TPLP303 - Distribution of the temperature in the section of a conduit of chimney

Summarized:

This test is resulting from the validation independent of version 3 in linear steady thermal.

It is about a plane $2D$ problem represented by seven modelizations mixing each one several element types.

The features tested are the following ones:
•plane thermal element,
•voluminal thermal element,
•limiting condition: convection.

The interest of the test lies in the mixture of different elements.

The results are compared with an analytical solution.

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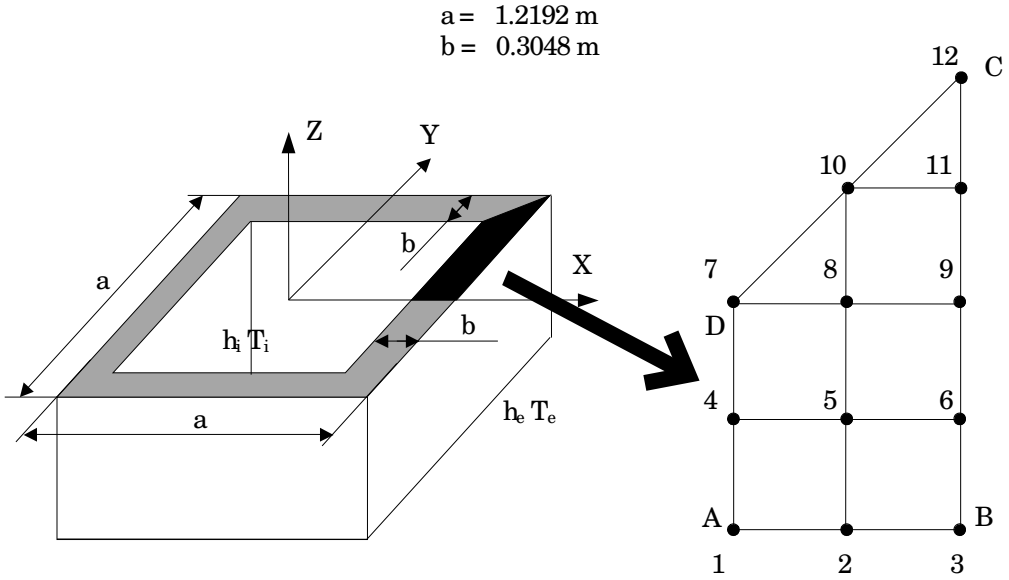
1 Problem of reference

1.1 Geometry



1.2 Properties of the thermal

$\lambda = 1.7307\, W/m°C$ material Conductivity

1.3 Boundary conditions and loadings

- Surfaces interior: $h_i = 68.135\, W/m^2°C$; $T_i = 37.78°C$,
- External Surface: $h_e = 17.034\, W/m^2°C$; $T_e = -17.78°C$.

1.4 Initial conditions

Without object.

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2 Reference solution

2.1 Method of calculating used for the reference solution

the original reference solution given in the book [bib1] is based on a method of relaxation numerical. This reference is quoted in the handbook of checking of ANSYS [bib2].

2.2 Results of reference

Temperature to the points $n°1$ to 11 .

2.3 Uncertainty on the Unknown

solution, it was not possible to get the original reference (delivers old, more published).

2.4 Bibliographical references

1.Kreith, F., “Principles of heat transfer”, International Textbook Co., Scranton, Pennsylvania, 2nd Printing, 1959.
2.ANSYS: “checking manual”, 1 St edition, June 1,1976

