

Vessel Systems (S.03.06) Shield Block Cooling

Min-Tsung Kao

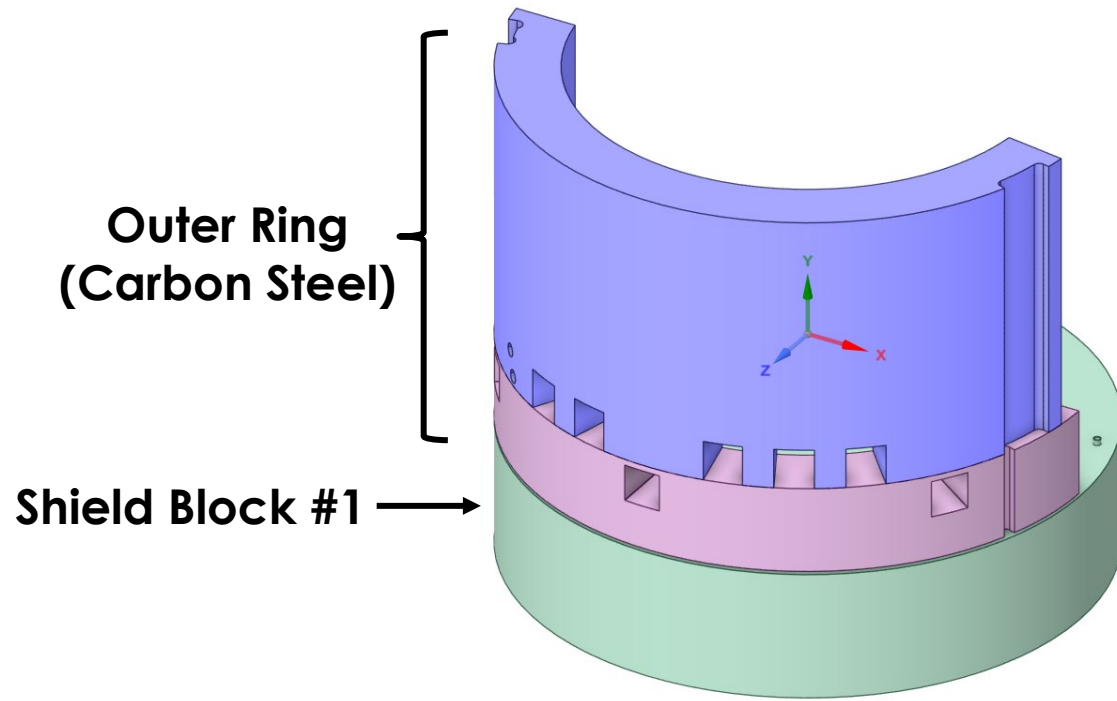
11/25/2024

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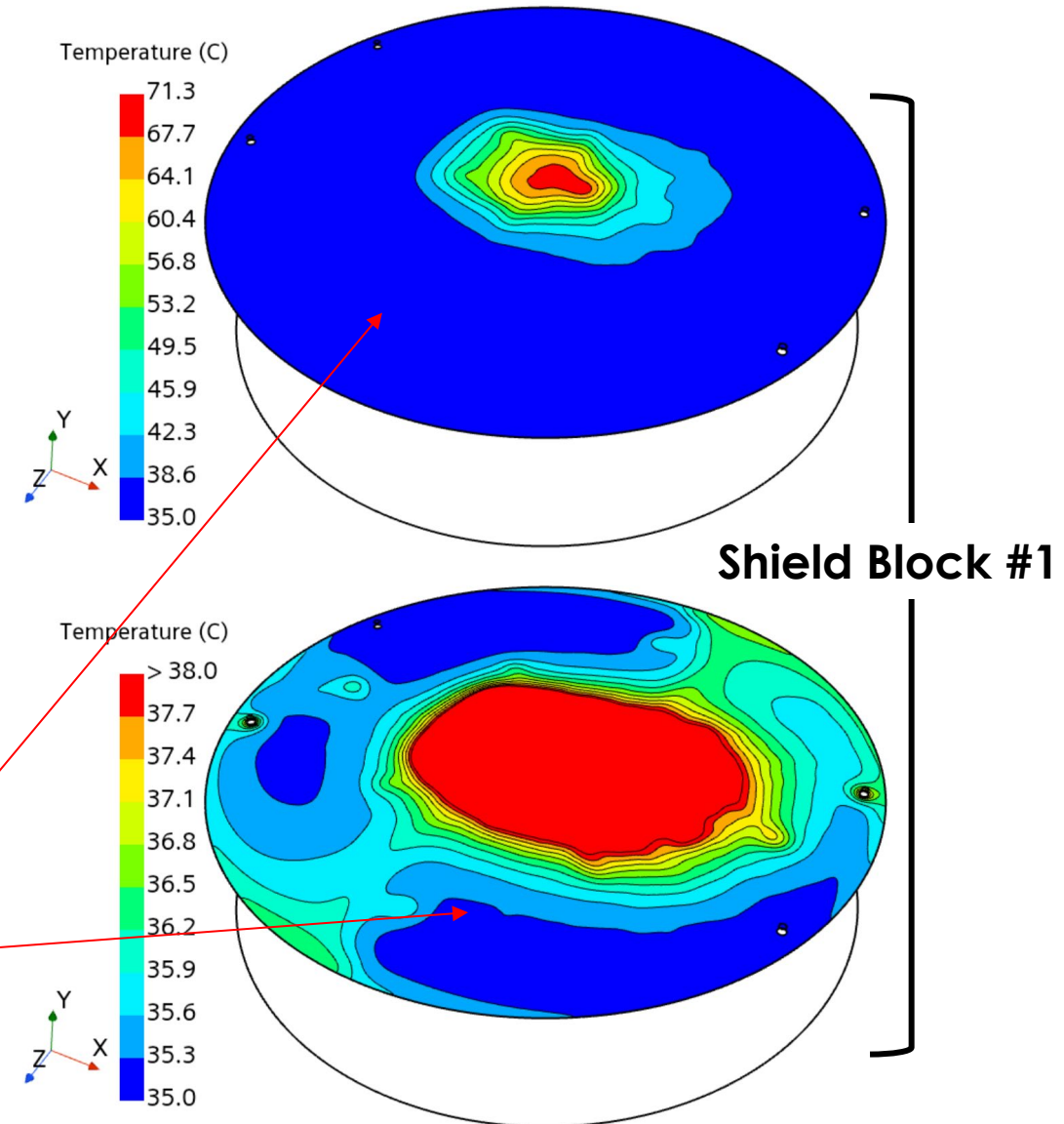


U.S. DEPARTMENT OF
ENERGY

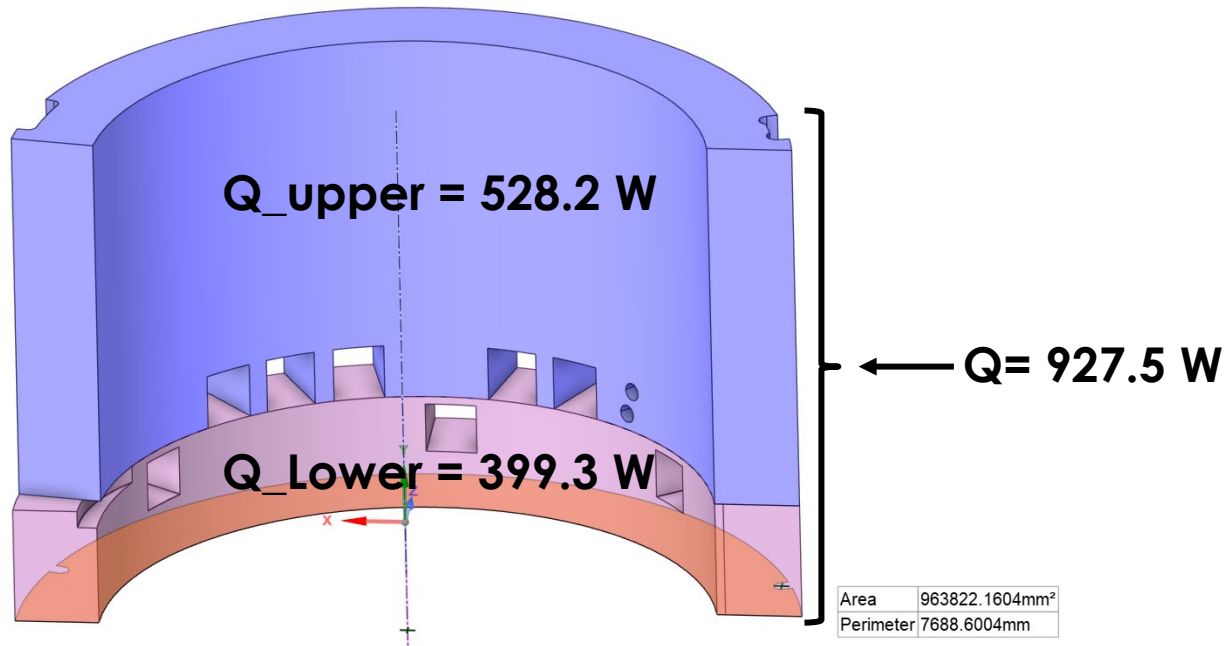
Top Surface Temperature of Shield Block #1 and Outer Ring



Outer ring is sitting on top of block #1.
The top surface of shield block #1 is
around **36.8°C**.



