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RamSeries - Validation Case 37

Transient Thermal Stress in a Cylinder

RamSeries

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15.1.0

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1 Validation Case 37 - Transient Thermal Stress in a Cylinder

Model description

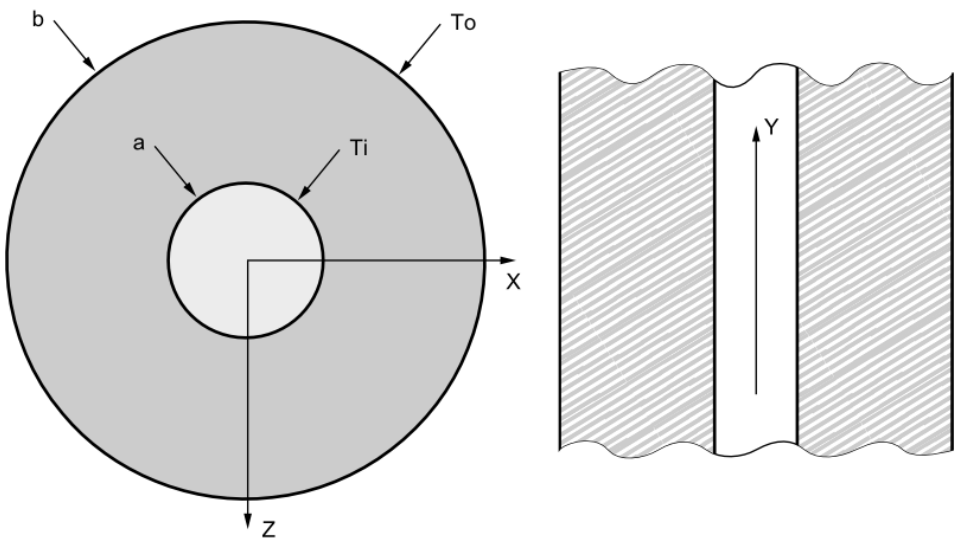
The purpose of this test is to validate the accuracy of a transient thermal analysis combined with a stress analysis. The following test can be performed in two different ways. The first one, is to run two separately analysis (thermal and structural analyses) and the comunication among them is carried out throught file. The second one, is to run both analyses simultaneously. The second one, is to run both analyses simultaneously. Both ways are used and their results are shown in this document.

A long thick-walled cylinder, initially at a uniform temperature T_0, has its outer radius temperature raised at a constant rate of 0.556 ºC/s to temperature T_f. After a steady state of heat flow has been reached, determine the tangential stress at the inner and outer surfaces.

The thermal analysis allows to know the temperature distribution through the wall thickness, and the stress analysis allows to determine the the tangential stress at the inner and outer surfaces at each step.

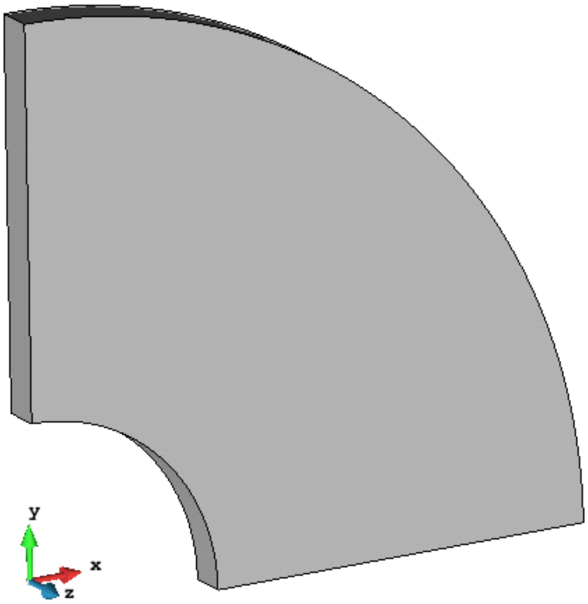
Geometric model

Following, a schematic picture is shown with dimensions.



