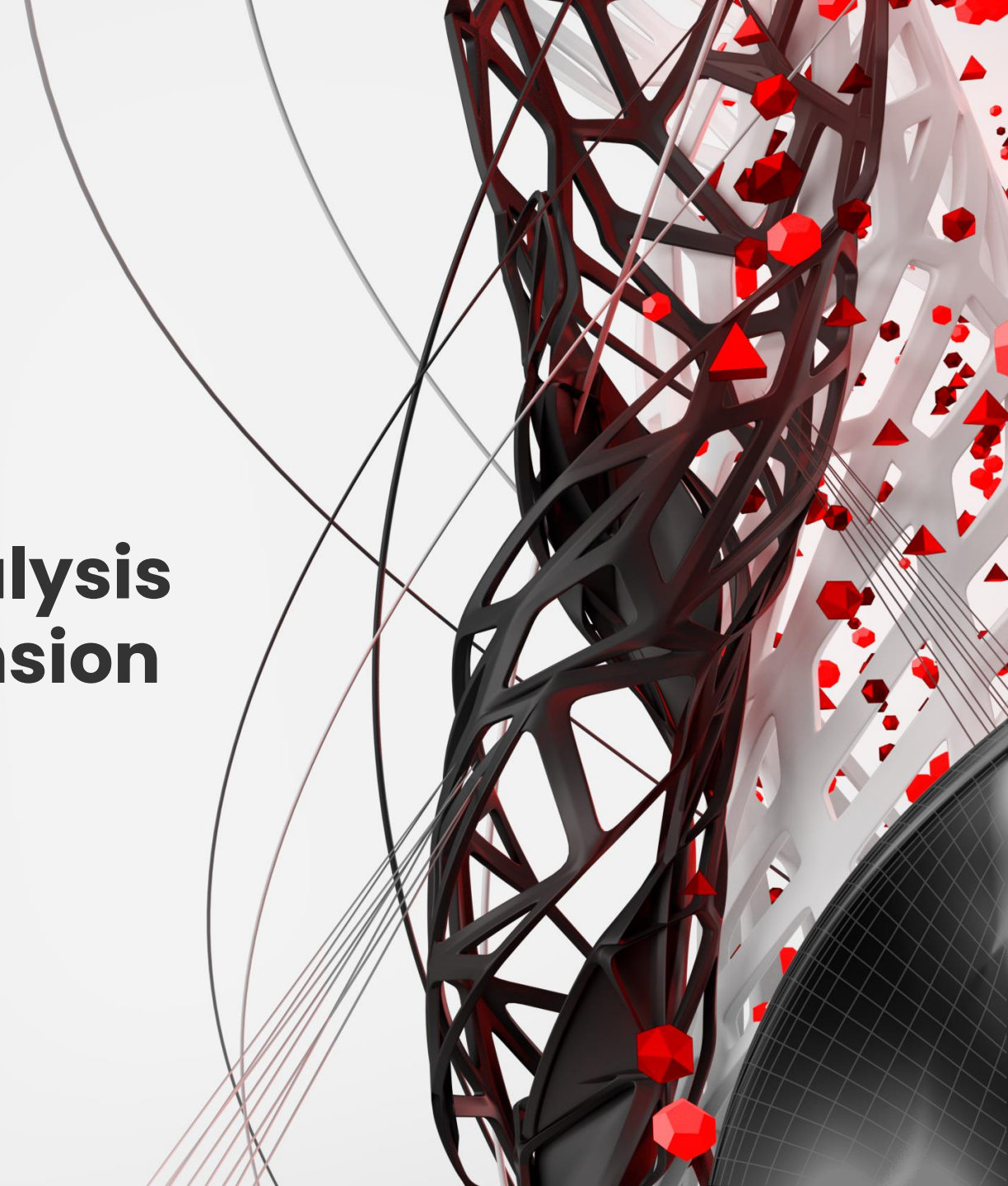

Workshop Structural Analysis
Stepped shaft in axial tension

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SIMULATING THE FUTURE

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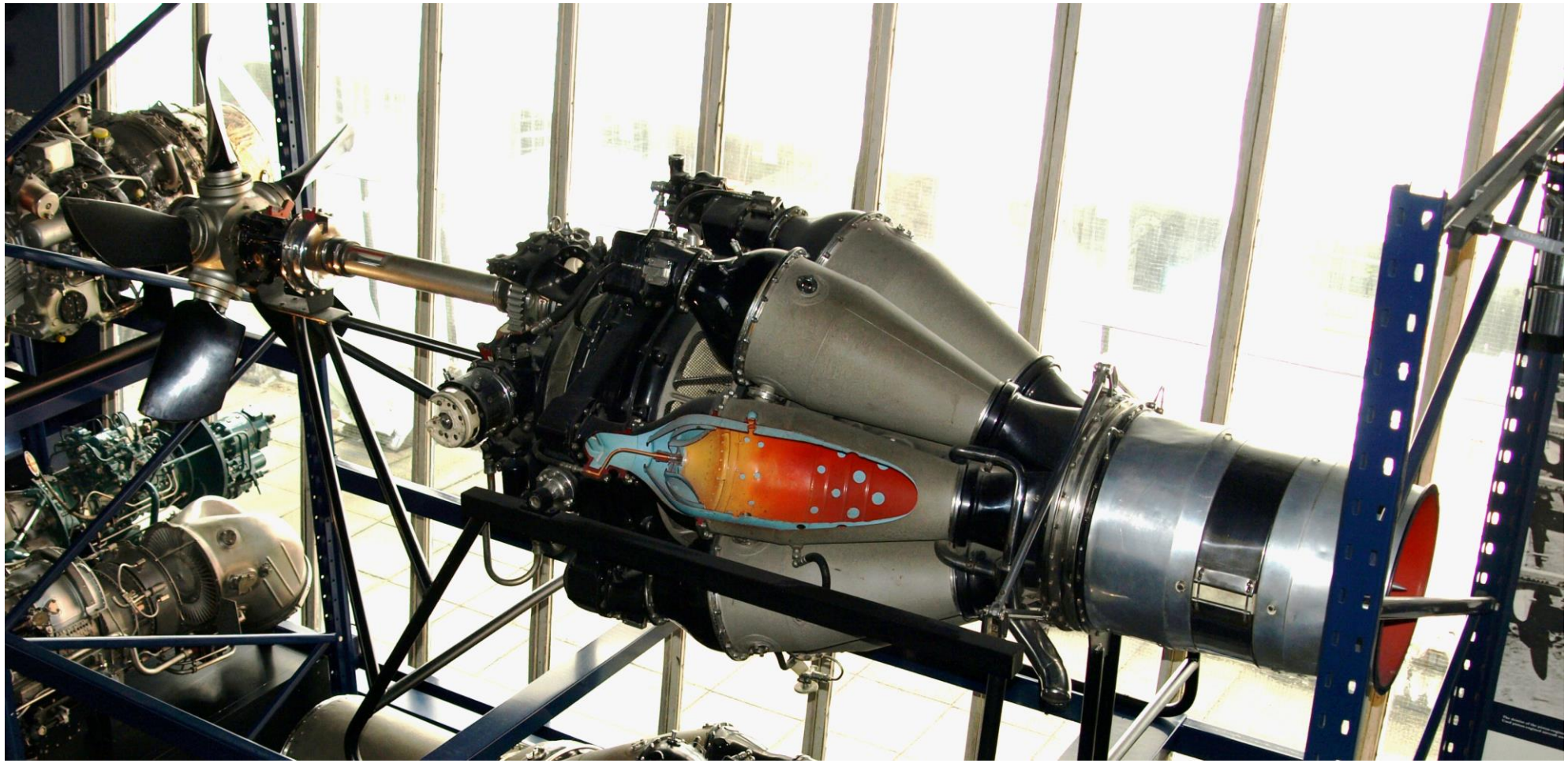
1 Introduction