Shield Block Outer Ring, Carbon Steel



Bottom surfaces at 43.5°C

$$\text{Area} = 963822 \text{ mm}^2$$

$$q'' = 927.5\text{W}/0.96382\text{m}^2 = 962.3 \text{ W/m}^2$$

Assume the thermal resistance at the bottom surface: $R = 0.0069 \text{ m}^2 - \text{K/W}$ (from previous bottom shield block evaluation)

$$\Delta T = R \cdot q'' = 0.0069 \cdot 962.3 = 6.6 \text{ }^\circ\text{C}$$

(Across the contact interface)

$$\Rightarrow 36.8 + 6.6 = 43.4 \text{ }^\circ\text{C}$$

$$\text{Area} = 963822.1604 \text{ [mm}^2\text{]}$$

$$Q = 927.4887 \text{ [W]}$$

$$qflux = \frac{Q}{\text{Area}} = \left[\frac{\text{W}}{\text{m}^2} \right] = 962.30273395569 \left[\frac{\text{W}}{\text{m}^2} \right]$$

$$R = 0.0069 \left[\text{m}^2 \cdot \frac{\text{K}}{\text{W}} \right]$$

$$dT = R \cdot qflux = 6.63988886429426 \text{ [K]}$$

Material Property

Carbon steel, 1020, annealed Material Properties From Ansys (also used for STARCCM+ CFD Analysis)

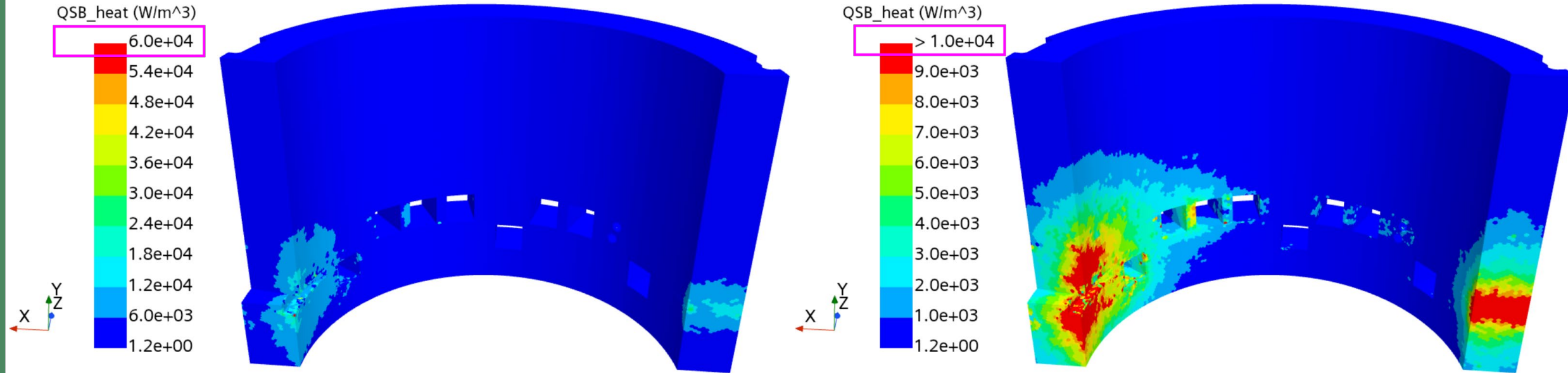
Carbon steel, AISI 1020, annealed
Data compiled by Ansys Granta, incorporating various
sources including JAHM and MagWeb.

Density (kg/m ³)	7850
Coefficient of Thermal Expansion (1/K)	1.143E-05
Specific Heat (J/kg-K)	501.8
Thermal Conductivity (W/m-K)	54.1
Young's Modulus (MPa)	2.124E5
Poisson's Ratio	0.29
Bulk Modulus (MPa)	1.6857E5
Shear Modulus (MPa)	82326
Tensile Ultimate Strength (MPa)	393
Tensile Yield Strength (MPa)	293.5

