | Wheel rim

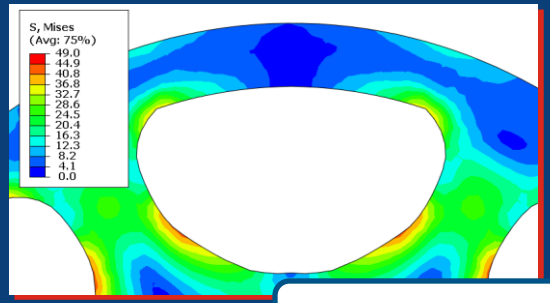
Step 9: Visualization



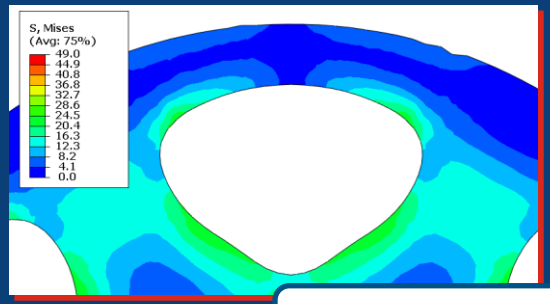
Scroll through each optimization cycle



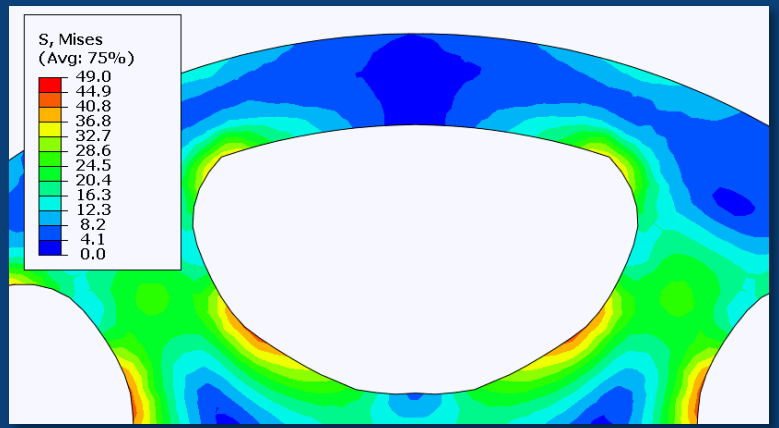
Shape Optimization



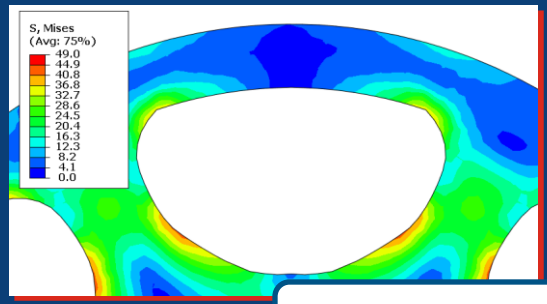
Original Design



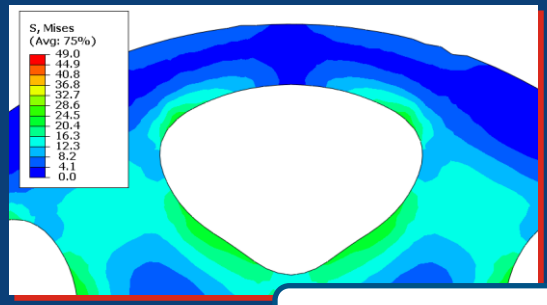
Optimized Design



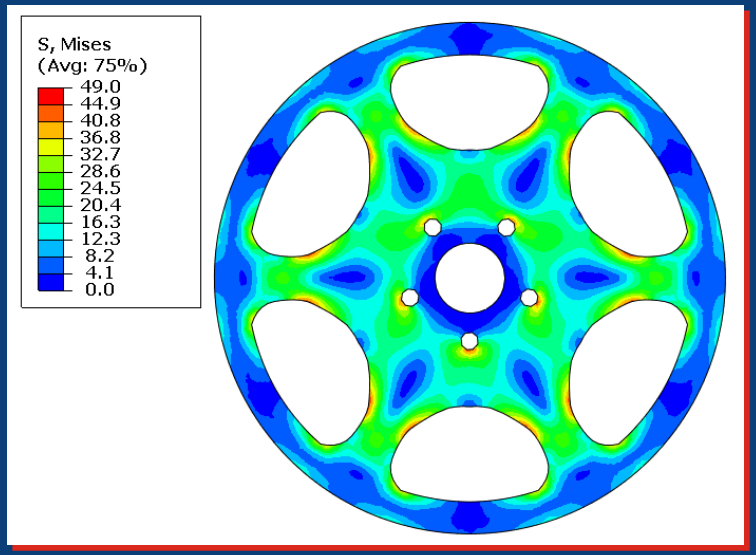
Shape Optimization



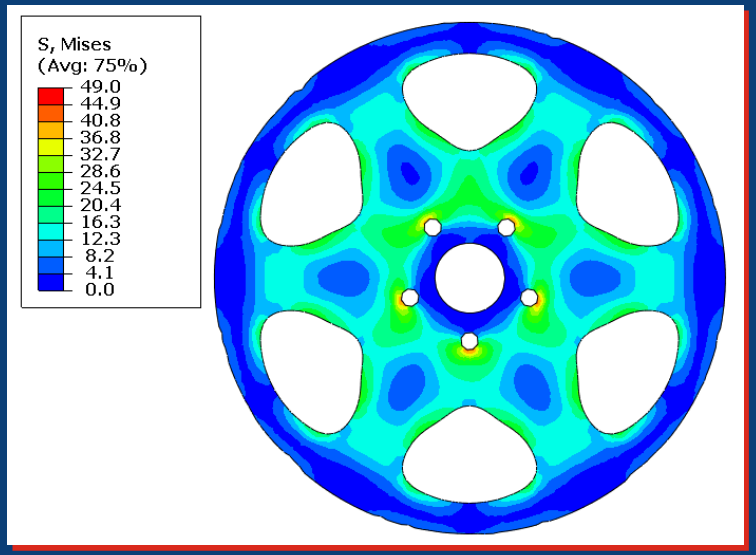
Original Design



Optimized Design



Original Design



Optimized Design