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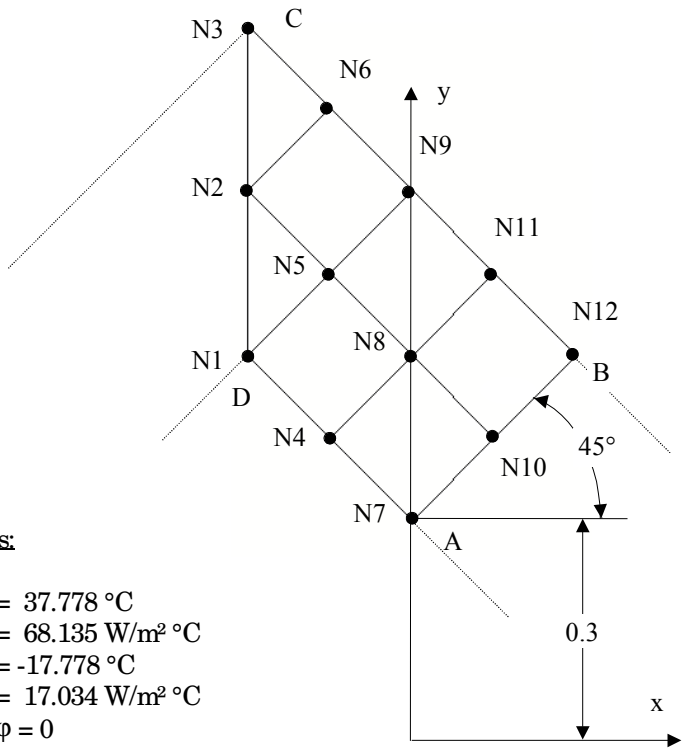
3 Modelization A

3.1 Characteristic of the modelization

PLANE (TRIA3, QUAD4)



Conditions aux limites:

- coté AD: T_{ext} = 37.778 °C
  h = 68.135 W/m² °C
- coté BC: T_{ext} = -17.778 °C
  h = 17.034 W/m² °C
- cotés AB, CD φ = 0

3.2 Characteristic of the mesh

Many nodes:	12
Number of meshes and types:	6 (5 QUAD4, 1 TRIA3)

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3.3 Quantities tested and relative

		Variation results %	Absolute Deviation
Identification	**Reference**	**Tolerance**	**Tolerance**
Temperature $(°C)$			
Points			
N1	30.889	4.0.2.0	
N2	-1.333		2.0
N3	-15.167	6.0.1.0	
N4	34.000	3.0.1.0	
N5	8.611	1.0.1.0	
N6	-11.278	5.0.1.0	
N7	34.278	1.0.1.0	
N8	12.556	2.0.1.0	
N9	-7.611	8.0.1.0	
N10	13.500	4.0.1.0	
N11	-5.889	1.0.1.0	
N12	-5.444	2.0.1.0	

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4 complementary Modelizations B, C, D, E, F and G

Modelization B :

- Mesh identical to that described in the file of modelization, on $1/8$ structure, but with quadratic elements,
- System of unit $(°C, W, m, s)$.

It is noted that the quadratic interpolation improves the results, the maximum change is of 49.16% for the value of reference nearest to 0.

Modelization C :

- Finer mesh (22 QUAD8 + 4 TRIA6), on $1/8$ structure,
- System of unit $(°C, W, m, s)$.

It is noted that compared to the modelization B, the maximum change does not decrease but increases (54.58%).

Modelization D :

- Mesh identical to that described in the file of modelization, on $1/8$ structure,
- System of English unit $(°F, Btu, feet, hr)$.

It is noted that the maximum relative variation decreases in an important way (-33.29%), this variation is not located more at the same place. On the other hand it is always located on the value of reference nearest to 0.

Modelization E :

- Mesh identical to that described in the file of modelization, on $1/8$ structure, but with quadratic elements,
- System of English unit $(°F, Btu, feet, hr)$.

It is noted that the quadratic elements improve the results by with a linear modelization (maximum change of -6.5%).

Modelization F :

- cutting identical to that described in the file of modelization (12 QUAD4) but on $1/4$ structure,
- System of English unit $(°F, Btu, feet, hr)$.

It is noted that this mesh with linear elements (without TRIA3) is much more precise, the maximum change is of -5.27% .

Modelization G :

- Cutting identical to that described in the file of modelization, but on $1/4$ structure and with quadratic elements,
- System of English unit $(°F, Btu, feet, hr)$.

It is noted that this mesh (without TRIA3) is much less precise than at the time of the modelization F , the maximum change is of -6.26% .

