TPLV07 - Cubic orthotropic

Summary:

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

It validates the voluminal thermal elements under conditions of imposed flow, of convection but also of variation linear of the outside temperature.

The results are compared with an analytical solution (VPCS).

In this test one also checks the calculation of integral on the edge of a thermal field as well as the calculation of thermal energy with orthotropic material on elements 3D.

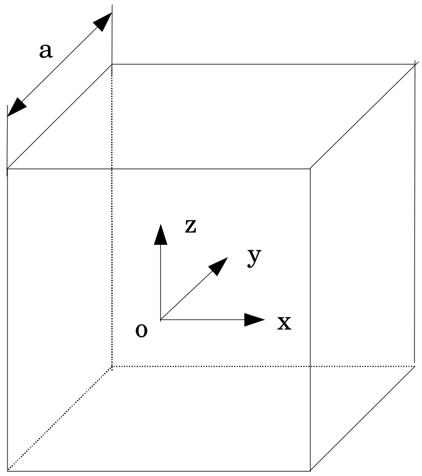
For this last point two calculations are done besides that with orthotropic material:

- a calculation with isotropic material (keyword THER of DEFI_MATERIAU) being used as reference
- a calculation with isotropic material but using the keyword THER_ORTH of DEFI_MATERIAU validated by the first calculation.

For really orthotropic calculation one will use a reference NON_REGRESSION .

1 Problem of reference

1.1 Geometry



Cube d'arête a = 0.2 m
Centre du cube = (0.,0.,0.)

1.2 Properties of material

$\lambda_x = 1.0\, W/m.°C$ Thermal conductivity along the axis x
$\lambda_y = 0.75\, W/m.°C$ Thermal conductivity along the axis y
$\lambda_z = 0.50\, W/m.°C$ Thermal conductivity along the axis z

1.3 Boundary conditions and loadings

- Density flux normal:
  - $\varphi_n = 60\, W/m^2$ face $y = -0.1$ (entering flow),
  - $\varphi_n = -60\, W/m^2$ face $y = 0.1$ (outgoing flow),
  - $\varphi_n = 30\, W/m^2$ face $z = -0.1$ (entering flow),
  - $\varphi_n = -30\, W/m^2$ face $z = 0.1$ (outgoing flow),
- Convection on the faces $x = -0.1$ and $x = 0.1$: $h = 15\, W/m^2 °C$,
- Linear variation of the outside temperatures,
  - $T_{ext} = 30 - 80\text{y} - 60\text{z}$ face $x = -0.1$,
  - $T_{ext} = 15 - 80\text{y} - 60\text{z}$ face $x = 0.1$.

1.4 Initial conditions

Without object.

2 Reference solution

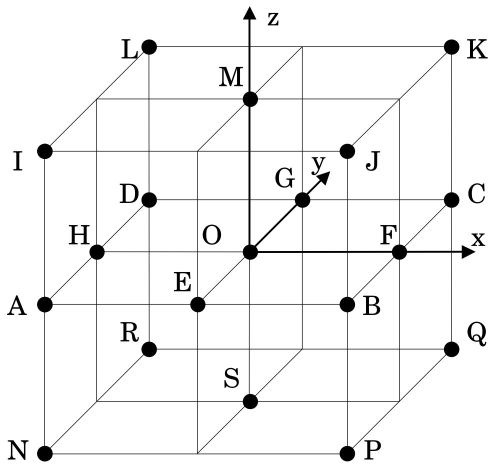
2.1 Method of calculating used for the reference solution

The reference solution is that given in card TPLV07/89 of guide VPCS.

It is about an analytical solution given by the following formula:

$$
\begin{aligned}
T(x,y,z) &= ax+by+cz+d \\
&= -45x-80y-60z+22.5
\end{aligned}
$$

Point	T(°C)
O	22.5
A	35.0
B	26.0
C	10.0
D	19.0
E	30.5
F	18.0
G	14.5
H	27.0
I	29.0
J	20.0
K	4.0
L	13.0
M	16.5
N	41.0
P	32.0
Q	16.0
R	25.0
S	28.5



$\phi_x = 45\ W/m^2$ = constante
$\phi_y = 60\ W/m^2$ = constante
$\phi_z = 30\ W/m^2$ = constante

Density flux normal imposed on the face $y=0.1$ being constant, resulting normal flow is determined analytically.

