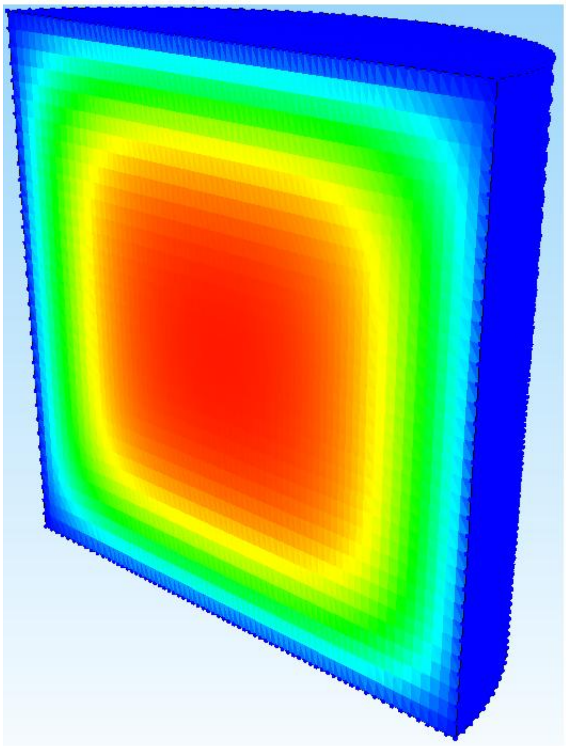
Part 16: Transient Temperature-Analysis with MEANS V12

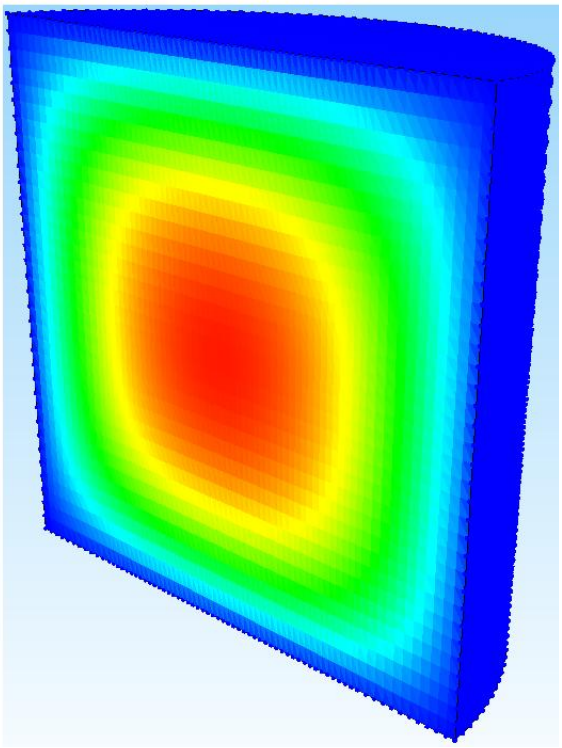
What is an transient temperature distribution

Transient heat conduction is understood to mean the heating and cooling of solid bodies, so the temperature is dependent on time.

Time-Step 9 - 10 sec = 58.7 °C



Time-Step 11 - 20 sec = 51.3 °C



Material data for the transient temperature:

Thermal Conductivity

Thermal Conduction is the transport of heat in a medium without mass transfer (such as Convection). Important Thermal Conductivities are Aluminum = 220 W/(mK), Steel = 40 W/(mK), Air = 0.0181 W/(mK), Water = 0.6 W/(mK), Ice = 2.13 W/(mK)

Specific Heat Capacity

The Specific Heat Capacity is a substance constant. It indicates how much heat has to be absorbed or released by a body so that the temperature of 1kg of the substance changes by 1 °C. Important Specific Heat Capacities are Aluminum = 895 J/(kgK), Steel = 540 J/(kgK), Air = 1010 J/(kgK), Water = 4190 J/(kgK), Ice = 2060 J/(kgK)

Density

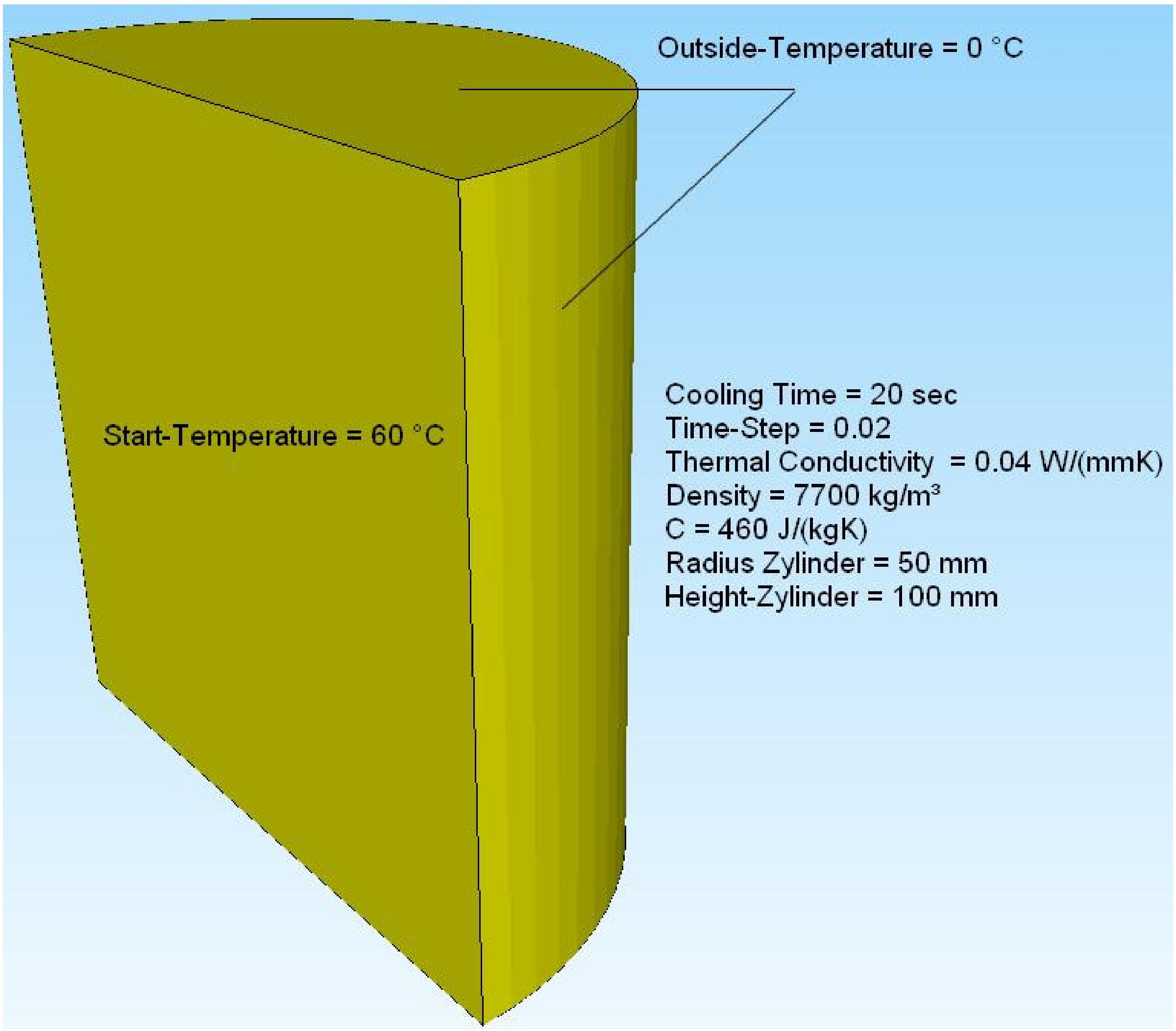
The density is only required for the transient analysis, important densities are: Aluminum = 2700 kg/m³, Steel = 7800 kg/m³, Air = 1.204 kg/m³, Ice = 920 kg/m³, water = 997 kg/m³

Total time, time step and start temperature

It is also necessary to enter the total time in seconds, the time step and the start temperature in °C.

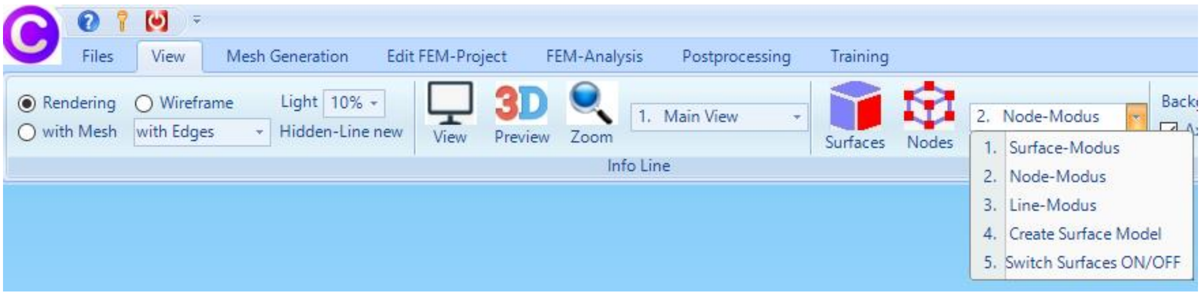
Example 1: Cooling of a cylinder

Cooling of a cylindrical body is considered, the Start-Temperature = 60 °C and the constant Outside Temperature is = 0 °C on the outer surfaces. The cooling time is 20 seconds.

