Part 15: Stationary Temperature-Analysis in a Double-Glazing with MEANS V11

Calculation of stationary temperature distribution and heat flux density in a double glazing with thermal convection in a outer and inner glass, air space and a metallic spacer.

Double-Glazing



FEM Model



16 Nodal Coordinates:

Х	(m)	Y (m)	Х ([m])	Y (m)
1.	0.00	0.00	9.	0.000625	0.00725
2.	0.000625	0.00	10.	0.004125	0.00725
3.	0.000625	0.016	11.	0.004125	0.00875
4.	0.00	0.016	12.	0.004075	0.00875
5.	0.004125	0.00	13.	0.004075	0.0073
6.	0.004525	0.00	14.	0.000675	0.0073
7.	0.004525	0.016	15.	0.000675	0.00875
8.	0.004125	0.016	16.	0.000625	0.00875

FEMM Mesh Generator

With the new FEMM-Interface for MEANS V11 it is now possible to generate the double glazing FEM model with the 2D mesh generator of the FEMM program. FEMM is very useful and powerful FEM freeware for solving electromagnetic problems.

Download FEMM

Please download and install the FEMM 2D freeware program from the website **http://www.femm.info/wiki/Download.**



After installing FEMM, it will start with the desktop icon

Now follow these steps to generate a FEM mesh with FEMM:

Magnetics Problem

Select "Magnetics Problem" from 4 different calculation options. However, only mesh generation is needed

eate a new problem	
Magnetics Problem	
Magnetics Problem	
Electrostatics Problem Heat Flow Problem	

Enter the Nodal Coordinates

First, select "nodes" in the toolbar and press the tab key each time to enter the coordinates in a dialogbox. With the icon the nodes can be zoomed onto the screen.



Enter the Lines

Connect the nodes with the icon by clicking with the left mouse button on the first and then on the second node of the line.



Define Properties

Now define the properties with the "Properties" and "Materials" menu and create the 4 properties "Outer Glass", "Inner Glass", "Metallic Spacer" and "Air Space".



Accept the preset material data as only the FEM mesh is interested in the electromagnetic calculation.

P	roperty Definition	×
	Property Name	
	Outer Glass	-
	Outer Glass	
	Inner Glassl Metallic Spacer Air Space Delete Property	
	Modify Property	

Place and select properties



Select the property with the right mouse button and click on the icon and select one of the 4 properties from the list.



Zoom in with the icon to the middle area so that the property "Metallic Spacer" can be placed.



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Generate FEM Mesh

Now save the nodes, lines and properties under FEMM1.FEM in the project directory and use the menu "Create Mesh" to generate a FEM Mesh of 3475 nodes.



Select Analyze

Select the menu "Analysis" and "Analyze" and carry out a short calculation to generate the required ANS file FEMM1.ANS. FEMM is no longer needed and can be closed.

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Import the FEMM Mesh

Now start the FEM system MEANS V11 with the desktop icon **TSG** and select the tab "Mesh generation" as well as "Import FEMM Mesh" to load the FEMM mesh **FEMM1.ANS**.

Edit FEM-	Project FEM-Analysis	Postprocessing	Training			
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ragon	femm1	31.10.2019 10:50	ANS-Datei	356 K	В	
-	femm1	31.10.2019 10:42	ANH-Datei	280 K	В	
	heat_meter3	29.10.2019 10:26	ANH-Datei	342 K	в	
	heat_meter2	29.10.2019 10:09	ANH-Datei	111 K	В	
	heat_meter1	29.10.2019 09:47	ANH-Datei	110 K	В	
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	<pre>femm_netzpunkte2</pre>	23.10.2019 17:26	ANH-Datei	39 K	B	
~						
				1	[
ne:				~	FEMM-2D (*.an*)	~
					Öffnen	Abbrechen

After the import a FEM Mesh with 6693 TRI3S elements, 3475 nodes and 5 element groups is created.

This FEM Mesh can now be used for all statics, dynamics or temperature calculations of MEANS V11.



Edit Element groups

Select the "Edit FEM Project" and "Element Groups" tabs and give each of the five element groups a color by clicking on the left color frame.

You can also switch the element groups on and off to edit one or to evaluate a specific or inner group

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Create Elem	ent groups	1) 					
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Change Element Groups:

If the two groups of elements 2 + 4 are combined for air, an element group can be saved. In the legend, select the "Create Element groups" menu and change the element groups as follows:

Increase number of element groups from 5 to 6 Change element group 2 to 6 Change element group 3 to 2 Change element group 6 to 3 Change element group 4 to 3 Change element group 5 to 4 Change number of element groups to 4

FEM System M	EANS V11	- FEM Structure File C	:\projekte\konvektion	\netz1.fem		
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Ø ON	EG= 3					Dragging a Model Region
Ø ON	EG= 4					Select all showing Nodes
⊠ ON	EG=5					○ Select several surfaces
⊠ ON	EG=6					X-Depth O Y-Depth O Z-Depth
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Draw hidden Surfaces as	EGs and Wireframe G					All elements get the element group 1
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Stationary Temperature

Select register "Edit FEM-Project" and the icon **Temperature** to enter the stationary temperature as well as the thermal conductivity and convection.