Inner radious (a) = 25.4 mm Outer radious (b) = 76.2 mm

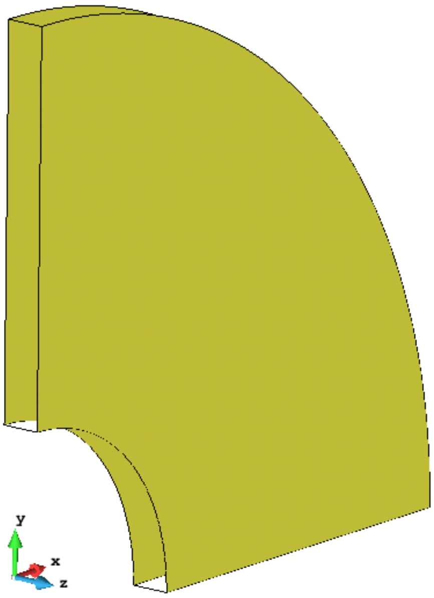
Because of the symmetry in loading conditions and in the geometry, this problem is solved as an axisymmetric problem. Moreover, the axial length is arbitrary and it is taken a value of 5.08 mm because model is a long cylinder.



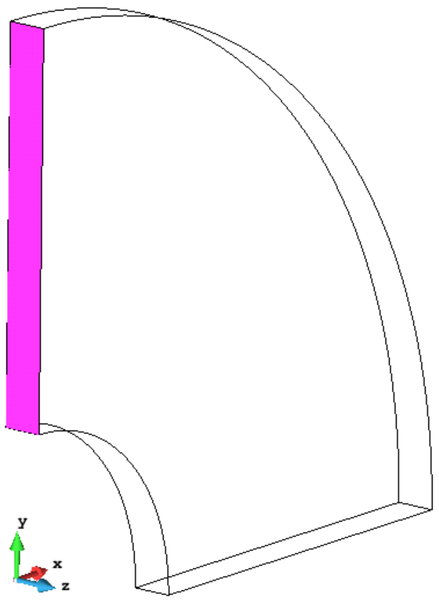
Geometric model used to perform the analysis with TDYN

Restrictions

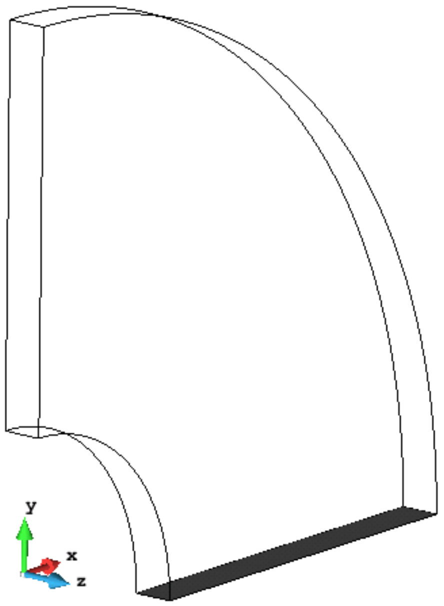
To apply symmetry conditions, the following restrictions must be created:



Restriction: Z direction



Restriction: X direction



Restriction: Y direction

Temperature conditions

- Outer surface temperature:
  - T_0 initial = 21.11 ºC
  - Constant rate = 0.556 ºC/s
  - Time period = 430 s
  - To final = 260 ºC
- Inner surface temperature:
  - Ti = 21.11 ºC

Material properties

E = 206843 MPa (Young's modulus)

ν = 0.3 (Poisson's ratio)

α = 1.51e-5 1/ºC (thermal expansion coefficient)

k = 46.9 W/mK (thermal conductivity)

ρ = 7864 kg/m^3 (density)