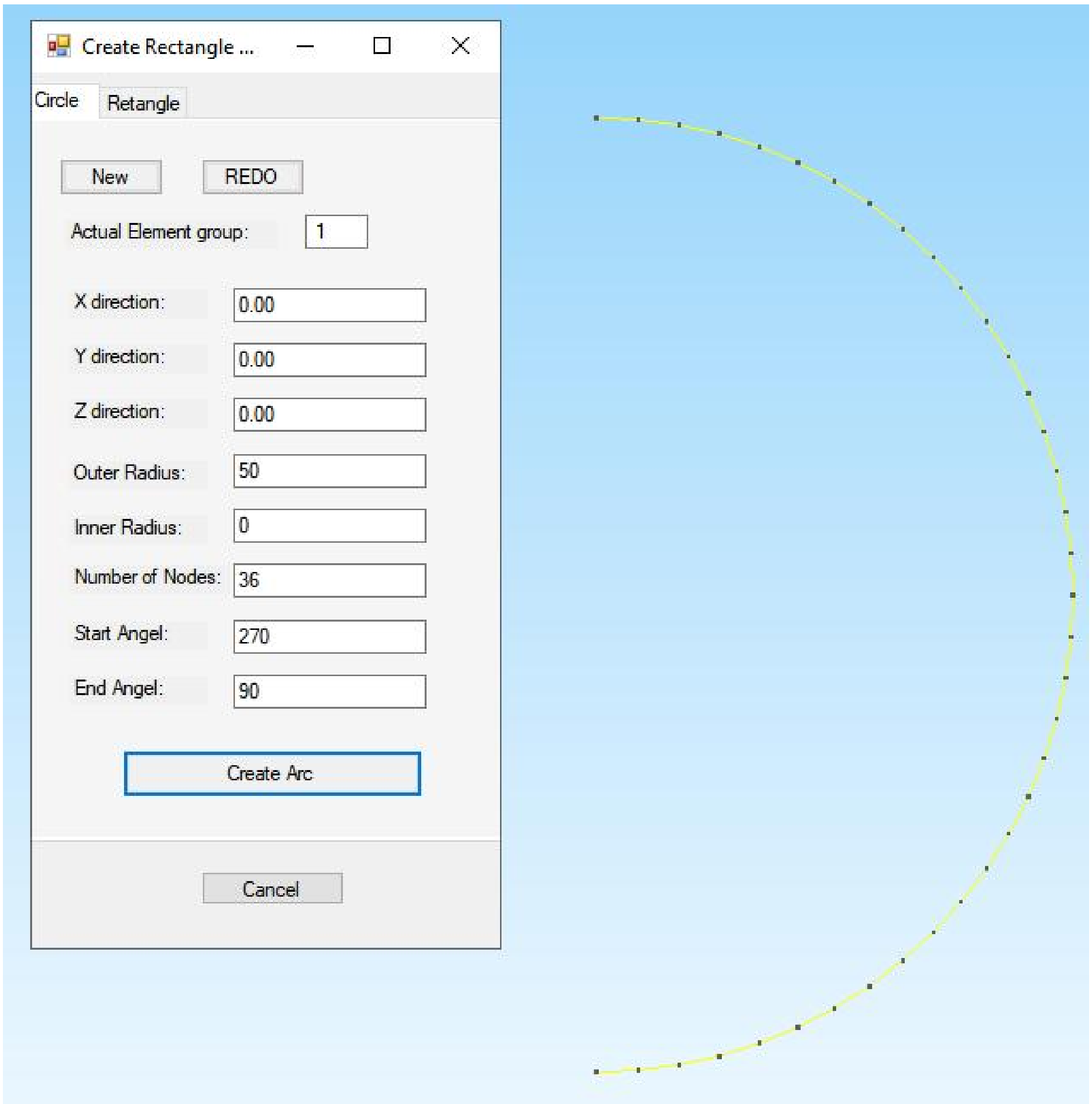


Create Arcs in Line-Mode

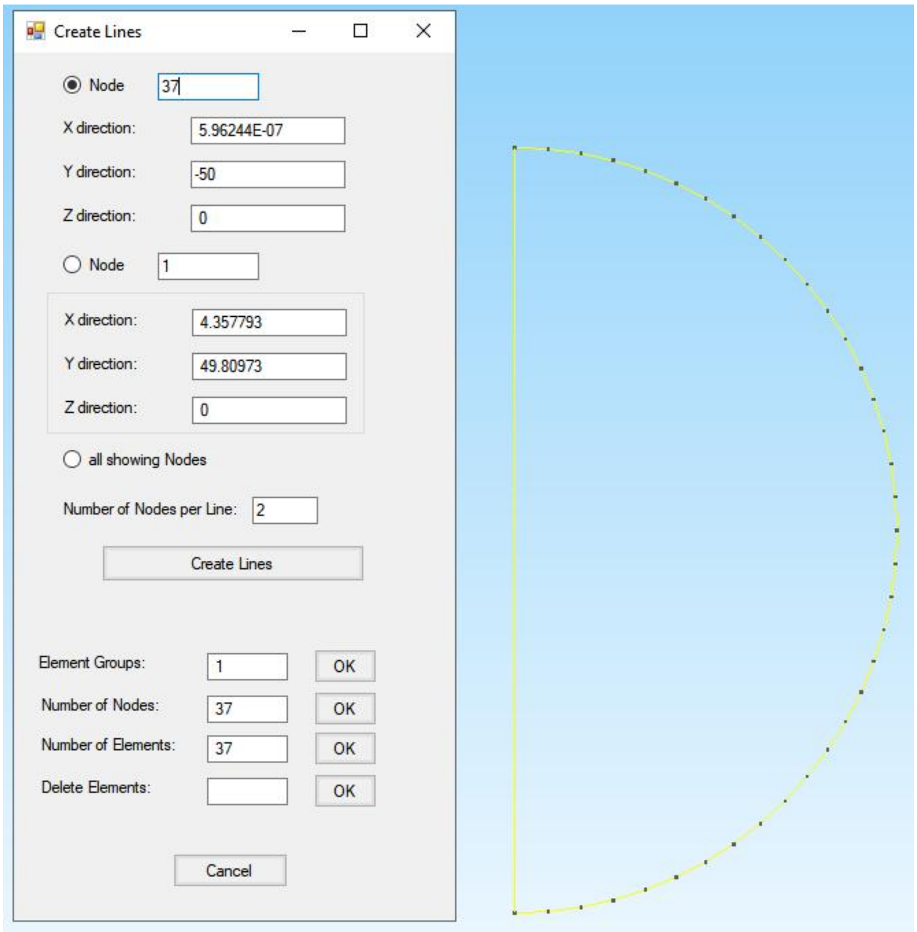
Start the "MEANS V12 for DirectX11" program via the desktop icon  and use the "View" tab and the "Line mode" drop-down menu to switch on a side menu on the right-hand side of the screen.



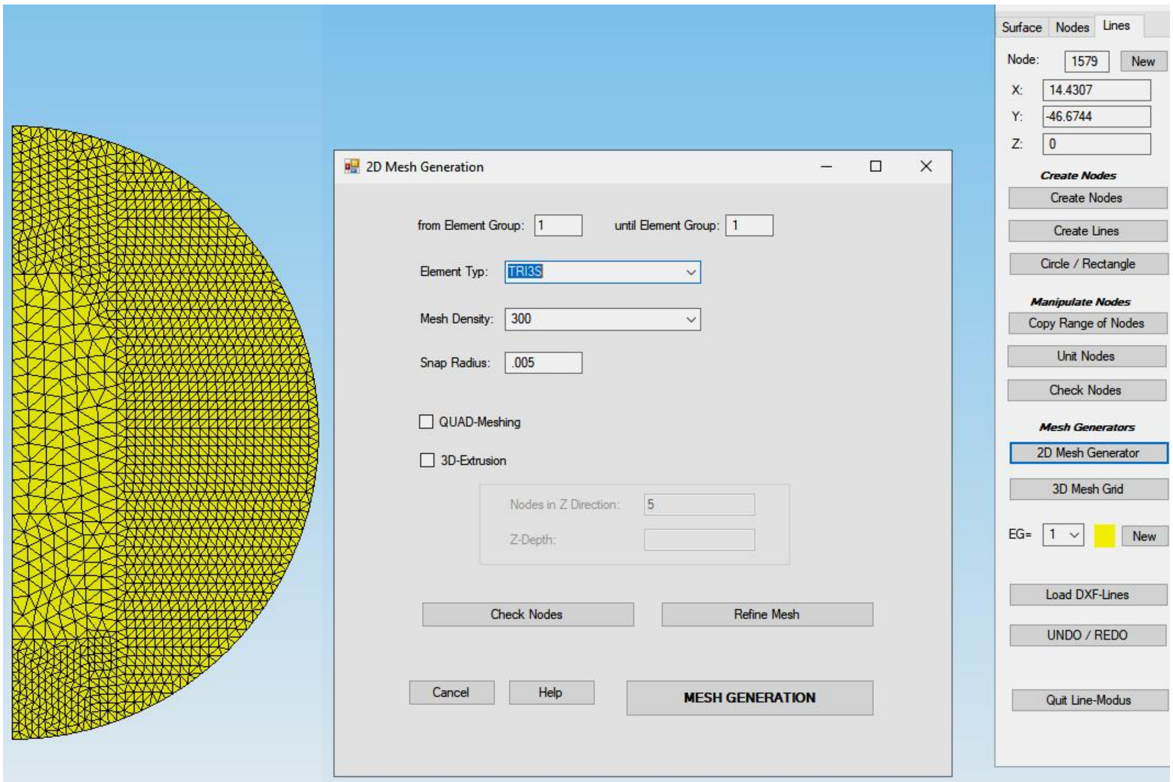
Select the "Create arc" menu to create a half arc with a radius of 50 mm from 270 degrees - 90 degrees:



Then select “Create Lined” to connect nodes 37 and 1 with a line. Choose the 2D Mesh Generator menu to generate a 2D mesh.

