

TTLV01 – Sphere: heat transfer by convection

Summary:

This test is resulting from the validation independent of version 3 in linear transitory thermics.

It is about a three-dimensional problem represented by four modelings, one voluminal, three the other axisymmetric ones.

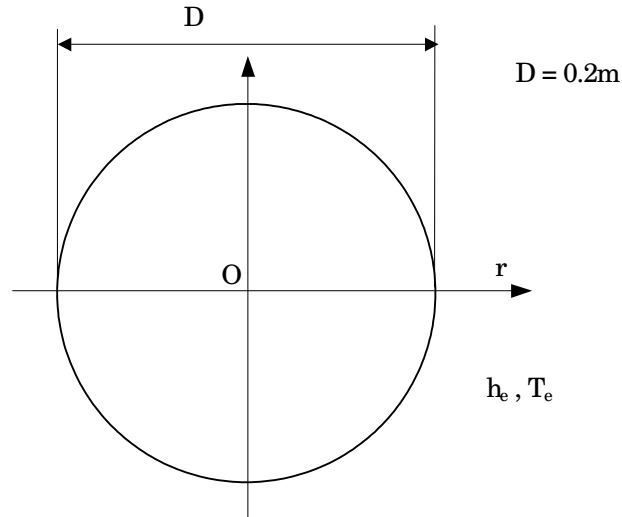
The features tested are the following ones:

- voluminal thermal elements,
- axisymmetric thermal elements,
- transitory algorithm of thermics,
- limiting conditions: convection.

The results are compared with those provided by VPCS.

1 Problem of reference

1.1 Geometry



1.2 Properties of material

$\lambda = 48.822 \text{ W/m}^\circ\text{C}$	thermal conductivity
$c_p = 669.0 \text{ J/kg}^\circ\text{C}$	specific heat
$\rho = 7200 \text{ kg/m}^3$	density

1.3 Boundary conditions and loadings

Convection on external surface with air:

- $h_e = 232.5 \text{ W/m}^2^\circ\text{C}$,
- $T_e = 1000^\circ\text{C}$.

1.4 Initial conditions

Initial temperature: $T(t=0) = 20^\circ\text{C}$

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is that given in card TTLV01/89 of guide VPCS.

- calculation of the coefficients,
- reading on abacus of Gurney-Lurie.

2.2 Results of reference

Temperature on the surface and in the center of the sphere for t understood enters 400_s and 2400_s

2.3 Uncertainty on the solution

< 2%

Below 600_s , uncertainty increases (difficult reading of the abacuses).

2.4 Bibliographical references

- Guide of validation of the software packages of structural analysis. French company of the Mechanics, AFNOR 1990 ISBN 2-12-486611-7

3 Modeling A

3.1 Characteristics of modeling

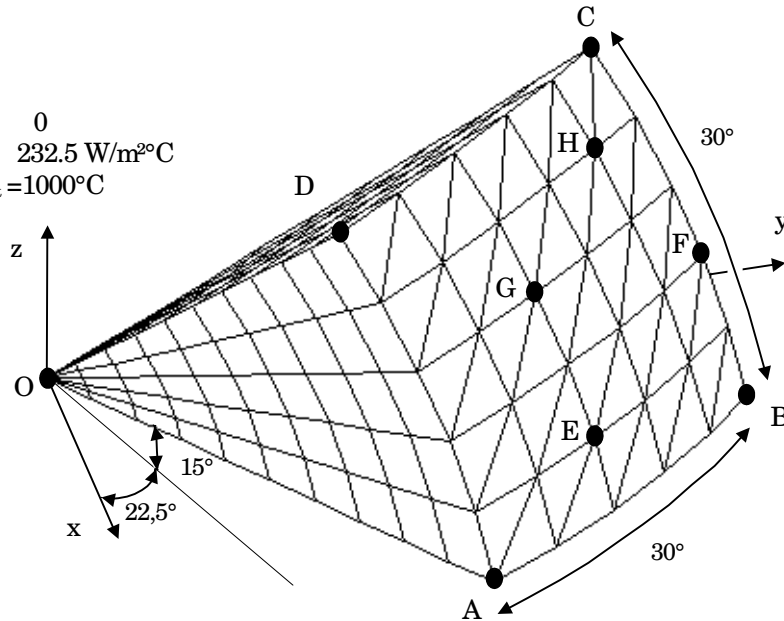
3D (PENTA6 and TETRA4)