	Stationary O Transient O Statics
Point Heat Source, Load Type 2 (W)	Material Datas
Contract Courses Local Taxs 7	Material Data Base
(W/m ²)	Convection Data Base
Convection, Load Type 8 (W/m³K)	htere d beler
	Internet-Links: <u>Wärmeleitfähigkeit für unter. Materialien</u>
Radiation, Load Type 9	Spez. Wärmekapazität für unter. Materialien

Create the Thermal Conductivities

Select "Material Datas" to take over the Thermal Conductivities of Glass, Steel and Air from the self-expandable Material Data Base of MEANS V11.

Outer Glass:	WL = 1 W/mK
Inner Glass:	WL = 1 W/mK
Air-Space:	WL = 0.0181 W/mK
Metallic Spacer :	WL = 10 W/mK
	Outer Glass: Inner Glass: Air-Space: Metallic Spacer :

🔛 Material Data Base						- 🗆 X
Material: Glass - E-Modulus (N/m²): 21000 Poisson Ratio: 0.28	Window Glass	Density (kg/m³): Heat Coefficient: Heat Conductivity (W/mK):	2500 0.000011 1	Specific H	eat Capacity (J/kg°C) 840	~
Add Delete Save	Take Up Material	Load Data Base	Save Data Base	e 🖲 Meter	() Millimeter	Cancel
Material	Young Modulus	Poisson-Value	Density	Heat Coefficient	Heat Conduct.	Specific Heat Capacity
Glass Window Glass Glass Guarz Glass Caraz Glass Echnical Gold Graphte Graphte Graphte Graphte Graphte Graphte Graphte Graphte Graphte Graphte Graphte Graphte Graphe Graphte Graphte Graphte Matole Messing Matole Messing Matole Messing Nickel Silver B406 PBT Ultradur B 4406 GF-10 Patin Polyamid 66 Polyatid 66 Polyatid 66 Polyatid 66 Steel Steel Steel Steel Steel Steel Steel Steel Steel Steel Steel Steel Steel Nickel Tin	21000000000 ▲ 7500000000 ▼ 78000000000 ₹ 78000000000 1880000000 12800000000 2110000000 2100000000 21200000000 4910000000 12300000000 490000000 1300000000 11000000000 1300000000 3000000000 300000000 3100000000 300000000 3100000000 300000000 3100000000 300000000 3100000000 21000000000 210000000000 21000000000 210000000000 21000000000 210000000000 21000000000 210000000000 210000000000 2100000000000 210000000000 2100000000000 21000000000000000 2100000000000 21000000000000000000000000000000000000	0.28 0.17 0.25 0.42 0.371 0.22 0.333 0.28 .35 0.36 0.29 2.8 .3 0.35 0.17 0.44 0.37 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.32 0.33 0.28 0.37 0.29 .28 0.37 0.29 0.33 0.37 0.29 0.33 0.33 0.33 0.33	2500 ^ ^ 2200 2200 7 15250 15550 15550 15550 15550 15550 15550 1555 1555 1555 1555 1555 1555 1555 1555 1555 15550 15500 15400 15400 15400 15500 15400 15400 15500 15400 15400 15500 15400 15400 15500 15400 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 15500 155000 15500 15500 15500 15500000000	0.000011 0.000054 0.000014 0.000019 0.000019 0.000016 0.000058 0 0.000016 0.000024 0 0.000013 0.000028 0 0 0.000013 0.000017 0.000017 0.000017 0.000017 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.000011 0.0000000000	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	840 703 830 128 710 0 0 2.3 80.2 385 3482 0 0 1046 0 120 0 35 0 0 1250 0 0 35 35 35 35 234 520 0 0 490 0 221

Select "Glass Window Glass" and "Take Up Material" to create the Material Datas:

	Name	Material Datas			
	Youngs modulus	0			
	Poisson Ratio	0			
	Density	2500			
	wк	1.1E-05			
	WL	1			
	CV	840			
	RV	1.1E-05			
	QD	0			
	DAMP	0			
	Thickness	1			
8					
Ð	ement Group: 1	Element TRI3S		<	>
	() Isotrop	Temperat	ur		
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Create Convection



Select the icon Temperatur again to enter the convection of the outer and inner glass. First select the following convection values from the self-expandable Convection Database:

Convection on outer Glass = $25 \text{ W} / \text{m}^2\text{K}$ and temperature = $-18 \degree \text{C}$ Convection on Inner Glass = 7,692 W / m^2K and temperature = $20 \degree \text{C}$