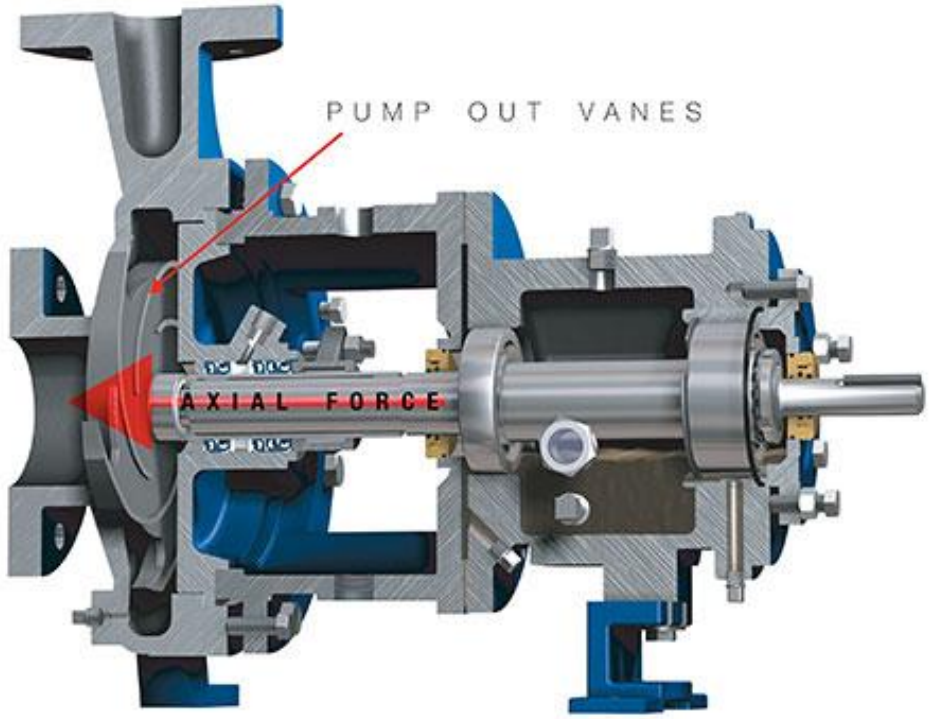
1. INTRODUCTION



https://en.wikipedia.org/wiki/Rolls-Royce_RB.50_Trent

1. INTRODUCTION

Árbol de levas VW Tiguan



https://www.pumpsandsystems.com/why-are-there-holes-my-new-impeller-part-1

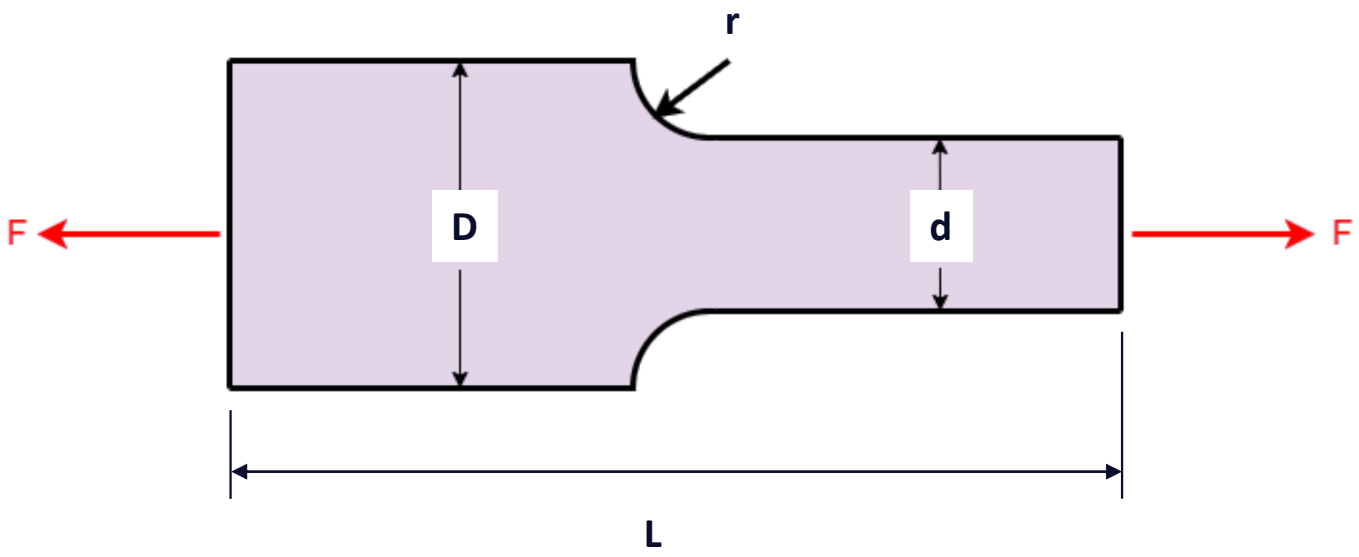
1. INTRODUCTION

https://hayn.com/cables/systems/architectural_adjuster_fork_system.html

https://blog.maxprocorp.com/the-difference-between-tension-shear-and-bending-joints

2 Problem Specification

2. PROBLEM SPECIFICATION



Value	Unit
$D = 100$	mm
$d = 75$	mm
$r = 10$	mm
$L = 400$	mm
$F = 3{,}0E5$	N

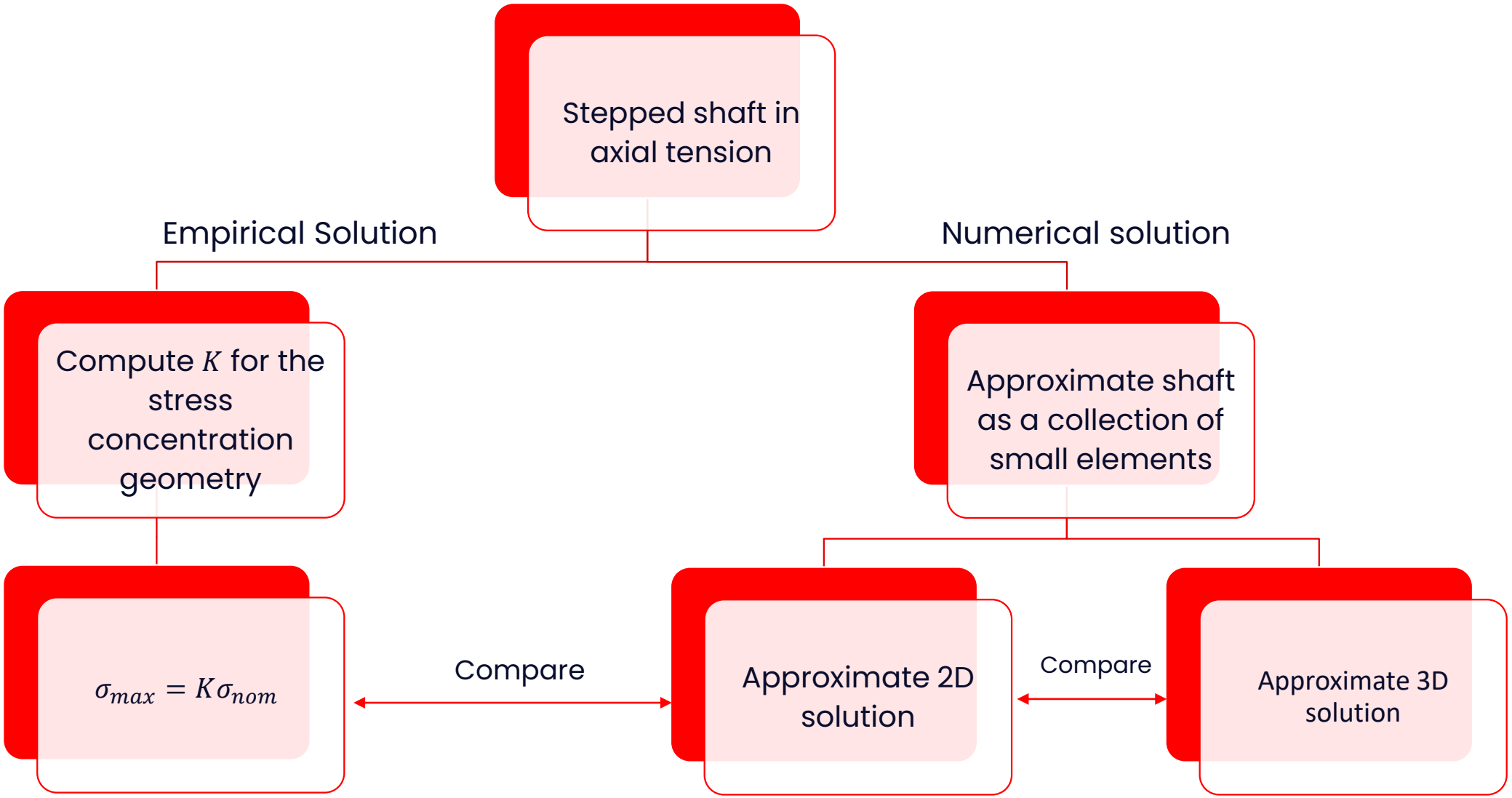
2. PROBLEM SPECIFICATION

AISI 4320 Normalized

Property	Value	Unit
Density	$7{,}9e3$	$\mathrm{kg/m^3}$
Young's Modulus	212	GPa
Poisson's rato	0,295	-
Yield Strength	515	MPa
Tensile Strength	875	MPa
Compressive Strength	515	MPa

3 Pre-Analysis

3. PRE-ANALYSIS



3. PRE-ANALYSIS

$$\sigma_{max} = K\sigma_{nom}$$

$$\sigma_{nom} = \frac{F}{A_{min}} = \frac{4F}{\pi d^2}$$

$$K = C_1 + C_2\frac{2h}{D} + C_3\left(\frac{2h}{D}\right)^2 + C_4\left(\frac{2h}{D}\right)^3$$

$$h = \frac{D-d}{2}$$

Roark's Formulas for Stress and Strain, Warren C. Young and Richard G. Budynas, 2002

$$C_1 = 1{,}225 + 0{,}831\sqrt{\frac{h}{r}} - 0{,}01\left(\frac{h}{r}\right)$$

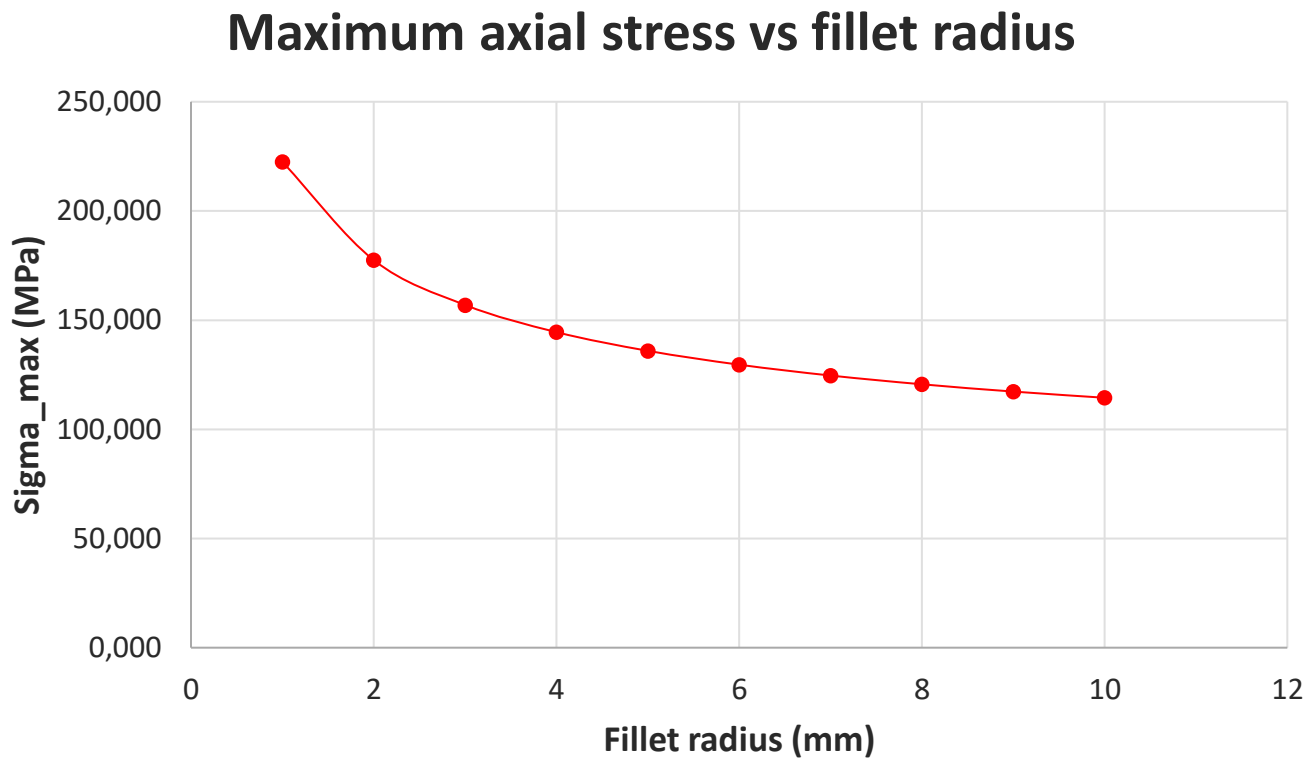
$$C_2 = -1{,}831 - 0{,}318\sqrt{\frac{h}{r}} - 0{,}049\left(\frac{h}{r}\right)$$

$$C_3 = 2{,}236 - 0{,}522\sqrt{\frac{h}{r}} + 0{,}176\left(\frac{h}{r}\right)$$

$$C_4 = -0{,}63 + 0{,}009\sqrt{\frac{h}{r}} - 0{,}117\left(\frac{h}{r}\right)$$

3. PRE-ANALYSIS

r (mm)	K	σ_{max} (MPa)
1	3,276	222,446
2	2,613	177,436
3	2,310	156,887
4	2,127	144,459
5	2,001	135,902
6	1,908	129,546
7	1,835	124,582
8	1,775	120,567
9	1,726	117,230
10	1,685	114,401