Conditions limites:

- faces OAB, OAD,
ODC, OBC
- face ABCD

$$\begin{aligned} \phi &= 0 \\ h &= 232.5 \text{ W/m}^2\text{°C} \\ T_{\text{ext}} &= 1000\text{°C} \end{aligned}$$

Point	Noeud
O	N291
A	N292
B	N345
C	N234
D	N179
E	N254
F	N133
G	N5
H	N198



3.2 Characteristics of the grid

Many nodes: 361
Many meshes and types: 450 PENTA6, 50 TETRA4 (and 50 TRIA3)

3.3 Remarks

One takes, for voluminal heat, $CP = \rho c_p = 4816800.0 \text{ J/m}^3 \text{°C}$.

The limiting condition $\phi = 0$ is implicit on the free edges.

Discretization of time: 36 intervals

of	0	100 seconds:	8 intervals of	12.5 s.
	with			
of	100	300 seconds:	8 intervals of	25.0 s.
	with			
of	300	700 seconds:	8 intervals of	50.0 s.
	with			
of	700	1400 seconds:	7 intervals of	100.0 s.
	with			
of	1400	2400 seconds:	5 intervals of	200.0 s.
	with			

4 Results of modeling A

4.1 Values tested

Identification	Reference	Aster	Relative variation (%)		Absolute deviation (°C)	
			difference	tolerance	difference	tolerance
Temperatures:						
In the center (O : N291 T(°C))						
T = 400 S	334	340.56	1,965%	5.%	6.56	20.
T = 600 S	500	493.15	1,371%	5.%	6.85	20.
T = 800 S	618	610.27	1,252%	5.%	7.73	20.
T = 1000 S	706	700.18	0,824%	5.%	5.82	20.
T = 1200 S	774	769.35	0,600%	5.%	4.65	20.
T = 1400 S	828	822.57	0,656%	5.%	5.43	20.
T = 1600 S	872	863.33	0,994%	5.%	8.67	20.
T = 1800 S	902	894.73	0,806%	5.%	7.27	20.
T = 2000 S	923	918.91	0,443%	5.%	4.09	20.
T = 2200 S	942	937.54	0,474%	5.%	4.46	20.
T = 2400 S	956	951.89	0,430%	5.%	4.11	20.
On the surface (T(°C) A : N292)						
T = 400 S	461	474.82	2,998%	5.%	13.8	20.
T = 600 S	608	596.37	1,913%	5.%	11.6	20.
T = 800 S	696	689.64	0,914%	5.%	6.36	20.
T = 1000 S	774	761.24	1,648%	5.%	12.8	20.
T = 1200 S	828	816.33	1,410%	5.%	11.7	20.
T = 1400 S	868	858.70	1,071%	5.%	9.30	20.
T = 1600 S	902	891.16	1,202%	5.%	10.8	20.
T = 1800 S	923	916.17	0,741%	5.%	6.83	20.
T = 2000 S	942	935.42	0,698%	5.%	6.58	20.
T = 2200 S	956	950.26	0,601%	5.%	5.74	20.
T = 2400 S	962	961.69	0,033%	5.%	0,314	20.

4.2 Remarks

The relative variations are higher than 2% for $t = 400.s$, inferiors for $t \geq 600.s$

On the surface, results calculated by Code_Aster are symmetrical compared to the diagonal AC. The maximum variation observed, into relative as in absolute, is of 0.29% is $1.4^{\circ}C$, between the point A (N291) and the point D (NI79) at the moment $t = 400.s$. These variations decrease in absolute value when time increases.

