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.



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/m^3 , Steel = 7800 kg/m^3 , Air = 1.204 kg/m^3 , Ice = 920 kg/m^3 , water = 997 kg/m^3

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 = $60 \degree C$ and the constant Outside Temperature is = $0 \degree C$ 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 with 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.

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View Preview Zoom Surfaces Nodes	 Surface-Modus Node-Modus
	3. Line-Modus
	 Create Surface Model Switch Surfaces ON/OFF

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

New Actual Element gro	REDO	
X direction:	0.00	
Y direction:	0.00	
Z direction:	0.00	
Outer Radius:	50	
Inner Radius:	0	
Number of Nodes	36	
Start Angel:	270	
End Angel:	90	
	Create Arc	
	Cancel	



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

🖁 Create Lines	-		×	
Node 37				
X direction:	5.96244E-07			
Y direction:	-50			
Z direction:	0			
Node 1				
X direction:	4.357793			
Y direction:	49.80973			
Z direction:	0			$ \rangle \rangle \rangle \langle \rangle \rangle$
Number of Nodes p	er Line: 2 Create Lines]		
Element Groups:	1	ОК		/- /-
Number of Nodes:	37	ок		1
Number of Elements:	37	ОК		/
Delete Elements:		ОК		
	Cancel			

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

₩ 2D Mesh Generation — □ X	Surface Nodes Lines Node: 1579 New X: 14.4307 Y: -46.6744 Z: 0
from Bemert Group: 1 Bemert Typ: 1 Bemert Typ: 1 Bemert Typ: 1 Mesh Density: 300 Snap Radius: 005 QUAD-Meshing OBErtrusion Nodes in Z Direction: 5 Z-Depth: Check Nodes Refine Mesh Cancel Help MESH GENERATION	Create Nodes Create Nodes Create Nodes Create Lines Circle / Rectangle Manipulate Nodes Copy Range of Nodes Unit Nodes Unit Nodes Check Nodes Mesh Generators 2D Mesh Generator 3D Mesh Grid EG= 1 New Load DXF-Lines UNDO / REDO Quit Line-Modus

Mesh Refinement

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

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Neu	REDO
Aktuelle Element	gruppe: 2
Rech	teck-Startpunkt:
X-Koordinate:	2
Y-Koordinate:	-15
Z-Koordinate:	0.00
Breite:	15
Höhe:	30
	Rechteck erzeugen
	Cancel

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.

🖳 2D Mesh Generation	-	×
from Bement Group: 1 until Bement Group: 2		
Element Typ: TRI3S		
Mesh Density: 300 🗸		
Snap Radius: .005		
QUAD-Meshing		
Nodes in Z Direction: 30		
Z-Depth: 100		
Check Nodes Refine Mesh		
Cancel Help MESH GENERATIO	N	

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.

n Edit	FEM-Pr	oject	FEM-Analysis Post	processing Tra	aining				
dary-Cond	litions	1. Bo ✔ Sho	undary-Condition: - w Boundary-Conditions	Element-Groups	Material-Datas	Editor	6. Loads	•	Temperature
			Info Li	íne					Γ _N

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.

Point Heat Source, Load Type 2	Material Datas
(VV)	Material Data Base
Surface Heat Source, Load Type 7 (W/m³)	Convection Data Base
Convection, Load Type 8 (W/m4K)	Internet-Links: Wärmeleitfähiokeit für unter Materialian
Radiation, Load Type 9	Spez. Wärmekapazität für unter. Materialien



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



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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

Temperature-Analysis	-					
Nodal Temperatures (°C) Point Heat Source, Load Type 2	Stationary Transient	Statics				
Surface Heat Source, Load Type 7	Material Data Base	🖳 Transient	Temperature		<u></u>	×
(W/m ⁴) Convection, Load Type 8 (W/m ² K)	Convection Data Base Internet-Links: Wärmeleitfähigkeit für unter. Materialik		Total Time: Time Step: Start Temperature:	20.0	(sec) (°C)	
Radiation, Load Type 9	Spez, Wärmekapazität für unter. Mate					
Cancel	ОК					