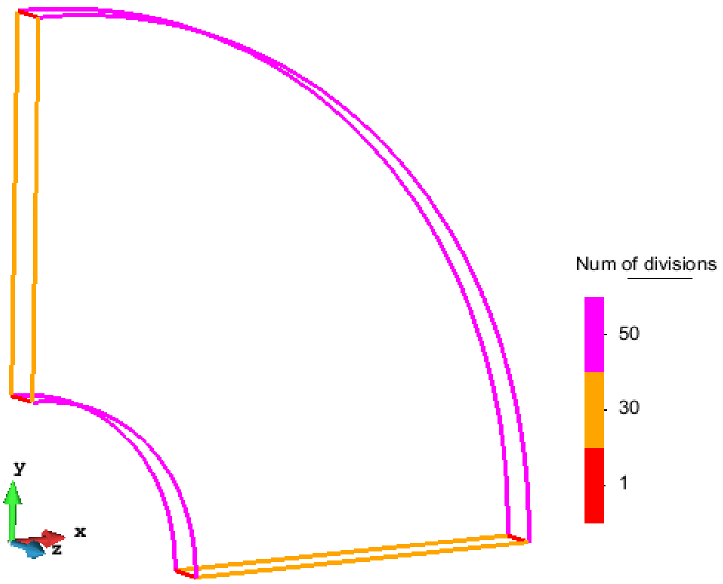
Results

A thermomechanic problem must be solved in two steps:

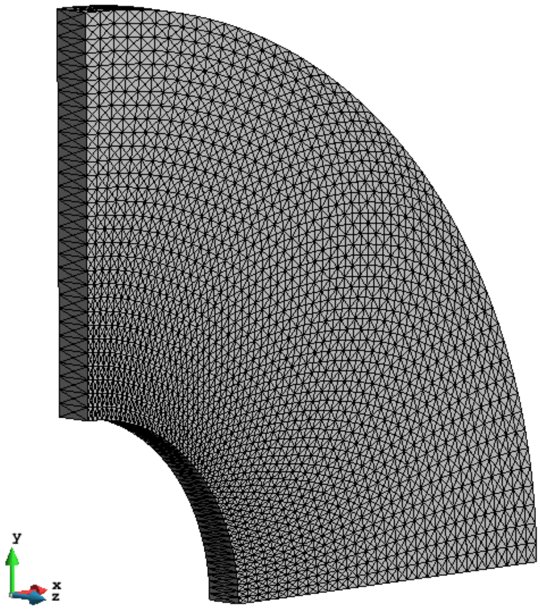
- A thermal analysis allows to know the temperature distribution for each step.
- A mechanic analysis that calculates the displacement and stress for each step using the results obtained in the previous thermal analysis.

Mesh

A mesh of tetrahedra is used in both analysis. The number of divisions applied in each edge is shown in the following picture and the mesh too:



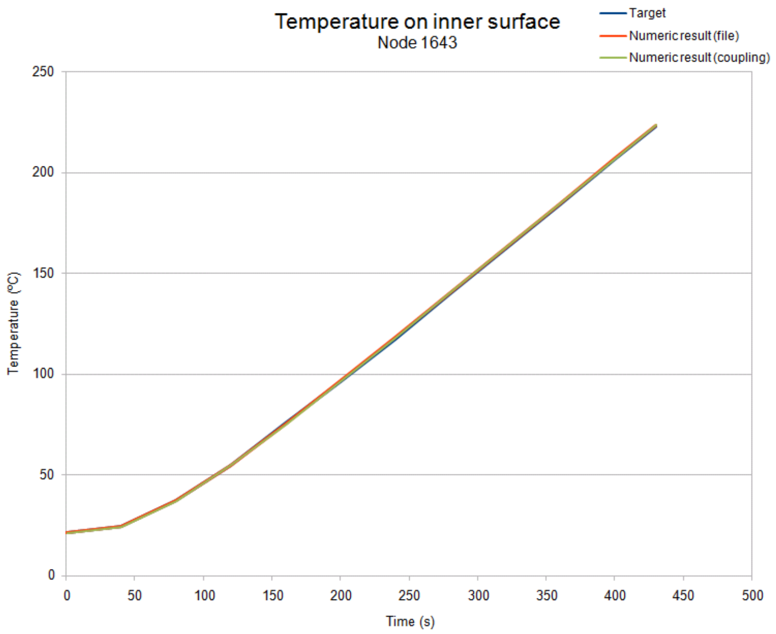
Number of divisions in each edge.



Mesh of tetrahedra. This mesh contains 48640 elements and 10742 nodes.

Thermal analysis results

The next picture shows the temporal evolution of the temperature on the inner surface. As this picture shows, there is not any difference among results obtained by numeric analysis and target results.

