# TPNA300 - Tube generating heat with variable conductivity

**Abstract:**

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

It is about a problem 2D axisymmetric represented by four modelizations, two axisymmetric, plane and the voluminal last.

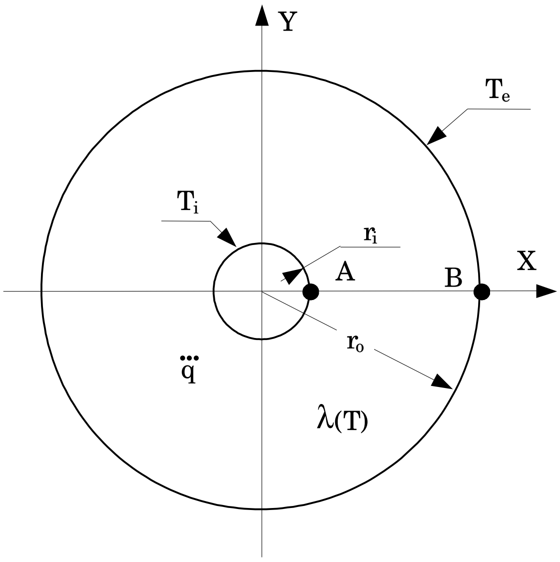
The features tested are the following ones:

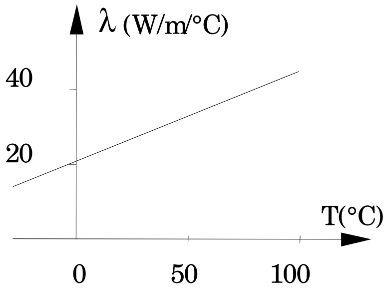
- axisymmetric thermal element,
- plane thermal element,
- voluminal thermal element,
- variable properties,
- limiting conditions (heat source, imposed temperature).

The interest of the test lies in the taking into account of variable properties and the nonlinear behavior.

# 1 Problem of reference

## 1.1 Geometry




$r_i = 6.35 . 10^{-3} m$

$r_e = 25.4 . 10^{-3} m$

## 1.2 Properties of the thermal

$\lambda = C_0 + C_1 T \, W/m° \, C$ material Conductivity

with $C_0 = 21.461 \, W/m° \, C$

$C_1 = 0.234 \, W/m° \, C^2$

## 1.3 Boundary conditions and loadings

- surfaces interior: $T_i = -17.78 ° \, C$
- external surface: $T_e = -17.78 ° \, C$
- heat source: $Q = 1.035 . 10^7 \, W/m3$

## 1.4 Initial conditions

Without object.

# 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 graphic estimate. This reference is quoted in the handbook of checking of ANSYS [bib2].

## 2.2 Results of reference

Temperature along $AB$ with $\Delta r = 2.167\ mm$

## 2.3 Uncertainty on the Unknown

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

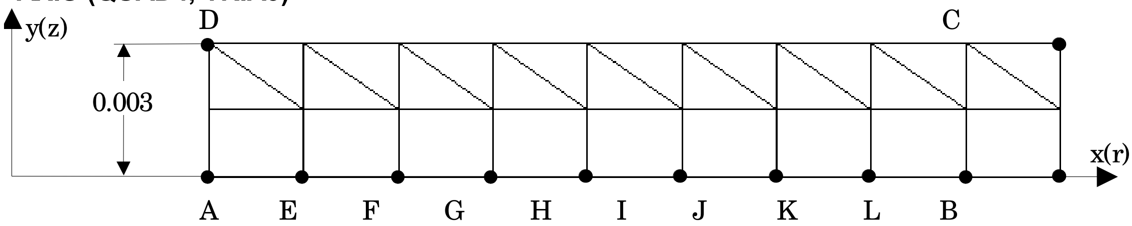
## 2.4 Bibliographical references

1. Schneider, P.J., “Conduction Heat Transfer”, Addison-Wesley Publishing Co., Inc. Reading, Farmhouse., 2nd Printing, 1957.
2. ANSYS, “checking manual”, 1st edition, June 1,1976