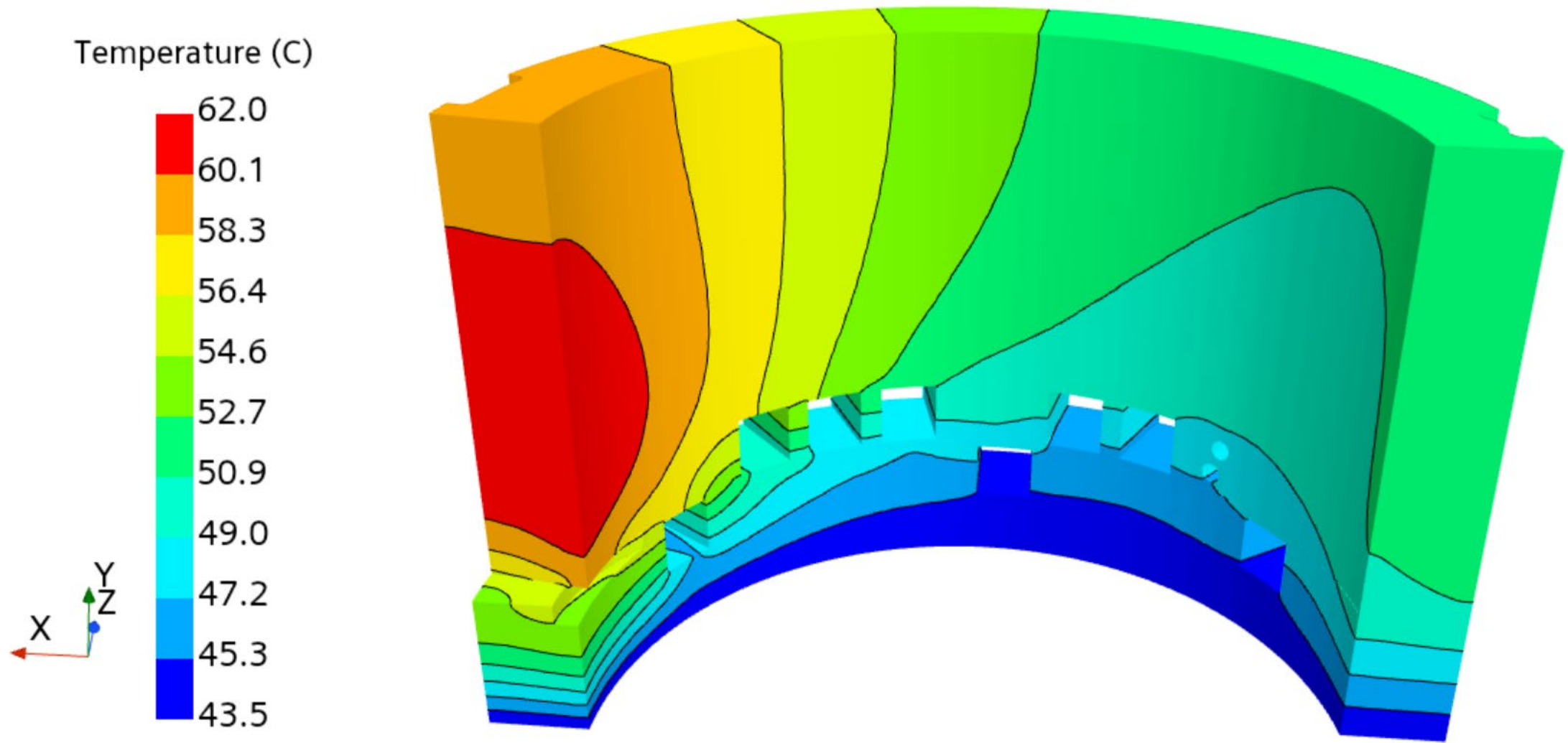
Environment Temperature : 35°C

Shield Block Outer Ring, Heat Source

$$Q = 927.5 \text{ W}$$



Shield Block Outer Ring, Carbon Steel Temperature



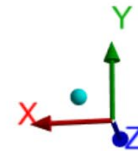
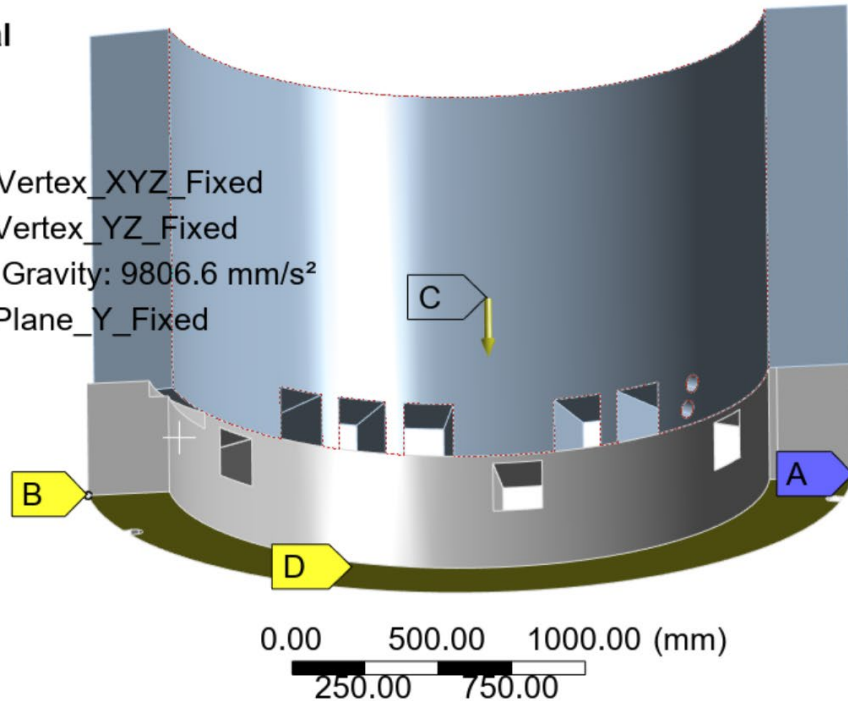
Shield Block Outer Ring, Carbon Steel Structural BCs

B: Static Structural

Static Structural

Time: 1. s

- A** Fixed Support_VerTEX_XYZ_Fixed
- B** Displacement_VerTEX_YZ_Fixed
- C** Standard Earth Gravity: 9806.6 mm/s²
- D** Displacement_Plane_Y_Fixed



- BC-A: Point fixed in x, y and z directions
 - Reference point
- BC-B: point can only move in x direction
 - Fixed in y : Block rests on flat surface
 - Fixed in z : symmetric, no rotation
- BC-D: Plane fixed in y
 - Block rests on flat surface
- BC-C: Gravity (-y direction)