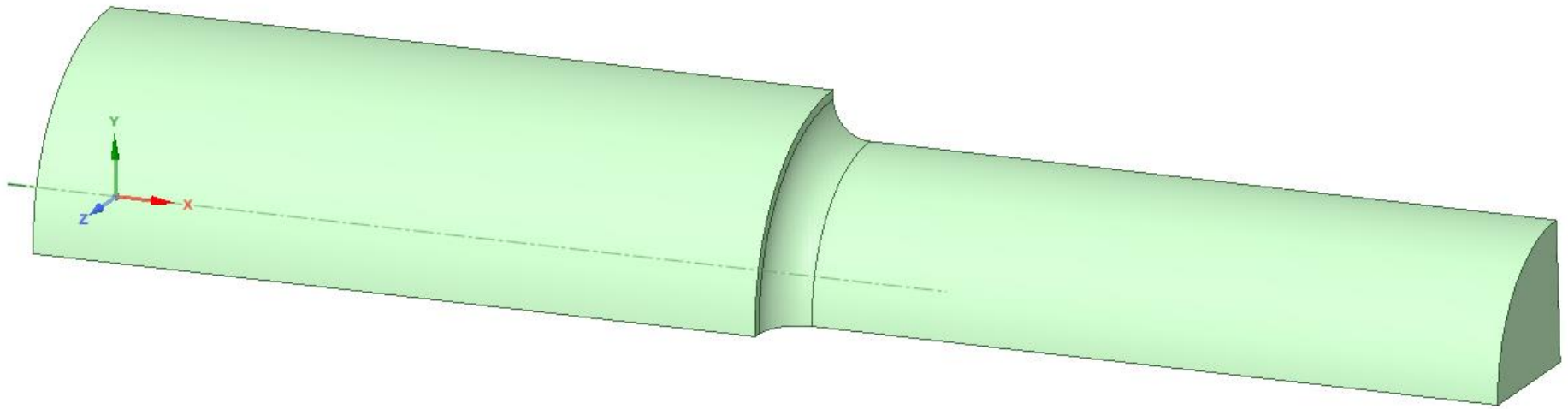
4 Geometry

4. GEOMETRY

2D - Symmetric

4. GEOMETRY

3D - Symmetric

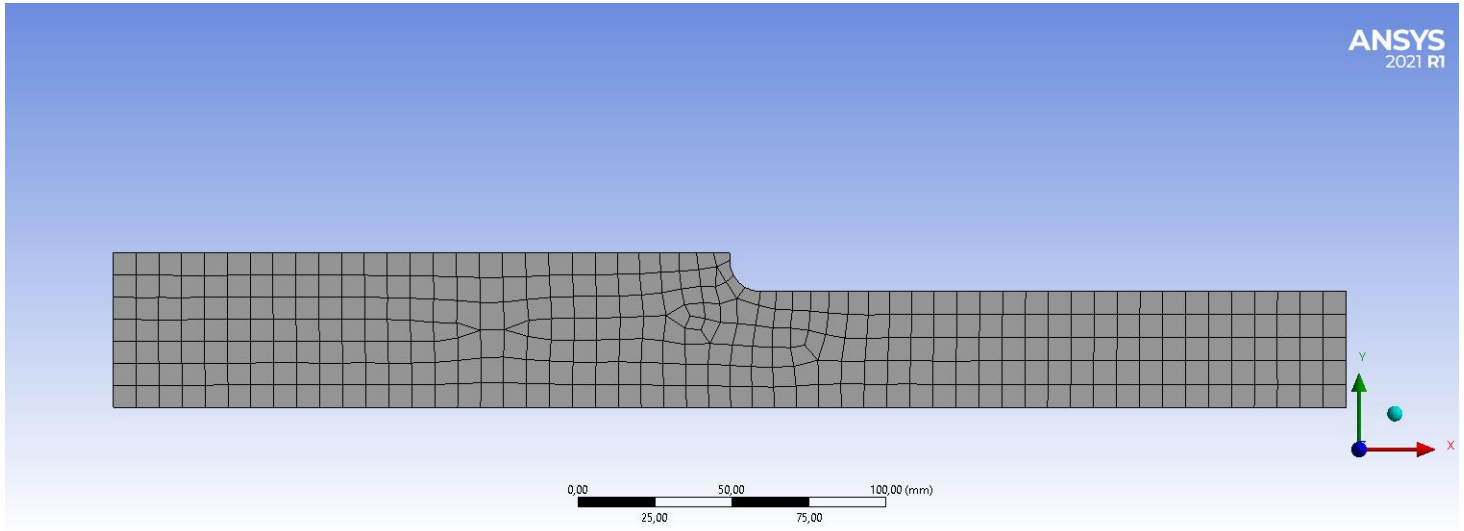


5 Mesh

5. MESH

2D-Mesh – nonlinear elements

- Tri-6
- Quad-8

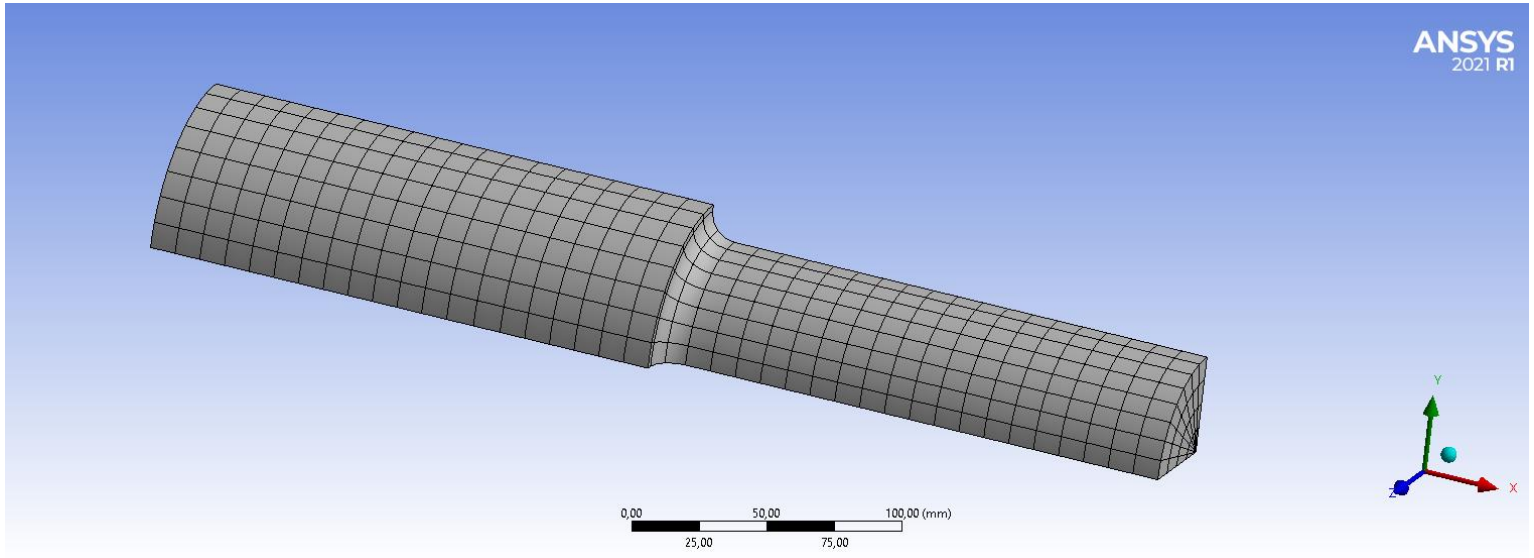


Face Sizing (mm)
7,5
5
3,33
2,22
1,48
0,99
0,66
0,44

5. MESH

3D-Mesh – nonlinear elements

- Hex-20
- Wed-15



Body Sizing (mm)
10
8
6
4
2,5
2
1,5
1

6 Physics Setup

6. PHYSICS SETUP

Material Assignment

Outline

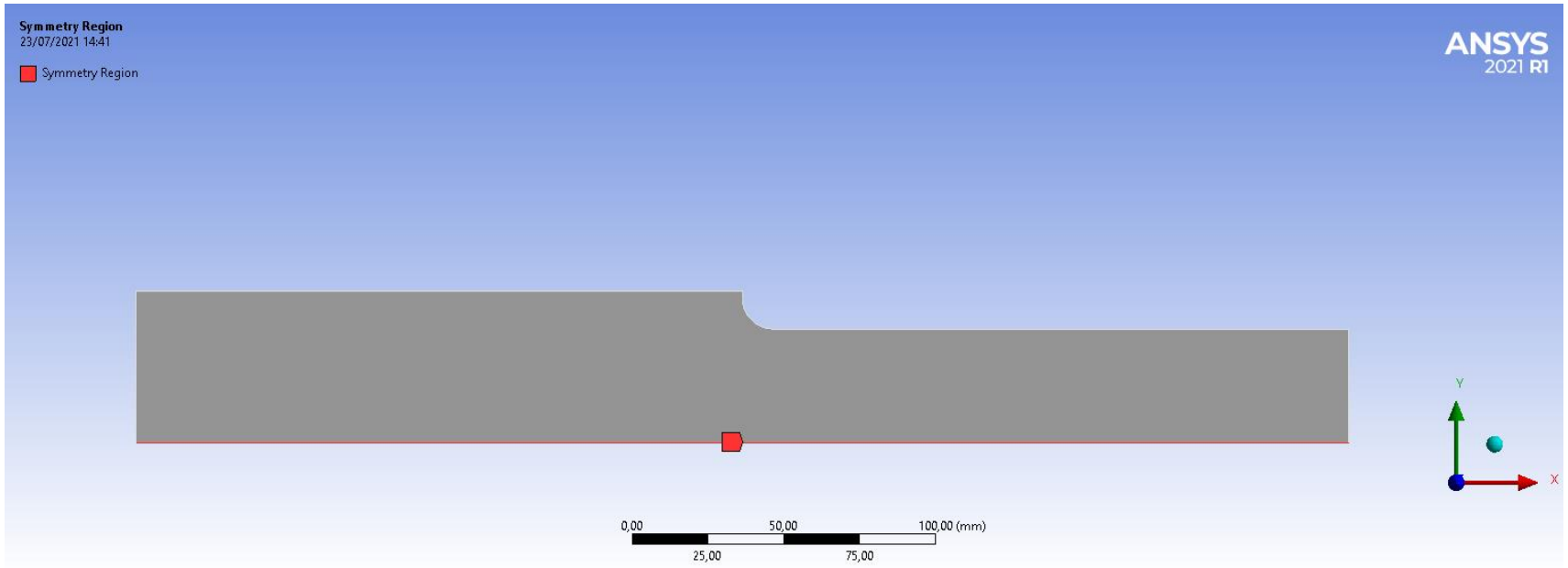
Name | Search Outline

- Project
  - Model (A4)
    - Geometry
      - SYS\Surface
    - Materials
    - Coordinate Systems
    - Symmetry
    - Mesh
    - Static Structural (A5)

Details of "SYS\Surface"