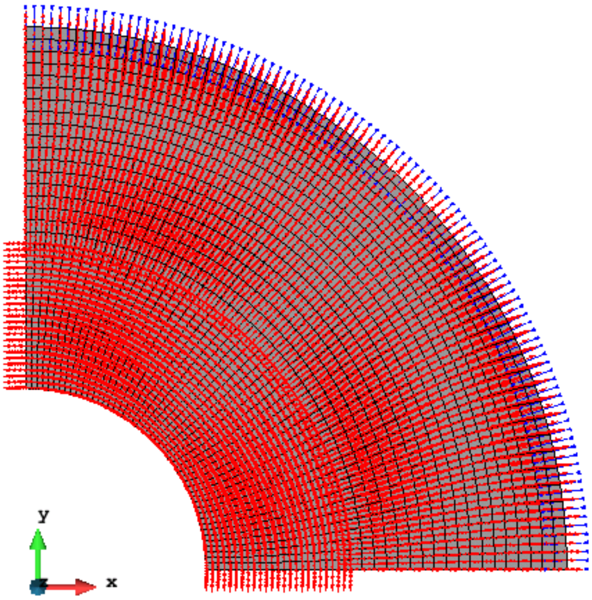


The temporal evolution of the temperature on the inner surface. The highest error among numerical results and target is 1.1%

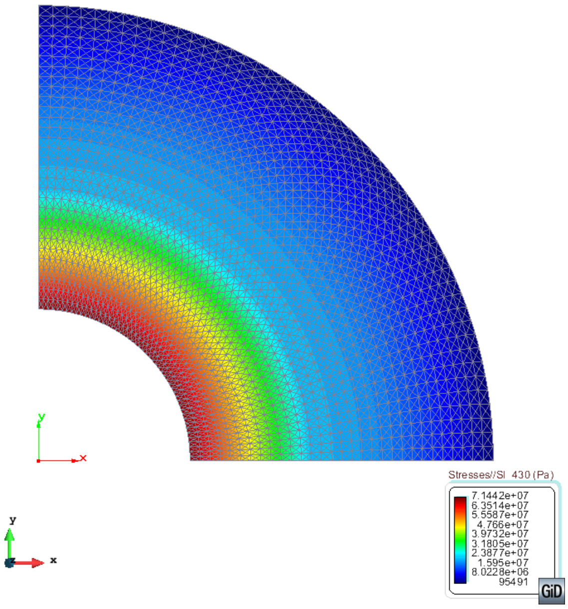
Stress analysis results

Below, the tangential stress at last time step calculated in a structural analysis performed with RamSeries is shown.

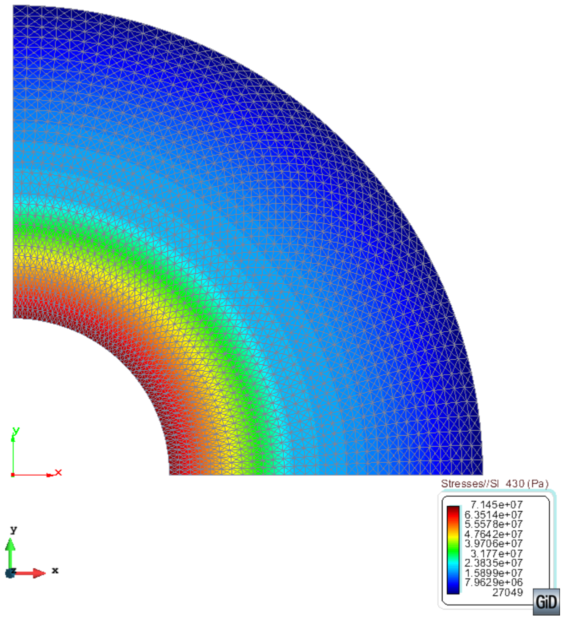
Tangential stress at the inner surface corresponds to first principal stress:



First principal stress directions (Si). At the inner surface, first principal stress corresponds to tangential stress.