	Interior Wall			
emperature (°C):	20			
onvection (W/m²K):	7.692			
Add Delete	Save Take Mater	Up Load Da	ata Base	Save Data Base
Name	Tempera	Convectio	n	
Garage -8 °C Ground of earth Inner Floor Inner Rsi 0.25 Interior Floor 8 °C Interior Wall Outer +20 °C Outer -10 °C Outer -18 °C Outer -5 °C Roof floor -4 °C Roof last layer	-8 8 20 20 8 20 20 -10 -18 -5 -4 -10	7.692 10 5.882 4 5.882 7.692 25 25 25 25 25 25 25 10 10	000000000000000000000000000000000000000	

Coordinate Range

Now select the menu "Convection, Load Type 8 (W/(m^2K)) and enter the value of convection = 25 W/ m^2K and the temperature of -18 ° C with the selection "Define a coordinate range" and select "Create Convection" to enter in the next dialogbox the coordinate range to create the convection on the outer glass:

from x = 0 until x = 0from y = 0 until y = 0.016from z = 0 until z = 0

	5. <u></u>		×			
] New (W/m ² K) Enheit in Grad	í)				
on Oinz on OVer (-Axis; RED: Z-Ax	direction tical to Surface	e				
O Dragging O Select all	a model regior showing node	n s				
Crea	te Convecti te Convecti	on				
nge —		×				
until X: [until Y: [from Z: [.016]				
ordinate Rang	e					
ordinate	Rang	Range	Range	Range	Range	Range

Create with the same steps for the inner glass with the convection = 7,692 W / m^{2} K and the temperature of 20 ° C also with the cooordinate range from x = 0.004525 until X = 0.004525 or with the selection "Dragging a model region".

Create a	e Coordinate Range	-		>
from X:	.004525	until X:	.004525	
from Y:	0	until Y:	.016	
until Z:	0	from Z:	0	
	Create a Coordi	nate Rar	nge	

Save the model

The FEM model is now complete and can be calculated. First save it with the "File" and "Save" tabs under the name "FEMM2.FEM" in the project directory.

FEM Analysis

Select register FEM-Analysis and menu "3. Temperature" to calculate the node temperatures.

Postprocessing

Use the register Postprocessing and the icon temperature distribution and the heat flux density.

to show the stationary

👼 Demo FEM System MEANS V	11 - FEM Structure File C:\	.projekte\konvektion\f	femm1_engl.f	fem	
Files View M	lesh Generation Edit F	EM-Project FEM-	Analysis	Postprocessir	g Training
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Pc	stprocessing		-	_ ×]
Res O	ults: Steady State Temperature Heat Flux Density Element Stress Contour	Load Case: C Reaction Contour of	1 v Forces f Forces		
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		Edit Color	urs for Legend		
Sele	ct Result Component:	Tick, Jean	in, dave value		
	Steady State Temperat	ure	~]	
[Cancel	Start Postproce	ssing		
L					-

Temperature Distribution

Max. Temperature = 2.9 °C Min. Temperature = -13.2 °C



Heat Flux Density

Middle Heat Flux Density = 10500 W/m² = 10.5 kW/m²



3D-Thermal Bridge

A 3D calculation follows by extruding the 2D thermal bridge with a Z depth into a 3D solid model.

Convert TRI6S to TRI3S

First, the quadratic TRI6S model must be converted to a TRI3S model without middle nodes. Select register "Mesh Generation" and menu "Quad-Meshes, Refine, Delete ..." and in the next dialogbox select register "Converter" and menu "QUA4S <-> QUA8S". After the conversion, the linear model named "QUA4S.FEM" is obtained.

ads	Refine	Converter	Extrusion	Rotation	Delete	Drehen				
	Change	e Element Ty	р	Line	ar <-> Qu	adratic	MEANS <->	ABAQU	JS	
	Plan	e Elements		QU	A4S <->(QUA8S	Pressure -> N	lodal Lo	ad	
	Plat	e Elements		Т	ET4 -> T	ET10	SHEL8	-> S8		
	She	I Elements		Т	ET10->`	TET4	C3D10->	TET10		
	Axial S	Sym. Element	s	н	IEX8 -> H	IEX20	TET10->	C3D10		
,	Actual Ele	ement Type:		H	EX20 ->	HEX8	C3D20->	HEX20		

Now select register "Extrusion" in the same dialog box and extrude the 2D mesh with the following setting

Number of nodes in the Z direction = 5 Z object height = 0.005 m

The new 3D mesh consisting of 60 237 PEN6 solid elements, 34 750 nodes and 4 element groups.