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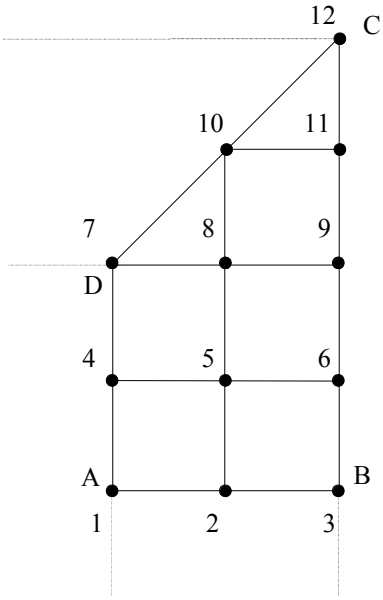
5 Results of the modelizations B, C, D, E, F and G

On the figure below we present the points of observation (for more details to see the corresponding test probe).



In the tables presented below we give for each modelization the results got with *the Code_Aster*, like for the modelization A the results got with code NISA (computations carried out by Mr. CLERK EDF/ DER/ADE). We grayed the upper deviations than the tolerance (2%).

Computations carried out in $w, m, °C$

		Modéisation A	Modelization B	Modelization C	Modelization A	
Points	ref.	Tolérance%	Tolerance %	Tolerance %	NISA	Variation %
1	34.278	1.0.1.0.1.0			34.114	– 0.480
2	13.500	4.0.2.0.2.0			13.973	3.506
3	– 5.444	2.0.6.0.5.0			– 5.377	– 1.229
4	34.000	3.0.1.0.1.0			34.718	2.111
5	12.556	2.0.4.0.4.0			12.716	1.274
6	– 5.889	1.0.7.0.7.0			– 5.909	0.336
7	30.889	4.0.5.0.6.0			29.795	– 3.541
8	8.611	1.0	19.0	19.0	8.566	– 0.518
9	– 7.611	8.0.9.0		10.0	– 8.152	7.111
10	– 1.333	150.0	50.0	67.0	– 2.528	89.632
11	– 11.278	5.0.3.0.3.0			– 10.810	– 4.152
12	– 15.167	6.0.1.0.1.0			– 16.036	5.729

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Computations carried out in $Btu\ ,\ feet\ ,\ °\ F$

		Modelization D	Modelization E	Modelization F	Modelization G
Points	ref.	Tolérance%	Tolérance%	Tolérance%	Tolérance%
1	93.7	1.0.1.0.1.0			1.0
2	56.3	2.0.1.0.2.0			1.0
3	22.2	1.0.2.0.1.0			2.0
4	93.2	2.0.1.0.2.0			1.0
5	54.6	1.0.2.0.1.0			2.0
6	21.4	1.0.4.0.3.0			4.0
7	87.6	3.0.3.0.9.0			3.0
8	47.5	1.0.6.0.6.0			7.0
9	18.3	6.0.7.0.6.0			6.0
10	29.6	8.0.4.0.2.0			6.0
11	11.7	8.0.5.0.2.0			4.0
12.4.7		34.0	5.0.3.0.5.0		

From these 7 analyses, we can make the following observations:

- the mesh suggested in the test probe (5 QUAD4 + 2 TRIA3) is not adapted. To approach the reference solution there are two possibilities:
  - to use the quadratic mesh on $1/8$ structure,
  - to use a linear mesh without triangle on ¼ structure,
- the choice of the system of unit to important considerable in the computation of the relative variation,
- for the same modelization (A) the results between *Code_Aster* and NISA are identical.

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6 Summary of the results

The modelization carried out on $1/8$ structure gives results of which many values exceed the tolerance fixed initially (2%). The maximum change obtained is of 89% , it is on the smallest value of reference. The analysis of the isotherms shows that those are not perpendicular to the right DC , the condition of symmetry is not respected.

To find an explanation to these important differences, several complementary modelizations were carried out (cf annexes B). The conclusions are the following ones:

- the change of the system of units $(°C \to °F)$ makes it possible to decrease the maximum change with a value of 33% ,
- the modelization with quadratic elements (and in $°F$) improves the results, the maximum change is of 6.8% ,
- the modelization of one $1/4$ of structure with only of the QUAD4 (and in $°F$) improves the results, the maximum change is of -5.27% ,
- the modelization A , carried out with software NISA, gives results identical to those of *Code_Aster*.

Moreover, it was not possible to get the original reference (delivers of Kreith) quoted in the handbook of checking of ANSYS. The method of acquisition of the reference solution and its uncertainty are thus not known.

The results are regarded as acceptable taking into account evoked points Ci - above. However it will be necessary to search complementary elements on the reference solution.

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