5 Modeling B

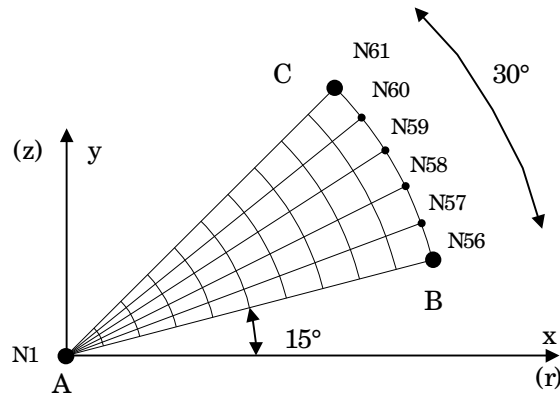
5.1 Characteristics of modeling

AXIS (TRIA3, QUAD4)

Conditions limites:

- coté AB, AC $\phi = 0$
- coté BC $h = 232.5 \text{ W/m}^2\text{°C}$
 $T_{\text{ext}} = 1000\text{°C}$

Point	Noeud
A	N1
B	N56
C	N61



5.2 Characteristics of the grid

Many nodes: 61
Many meshes and types: 45 QUAD4, 5 TRIA3 (and 5 SEG2)

5.3 Remarks

One takes, for voluminal heat, $CP = \rho c_p = 4816800.0 \text{ J/m}^3 \text{ °C}$.

The limiting condition $\varphi = 0$, is implicit on the free edges.

Discretization of time: 36 intervals

of	0	100 seconds:	8 intervals of	12.5 s.
	with			
of	100	300 seconds:	8 intervals of	25.0 s.
	with			
of	300	700 seconds:	8 intervals of	50.0 s.
	with			
of	700	1400 seconds:	7 intervals of	100.0 s.
	with			
of	1400	2400 seconds:	5 intervals of	200.0 s.
	with			

6 Results of modeling B

6.1 Values tested

Identification	Reference	Aster	Relative variation (%)		Absolute deviation (°C)	
			difference	tolerance	difference	tolerance
Temperatures:						
In center (a: N1) $T(^{\circ}C)$						
T = 400 S	334	339.95	1,780%	5.%	5.95	20.
T = 600 S	500	492.47	1,506%	5.%	7.53	20.
T = 800 S	618	609.59	1,361%	5.%	8.41	20.
T = 1000 S	706	699.55	0,914%	5.%	6.45	20.
T = 1200 S	774	768.78	0,675%	5.%	5.22	20.
T = 1400 S	828	822.05	0,718%	5.%	5.95	20.
T = 1600 S	872	862.88	1,046%	5.%	9.12	20.
T = 1800 S	902	894.34	0,849%	5.%	7.66	20.
T = 2000 S	923	918.58	0,479%	5.%	4.42	20.
T = 2200 S	942	937.26	0,503%	5.%	4.74	20.
T = 2400 S	956	951.65	0,455%	5.%	4.35	20.
On the surface (NR: N56) $T(^{\circ}C)$						
T = 400 S	461	475.14	3,068%	5.%	14.1	20.
T = 600 S	608	596.46	1,899%	5.%	11.5	20.
T = 800 S	696	689.58	0,922%	5.%	6.42	20.
T = 1000 S	774	761.11	1,666%	5.%	12.9	20.
T = 1200 S	828	816.15	1,431%	5.%	11.8	20.
T = 1400 S	868	858.51	1,093%	5.%	9.49	20.
T = 1600 S	902	890.97	1,223%	5.%	11.0	20.
T = 1800 S	923	915.99	0,760%	5.%	7.01	20.
T = 2000 S	942	935.26	0,715%	5.%	6.74	20.
T = 2200 S	956	950.11	0,616%	5.%	5.89	20.
T = 2400 S	962	961.56	0,046%	5.%	-0,441	20.

6.2 Remarks

The relative variations are higher than 2% for $t=400.s$, inferiors for $t \geq 600.s$

The maximum variation observed between two nodes on surface, into relative as in absolute, is of 0,012% is $0,055^{\circ}C$, between the point B (N56) and the point C (N61) at the moment $t=400.s$. These variations decrease in absolute value when time increases.