# 3 Modelization A

## 3.1 Characteristic of modelization

**AXIS (QUAD4, TRIA3)**




Conditions aux limites:

- cotés AB, CD: φ = 0
- cotés AD, BC: T=-17.78°C

| Noeud | r ($10^{-3}$m) | z ($10^{-3}$m) | Points |
|---|---|---|---|
| N4 | 8.47 | 0.0 | E |
| N7 | 10.58 | 0.0 | F |
| N10 | 12.70 | 0.0 | G |
| N13 | 14.82 | 0.0 | H |
| N16 | 16.92 | 0.0 | I |
| N19 | 19.05 | 0.0 | J |
| N22 | 21.17 | 0.0 | K |
| N25 | 23.28 | 0.0 | L |

| Noeud | r ($10^{-3}$m) | z ($10^{-3}$m) |
|---|---|---|
| N6 | 8.47 | 3.0 |
| N9 | 10.58 | 3.0 |
| N12 | 12.70 | 3.0 |
| N15 | 14.82 | 3.0 |
| N18 | 16.92 | 3.0 |
| N21 | 19.05 | 3.0 |
| N24 | 21.17 | 3.0 |
| N27 | 23.28 | 3.0 |

## 3.2 Characteristic of the mesh

Many nodes: 30
Number of meshes and types: 27: (9 QUAD4, 18 TRIA3)

# 4 Results of the modelization A

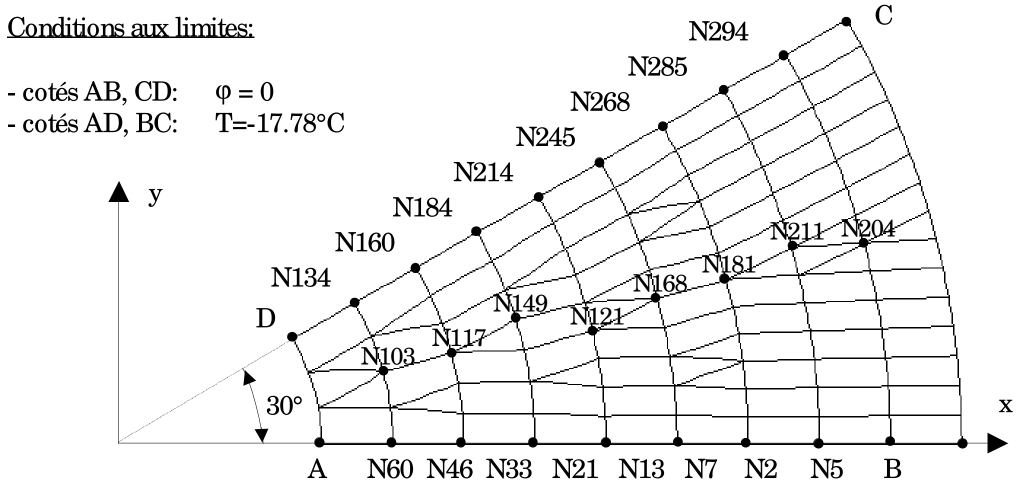
## 4.1 Values tested

| Identification | Reference | *Aster* | % difference | tolerance |
|---|---|---|---|---|
| Temperature (°C) | | | | |
| N4 | -5.00 | -4.92 | -1.70 | 5% |
| N7 | 2.22 | 2.06 | **-7.35** | 5% |
| N10 | 5.56 | 5.57 | 0.10 | 5% |
| N13 | 6.67 | 6.60 | -1.07 | 5% |
| N16 | 5.56 | 5.60 | 0.76 | 5% |
| N19 | 2.78 | 2.76 | -0.71 | 5% |
| N22 | -1.67 | -1.93 | **15.30** | 5% |
| N25 | -8.89 | -8.63 | -2.90 | 5% |
| | | | | |
| N6 | -5.00 | -4.96 | -0.87 | 5% |
| N9 | 2.22 | 2.04 | **-8.18** | 5% |
| N12 | 5.56 | 5.56 | 0.04 | 5% |
| N15 | 6.67 | 6.60 | -1.02 | 5% |
| N18 | 5.56 | 5.61 | 0.91 | 5% |
| N21 | 2.78 | 2.77 | -0.26 | 5% |
| N24 | -1.67 | -1.91 | **14.24** | 5% |
| N27 | -8.89 | -8.61 | -3.17 | 5% |