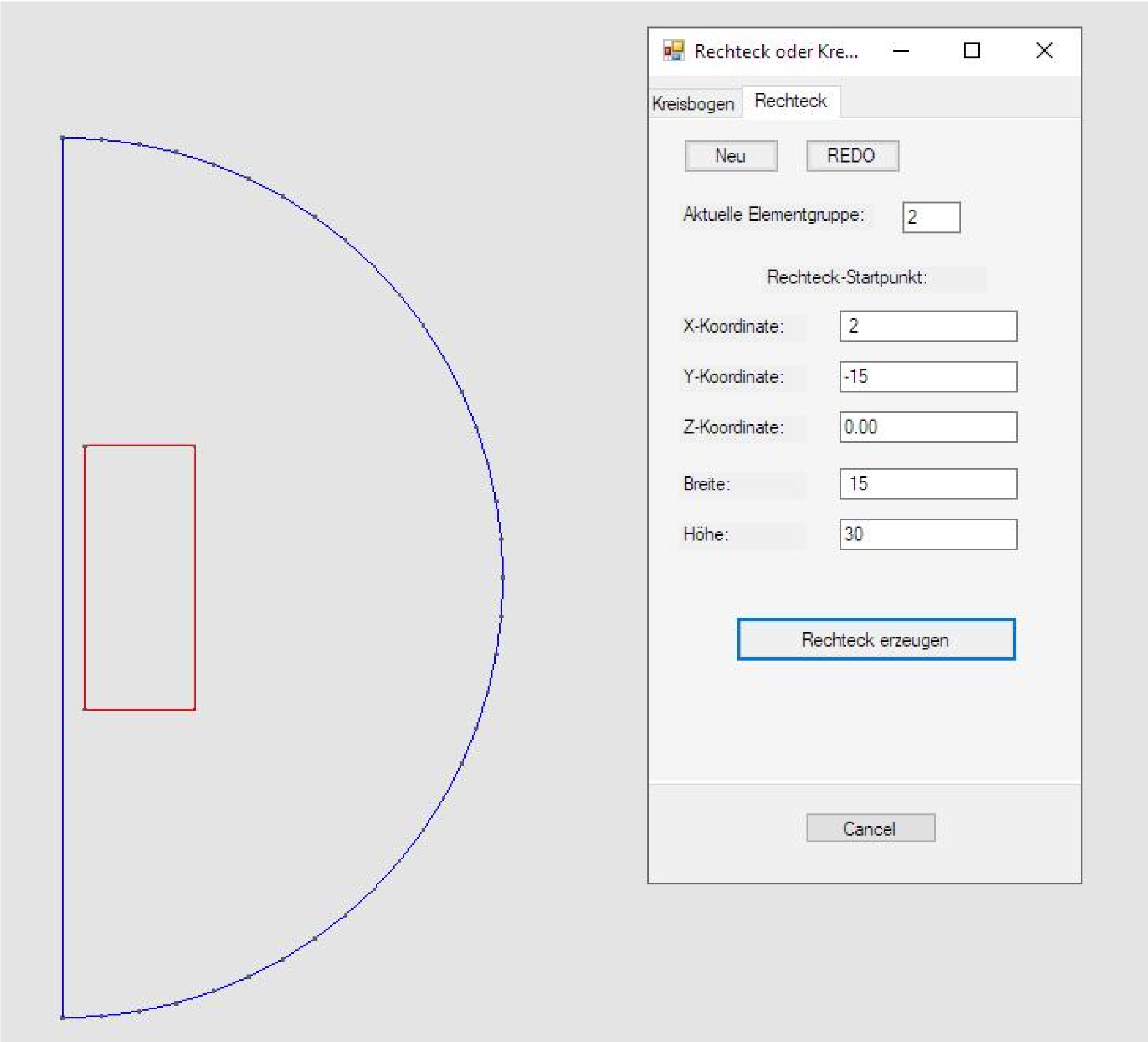


which has a mesh that is too coarse in the middle and needs to be refined.



Mesh Refinement

Use the “Circle/Rectangle” menu to create the following rectangle with EG=2 and

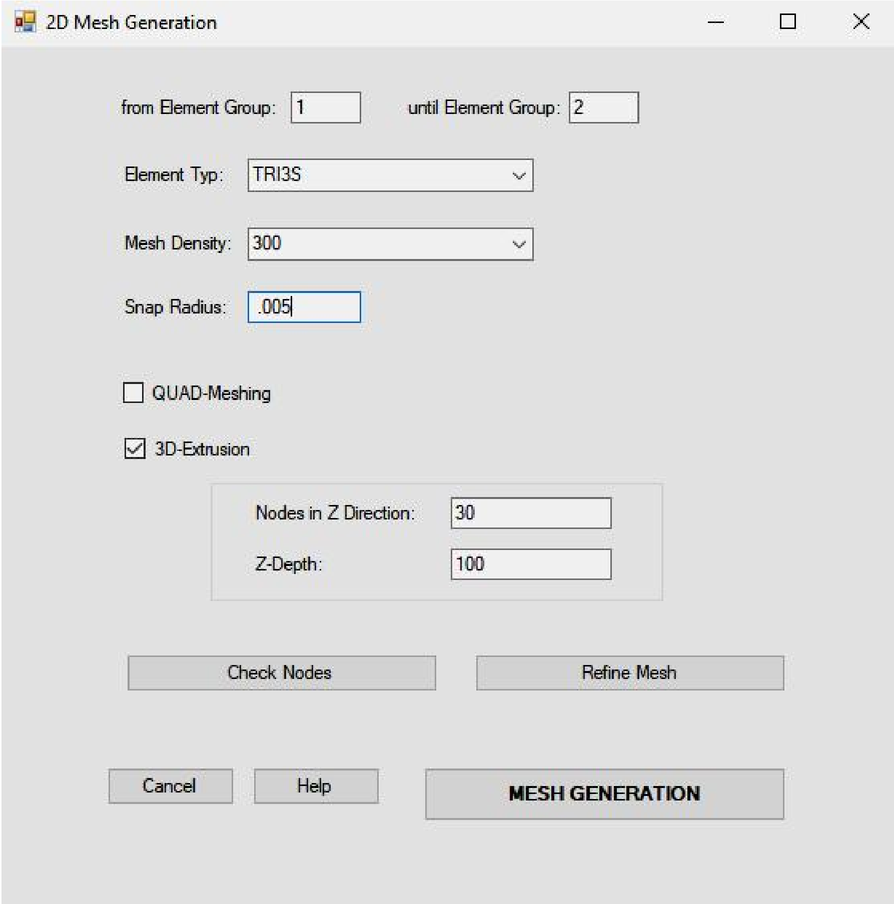


then select the "Mesh Refinement" menu in the 2D mesh generator to refine the mesh in this area.

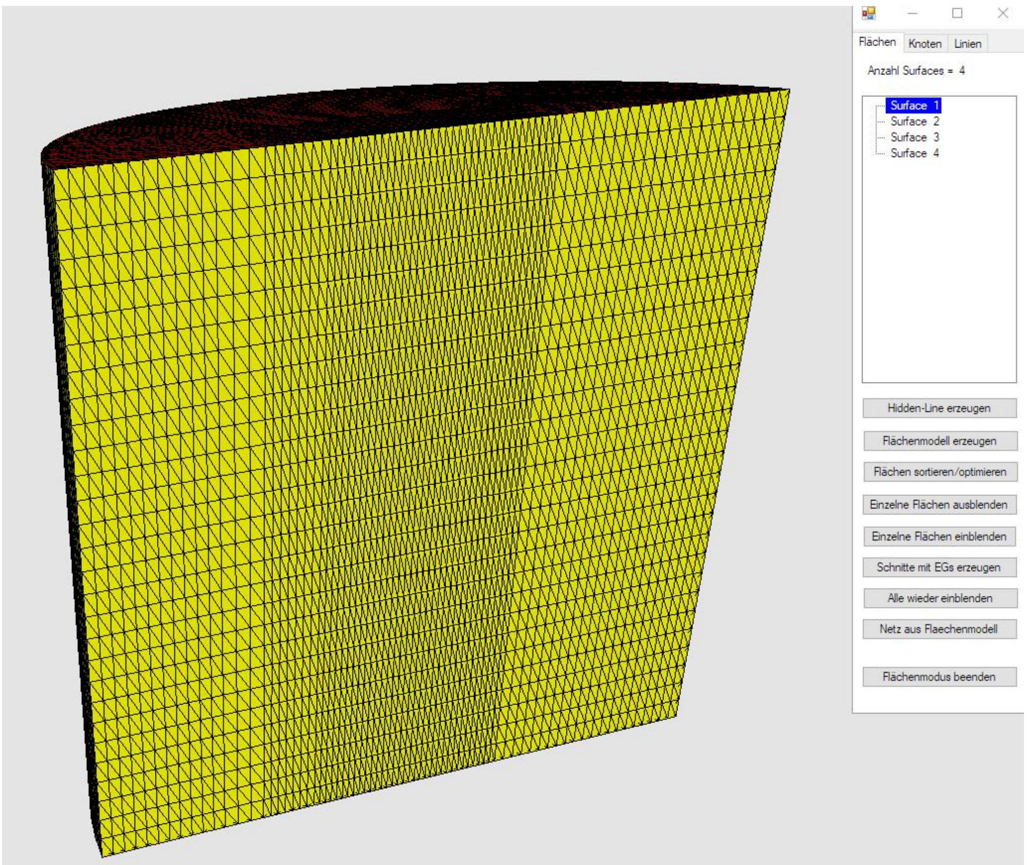
Refine Mesh

	No.	Main Group	Subgroup	Refine	Holes
	1	1	0	0	0
	2	2	1	1	0
▸*					

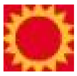
Then use the "2D mesh generator" menu to first generate a 2D mesh with a subsequent 3D extrusion with the "Extrude 3D model" setting Nodes in Z Direction = 30 and a Z-Depth = 100.