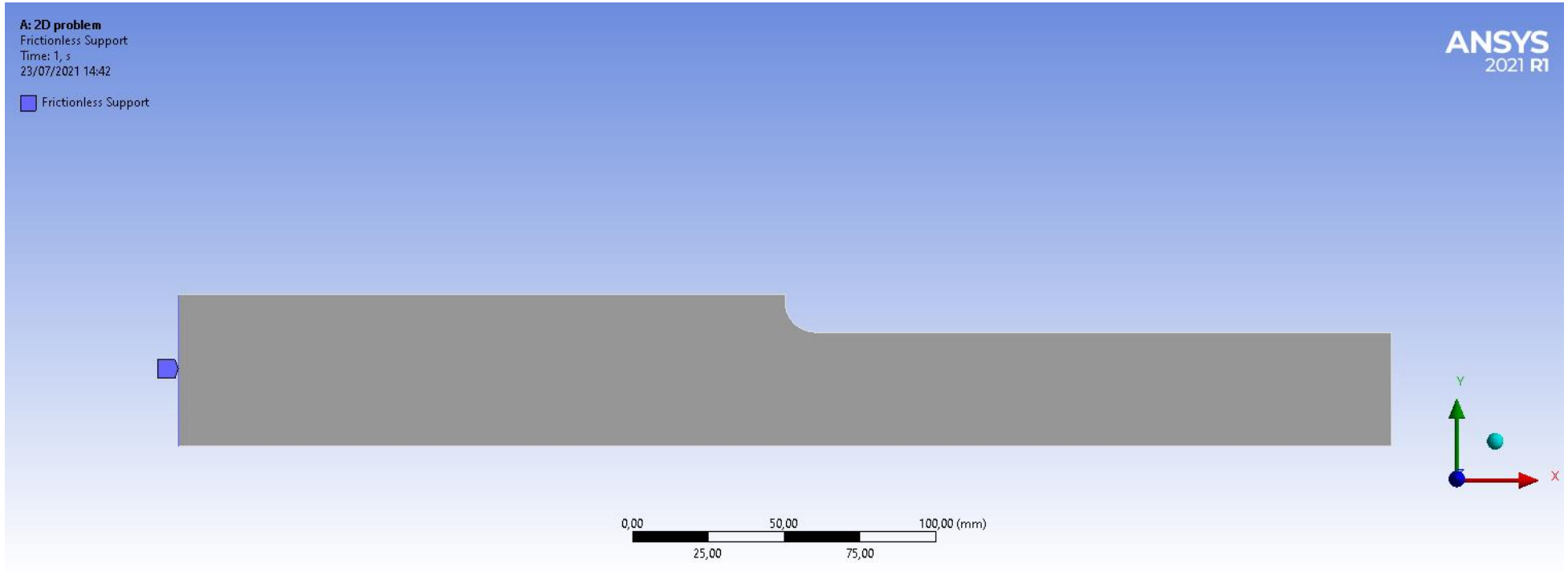
Graphics Properties	
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	AISI 4320
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Properties	
Statistics	
CAD Attributes	
PartTolerance:	0,00000001
Color:143.175.143	

Symmetry Region – 2D problem



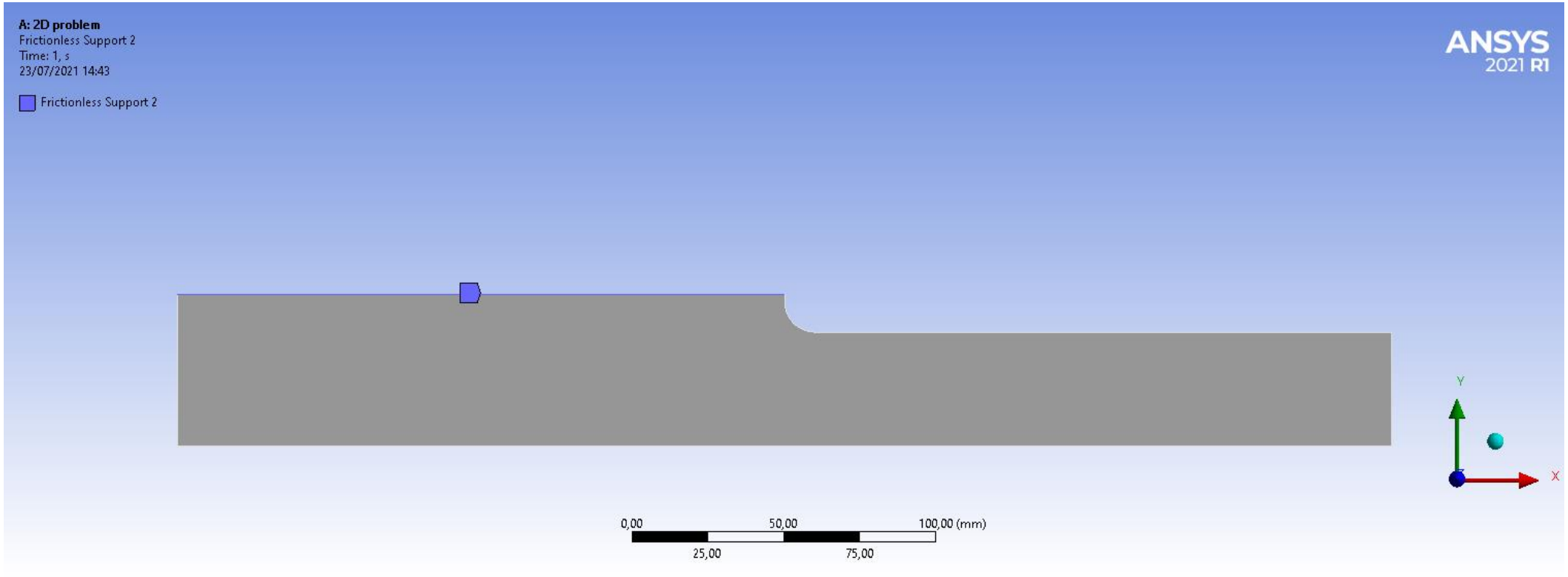
6. PHYSICS SETUP

Frictionless Support – 2D problem



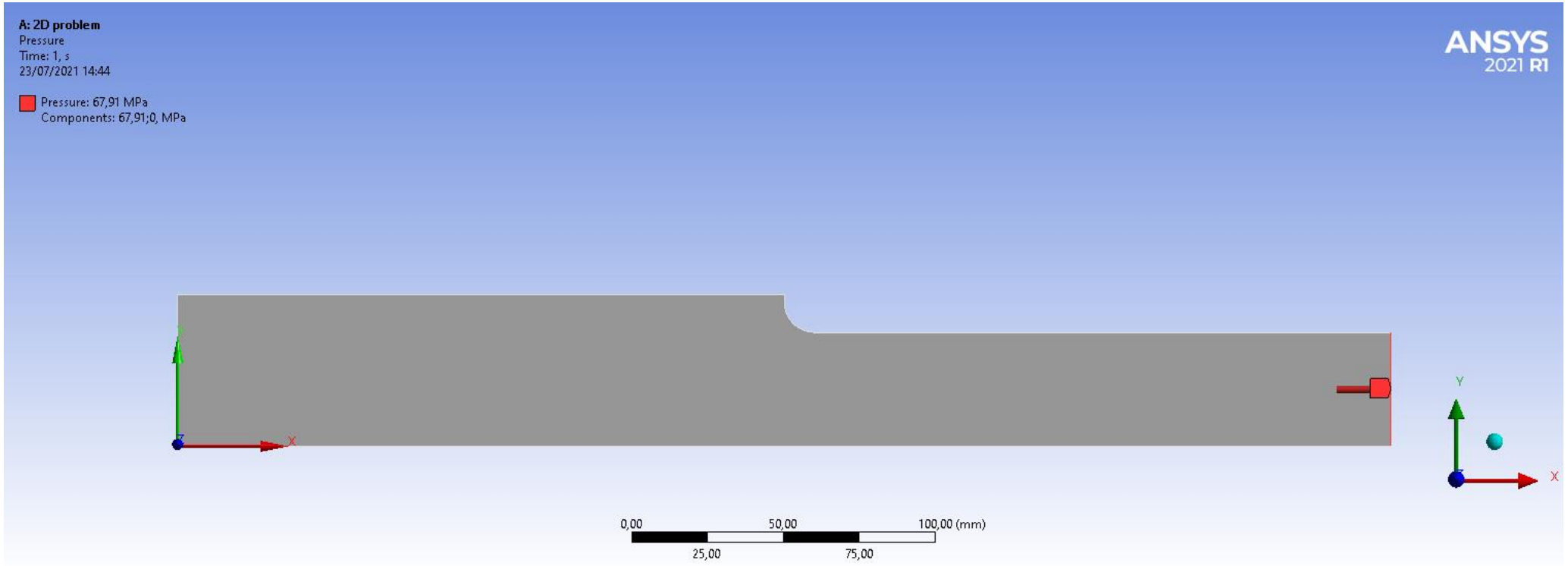
6. PHYSICS SETUP

Frictionless Support 2 – 2D problem



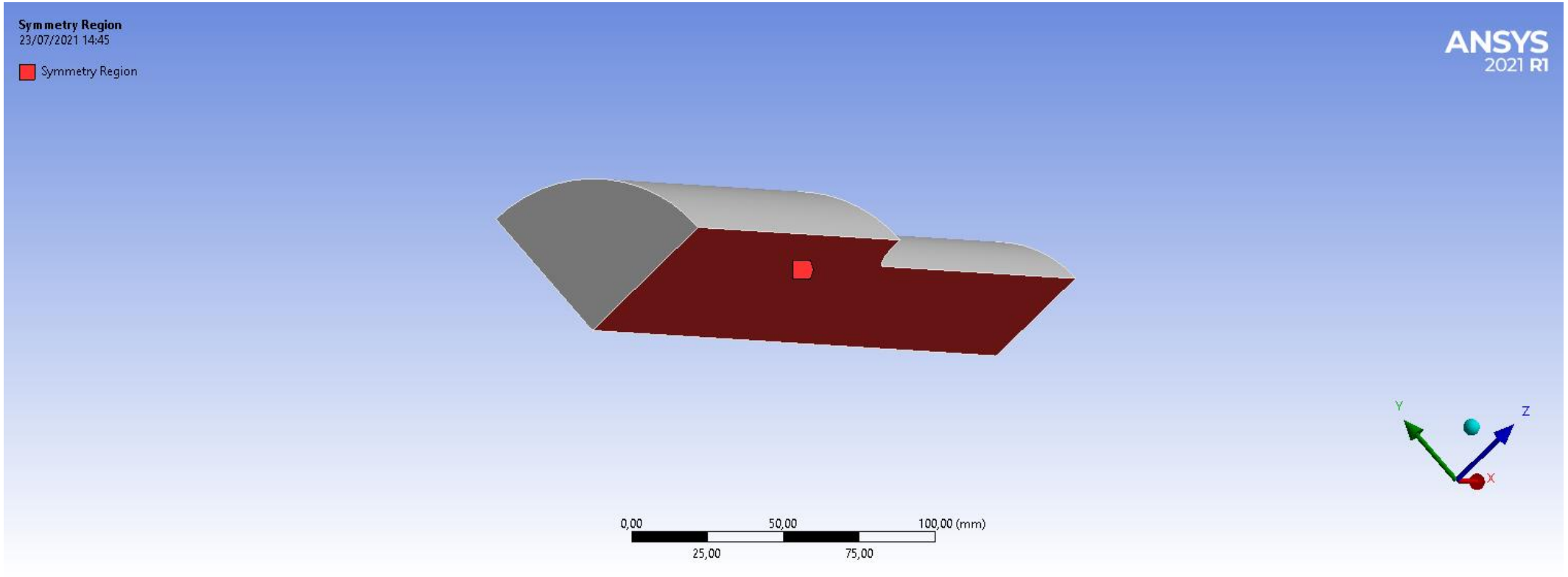
6. PHYSICS SETUP

Pressure = 67,91 MPa (2D Problem)