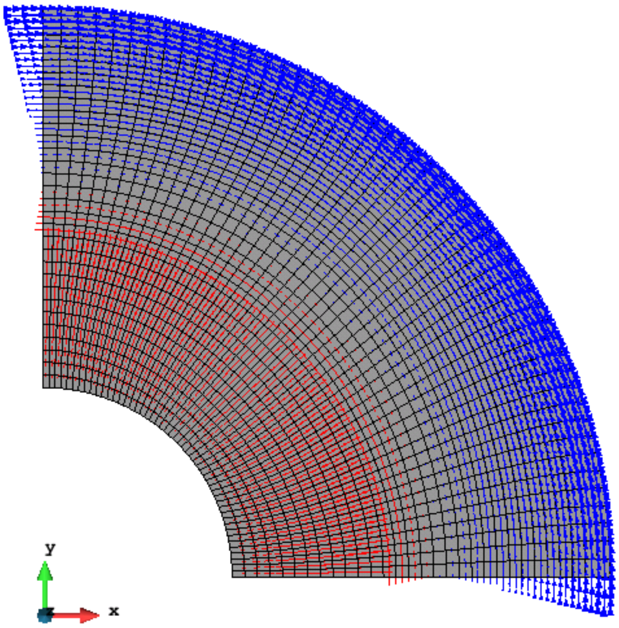


Results of separated analyses. Tangential stress on the inner surface. Value at 6040 node: 70 MPa

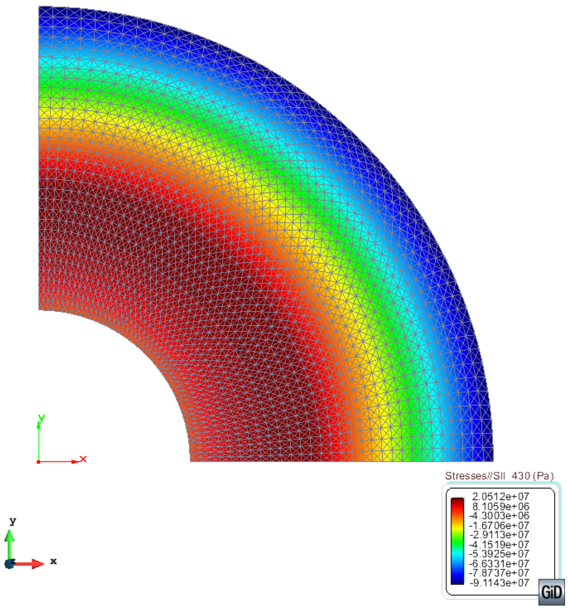


Results of coupled analysis. Tangential stress on the inner surface. Value at 6040 node: 70 MPa

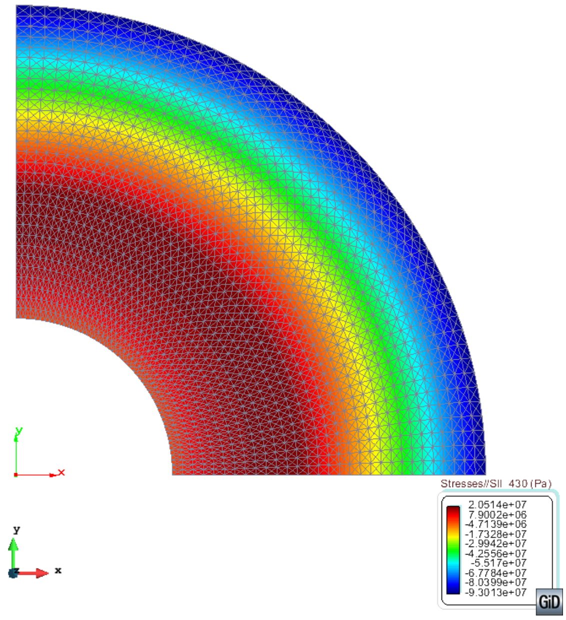
And tangential stress on the outer surface corresponds to second principal stress:



Second principal stress directions (Sii). At the outer surface, second principal stress corresponds to tangential stress.



Results of separated analyses. Tangential stress on the outer surface. Value at 5644 node: -90 MPa



Results of coupled analysis. Tangential stress on the outer surface. Value at 5644 node: -91 MPa

Sumarize of results

Below, a table with the numerical results obtained by separated analyses and other table with numerical results from coupled analysis are shown. Both tables compare numerical results with the values form Reference 1.