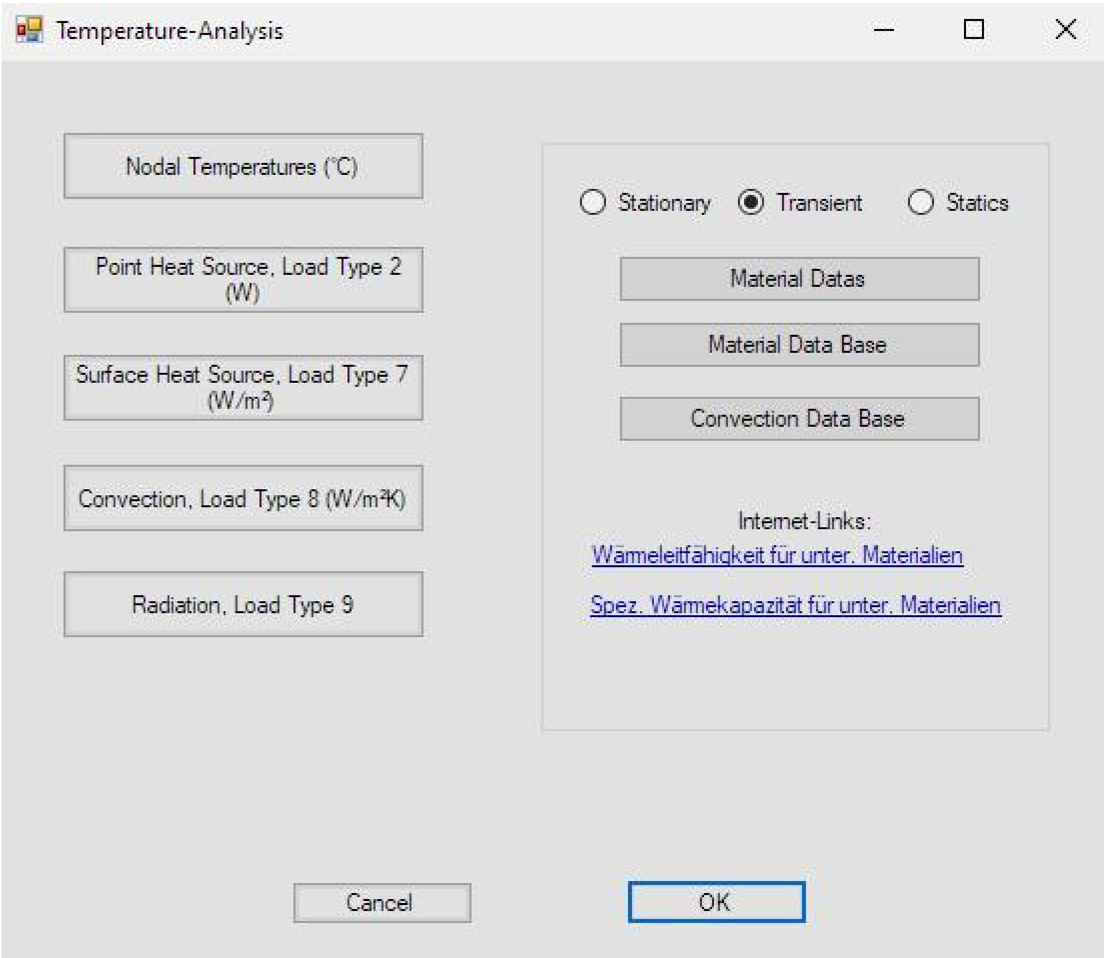
A FEM mesh of 67728 PEN6 volume elements and 37380 nodes is obtained.

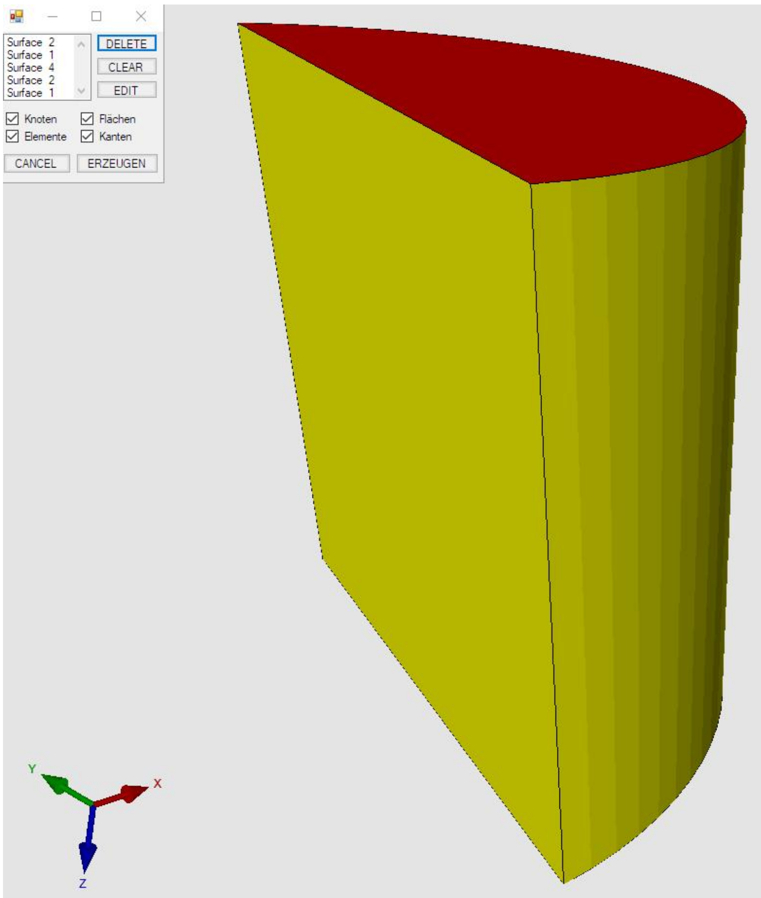


Enter the Outside Temperature

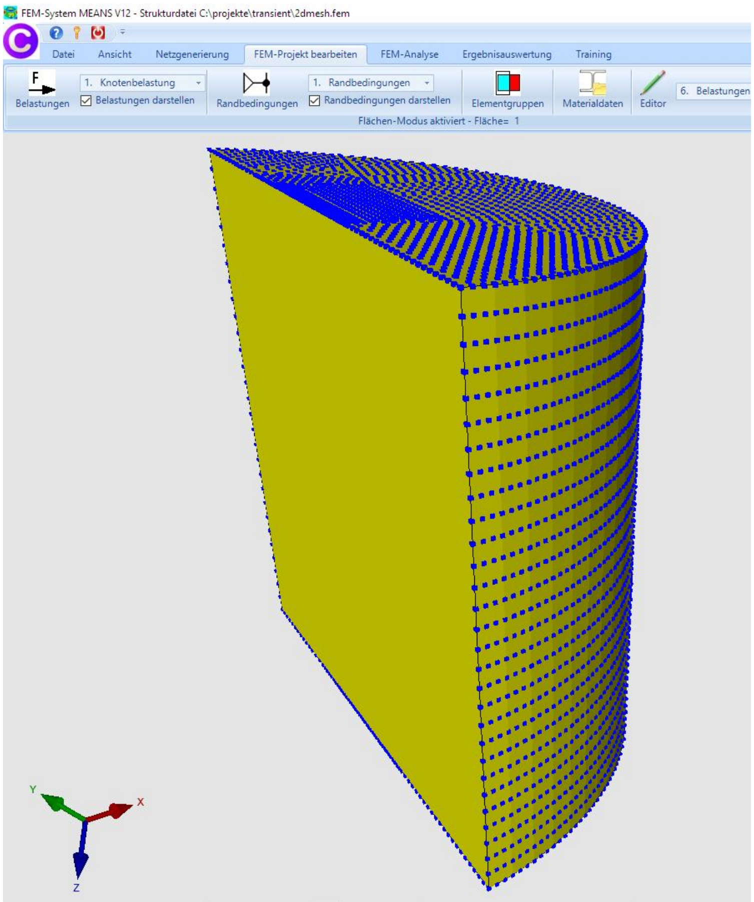
Select the "Edit FEM project" tab and the icon  to enter the constant outside temperature of 0 °C.

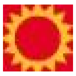
Select the "Nodal Temperatures" menu and click on the outer surfaces 1, 2 and 4. These are displayed in the select box, generate the boundary temperatures there with the "Create" menu.

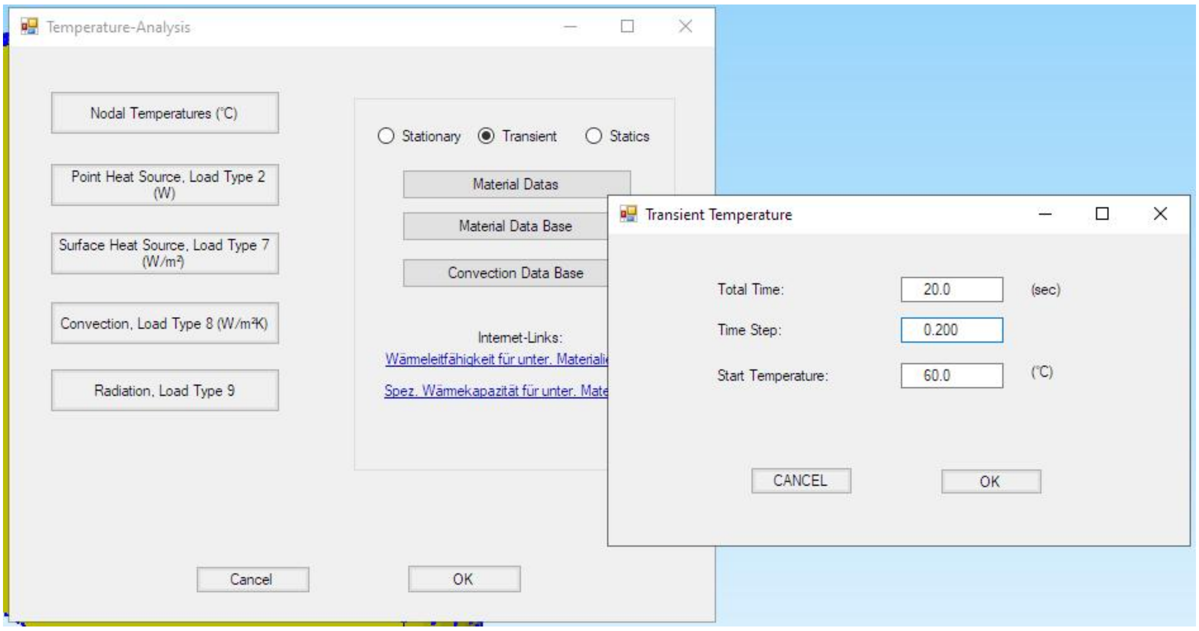




and receives the boundary conditions with the value = 0 shown as blue points.