7 Modeling C

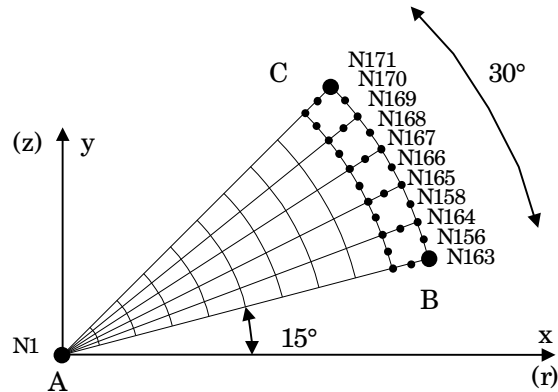
7.1 Characteristics of modeling

AXIS (TRIA6, QUAD8)

Conditions limites:

- coté AB, AC $\phi = 0$
- coté BC $h = 232.5 \text{ W/m}^2\text{°C}$
 $T_{\text{ext}} = 1000\text{°C}$

Point	Noeud
A	N1
B	N163
C	N171



7.2 Characteristics of the grid

Many nodes: 171
Many meshes and types: 45 QUAD8, 5 TRIA6 (and 5 SEG3)

7.3 Remarks

One takes, for voluminal heat, $CP = \rho c_p = 4816800.0 \text{ J/m}^3 \text{°C}$.

The limiting condition $\varphi = 0$ is implicit on the free edges.

Discretization of time: 36 intervals

of	0	100 seconds:	8 intervals of	12.5 s.
	with			
of	100	300 seconds:	8 intervals of	25.0 s.
	with			
of	300	700 seconds:	8 intervals of	50.0 s.
	with			
of	700	1400 seconds:	7 intervals of	100.0 s.
	with			
of	1400	2400 seconds:	5 intervals of	200.0 s.
	with			

8 Results of modeling C

8.1 Values tested

Identification	Reference	Aster	Relative variation (%)		Absolute deviation (°C)	
			difference	tolerance	difference	tolerance
Temperatures:						
In center (a: N1) $T(^{\circ}C)$						
T = 400 S	334	341.10	2,126%	5.%	7.10	20.
T = 600 S	500	493.15	1,370%	5.%	6.85	20.
T = 800 S	618	609.65	1,303%	5.%	8.05	20.
T = 1000 S	706	699.70	0,893%	5.%	6.30	20.
T = 1200 S	774	768.80	0,672%	5.%	5.20	20.
T = 1400 S	828	822.00	0,725%	5.%	6.00	20.
T = 1600 S	872	862.78	1,058%	5.%	9.22	20.
T = 1800 S	902	894.22	0,863%	5.%	7.78	20.
T = 2000 S	923	918.45	0,493%	5.%	4.55	20.
T = 2200 S	942	937.14	0,516%	5.%	4.86	20.
T = 2400 S	956	951.54	0,467%	5.%	4.46	20.
On the surface (NR: N163) $T(^{\circ}C)$						
T = 400 S	461	474.78	2,989%	5.%	13.8	20.
T = 600 S	608	596.02	1,971%	5.%	12.0	20.
T = 800 S	696	689.12	0,989%	5.%	-6.88	20.
T = 1000 S	774	760.65	1,725%	5.%	13.3	20.
T = 1200 S	828	815.72	1,483%	5.%	12.3	20.
T = 1400 S	868	858.12	1,138%	5.%	-9.88	20.
T = 1600 S	902	890.63	1,261%	5.%	11.4	20.
T = 1800 S	923	915.69	0,792%	5.%	7.31	20.
T = 2000 S	942	935.00	0,743%	5.%	7.00	20.
T = 2200 S	956	949.90	0,639%	5.%	6.10	20.
T = 2400 S	962	961.37	0,065%	5.%	0,625	20.

8.2 Remarks

The relative variations are higher than 2% for $t=400.s$, inferiors for $t \geq 600.s$
Variations observed between the results calculated by Code_Aster on two nodes of external surface, are lower than $0,011^{\circ}C$ (either 0,002%).