- Separated analyses:

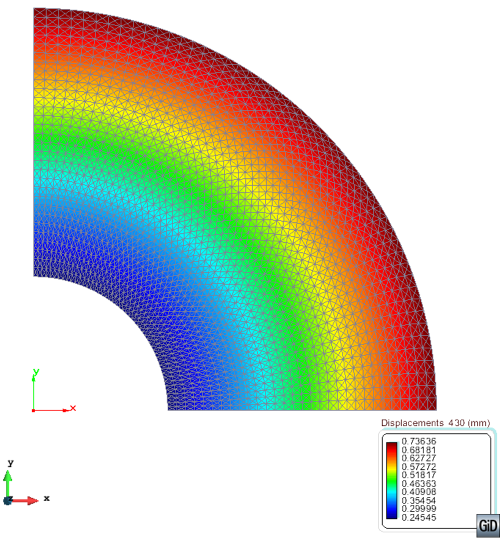
	Target (Ref.[1]) [MPa]	RamSeries Results [MPa]	Error [%]
Tangential Stress inner surface	71	70	1,4
Tangential Stress outer surface	-90	-90	0

- Coupled analysis:

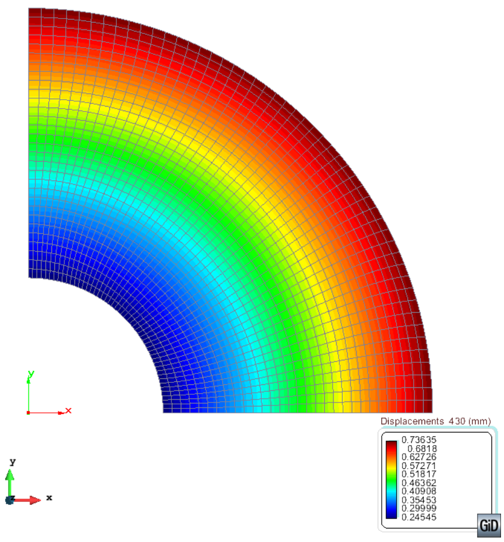
	Target (Ref.[1]) [MPa]	RamSeries Results [MPa]	Error [%]
Tangential Stress inner surface	71	70	1,4
Tangential Stress outer surface	-90	-91	1,1

The following images show displacement and stress results of separated and coupled analyses:

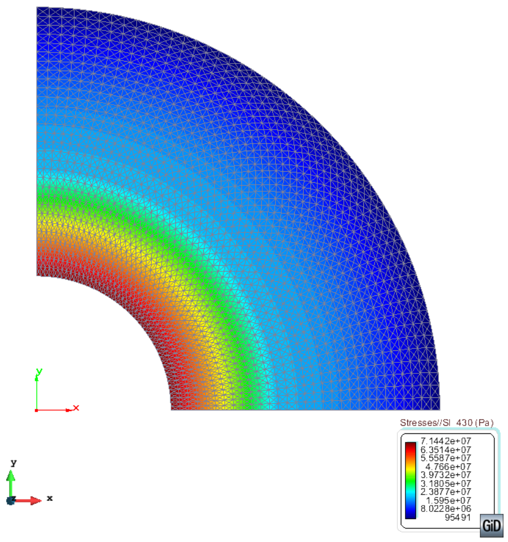
- Separated analysis:



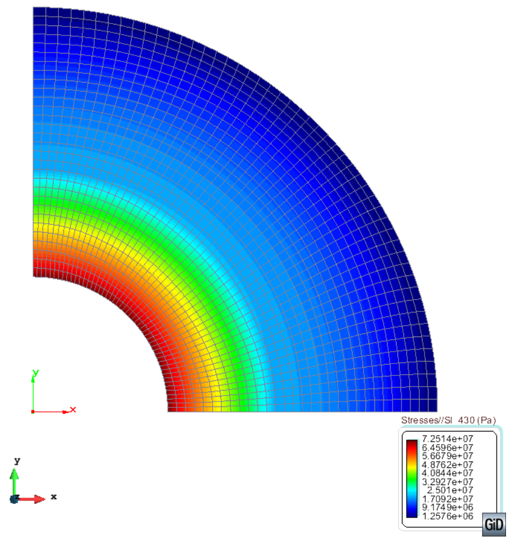
Displacement result in a separated analysis with tetrahedra