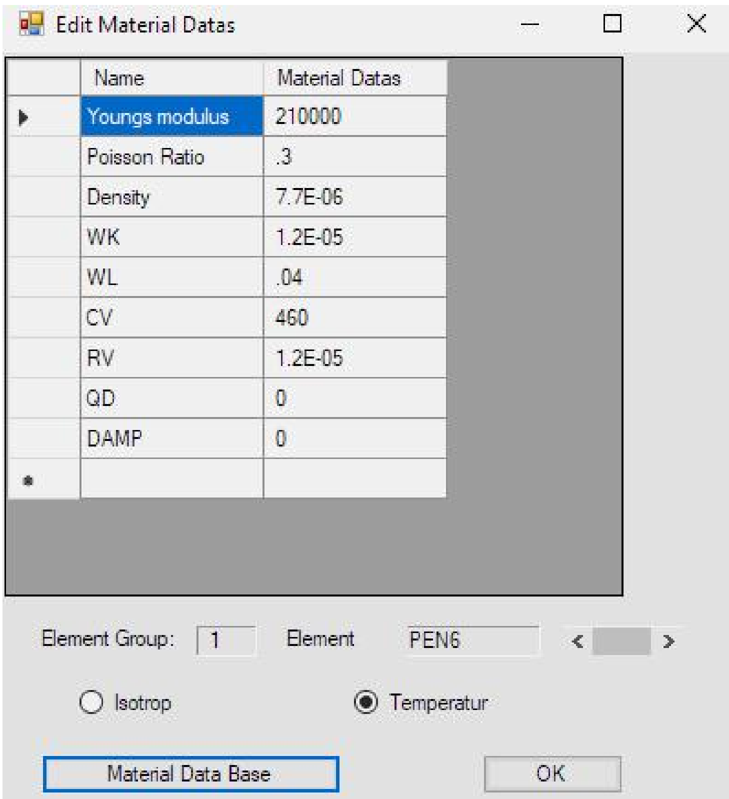


Finally, select  and the "transient" menu to enter the transient temperature analysis with the total time = 20 seconds, the time step size = 0.2 and the start temperature = 60 °C



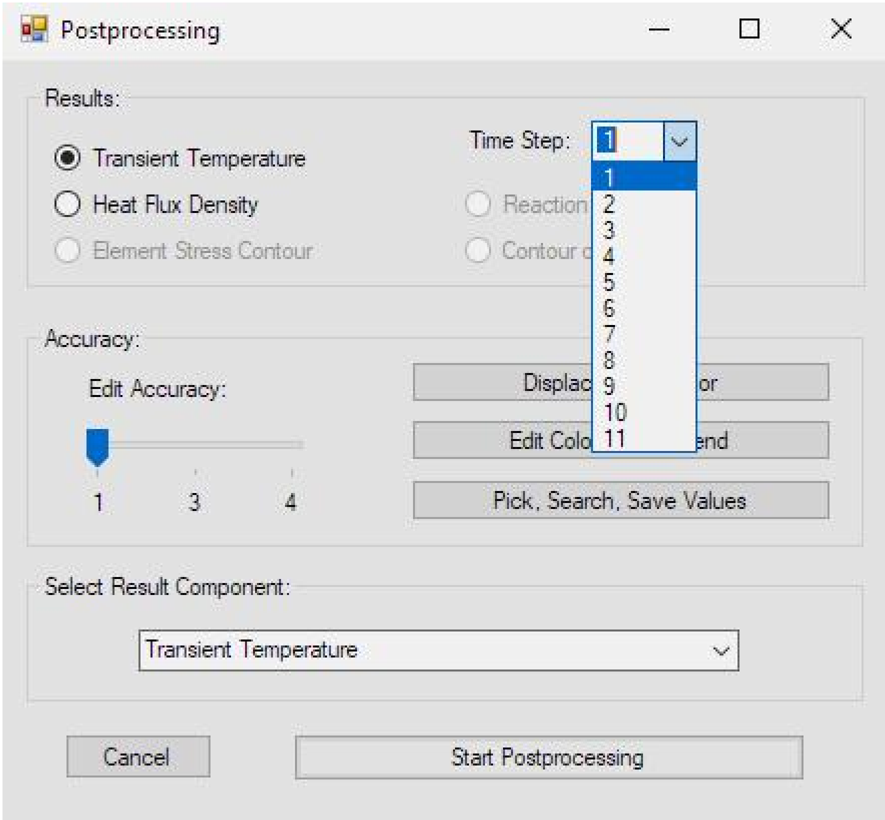
Material datas

Select the "Edit FEM project" tab and the icon  and enter the following material datas:

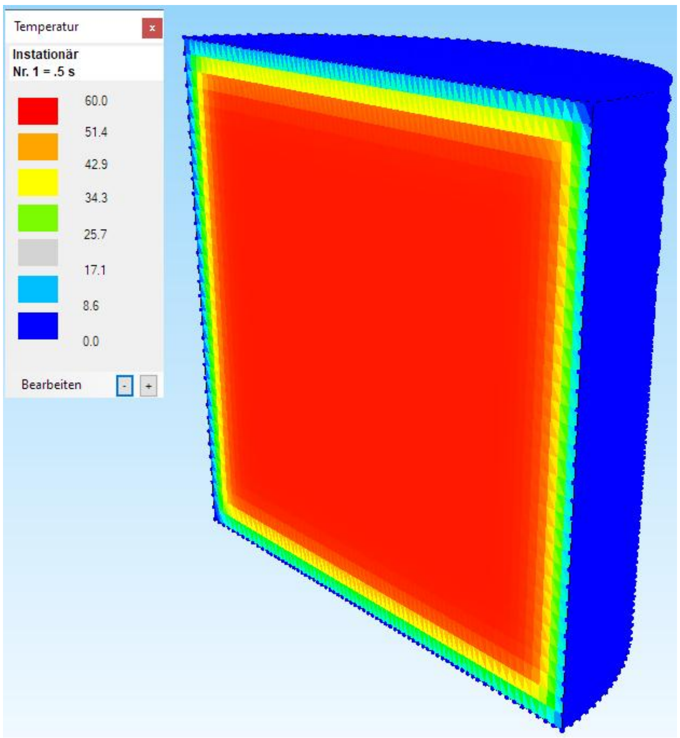


Postprocessing

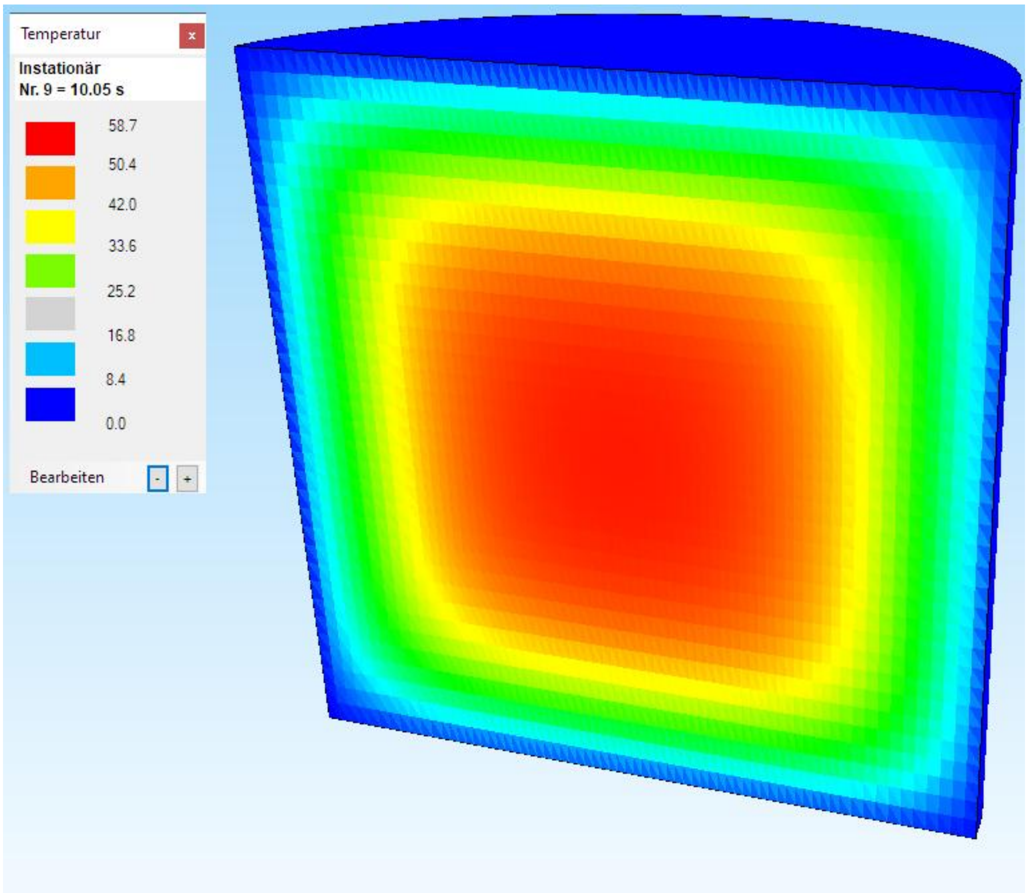
After the FEM analysis with the quick solver, select the icon  of the „Postprocessing“ tab to evaluate the results of the temperature distributions for each time step as a 3D graphic or with a 2D diagram.



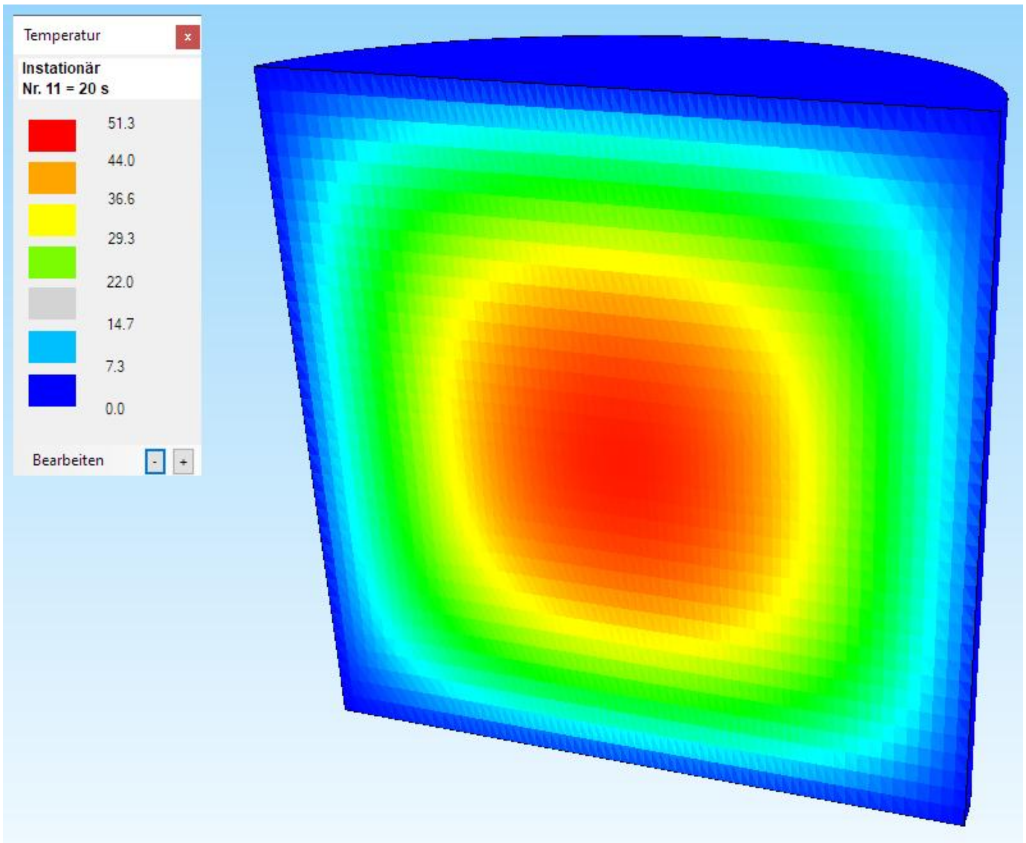
Time step 1 with the start temperature 60 °C