Shield Block Outer Ring, Von Mises Stress

B: Static Structural

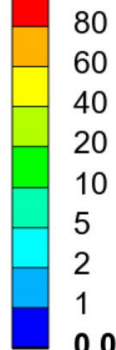
Equivalent Stress

Type: Equivalent (von-Mises) Stress

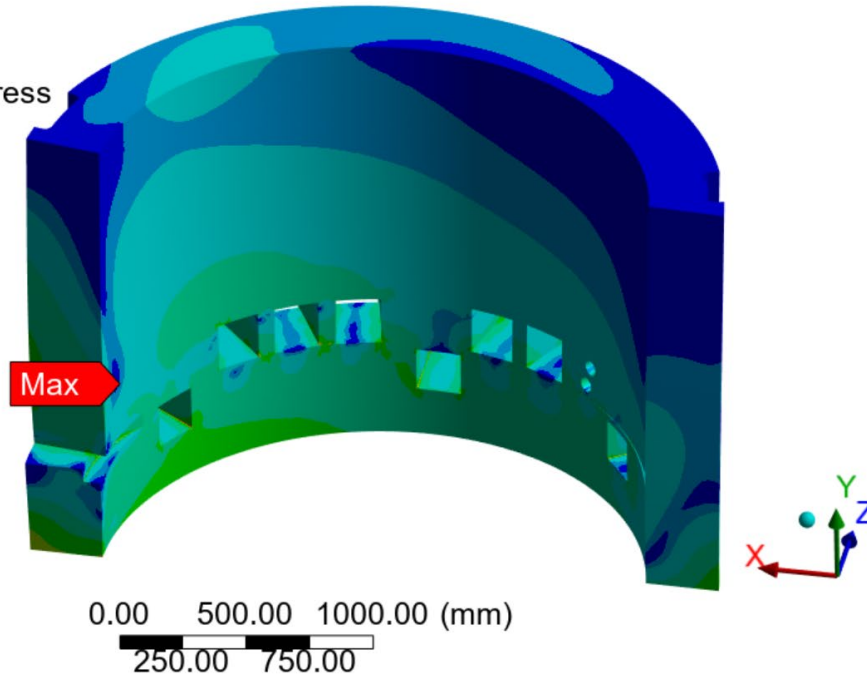
Unit: MPa

Time: 1 s

98.155 Max



0.00054914 Min



B: Static Structural

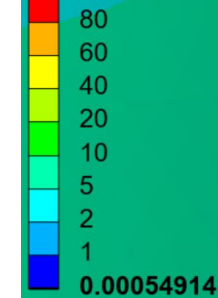
Equivalent Stress

Type: Equivalent (von-Mises) Stress

Unit: MPa

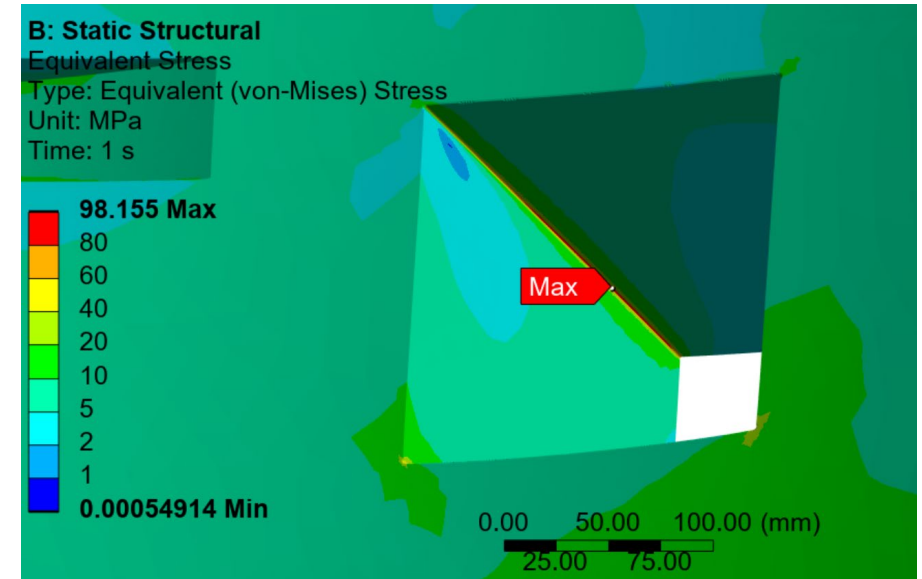
Time: 1 s

98.155 Max



0.00054914 Min

0.00 50.00 100.00 (mm)
25.00 75.00



B: Static Structural

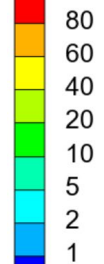
Equivalent Stress

Type: Equivalent (von-Mises) Stress

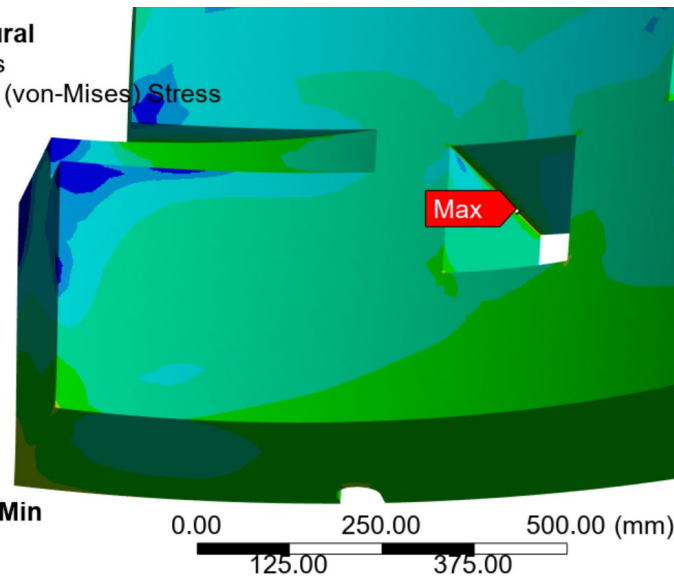
Unit: MPa

Time: 1 s

98.155 Max



0.00054914 Min



B: Static Structural

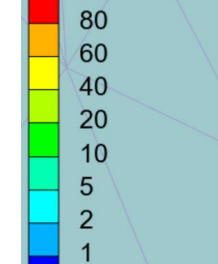
Equivalent Stress

Type: Equivalent (von-Mises) Stress

Unit: MPa

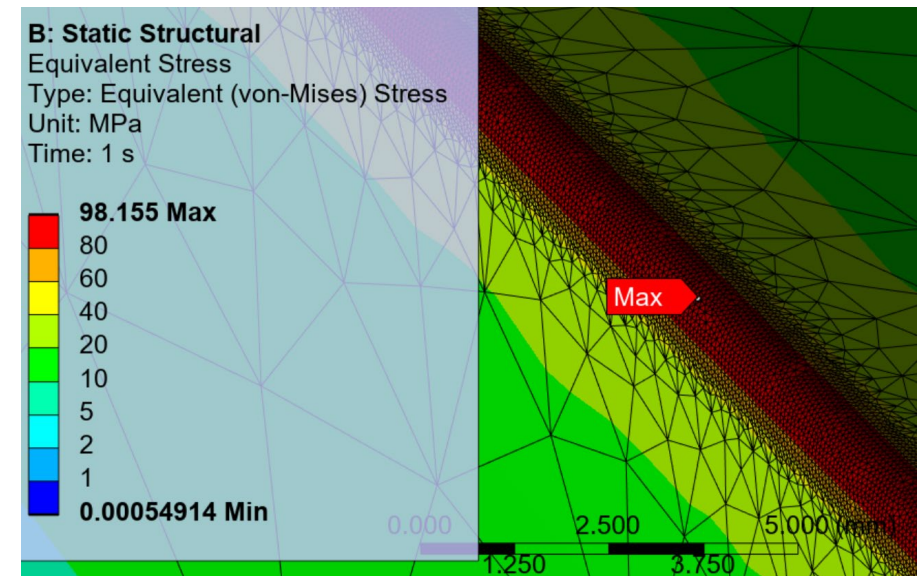
Time: 1 s

98.155 Max



0.00054914 Min

0.000 2.500 5.000 (mm)
1.250 3.750

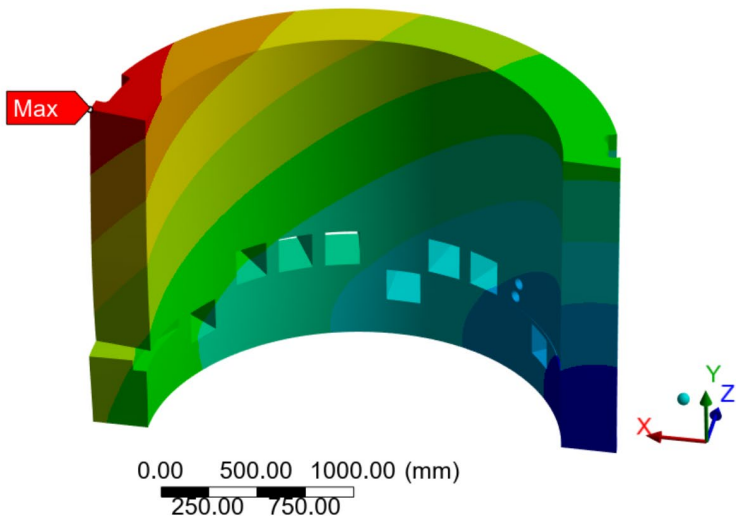
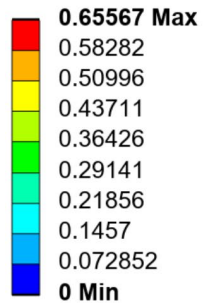


Displacement

Deformation scale = 3.6E2

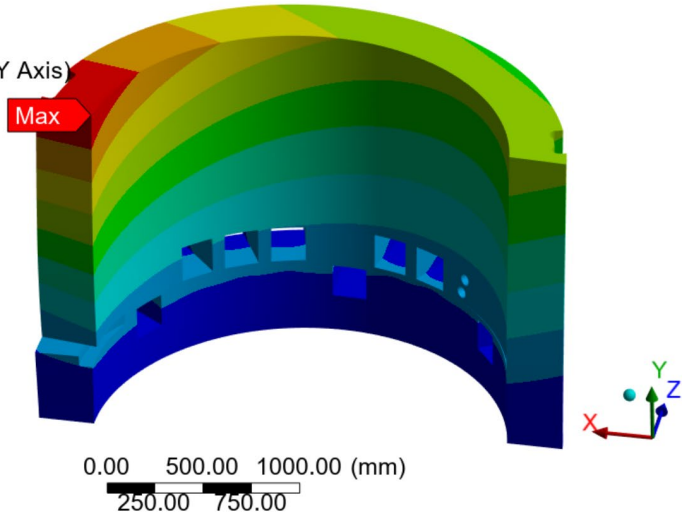
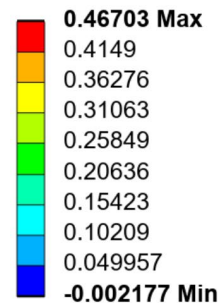
Total Deformation

B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s



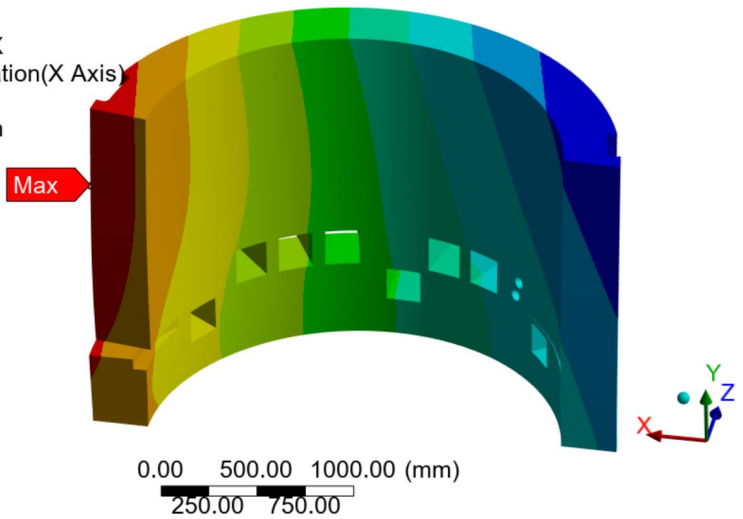
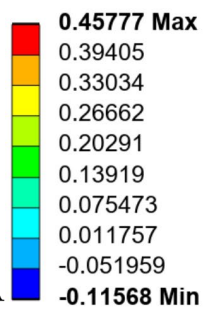
Y - Deformation

B: Static Structural
Directional Deformation_Y
Type: Directional Deformation(Y Axis)
Unit: mm
Global Coordinate System
Time: 1 s



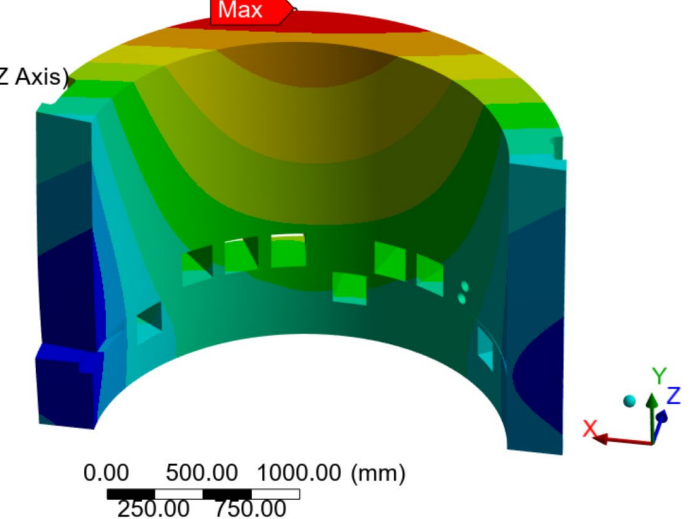
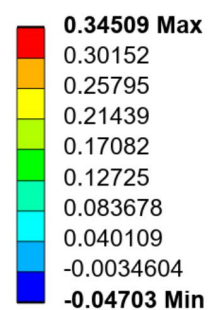
X - Deformation

B: Static Structural
Directional Deformation_X
Type: Directional Deformation(X Axis)
Unit: mm
Global Coordinate System
Time: 1 s