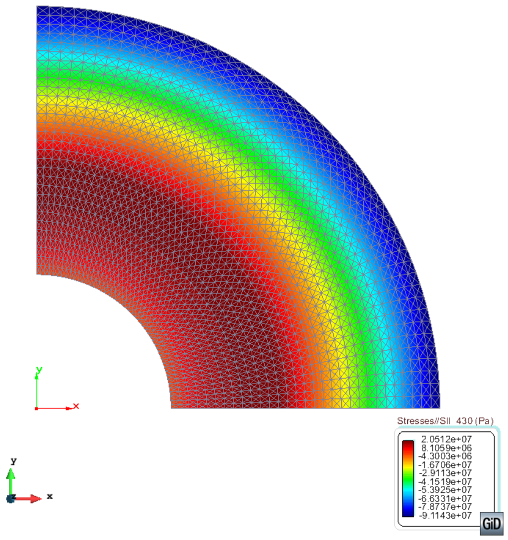
Displacement result in a separated analysis with hexahedra



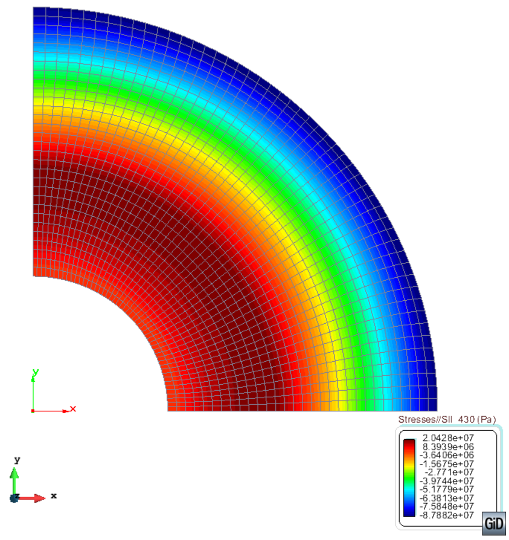
Si result in a separated analysis with tetrahedra