Material datas



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

	Name	Material Datas		
	Youngs modulus	210000		
	Poisson Ratio	.3		
	Density	7.7E-06		
	WK	1.2E-05		
	WL	.04		
	CV	460		
	RV	1.2E-05		
	QD	0		
	DAMP	0		
E	ement Group: 1	Element PEN6	 	>
_				

Postprocessing

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After the FEM analysis with the quick solver, select the icon **Select** 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.

Transient Temperature	Time Step:	~
O Heat Flux Density	O Reaction 2	
O Element Stress Contour	Contour c 3 4 5	
Accuracy:	67	
Edit Accuracy:	Displac 9	or
	Edit Colo 11	end
1 3 4	Pick, Search, Sa	ive Values
Gelect Result Component:		
Transient Temperature	*	~

Time step 1 with the start temperature 60 °C

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nstationär Ir. 1 = .5 s		
60.0		IL I
51.4		
42.9		
34.3	t i i i i i i i i i i i i i i i i i i i	
25.7		
17.1	$= \frac{1}{2}$	
8.6	t i se	
0.0		
Bearbeiten 💽 💽		



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".

Gesamtzeit (sec) = [Zeit-Schrittweite = [peratur-Verlauf 20Kne	iten für Temperatur: Max		×
Zeitschritt	Zeit (sec) 2 4 7 1.15 1.82 2.83 1.35 6.63 10.05 15.17 20	Knoten 1670 35538 31421 161322 179402 175086 18348 18348 18348 18348 18348 18348	Temperatur (°C) 00.833 65.3543 60.0176 60 59.9999 59.9731 59.7659 58.7435 55.4872 51.2792	
 Fertig, die Diagra	mme können nun dargeste	ilt werden!	Diagramm darstellen	

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 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.

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Files View Mesh Generation Edit FEM-Project FEM-Analysis Postprocessing Training	
Rendering O Wireframe Light 10% - In Main View - I In Main View - In Main View	2. Node-Modus
View Preview Zoom Surfaces Nodes	1. Surface-Modus
Info Line	2. Node-Modus
	3. Line-Modus
	4. Create Surface Model
	5. Switch Surfaces ON/OFF

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

Create Rectar	ngle or Ci — 🗆 🗙	Surface Nodes Lines Node: 47 New X: -1.174709E-07
New Actual Element g Middle-F	REDO roup: 1	Y: .0125 Z: 0 Create Nodes
X direction:	0.00	Create Lines
Y direction:	0.00	Circle / Rectangle
Z direction:	0.00	Manipulate Nodes
Radius:	0.0125	Copy Range of Nodes
Number of Node	es: 46	Unit Nodes
Start Angel:	270	Check Nodes
End Angel:	90	2D Mesh Generators
	Create Arc	3D Mesh Grid
	Cancel	EG= 1 V New
		Load DXF-Lines
		UNDO / REDO
		Quit Line-Modus

Material Datas



Select register "Edit FEM-Project" with ^{Temperature} 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).

	Name	Material Datas			
	Youngs modulus	0			
	Poisson Ratio	0			
	Density	7600			
	WK	0			
	WL	40			
	CV	474			
	RV	0			
	QD	0			
	DAMP	0			
Ele	ement Group: 1	Element TRIX6	ur	<	>