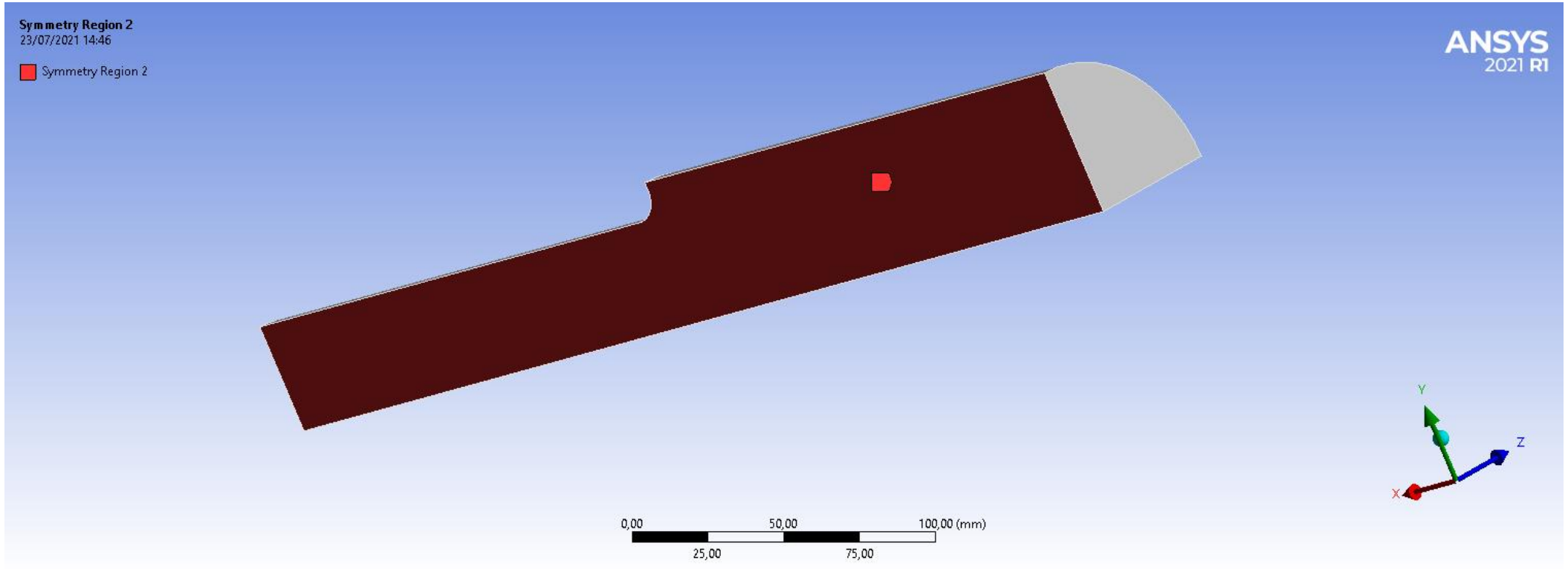
6. PHYSICS SETUP

Symmetry 1 – 3D problem



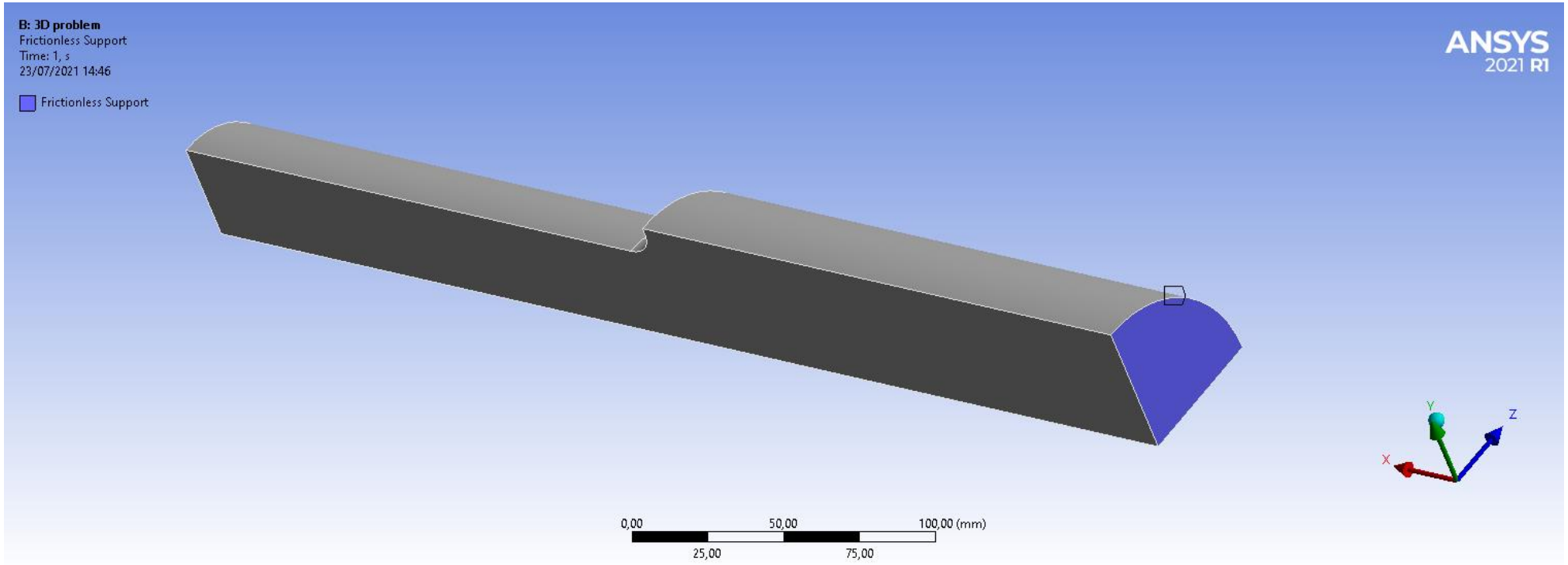
6. PHYSICS SETUP

Symmetry 2 – 3D problem



6. PHYSICS SETUP

Frictionless support – 3D problem



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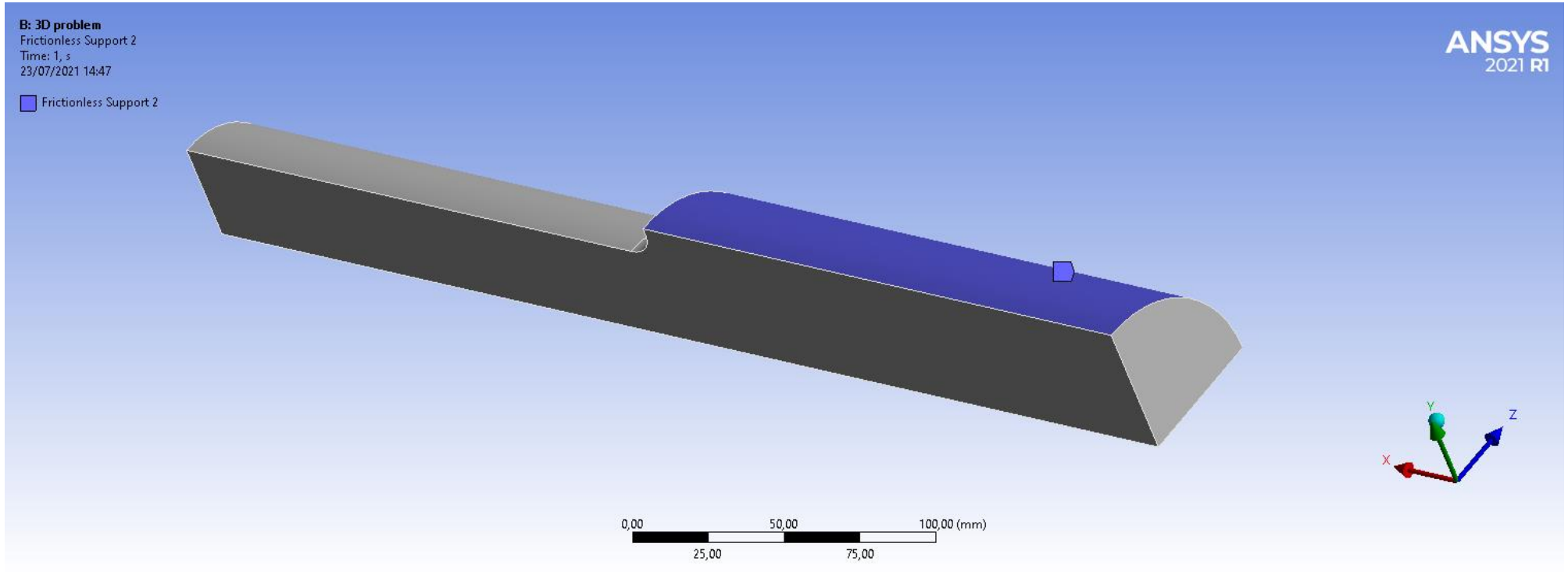
Frictionless support 2 – 3D problem