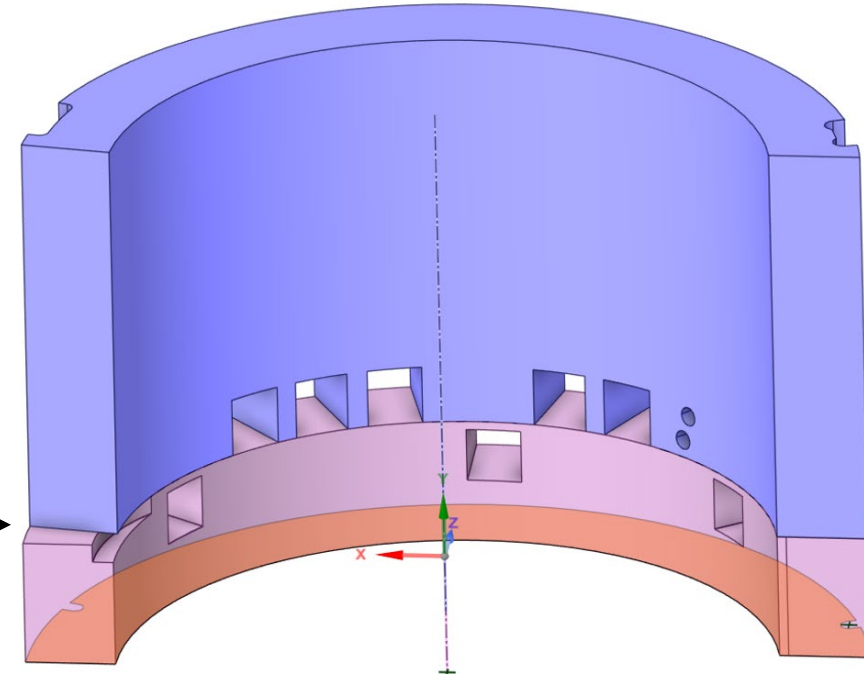
Z - Deformation

B: Static Structural
Directional Deformation_Z
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s

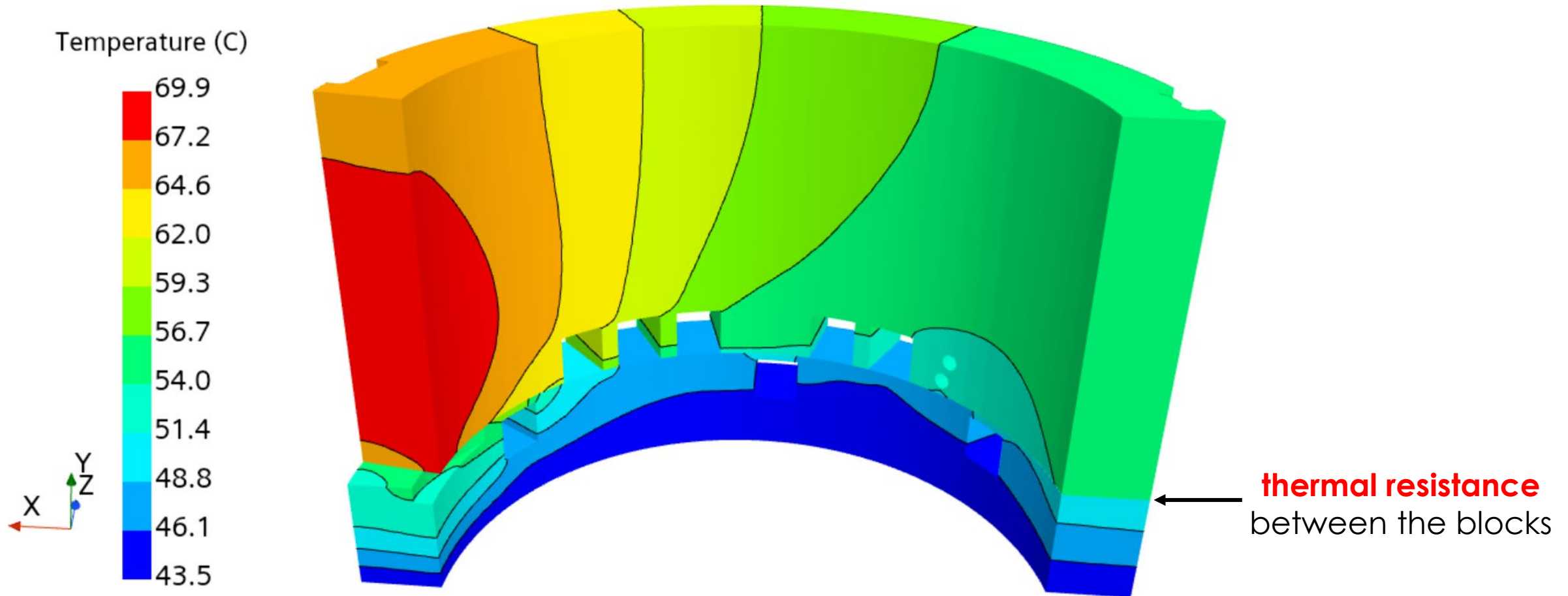


Updates

1. Add **thermal resistance** ($R = 0.0069 \text{ m}^2 - K/W$) between the blocks.
2. Modify the **contact** condition from **bounded**: Gap not open, no sliding allowed to **frictional**: Gap can open, sliding allowed



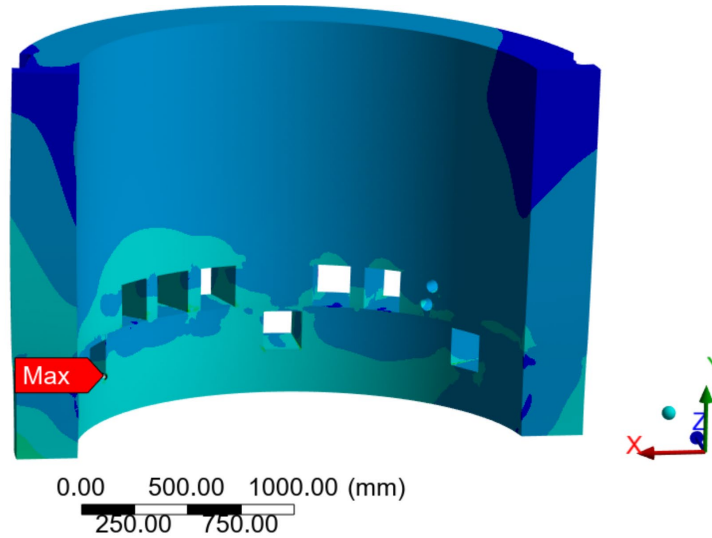
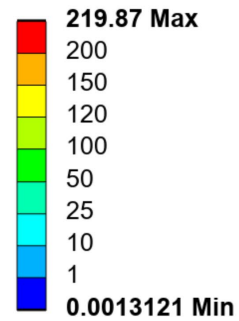
Shield Block Outer Ring, Carbon Steel Temperature



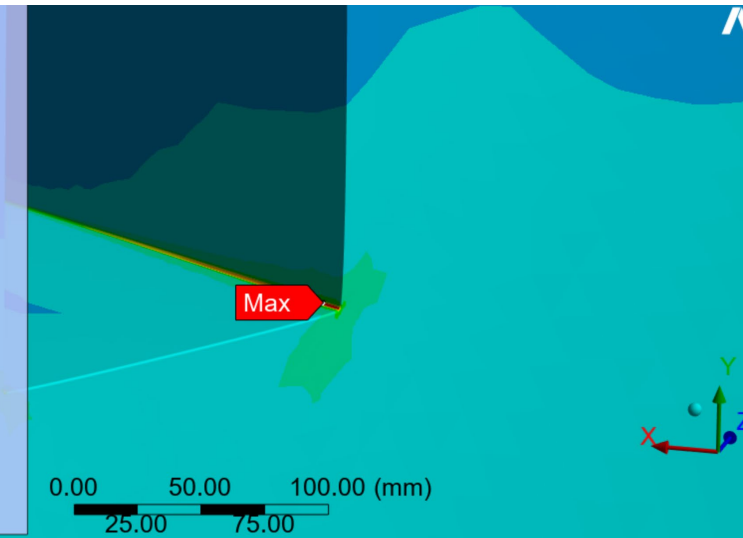
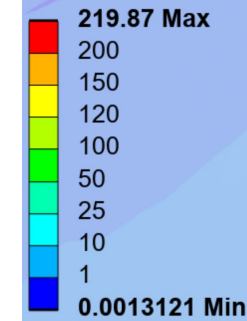
Shield Block Outer Ring, Von Mises Stress