# 5 Modelization B

## 5.1 Characteristic of the modelization

PLANE (QUAD8, TRIA6)




## 5.2 Characteristic of the mesh

| | |
|---|---|
| Many nodes: | 300 |
| Number of meshes and types: | 95 (73 QUAD8, 22 TRIA6) |

# 6 Results of the modelization B

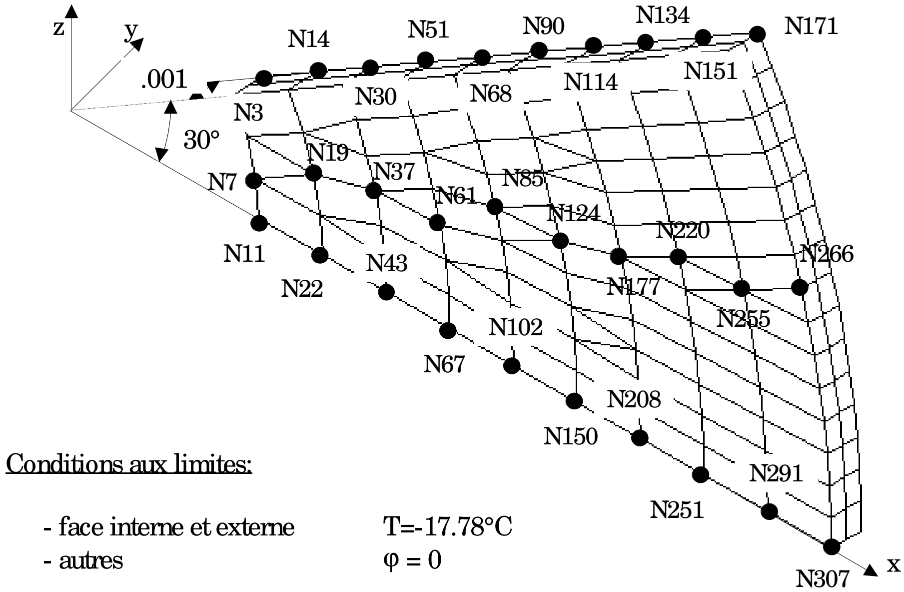
## 6.1 Values tested

| Identification | Reference | *Aster* | % difference | tolerance |
|---|---|---|---|---|
| Temperature (°C) | | | | |
| N60 | -5.00 | -4.84 | -3.194 | 5% |
| N46 | 2.22 | 2.14 | -3.491 | 5% |
| N33 | 5.56 | 5.65 | 1.544 | 5% |
| N21 | 6.67 | 6.66 | -0.082 | 5% |
| N13 | 5.56 | 5.65 | 1.694 | 5% |
| N7 | 2.78 | 2.80 | 0.665 | 5% |
| N2 | -1.67 | -1.90 | **13.788** | 5% |
| N5 | -8.89 | -8.62 | -3.089 | 5% |
| | | | | |
| N134 | -5.00 | -4.84 | -3.194 | 5% |
| N160 | 2.22 | 2.14 | -3.491 | 5% |
| N184 | 5.56 | 5.65 | 1.543 | 5% |
| N214 | 6.67 | 6.66 | -0.082 | 5% |
| N245 | 5.56 | 5.65 | 1.694 | 5% |
| N268 | 2.78 | 2.80 | 0.665 | 5% |
| N285 | -1.67 | -1.90 | **13.737** | 5% |
| N294 | -8.89 | -8.62 | -3.089 | 5% |
| | | | | |
| N103 | -5.00 | -4.84 | -3.141 | 5% |
| N117 | 2.22 | 2.15 | -3.365 | 5% |
| N149 | 5.56 | 5.65 | 1.557 | 5% |
| N121 | 6.67 | 6.66 | -0.078 | 5% |
| N168 | 5.56 | 5.65 | 1.694 | 5% |
| N181 | 2.78 | 2.80 | 0.650 | 5% |
| N211 | -1.67 | -1.90 | **13.777** | 5% |
| N204 | -8.89 | -8.62 | -3.075 | 5% |