Si result in a separated analysis with hexahedra

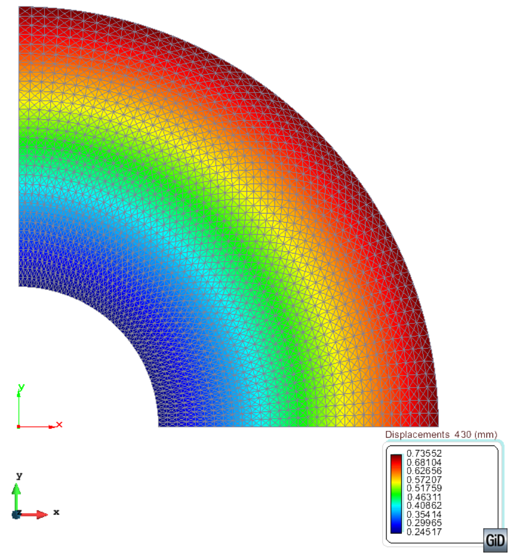


Sii result in a separated analysis with tetrahedra

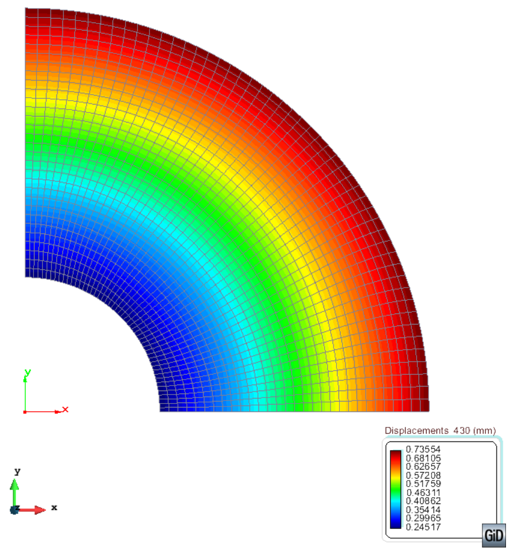


Sii result in a separated analysis with hexahedra

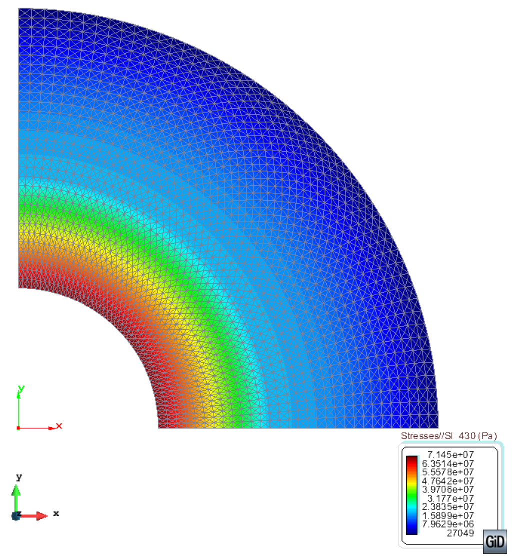
- Coupled analysis



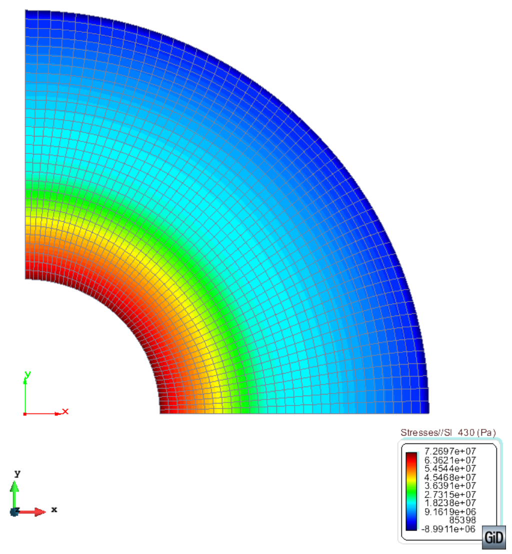
Displacement result in a coupled analysis with tetrahedra



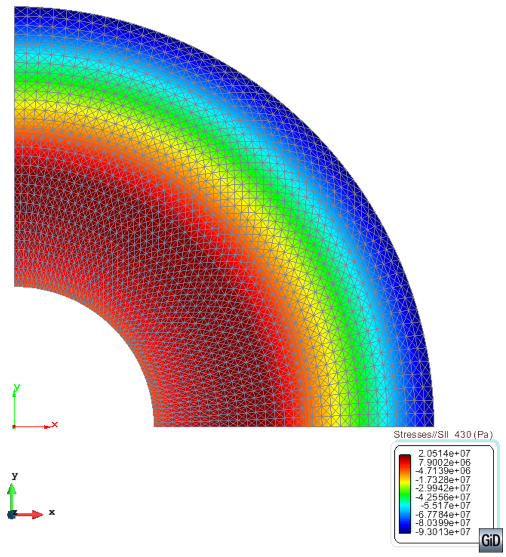
Displacement result in a coupled analysis with hexahedra



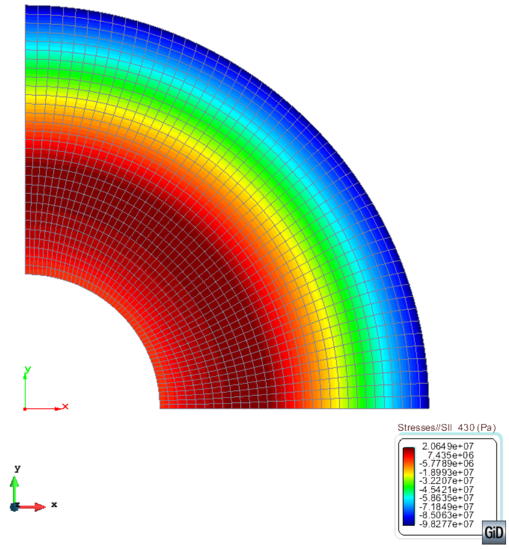
Si result in a coupled analysis with tetrahedra



Si result in a coupled analysis with hexahedra



Sii result in a coupled analysis with tetrahedra



Sii result in a coupled analysis with tetrahedra

References

[1] ANSYS. ANSYS Mechanical APDL Verification Manual, pag 99-102. November 2013. Release 15.0.

Validation Summary

CompassFEM version	15.1.0
Tdyn solver version	15.1.0
RamSeries solver version	15.1.0
Benchmark status	Successfull
Last validation date	27/11/2018