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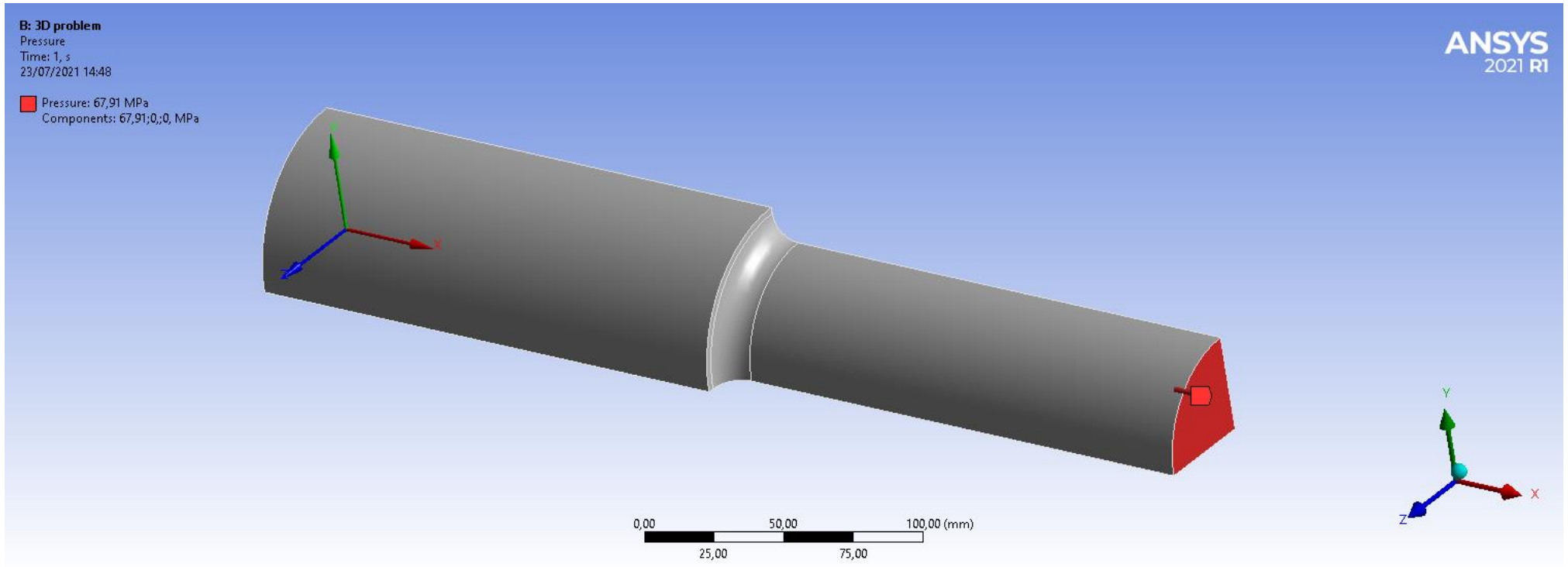
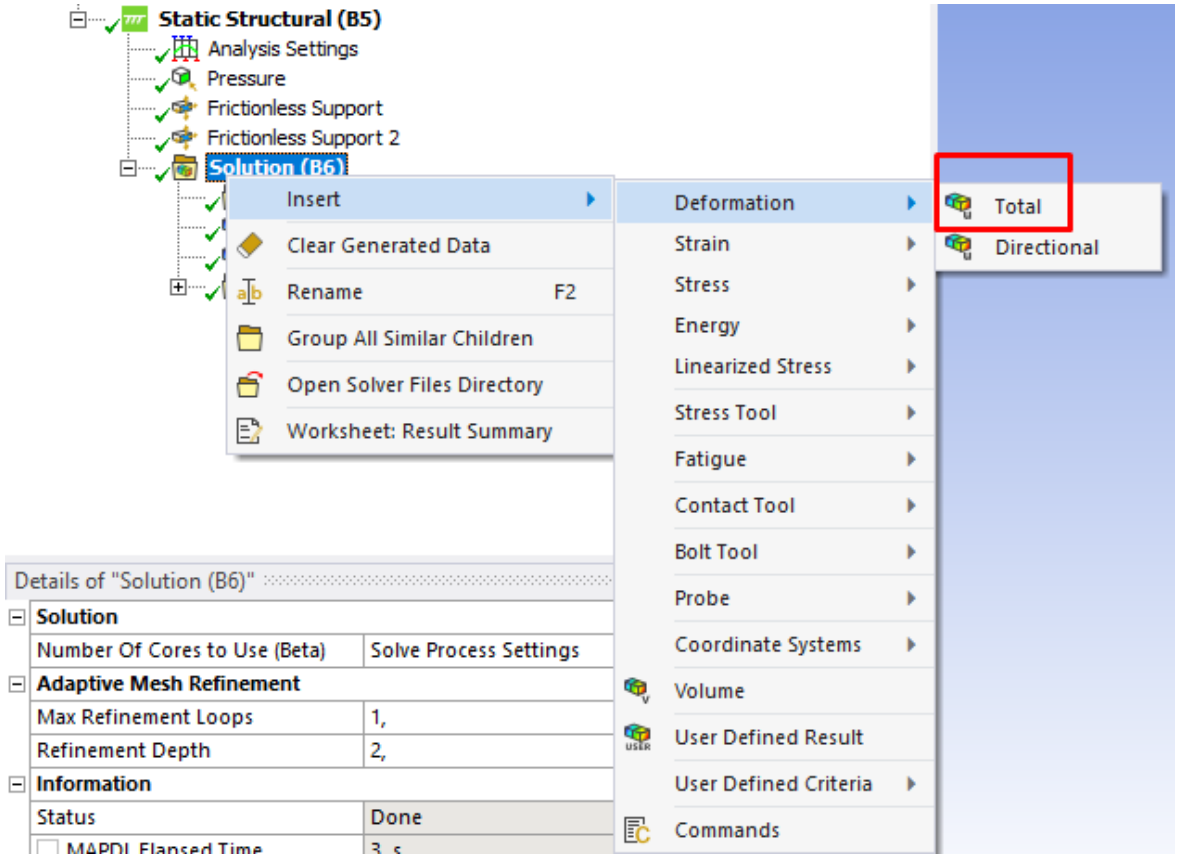
Pressure = 67,91 MPa (3D problem)