# 7 Modelization C

## 7.1 Characteristic of the modelization

3D (HEXA8, PENTA6)




## 7.2 Characteristic of the mesh

| | |
|---|---|
| Many nodes: | 309 |
| Number of meshes and types: | 190 (144 HEXA8, 46 PENTA6) |

# 8 Results of the modelization C

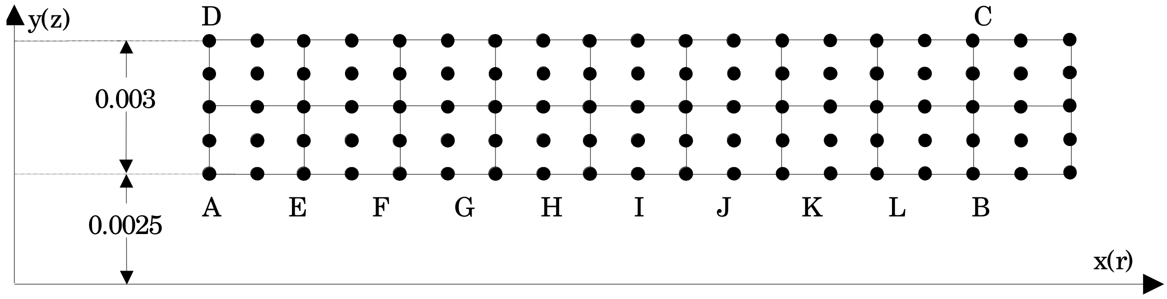
## 8.1 Values tested

| Identification | Reference | *Aster* | % difference | tolerance |
|---|---|---|---|---|
| Temperature (°C) | | | | |
| N22 | -5.00 | -4.90 | -1.909 | 5% |
| N43 | 2.22 | 2.09 | **-5.933** | 5% |
| N67 | 5.56 | 5.58 | 0.408 | 5% |
| N102 | 6.67 | 6.63 | -0.561 | 5% |
| N150 | 5.56 | 5.62 | 0.993 | 5% |
| N208 | 2.78 | 2.77 | -0.217 | 5% |
| N251 | -1.67 | -1.92 | **15.047** | 5% |
| N291 | -8.89 | -8.63 | -2.960 | 5% |
| | | | | |
| N14 | -5.00 | -4.90 | -1.908 | 5% |
| N30 | 2.22 | 2.09 | **-5.933** | 5% |
| N51 | 5.56 | 5.58 | 0.408 | 5% |
| N68 | 6.67 | 6.63 | -0.561 | 5% |
| N90 | 5.56 | 5.62 | 0.993 | 5% |
| N114 | 2.78 | 2.77 | -0.217 | 5% |
| N134 | -1.67 | -1.92 | **15.047** | 5% |
| N151 | -8.89 | -8.63 | -2.960 | 5% |
| | | | | |
| N19 | -5.00 | -4.93 | -1.440 | 5% |
| N37 | 2.22 | 2.16 | -2.596 | 5% |
| N61 | 5.56 | 5.54 | -0.274 | 5% |
| N85 | 6.67 | 6.65 | -0.260 | 5% |
| N124 | 5.56 | 5.60 | 0.705 | 5% |
| N177 | 2.78 | 2.82 | 1.536 | 5% |
| N220 | -1.67 | -1.90 | **13.946** | 5% |
| N255 | -8.89 | -8.58 | -3.474 | 2% |

# 9 Modelization D

## 9.1 Characteristic of modelization

**AXIS (QUAD9)**




Conditions aux limites:

- cotés AB, CD: φ = 0
- cotés AD, BC: T=-17.78°C

| Noeud | r ($10^{-3}$m) | z ($10^{-3}$m) | Points |
|---|---|---|---|
| N11 | 8.47 | 2.5 | E |
| N21 | 10.58 | 2.5 | F |
| N31 | 12.70 | 2.5 | G |
| N41 | 14.82 | 2.5 | H |
| N51 | 16.92 | 2.5 | I |
| N61 | 19.05 | 2.5 | J |
| N71 | 21.17 | 2.5 | K |
| N81 | 23.28 | 2.5 | L |

| Noeud | r ($10^{-3}$m) | z ($10^{-3}$m) |
|---|---|---|
| N15 | 8.47 | 5.5 |
| N25 | 10.58 | 5.5 |
| N35 | 12.70 | 5.5 |
| N45 | 14.82 | 5.5 |
| N55 | 16.92 | 5.5 |
| N65 | 19.05 | 5.5 |
| N75 | 21.17 | 5.5 |
| N85 | 23.28 | 5.5 |

## 9.2 Characteristic of the mesh

Many nodes: 95
Number of meshes and types: 18 QUAD9

# 10 Results of the modelization D

## 10.1 Values tested

| | | | relative Variation % | | Absolute Deviation | |
|---|---|---|---|---|---|---|
| **Identification** | **Reference** | ***Aster*** | **difference** | **tolerance** | **difference** | **tolerance** |
| Temperature (°C) | | | | | | |
| | | | | | | |
| N11 | -5.00 | -4.83 | -3.333 | 5% | 0.167 | 0.3 |
| N21 | 2.22 | 2.15 | -3.347 | 5% | -0.074 | 0.3 |
| N31 | 5.56 | 5.65 | 1.551 | 5% | 0.086 | 0.3 |
| N41 | 6.67 | 6.66 | -0.078 | 5% | -0.005 | 0.3 |
| N51 | 5.56 | 5.65 | 1.694 | 5% | 0.094 | 0.3 |
| N61 | 2.78 | 2.80 | 0.663 | 5% | 0.018 | 0.3 |
| N71 | -1.67 | -1.90 | **13.741** | 5% | -0.229 | 0.3 |
| N81 | -8.89 | -8.62 | -3.088 | 5% | 0.275 | 0.3 |
| | | | | | | |
| N15 | -5.00 | -4.83 | -3.333 | 5% | 0.167 | 0.3 |
| N25 | 2.22 | 2.15 | -3.347 | 5% | -0.074 | 0.3 |
| N35 | 5.56 | 5.65 | 1.551 | 5% | 0.082 | 0.3 |
| N45 | 6.67 | 6.66 | -0.078 | 5% | -0.005 | 0.3 |
| N55 | 5.56 | 5.65 | 1.694 | 5% | 0.094 | 0.3 |
| N65 | 2.78 | 2.80 | 0.663 | 5% | 0.018 | 0.3 |
| N75 | -1.67 | -1.90 | **13.741** | 5% | -0.229 | 0.3 |
| N85 | -8.89 | -8.62 | -3.088 | 5% | 0.275 | 0.3 |

# 11 Summary of the results

the four modelizations give results whose certain values exceed the tolerance fixed initially (5%):

- for modelization A (AXIS: QUAD4, TRIA3), the maximum change is of 15,3% and 4 values out of 16 exceed the tolerance,
- for the modelization B (PLANE: QUAD8, TRIA6), the maximum change is of 13,8% and 3 values out of 24 exceed the tolerance,
- for the modelization C (3D: HEXA8, PENTA6), the maximum change is of 15% and 5 values out of 24 exceed the tolerance,
- for modelization D (AXIS: QUAD9), the maximum change is of 13,7% and 4 values out of 16 exceed the tolerance.

These goings beyond tolerance are observed for values close to 0.

Computations were carried out in °C. The determination of the variation, by considering the temperatures in °F (as in the reference solution), gives a maximum change very different from that obtained in °C (3% instead of 15%).

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 the reference solution (graphic estimate) and its uncertainty are thus not known.

The results are regarded as acceptable taking into account the points evoked above.

This test made it possible to test the taking into account a variable thermal conductivity within several modelizations. The principal commands tested are the following ones:

- `DEFI_MATERIAU` associated with key word `THER_NL`, making it possible to define the characteristics of a material whose characteristics vary according to the temperature,
- `THER_NON_LINE` orders allowing the resolution of a steady thermal nonlinear problem or not.