🖳 Material Data Bas	e										- 🗆 X	
Material: Steel unalloyed (1 °C)		nalloyed (1 °C)	(1 °C) Density (kg/m³):		7600	7600		Specific Heat Capacity (J/kg°C)		474		
E-Modulus (N/m²):	21000	000000		Heat Coefficient:		0.000011						
Poisson Ratio:	0.28			Heat Conductivity (W/m	K):	40		Sc	rt by: Alphabetica	ally	~	
Add Delete	Save	Take Up Material]	Load Data Base		Save Data Ba	se	Meter	O Millimeter		Cancel	
Material		Young Modulus		Poisson-Value		Density	Heat	Coefficient	Heat Conduct.		Specific Heat Capacity	
Steel unalloyed (1 °C) Kupfer Bronze Silver Aluminium Tin Gold Mesaing Zinc Ion Rubber hard Cilicium Nokel Rubber soft Silicon Ioe (4 °C) PBT CRASTIN T841 F Acrylic Glass Cadmium Celluloid Cilicker Constantan Celluloid Cilicker Constantan Celluloid Cilicker Constantan Celluloid Cilicker Constantan Celluloid Silicon Silicon Celluloid Cilicker Constantan Celluloid Cilicker Constantan Silicon Silicon Silicon Silicon Silicon Silicon Silicon Silicon Silicon Silicon Colluber soft Silicon Sili	* FR 5F-10	21000000000 12300000000 7300000000 7300000000 7300000000	~	0.28 .35 0.44 0.371 0.34 0.33 0.39 0.42 0.39 0.42 0.25 0.25 0.25 0.44 0.28 0.44 0.44 0.44 0.44 0.33 0.32 0.35 0.3 0.32 0.35 0.3 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.33 0.32 0.35 0.35 0.25 0.35 0.35 0.32 0	 7 8 11 22 11 11 9 11 11 11 11 12 14 14<!--</td--><td>7600 8933 7700 10500 7200 7200 7200 7200 7200 134000 13400 13400 13400 13400 134000 134000 13400 13400</td><td>0.000011 0.000016 0.0000189 0.000028 0.000029 0.000028 0.000014 0.000014 0.000014 0.000014 0.000014 0.000014 0.000014 0.000014 0.000017 0.000017 0.000017 0.000017 0.000017 0.0000104 0 0 0.0000058 0 0 0.0000058 0 0 0.0000058 0 0.0000058 0 0.00000104 0.00000104 0.00000104 0.00000104 0.00000104 0.00000104 0.0000000000</td><td></td><td>40 401 58 429 230 67 71 314 120 110 80.2 80 84.7 35 35 35 35 35 2.3 0.26 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>~</td><td>474 • 385 377 234 230 221 133 128 120 110 80.2 80.2 280 50 35 325 2.3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>	7600 8933 7700 10500 7200 7200 7200 7200 7200 134000 13400 13400 13400 13400 134000 134000 13400 13400	0.000011 0.000016 0.0000189 0.000028 0.000029 0.000028 0.000014 0.000014 0.000014 0.000014 0.000014 0.000014 0.000014 0.000014 0.000017 0.000017 0.000017 0.000017 0.000017 0.0000104 0 0 0.0000058 0 0 0.0000058 0 0 0.0000058 0 0.0000058 0 0.00000104 0.00000104 0.00000104 0.00000104 0.00000104 0.00000104 0.0000000000		40 401 58 429 230 67 71 314 120 110 80.2 80 84.7 35 35 35 35 35 2.3 0.26 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	~	474 • 385 377 234 230 221 133 128 120 110 80.2 80.2 280 50 35 325 2.3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	

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

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

Temperature-Analysis	- 0 X				
Nodal Temperatures ('C)	O Stationary Transient Statics	Transient Temperature		-	×
Point Heat Source, Load Type 2 (W)	Material Datas				~
Surface Heat Source, Load Type 7 (W/m²)	Material Data Base Convection Data Base	Total Time: Time Step:	0.1	(sec)	
Convection, Load Type 8 (W/m ² K)	Internet-Links: Wärmeleitfähigkeit für unter. Materialien	Start Temperature:	620	(°C)	
Radiation, Load Type 9	Spez. Wärmekapazität für unter. Materialien	CANCEL	OK		
Cancel	OK				

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)

