Tdyn-CFD+HT - Validation Case 9

Two-dimensional heat conduction with heat generation

Tdyn

Version
15.1.0

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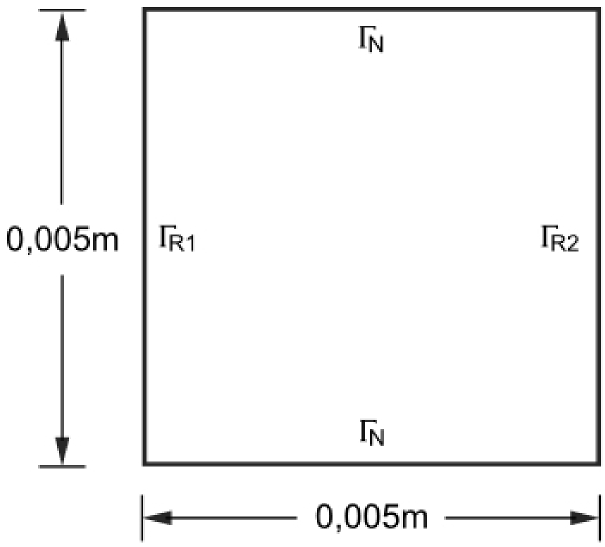
Table of Contents

1 Validation case 9

This transient heat transfer validation test is performed over a two-dimensional space domain Ω of 0.005 meter wide by 0.005 meter high.

It has been considered an initial uniform temperature of 100ºC on all the space domain. A heat flux boundary condition is set on the right boundary, with a convective heat transfer coefficient of 500 $W/m^2 \cdot ºC$ and $20^{\circ}C$ of ambient temperature. A different heat flux boundary condition is set on the left boundary, with a convective heat transfer coefficient of $400 W/m^2 \cdot ºC$ and $120^{\circ}C$ of ambient temperature. An homogeneous Neumann condition is set on the rest of the boundary.



The initial and boundary conditions of the problem are summarized as follows:

- $T(x,0)=100ºC$ in Ω
- Heat flux=400 W/m^2 on Γ_{R1} (Left boundary)
- Reactive heat flux=400 $W/m^2 \cdot C$ on Γ_{R1} (Left boundary)
- Heat flux=500 W/m^2 on Γ_{R2} (Right boundary)
- Reactive heat flux=500 $W/m^2 \cdot C$ on Γ_{R2} (Right boundary)
- $\partial T/\partial n=0$ on $\Gamma_N=\partial\Omega \backslash (\Gamma_{R1} U\ \Gamma_{R2})$ (Lower & upper boundary)

A complete description of this problem is presented in reference [1].

Problem description

The problem consists of a 2D transient heat conduction with heat generation, and the following characteristics:

- User defined problem

Simulation dimension: 2D plane

Multi-physics analysis: Fluid flow & Fluid heat transfer

- Geometry

0.005x0.005 meters square domain.

- Domain

Transient.

- Material properties

Thermal conductivity K=19 W/m·ºC

Specific Heat C=490 J/kg·ºC

Density ρ=7800 kg/m^3

Heat source field Q=50 MW/m^3

- Boundary Conditions

Insulation: Leaving both bottom and top boundaries without any condition assigned, makes it a perfect insulator.

  - $\partial T/\partial n=0$ on $\Gamma_N=\partial\Omega\backslash(\Gamma_{R1} \cup \Gamma_{R2} \cup \Gamma_D)$ (Lower & upper boundaries)

Convection boundary: Two different convective heat transfer conditions have been assigned on the vertical boundaries of the domain:

Ambient temperature of 120ºC and convective heat transfer coefficient h=400 W/m^2C on the left boundary.

  - Heat flux=400 W/m^2 on Γ_{R1} (Left boundary)
  - Reactive heat flux=400 W/m^2·ºC on Γ_{R1} (Left boundary)

Ambient temperature of 20ºC and convective heat transfer coefficient h=500 W/m^2C on the right boundary.

  - Heat flux=500 W/m^2 on Γ_{R2} (Right boundary)
  - Reactive heat flux=500 W/m^2·ºC on Γ_{R2} (Right boundary)

- Initial condition:

Uniform temperature:

T(x,0)=100ºC in Ω

- Solver parameters

Time step: 0.09 s

Number of steps: 100

Assembling type: mixed.

Non-symmetric solver: Bi-conjugate Gradient (tolerance = 1.0E-07) with ILU preconditioner.

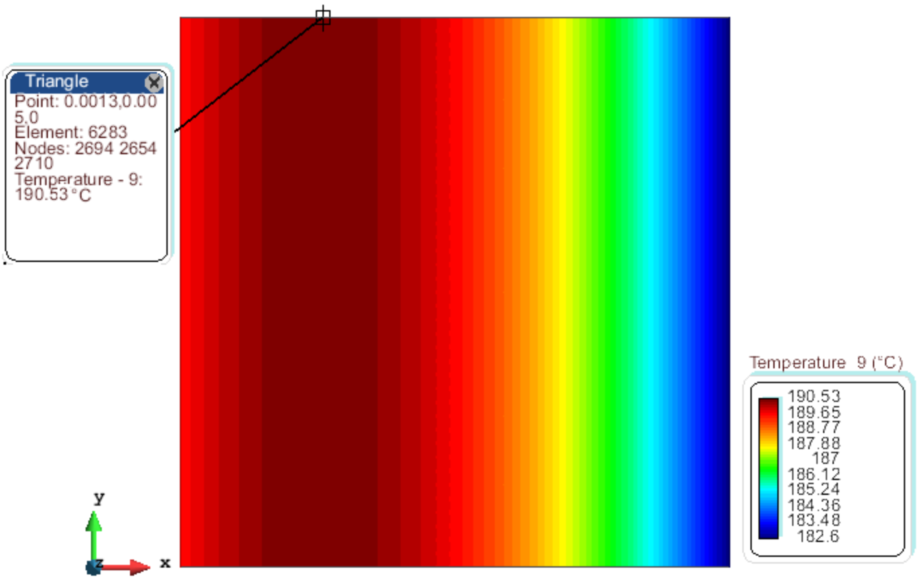
Symmetric solver: Conjugate Gradient (tolerance = 1.0E-07) with ILU preconditioner.

Mesh

The two-dimensional space domain is discretized by a 40x40 grid of linear triangular elements. The finite elements mesh has 3281 nodes and 6560 elements (triangles).

Results

Tdyn result given below corresponds to the temperature distribution on the space domain Ω at the last time step t=9.0s.



Thermal distribution on the domain and temperature at point (0.0013,0.005,0.000)

The following table shows the temperature values in ºC associated with the numerical solution for the given mesh, of three different software packages (STAND 7, MecSolver and Tdyn) versus the exact analytical result, at the point (0.0013,0.005,0.000) of the domain.

Reference	Temperature [ºC]	Relative error (%)
Exact analytical result	190.70	--
STAND 7	190.45	-0.0013 (-0.13%)
MecSolver (Midas NFX Structure)	190.37	-0.0017 (-0.17%)
Tdyn	190.53	-0.0006 (-0.06%)

The table above also shows the relative error (the difference between the exact value and the approximation), and the percent error, for each solver. The difference in percentage between Tdyn and the rest of solvers is enough significant. It should be emphasized that Tdyn offers the best approximation to the exact result, as can be seen in the table.

Validation Summary

CompassFEM version	15.1.0
Tdyn solver version	15.1.0
RamSeries solver version	15.1.0
Benchmark status	Successfull
Last validation date	27/11/2018

References

[1] J.P. Holman. Heat Transfer. McGraw-Hill, 1989.