2.2 Results of reference

Temperature at the points quoted in the table above.
Value of resulting normal flow on the face located in $y=0.1$.

2.3 Uncertainty on the solution

No (analytical solution).

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 (HEXA8)

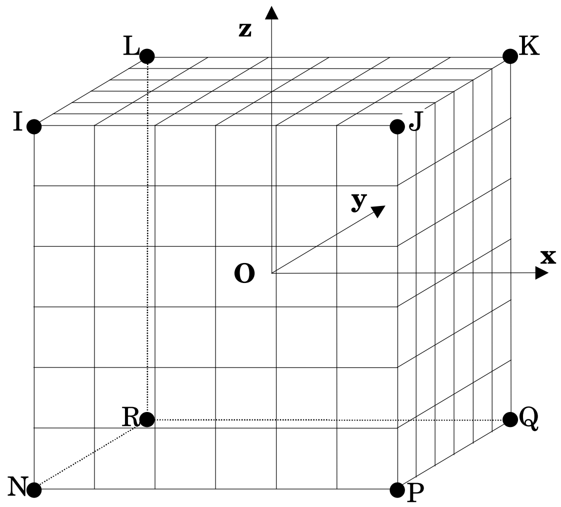
Conditions limites:

- face NPJI ϕ_n = 60 W/m²
- face RQKL ϕ_n = -60 W/m²
- face NPQR ϕ_n = 30 W/m²
- face IJKL ϕ_n = -30 W/m²

- face NRLI h = 15 W/m²°C
  T_{ext} = 30-80y-60z
- face PQKJ h = 15 W/m²°C
  T_{ext} = 15-80y-60z

Découpage:

- 6 éléments suivant x
- 6 éléments suivant y
- 6 éléments suivant z



3.2 Characteristics of the grid

Many nodes:	343
Many meshs and types:	216 HEXA8 (and 216 QUAD8)

3.3 Remarks

Voluminal heat ρC_P does not intervene in this test, but must be declared for *Code_Aster*. One takes $\rho C_P = 1.0\, J/m^3\ °C$.

3.4 Values tested

Identification		Reference
Not	Node	$T(°C)$
O	$N169$	22.5
A	$N5$	35.0
B	$N301$	26.0
C	$N337$	10.0
D	$N49$	19.0
E	$N151$	30.5
F	$N316$	18.0
G	$N196$	14.5
H	$N24$	27.0
I	$N1$	29.0
J	$N298$	20.0

K	$N340$	4.0
L	$N44$	13.0
M	$N172$	16.5
N	$N2$	41.0
P	$N297$	32.0
Q	$N338$	16.0
R	$N43$	25.0
S	$N173$	28.5

Not	Mesh	Node	$\phi(W/m^2)$
$\phi_x\ K$	$M211$	$N340$	45.0
$\phi_x\ F$	$M201$	$N316$	45.0
$\phi_x\ O$	$M129$	$N169$	45.0
$\phi_y\ K$	$M211$	$N340$	60.0
$\phi_y\ F$	$M201$	$N316$	60.0
$\phi_y\ O$	$M129$	$N169$	60.0
$\phi_z\ K$	$M211$	$N340$	30.0
$\phi_z\ F$	$M201$	$N316$	30.0
$\phi_z\ O$	$M129$	$N169$	30.0

Face	Resulting normal flow $\int_{face} \varphi . \boldsymbol{n}\, dS$ (W)
$y=0.1$	-60.0

Tests of the thermal field of energy `ETHE_ELEM` :

Isotropic material

Mesh	Value of reference	Precision (in %)	Reference
$M109$	$-170,1559513297$	0,1	`AUTRE_ASTER`

Orthotropic material

Mesh	Value of reference	Precision (in %)	Reference
$M109$	$-332,36296035464$	1,0E-04	`NON_REGRESSION`

4 Summary of the results

The got results are excellent. Computed values by *Aster* are identical to the values of reference. That is "a normally expected" result since the field solution which is linear belongs to the space of interpolation of the element tested.

This test made it possible to test the following orders:

- DEFI_NAPPE allowing to define a variation in the external temperature according to the X-coordinate x and of the ordinate y,
- DEFI_MATERIAU associated with the keyword THER_ORTH, allowing to define the characteristics of an orthotropic material,
- AFFE_CARA_ELEM associated with the keyword SOLID MASS, allowing to define the axes of orthotropism.