Time step 9 after 10 sec with the max. temperature = 58.7 °C (exactly = 59.3 °C)

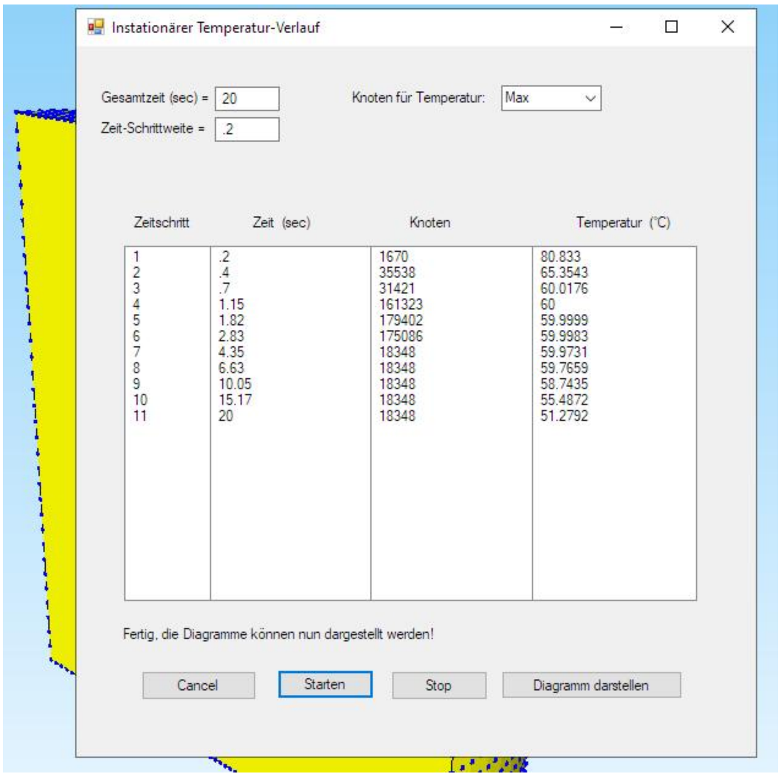


Step 11 after 20 sec with the max. temperature = 51.3 °C (exactly = 51.1 °C)



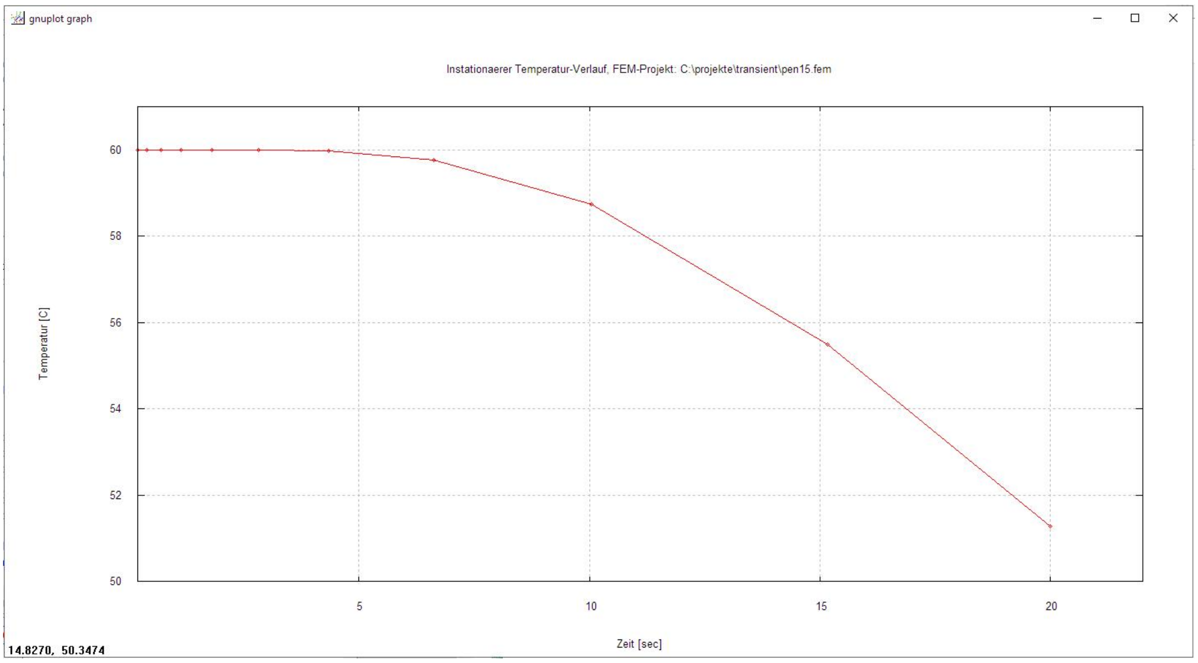
Time-Step-Temperature Diagram

The time steps can be displayed in a diagram, select the "Postprocessing" and "Diagram 2" tabs. There you select "Start" to display the time-step temperature diagram after listing the max. node temperatures with the menu "Show Diagram".



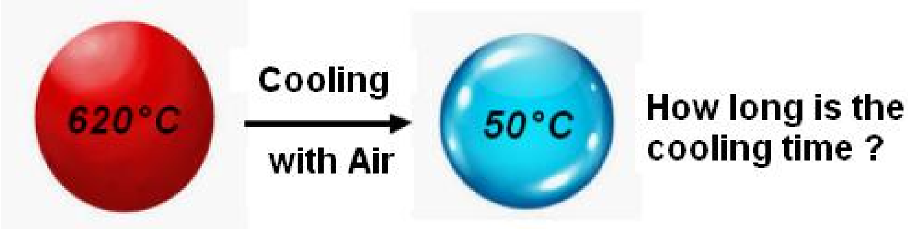
Edit diagram

The current project directory contains **diagram.dat** and **diagram.plt**, which can be edited with a text editor and reloaded and plotted with the GNUPLOT.EXE application in the GNUPLOT directory with the "Open" menu.



Example 2: Cooling of Metal Balls

The following example is from Rudi Marek's book “Praxis der Wärmeübertragung”, ISBN 978-3-446-46124-6 and is compared with the result of MEANS V11



Metal balls with the following material data

Thermal Conductivity = 40 W/(mK)

Density = 7600 kg/m³

C = 474 J/(kgK)