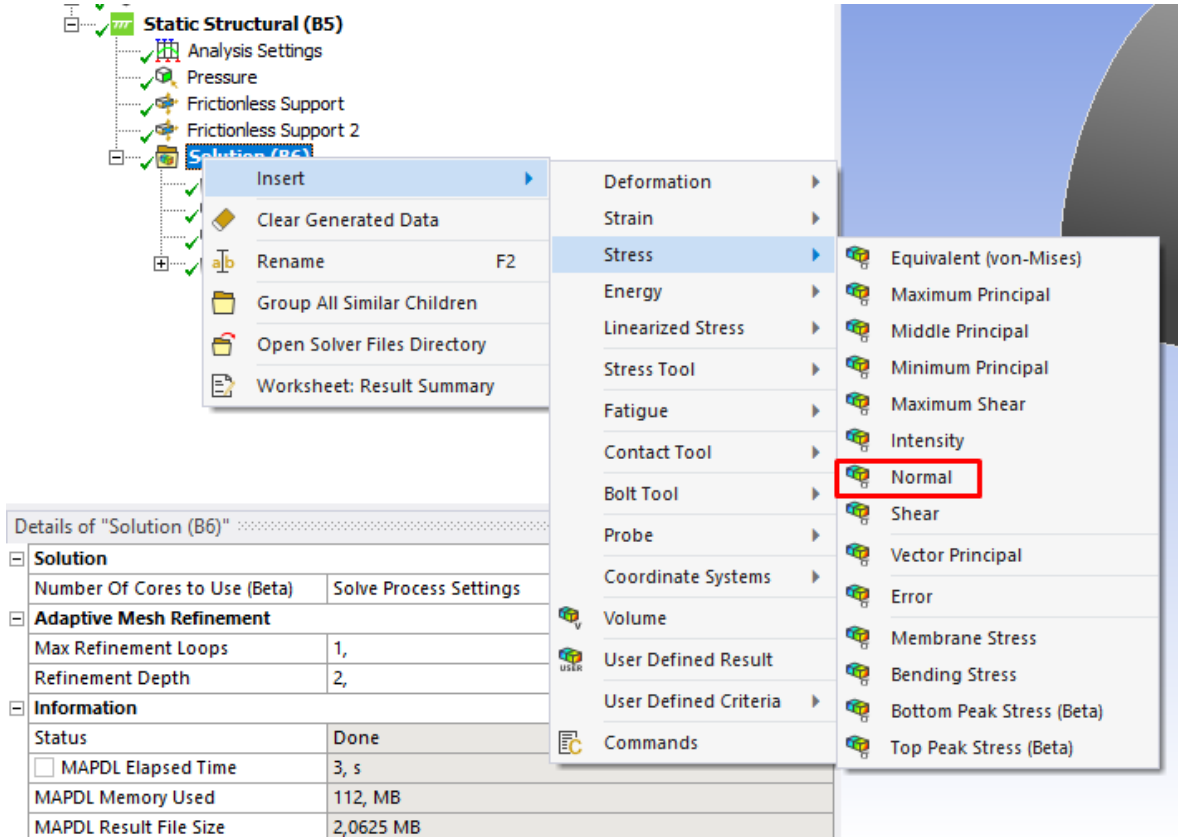
7 Numerical Solution

7. NUMERICAL SOLUTION

Displacement

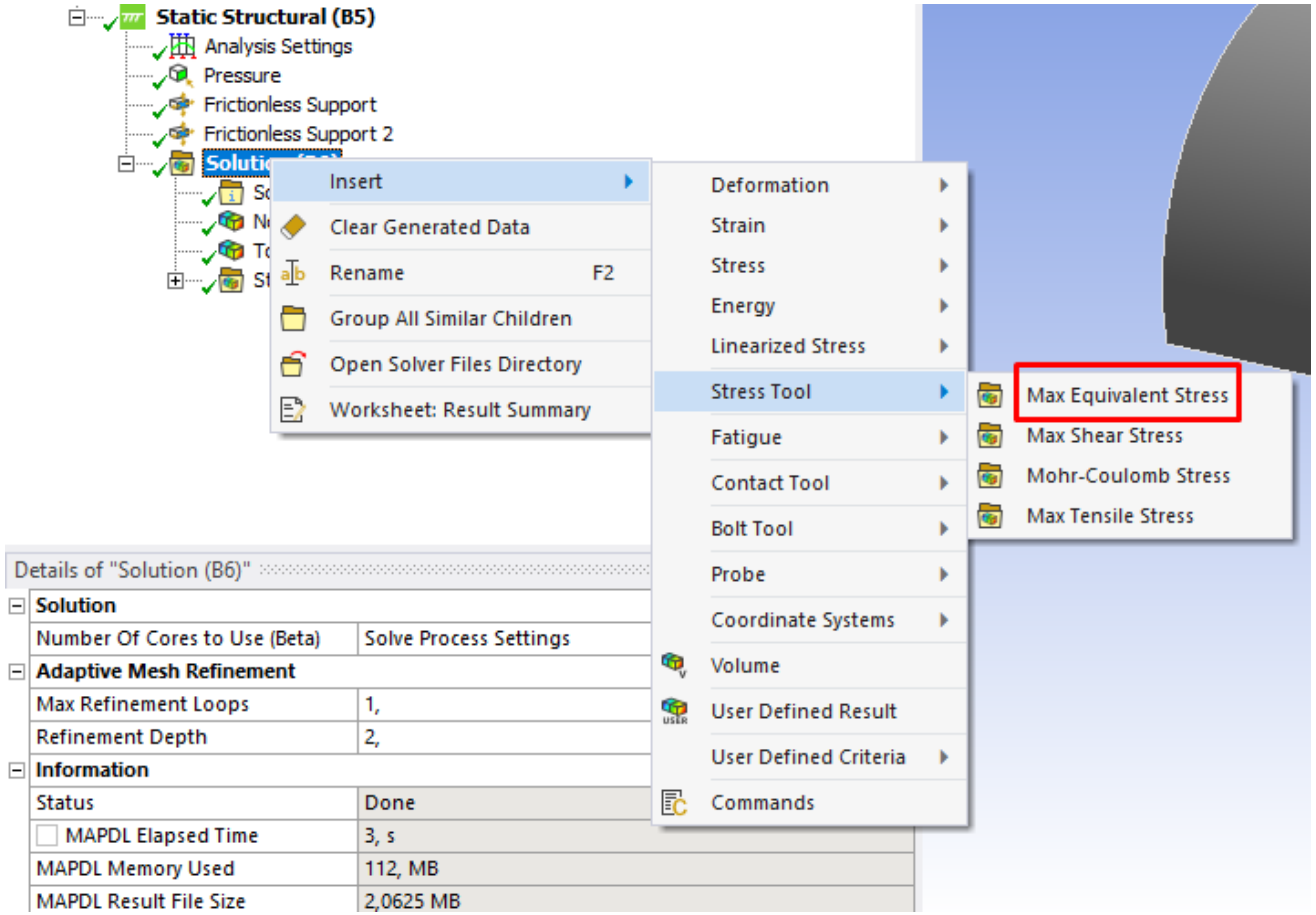


Normal Stress



7. NUMERICAL SOLUTION

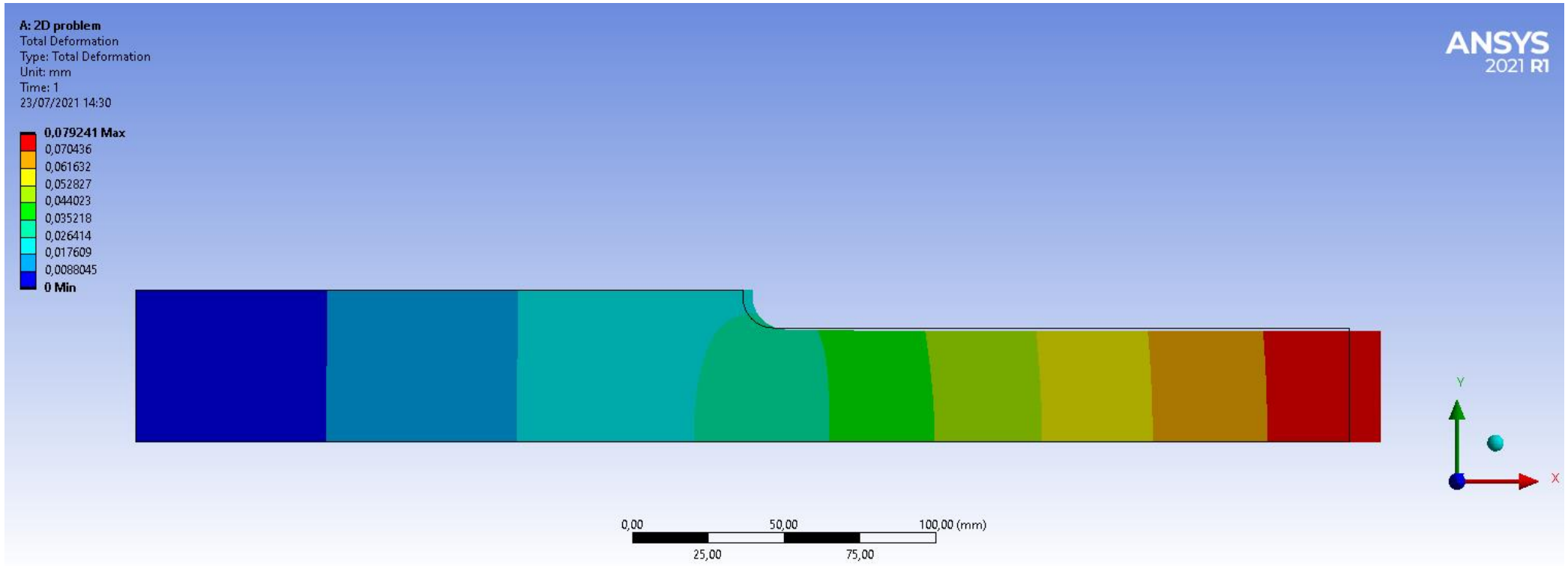
Safety Factor



8 Numerical Results

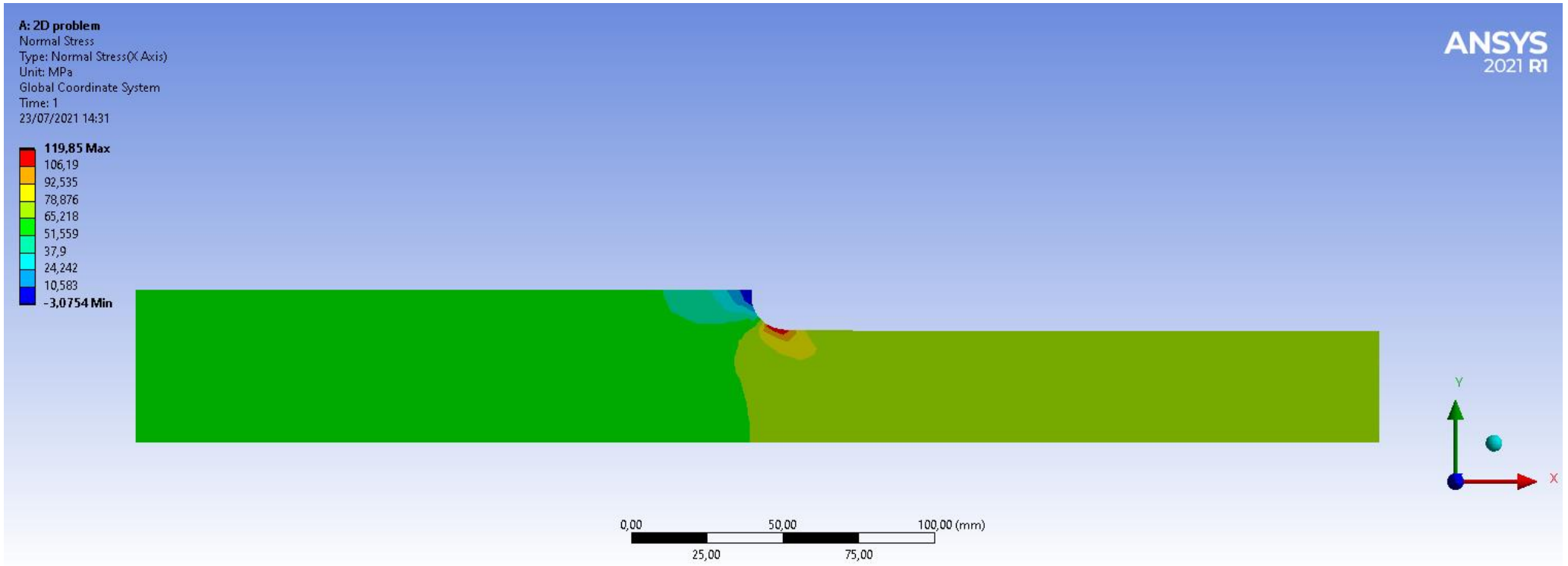
8. NUMERICAL RESULTS

Displacement 2D – Coarse Mesh



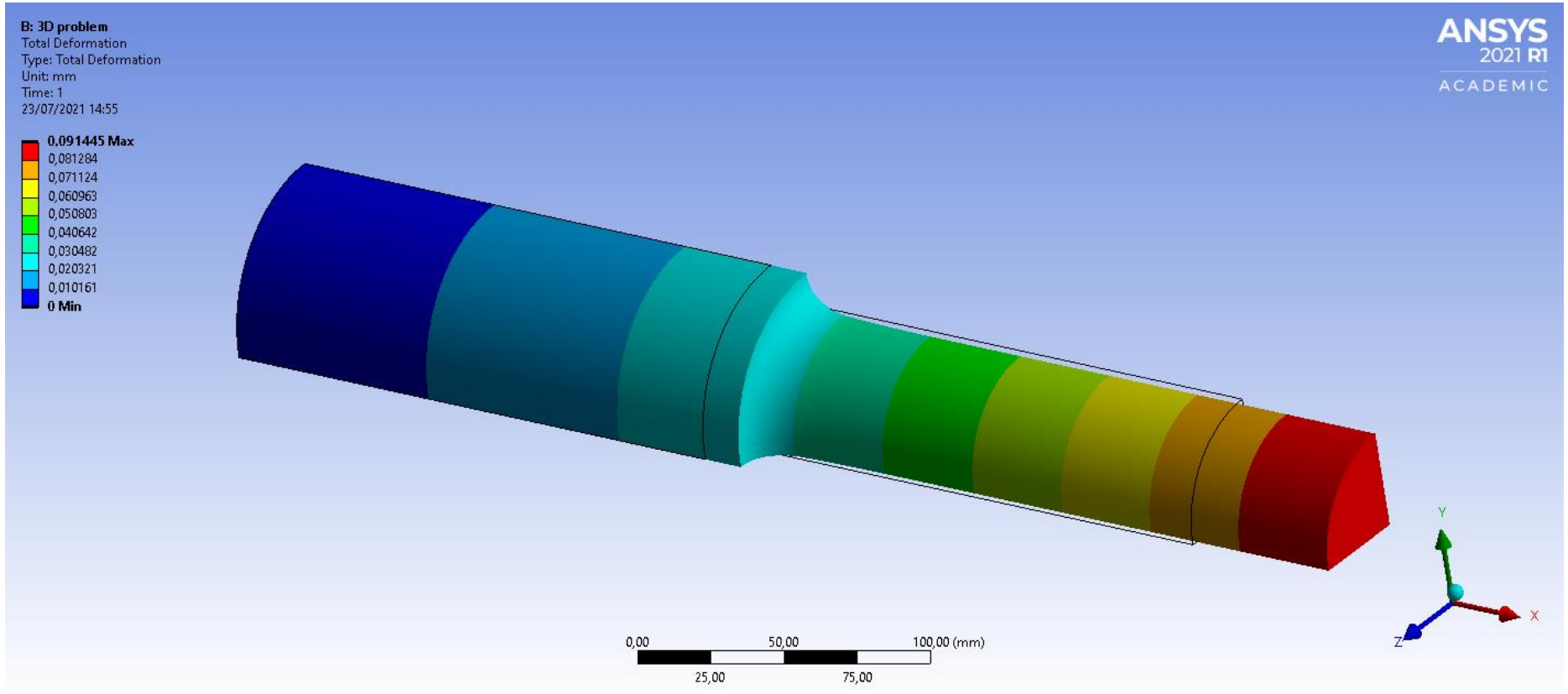
8. NUMERICAL RESULTS

Normal Stress 2D – Coarse Mesh



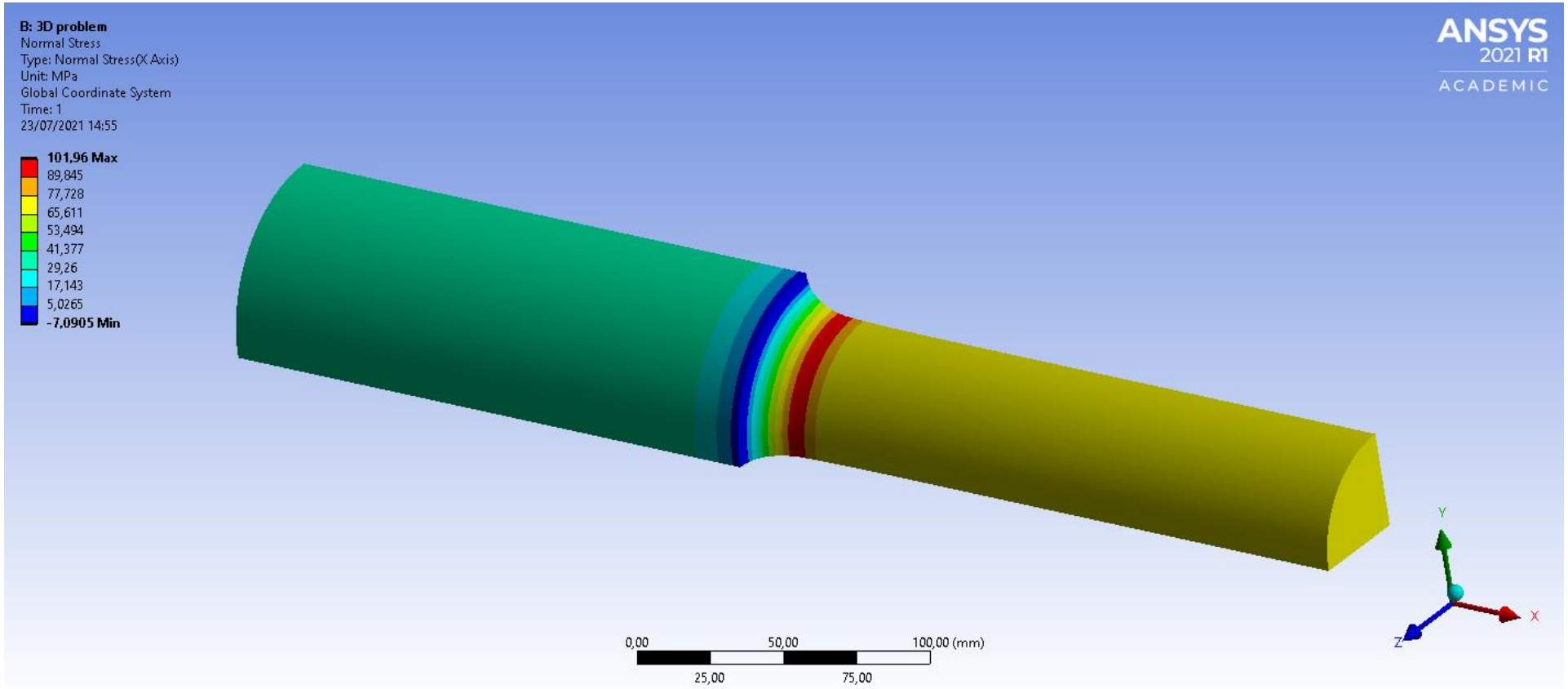
8. NUMERICAL RESULTS

Displacement 3D – Coarse Mesh



8. NUMERICAL RESULTS

Normal Stress 3D – Coarse Mesh



9 Verification

9. VERIFICATION

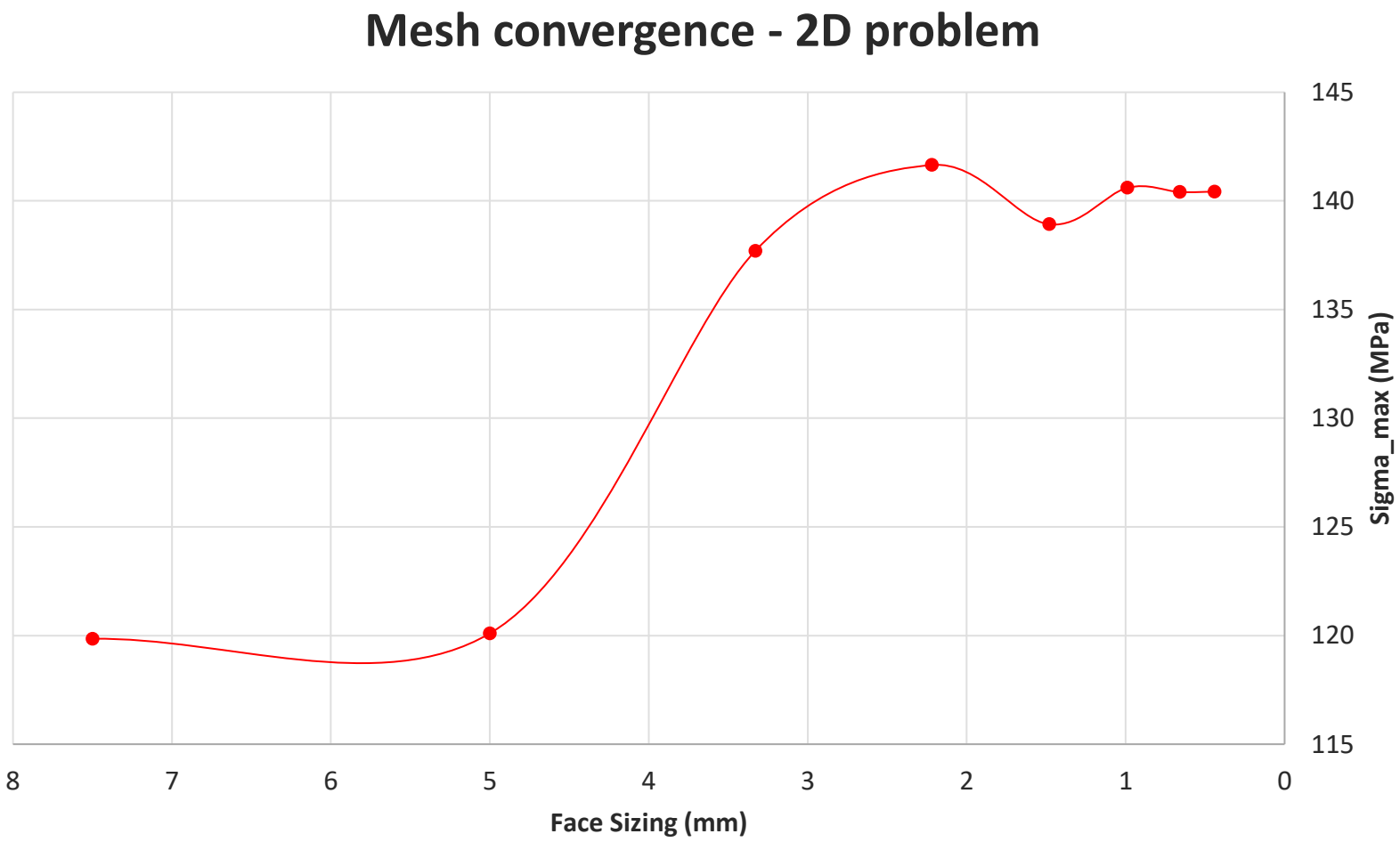
Results for r = 10 mm (Coarser mesh)