Quads	Refine	Converter	Extrusion	Rotation	Delete	Drehen		
		(For Ext	rusion you n	eed a 2D r	nesh with	i Z=0)		
			Density	/ in <mark>Z dire</mark> ct	tion=	5		
			Elevati	on in Z dire	ection=	.005		
1	DVE		LINDO	1. 19		Create a 3D Mesh	Cancel	

After the extrusion, the numbering is automatically checked and the hidden line and area model with 5 surface areas is generated.

Here you can see the extruded pentahedron model with and without mesh:



3D Convection



Select the icon Temperatur again to enter the convection of the outer and inner glass. First select the following convection values from the self-expandable Convection Database:

Convection on outer Glass = $25 \text{ W} / \text{m}^2\text{K}$ and temperature = $-18 \degree \text{C}$ Convection on Inner Glass = 7,692 W / m^2K and temperature = $20 \degree \text{C}$

Point Heat Source, Load Type 2 (W)	Material Datas
	Material Data Base
iurface Heat Source, Load Type 7 (W/m²)	Convertion Data Base
	Convection Data Base
Convection, Load Type 8 (W/m ² K)	Internet-Links:
	Wämeleitfähigkeit für unter. Materialien
Radiation, Load Type 9	Spez. Wärmekapazität für unter. Materialien
1	

Select menu "Convection, Load Type 8 (W/m^2K) and enter the 3D convection on the outer glass with the surface 1 and the convection on the inner glass with the surface 4.

Surface 4 DELETE CLEAR EDIT Nodes Surfaces EDIT Nodes EDIT CLEAR EDIT CLEAR EDIT CLEAR EDIT CLEAR EDIT		Surfac Num	Nodes Nodes Surface 1 Surface 2 Surface 3 Surface 4 Surface 5 Surface 6	Lines aces = 6	×
Convection — × Current Loadcase 1 Number of Loads 312 New Value of Loads 312 New Value of Loads 7.692 (W/m³K) Temperatur: 20 (Enheit in Grad) Degree of Freedom in x direction in z direction O in y direction O in y direction O in z direction (Colour of Axis: BLACK: X-Axis; BLUE; Y-Axis; RED; Z-Axis)			Create a Su Sort and Hi	uface Moo	iel
Selection: Dragging a model region Select Nodes Select all showing nodes Define a coordinate range 			Hide some Show only Create Cut	e Surfaces y Surfaces is with EG Surfaces	s
Cancel Editor Create Convection Delete Convection			Quit Surfa	ce-Modus	
×					

First save the model under the name "PEN6.FEM" and select FEM-Analysis to calculate the temperatures and heat flux density.

Postprocessing

Use the register Postprocessing and the icon temperature distribution and the heat flux density.

to show the stationary

Temperature Distribution

Max. Temperature = 3 °C Min. Temperature = -13 °C

🚟 Demo FEM System MEANS V11 - FEM Structure File C:\projekte\konvektion\pen6a.fem 0 1 🙆 = View Files Mesh Generation Edit FEM-Project FEM-Analysis Postprocessing Training Displacement-Factor Legend 1 -List FEM-File FKM-Richtlinie for we Show Results Value-Animation -List STA-File Pick, Search Values + Diagram 1 🕞 Factor/Values 🕼 Legend/Diagram 🖓 Animations 🖓 List Files 🖓 Postprocessing Fatique-Analysis Temperature Steady State Temperature 3.0 0.7 -1.6 -3.9 -6.1 -8.4 -10.7 -13.0 Edit • +

Heat Flux Density

Middle Heat Flux Density = 11000 W/m² = 11 kW/m²



3D Point Heat Source

Now a 3D Heat Source Simulation is calculated with MEANS V11, which is not possible with a 2D program.

What temperature is set on the outer glazing when there is a heat source of 0.1 W in the middle of the metallic spacer.

Show Metallic Spacer

Select register "Edit FEM Project" and "Element Group" and activate only element group 4 so that the spacer is shown alone. Use the "View" and "Hidden Line New" tabs to recalculate the hidden line.



Create a Range of Nodes

Now create a Point Heat Source of 0.1 W in the middle of the metallic spacer as follows:

Select Node-Modus and create a selectable range of nodes of element group 4.

With the icon repeater, select the menu "Point Heat Source, Load Type 2 (W)" and with load case 2 and the value = 0.1 and the selection "Select Nodes", double-click on node 15358 so that it is displayed in the select box, there with "Create" generate the point source in load case 2 and the convection in load case 1.



Then calculated the new temperature distribution with element groups 1 and 4

Temperatures with Element Group 1 and 4

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	EG= 1	Stationäre	raturan						
	EG= 2	1	85.3						
	EG= 3	1	58.4						
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	EG-5	1	08.4						
	50.0	8	3.3						
	EG=6	5	8.3						
⊻ ON	EG=7	3	3.3						
ür neue Farbe auf Fa	arbrahmen klicken	10	0.1						
Drahtgitter c	te EGs als Iarstellen	Development							
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