Thermal resistance; bounded contact

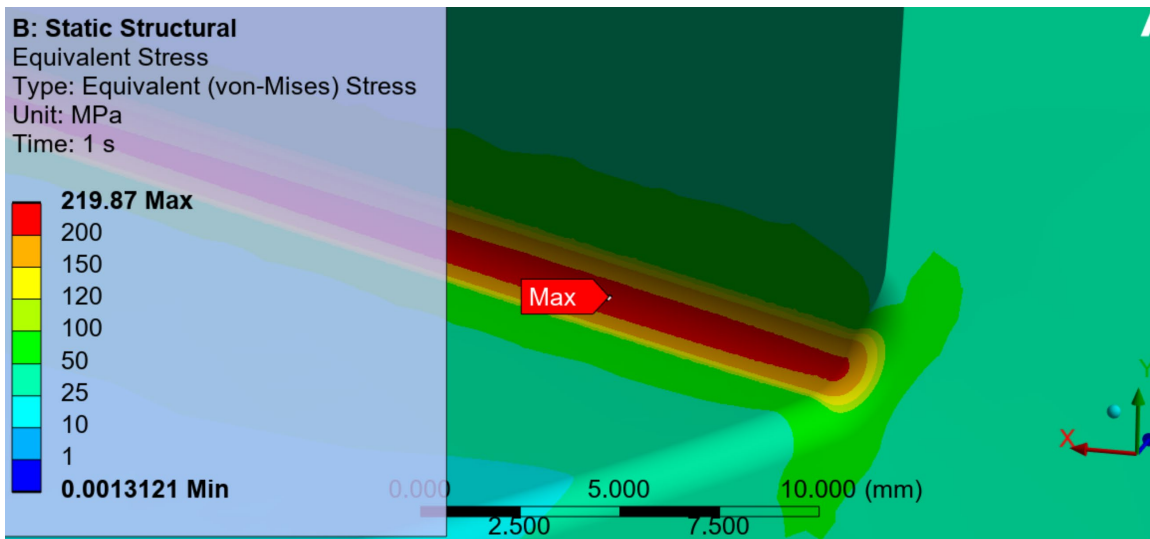
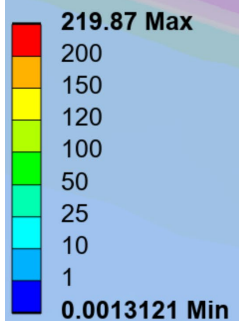
B: Static Structural
 Equivalent Stress
 Type: Equivalent (von-Mises) Stress
 Unit: MPa
 Time: 1 s



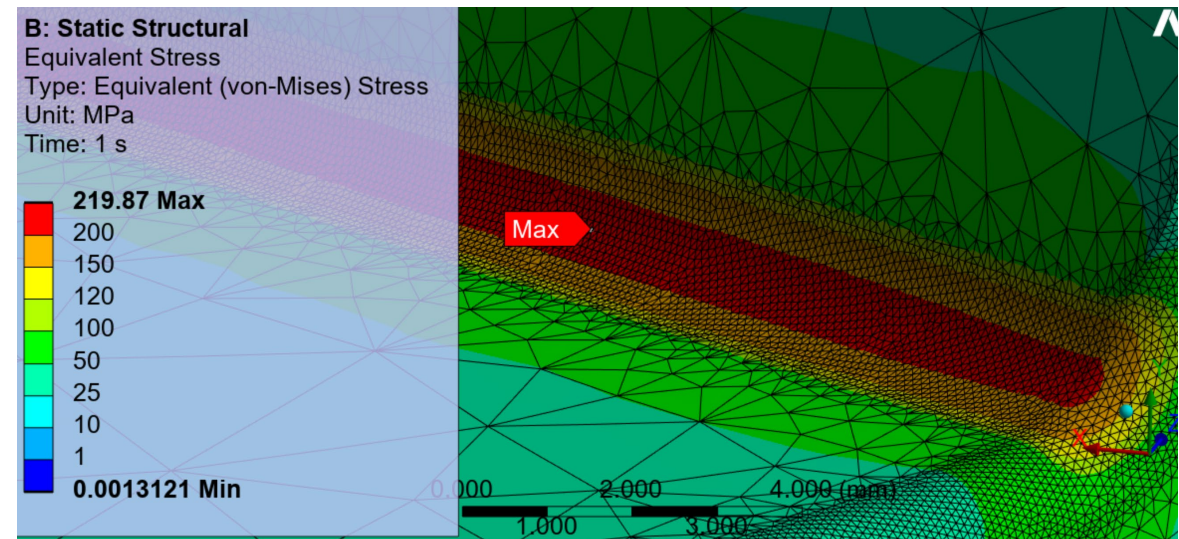
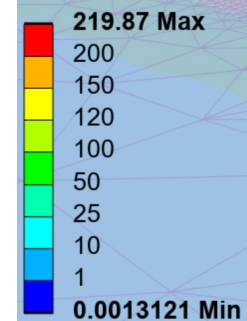
B: Static Structural
 Equivalent Stress
 Type: Equivalent (von-Mises) Stress
 Unit: MPa
 Time: 1 s



B: Static Structural
 Equivalent Stress
 Type: Equivalent (von-Mises) Stress
 Unit: MPa
 Time: 1 s

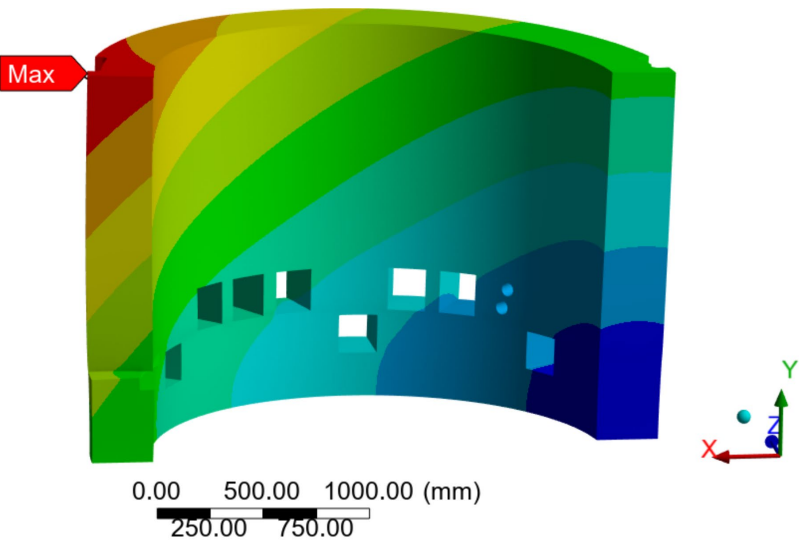
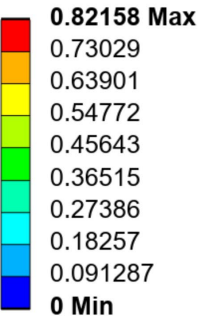


B: Static Structural
 Equivalent Stress
 Type: Equivalent (von-Mises) Stress
 Unit: MPa
 Time: 1 s



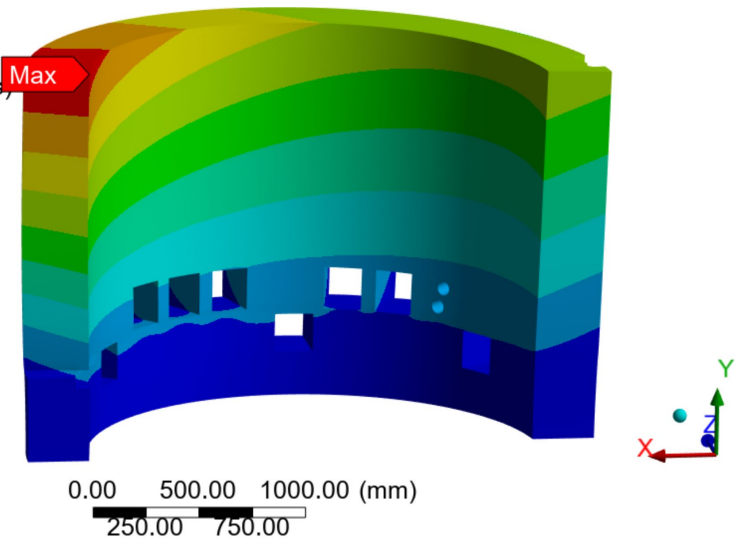
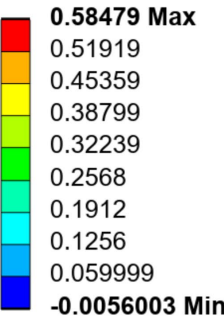
Total Deformation