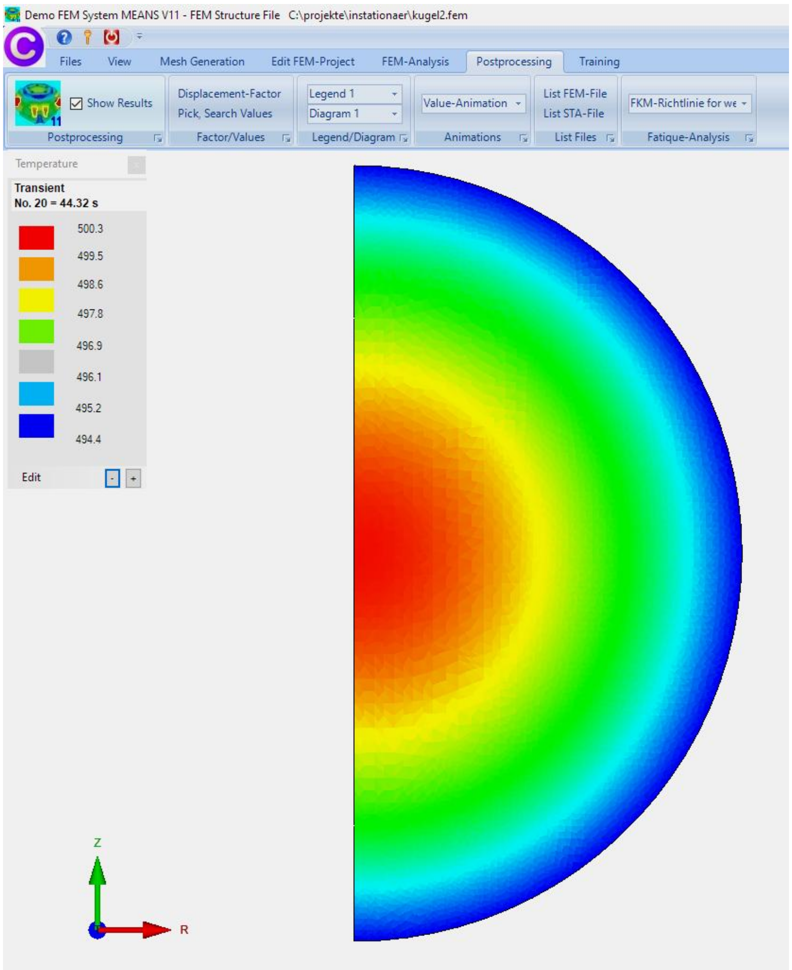
D = 24 mm

from the initial temperature = 620 ° C in an air flow with the

Heat transfer coefficient = 80 W/(m²K) and the

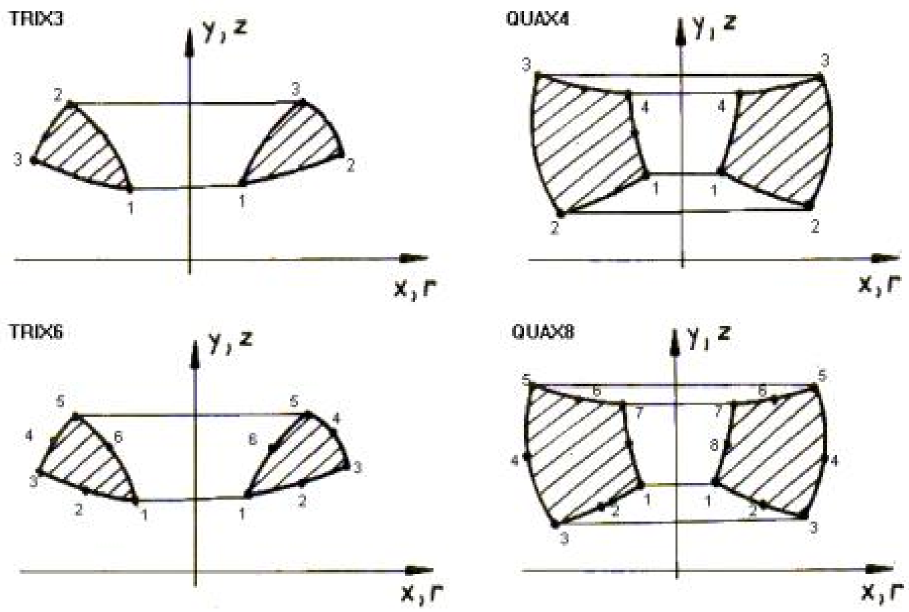
temperature 20 ° C

cooled to the final temperature = 50 ° C.



2D-Calculation

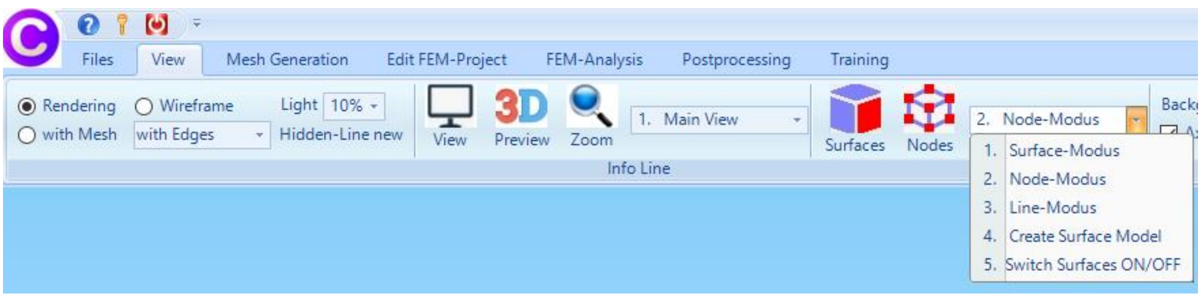
A 2D calculation follows with the axially symmetrical rotating discs TRIX6 and QUAX8.



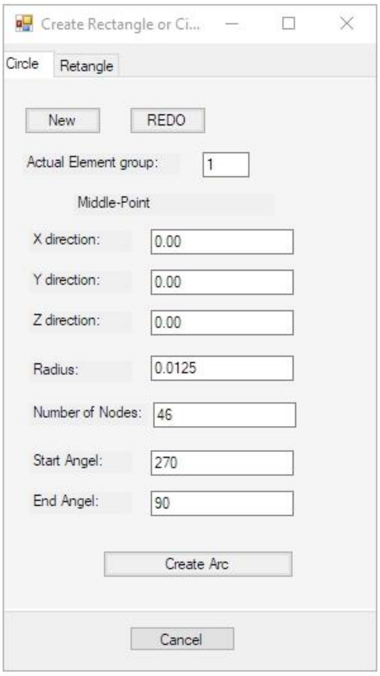
Start the "MEANS V11 for DirectX11" program via the desktop icon  and switch on the Line-Modus with register "View" and the "Line-Modus" dropdown menu.

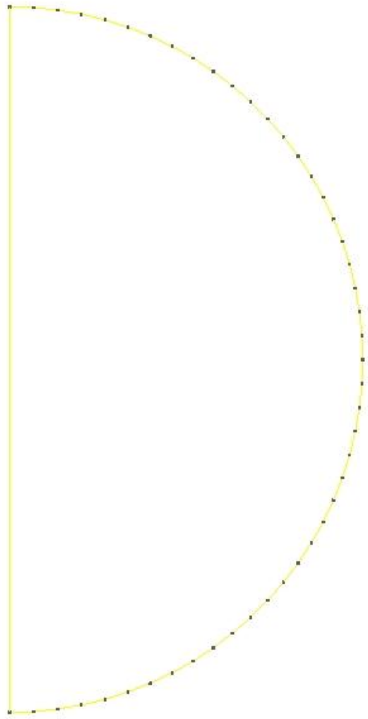
Create a half Arc

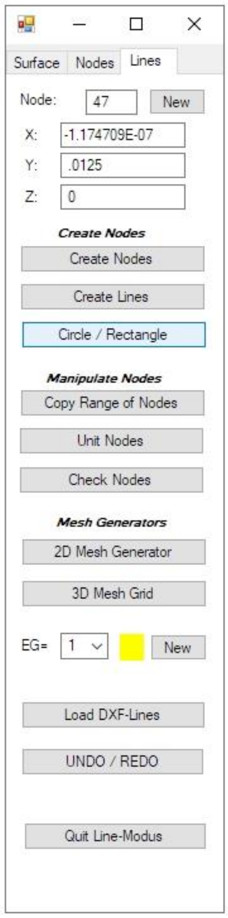
A new side menu appears on the right, select the "Circle / Rectangle" menu to create a half arc with a radius = 0.0125 m from 270 degrees - 90 degrees. With menu “Create Lines” connect nodes 46 and 1 with a line.



Select “2D Mesh Generator” and generate a 2D mesh with TRIX3 elements



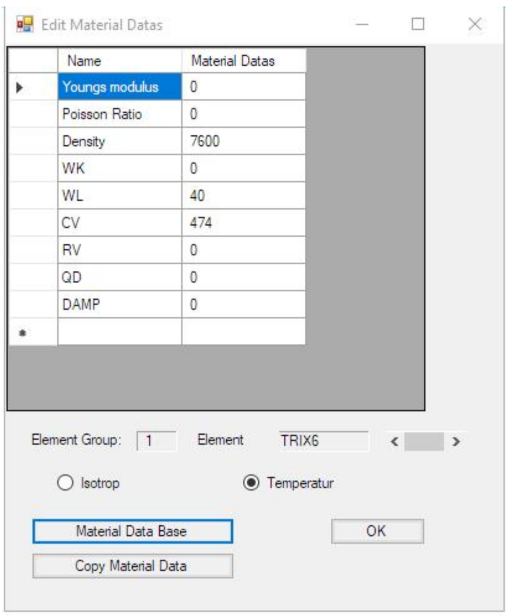




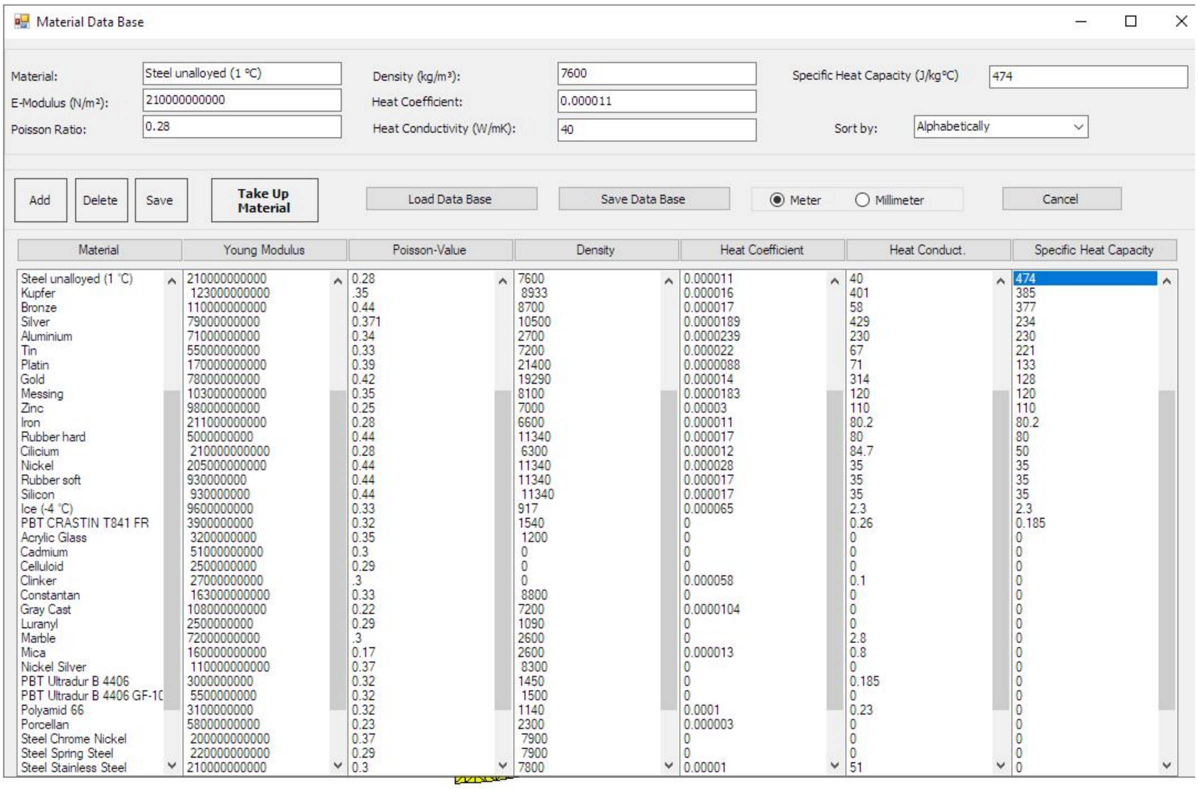
Material Datas

Select register “Edit FEM-Project” with 

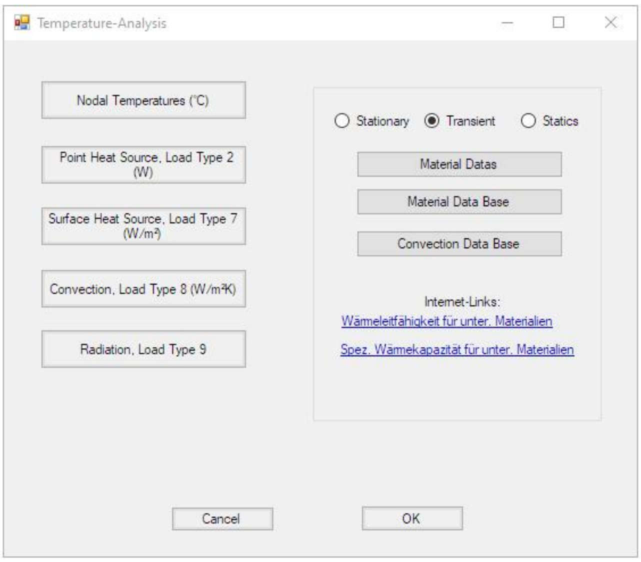
and enter in the self expandable “Material Data Base” the material “Steel” to take over the Density of 7600 kg/m³, Thermal Conductivity of 40 W/mK and the Specific Heat Capacity of 474 J/(kgK).