9 Modeling D

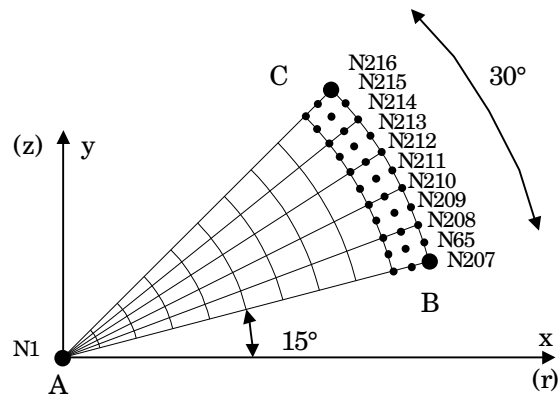
9.1 Characteristics of modeling

AXIS (TRIA6, QUAD9)

Conditions limites:

- coté AB, AC $\phi = 0$
- coté BC $h = 232.5 \text{ W/m}^2\text{°C}$
 $T_{\text{ext}} = 1000\text{°C}$

Point	Noeud
A	N1
B	N207
C	N216



9.2 Characteristics of the grid

Many nodes: 216
Many meshes and types: 45 QUAD9, 5 TRIA6 (and 5 SEG3)

9.3 Remarks

One takes, for voluminal heat, $CP = \rho c_p = 4816800.0 \text{ J/m}^3 \text{°C}$.

The limiting condition $\phi = 0$ is implicit on the free edges.

Discretization of time: 36 intervals

of	0 with	100 seconds:	8	intervals of	12.5 s.
of	100 with	300 seconds:	8	intervals of	25.0 s.
of	300 with	700 seconds:	8	intervals of	50.0 s.
of	700 with	1400 seconds:	7	intervals of	100.0 s.
of	1400 with	2400 seconds:	5	intervals of	200.0 s.

10 Results of modeling D

10.1 Values tested

Identification	Reference	Aster	Relative variation (%)		Absolute deviation (°C)	
			difference	tolerance	difference	tolerance
Temperatures:						
In center (a: N1) $T(^{\circ}C)$						
T = 400 S	334	341.10	2,125%	5.%	7.10	20.
T = 600 S	500	493.14	1,371%	5.%	6.86	20.
T = 800 S	618	609.95	1,303%	5.%	8.05	20.
T = 1000 S	706	699.70	0,893%	5.%	6.30	20.
T = 1200 S	774	768.79	0,673%	5.%	5.21	20.
T = 1400 S	828	821.99	0,726%	5.%	6.01	20.
T = 1600 S	872	862.78	1,058%	5.%	9.22	20.
T = 1800 S	902	894.22	0,863%	5.%	7.78	20.
T = 2000 S	923	918.45	0,493%	5.%	4.55	20.
T = 2200 S	942	937.13	0,516%	5.%	4.87	20.
T = 2400 S	956	951.54	0,467%	5.%	4.46	20.
On the surface (NR: N207) $T(^{\circ}C)$						
T = 400 S	461	474.78	2,989%	5.%	13.8	20.
T = 600 S	608	596.01	1,971%	5.%	12.0	20.
T = 800 S	696	689.12	0,989%	5.%	-6.88	20.
T = 1000 S	774	760.65	1,725%	5.%	13.4	20.
T = 1200 S	828	815.72	1,483%	5.%	12.3	20.
T = 1400 S	868	858.12	1,138%	5.%	9.88	20.
T = 1600 S	902	890.63	1,261%	5.%	11.4	20.
T = 1800 S	923	915.69	0,792%	5.%	7.31	20.
T = 2000 S	942	935.00	0,743%	5.%	7.00	20.
T = 2200 S	956	949.89	0,639%	5.%	6.11	20.
T = 2400 S	962	961.37	0,065%	5.%	0,626	20.

10.2 Remarks

The relative variations are higher than 2% for $t=400.s$, inferiors for $t \geq 600.s$
Results calculated by Code_Aster on the nodes of external surface are almost identical (maximum: $5.10^{-5}^{\circ}C$ that is to say 10^{-7} into relative).

11 Summary of the results

The got results are satisfactory. The maximum change obtained (3%) is on surface external of the sphere for the weakest moment the T. This variation decreases when the moment T increases.

Whatever the modeling, the results are increasingly more precise in the center than on the surface external of the sphere.

With identical cutting the results between the linear and quadratic elements are appreciably the same ones.