B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s



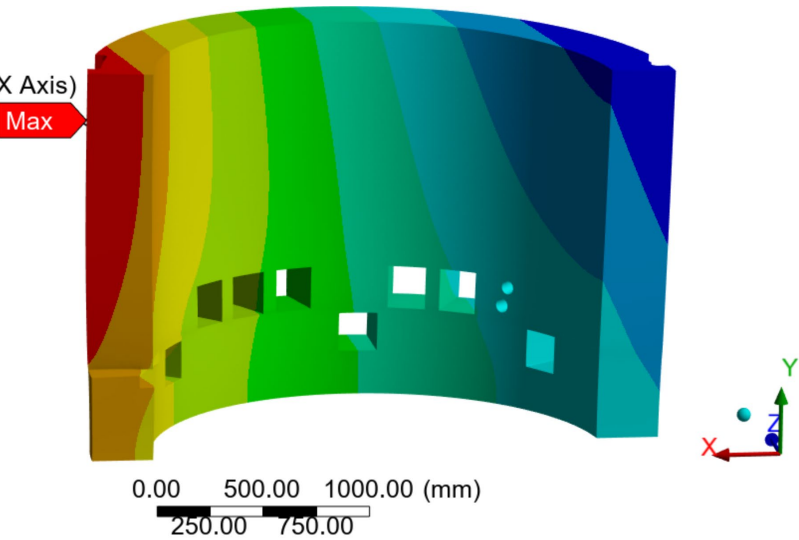
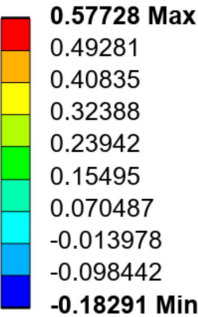
Y - Deformation

B: Static Structural
Directional Deformation_Y
Type: Directional Deformation(Y Axis)
Unit: mm
Global Coordinate System
Time: 1 s



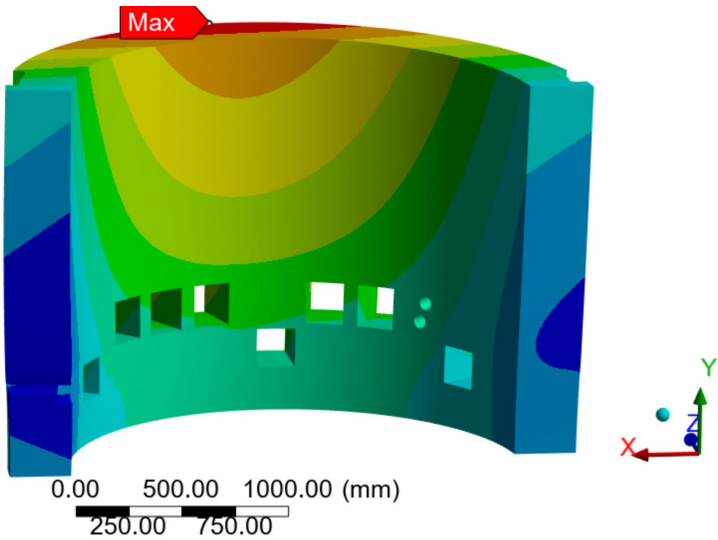
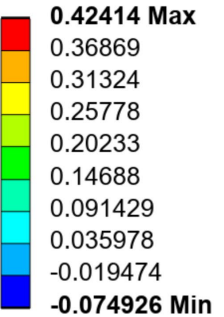
X - Deformation

B: Static Structural
Directional Deformation_X
Type: Directional Deformation(X Axis)
Unit: mm
Global Coordinate System
Time: 1 s



Z - Deformation

B: Static Structural
Directional Deformation_Z
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s



Coefficient of Friction for Steel

<https://hypertextbook.com/facts/2005/steel.shtml>

Coefficients of Friction for Steel

An educational, fair use website



Bibliographic Entry	Result (w/surrounding text)			Standardized Result	
Sullivan, James F. <i>Technical Physics</i> . USA: Wiley, 1988: 204.	<u>Materials</u> Steel on Steel	<u>Static Friction</u> 0.7	<u>Kinetic Friction</u> 0.6	μ_s 0.7	μ_k 0.6
Encarta Encyclopedia 2004. Microsoft Corporation.	Steel on Steel (dry)	<u>Static Friction</u> 0.7	<u>Kinetic Friction</u> 0.6	μ_s 0.7	μ_k 0.6
<i>CRC Handbook of Physical Quantities</i> . Boca Raton, FL: CRC Press, 1997: 145-156.	Steel on Steel	<u>Static Friction</u> 0.74	<u>Kinetic Friction</u> 0.57	μ_s 0.74	μ_k 0.57
Weber, Robert L.; Manning, Kenneth V.; White, Marsh W. <i>College Physics-4th Edition</i> . USA: McGraw-Hill, 1965: 66	Steel on Steel (dry)	<u>Static Friction</u> 0.15	<u>Kinetic Friction</u> 0.09	μ_s 0.15	μ_k 0.09
Determining the Coefficient of Friction - Succeed in Physical Science . School for Champions.	<u>Surfaces</u> Steel on steel (dry)	<u>Static Friction</u> 0.6	<u>Kinetic Friction</u> 0.4	μ_s 0.6	μ_k 0.4

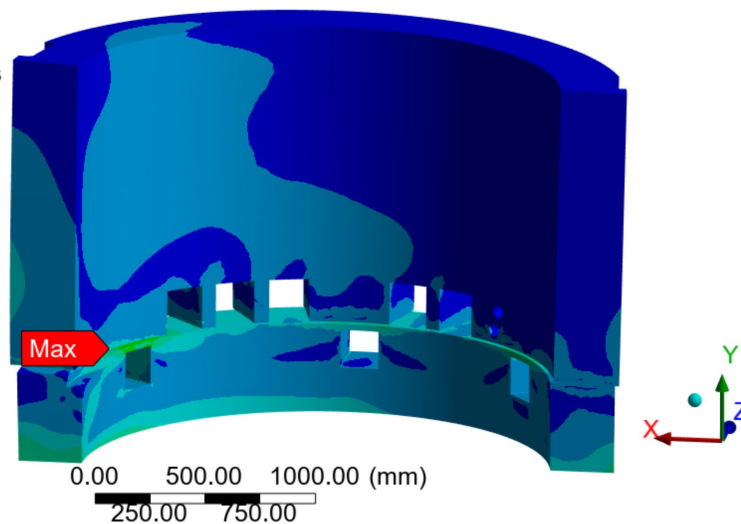
Friction coefficient of **0.7** is used for this analysis.

Shield Block Outer Ring, Von Mises Stress

Thermal resistance; frictional contact

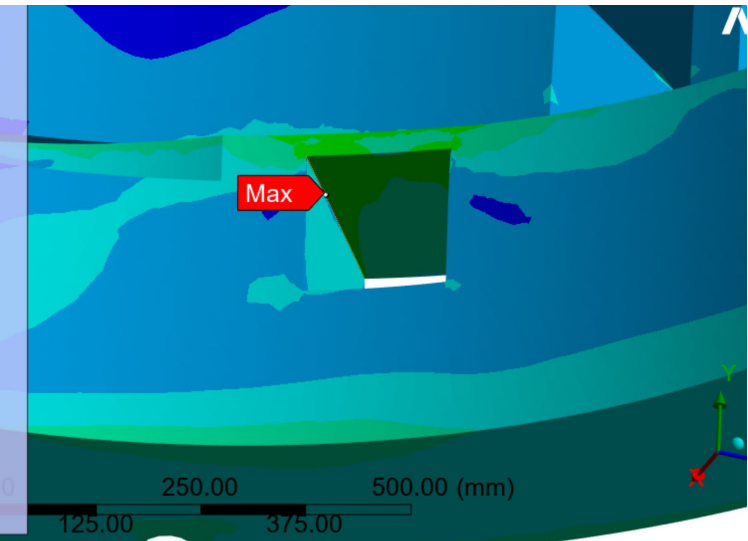
B: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s