Empirical	2D problem	3D problem
114,401 MPa	119,85 MPa	101,96 MPa
-	4,76 %	10,87 %

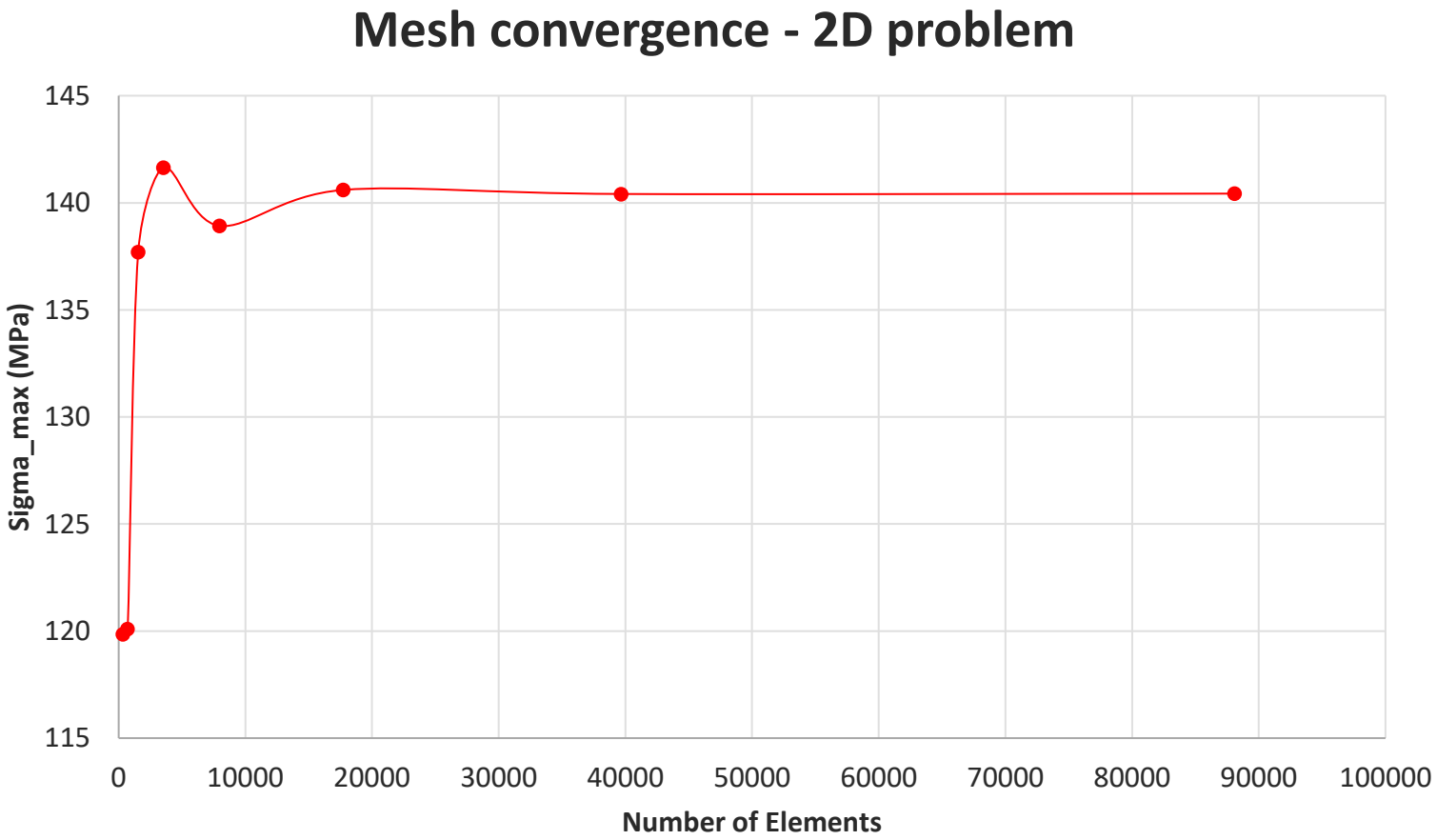
Results for r = 10 mm (Finer mesh)

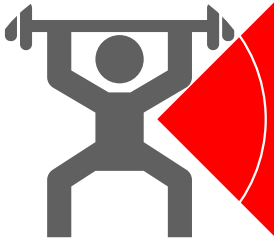
Empirical	2D problem	3D problem
114,401 MPa	140,43 MPa	117,35 MPa
-	22,75 %	2,58 %

9. VERIFICATION



9. VERIFICATION





Exercises

EXERCICES

1. Based on the safety factor, find the minimum fillet radius.
2. Do a parametric analysis and plot the maximum normal stress versus the fillet radius.
3. Do a mesh convergence analysis using parametric analysis.
4. What happens if we change the material?
5. How can we reduce the maximum stress without changing either diameters and fillet radius?