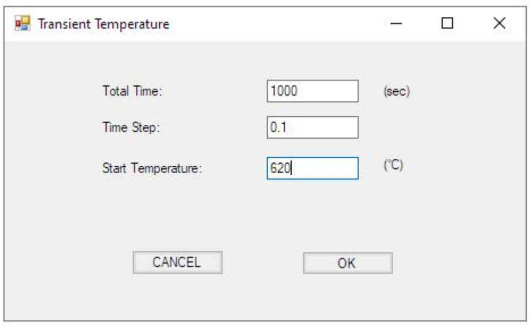


Select "Material Data Base" with the self expandable Material Data Base



Select Transient to enter the Total Time, Time Step and Start



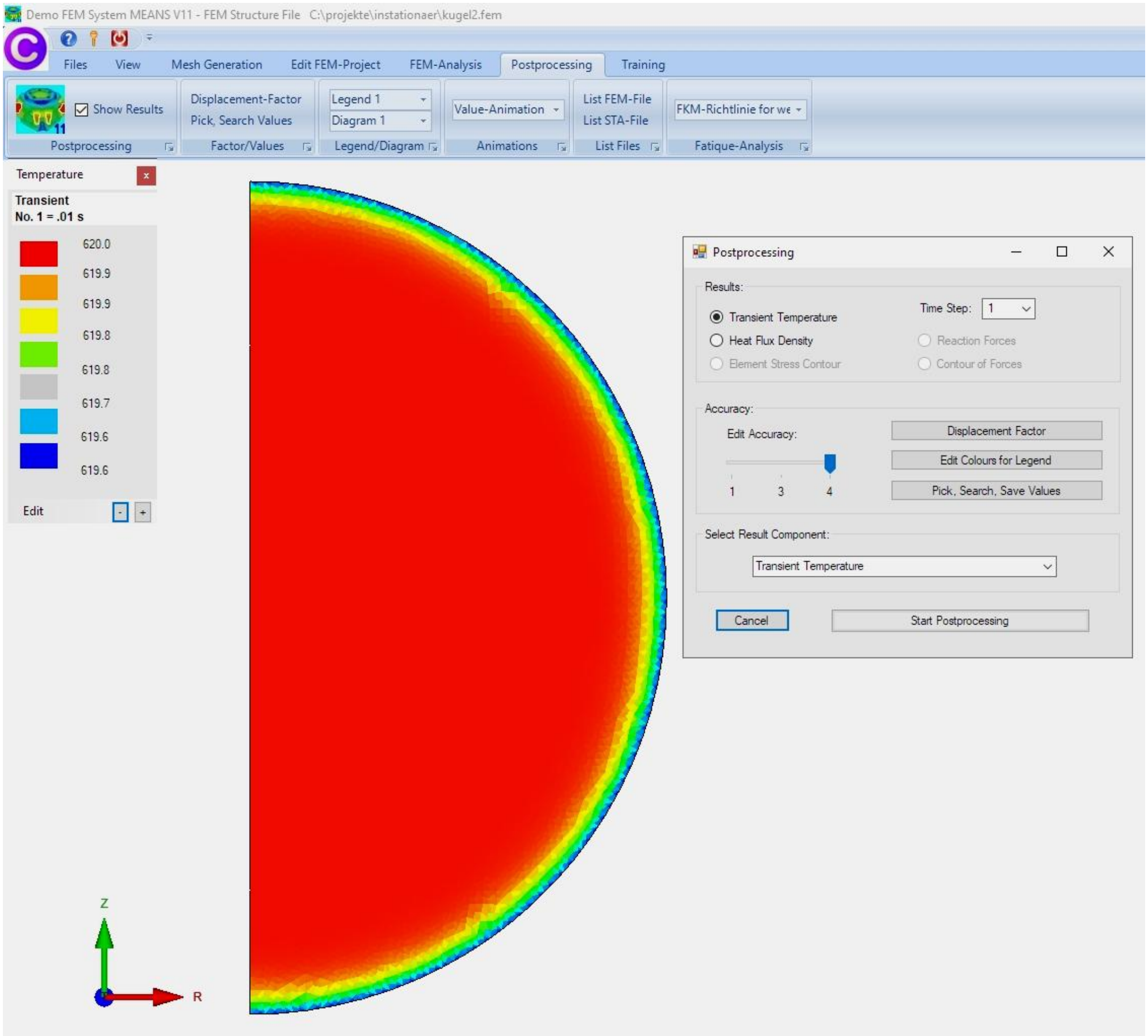


Postprocessing

Use the register Postprocessing and the icon  to show the transient temperature distribution and the heat flux density for every time step.

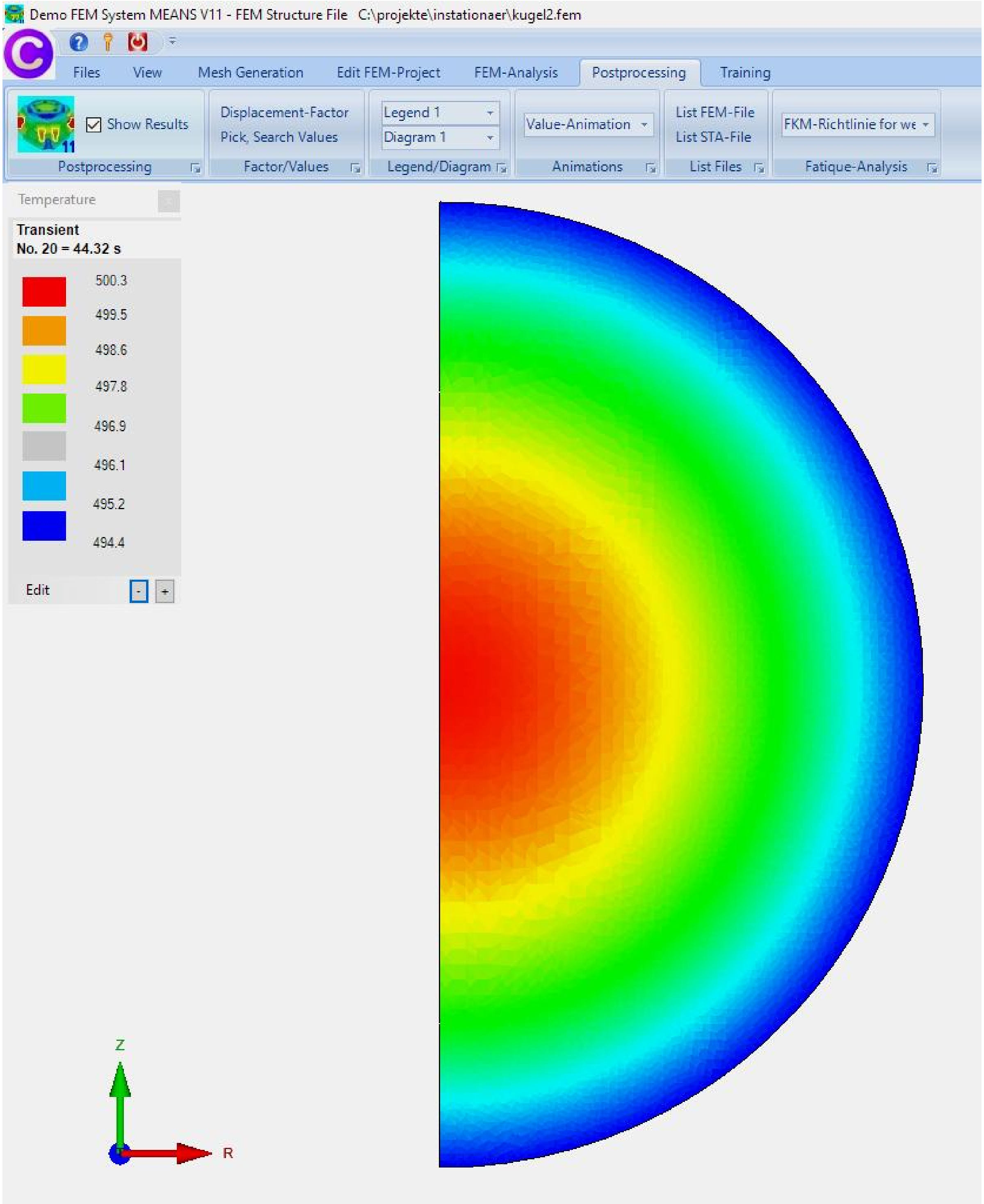
Time Step 1

Start Temperature distribution is 620°C



Time Step 20

Temperature distribution after 44.32 sec with 500.3 °C



Time Step 25

Temperature distribution with QUAX8 after 664.95 sec is 56 ° C

The cooling time at 50 °C is

50 °C * 665 sec / 56 °C = 593 sec = 9.8 min

(Cooling time according to Marek book = 8.99 min)