121.29 Max
110
100
80
50
25
10
5
1
0.0003243 Min



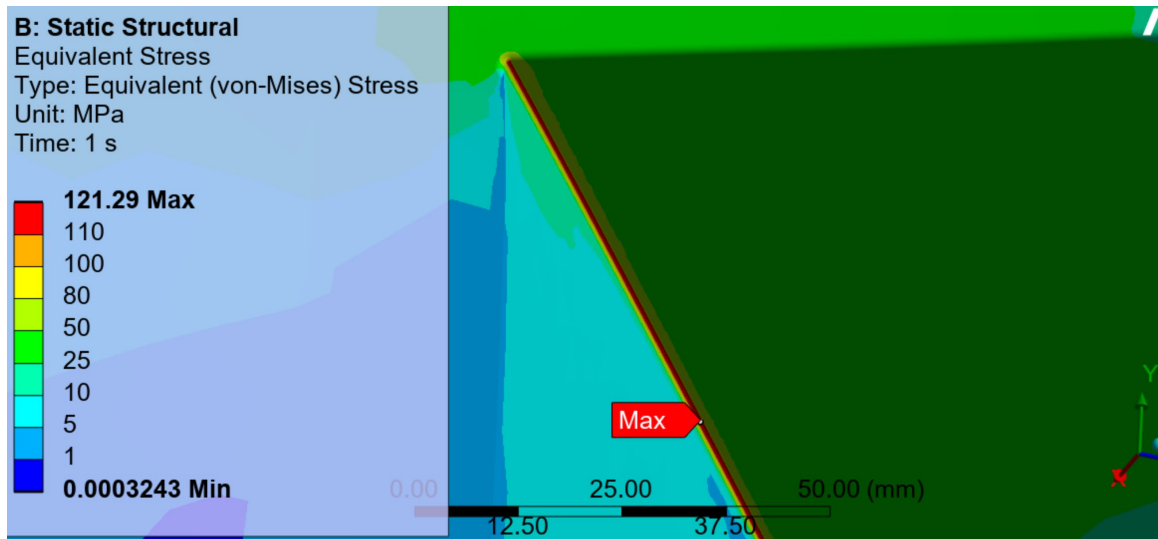
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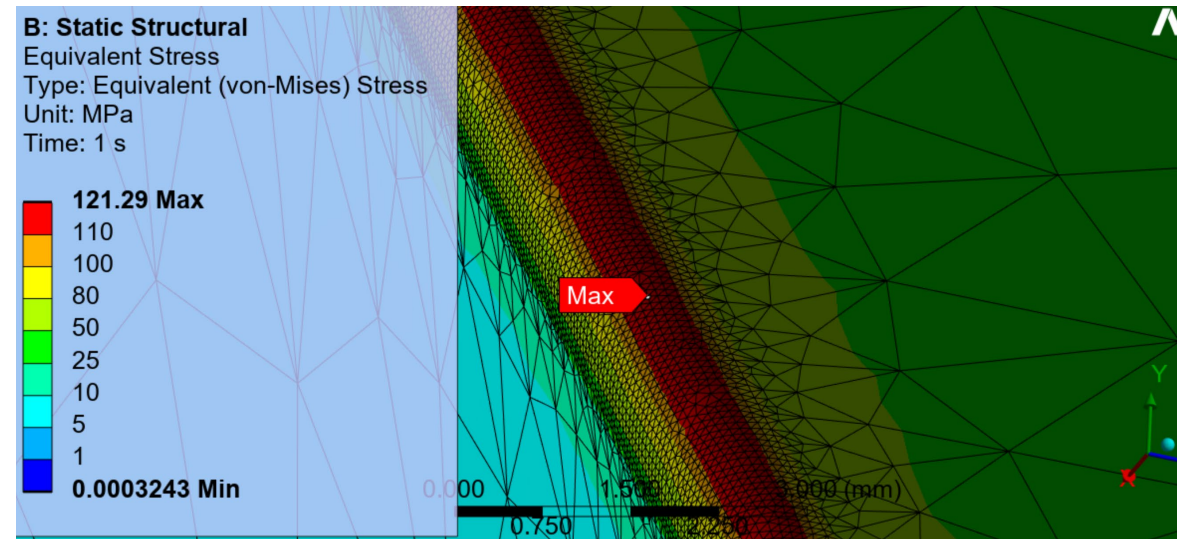
B: Static Structural
Equivalent Stress
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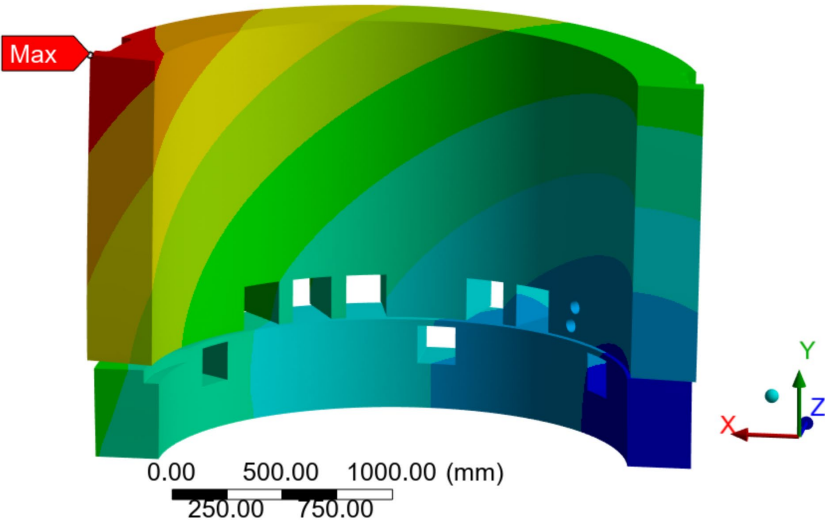
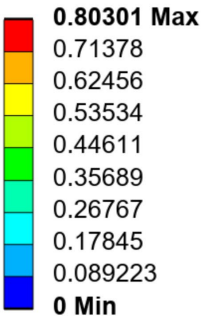
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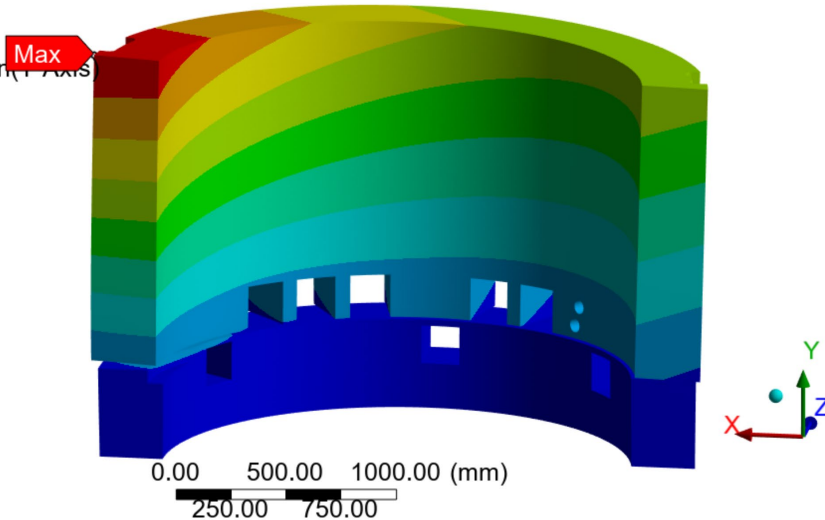
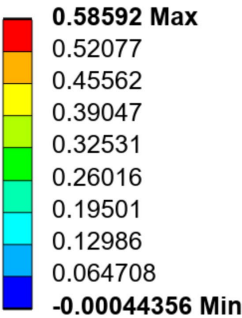
Total Deformation

B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s



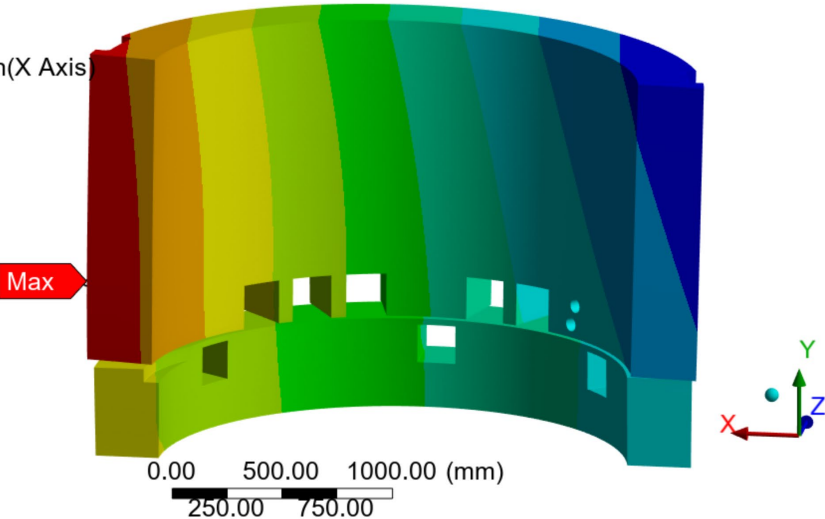
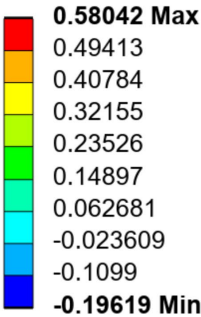
Y - Deformation

B: Static Structural
Directional Deformation_Y
Type: Directional Deformation(Y Axis)
Unit: mm
Global Coordinate System
Time: 1 s



X - Deformation

B: Static Structural
Directional Deformation_X
Type: Directional Deformation(X Axis)
Unit: mm
Global Coordinate System
Time: 1 s



Z - Deformation

B: Static Structural
Directional Deformation_Z
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s

