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Validation case 10

Radiation scattering in a 2D enclosure

Tdyn

Version
15.1.0

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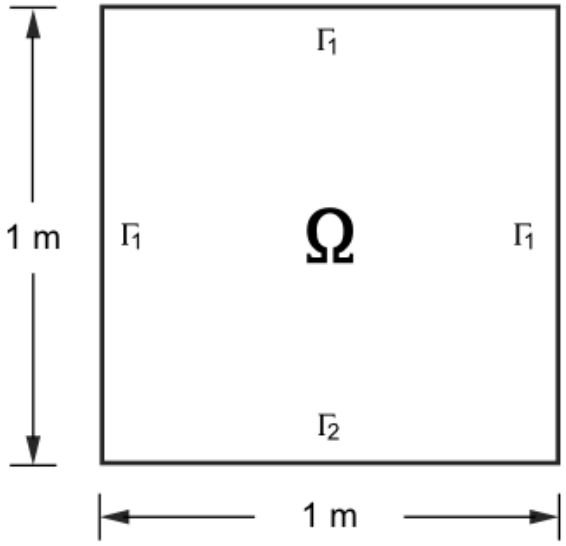
1 Radiation scattering in a 2D enclosure

The present test case deals with the numerical calculation of the temperature distribution within a plane layer (plane 2D simulation) of radiating and scattering medium with constant thermal conductivity k, optical thickness k_D, and albedo Ω. The computational domain is enclosed by gray plates of emissivity ε. The domain of analysis is shown in the following figure and simply consists on a square enclosure of unit side-length.



This problem has a stationary solution whose temperature profiles can be compared against those reported in [1]. To solve this problem, the P-1 radiation model is used within Tdyn CFD+HT. The P-1 radiation model is the simplest case of the more general P-N model, and is used to take into account the scattering effect due to participating media.

Various cases are run for different values of the dimensionless conduction/radiation number N given by:

$$N = k(a+\sigma_s)/(4\cdot\sigma\cdot T_{w2}^3)$$

where k is the thermal conductivity of the medium, a and σ_s are the absorption and scattering coefficients respectively, σ is the Boltzmann constant and T_{w2} is the bottom boundary wall temperature.

The various values of N under consideration are obtained by varying the thermal conductivity of the medium while keeping constant the remaining parameters of the problem as indicated in what follows:

$a = 0.5\ m^{-1}$

$\sigma_s = 0.5\ m^{-1}$

$\sigma = 5.670373 \times 10^{-8}\ W/m^2 \cdot K^4$

$T_{w2} = 200\ K$

$k = 18145 / 1.8145 / 0.1815 / 0.0907 / 0.0181\ W/m \cdot K$

$N = 10000 / 1 / 0.1 / 0.05 / 0.01$

While the bottom boundary wall (Γ_2) is kept at a constant temperature T_{w2} = 200 K, the top and lateral bounding plates (Γ_1) have a temperature T_{w1} = 100 K. Finalle, all boundaries (Γ_1 andΓ_2) are assigned an emissivity ε=1.0

Problem description

The problem consists on the analysis of a 2D squared plate, with the following characteristics:

- User defined problem

Simulation dimension: 2D

Simulation type: solid heat transfer

- Geometry

1.0 x 1.0 meters squared domain

- Domain of analysis

Steady-state, stationary

- Material properties (thermal properties)

Density: 1 kg/m^3

Specific heat: 1 J/(kg·K)

Floatability: 0

Absorptivity: 0.5 1/m

Scattering: 0.5 1/m

Heat source field: 0.0 W/m^3

Heat reaction field: 0.0 $W(m^3 \cdot K)$

Thermal conductivity matrix: varying scalar. Values are adjusted to match the desired values of the dimensionless conduction/radiation number N.

- Boundary conditions

Fix temperature 1: the top and lateral bounding plates (Γ_1) have a temperature T_{w1} = 100 K.

Fix temperature 2: bottom boundary wall (Γ_2) is kept at a constant temperature T_{w2} = 200 K.

Radiation flux solids 1: the top and lateral bounding plates (Γ_1) have assigned an emissivity ε = 1.0 and a wall temperature T_{w1} = 100 K.

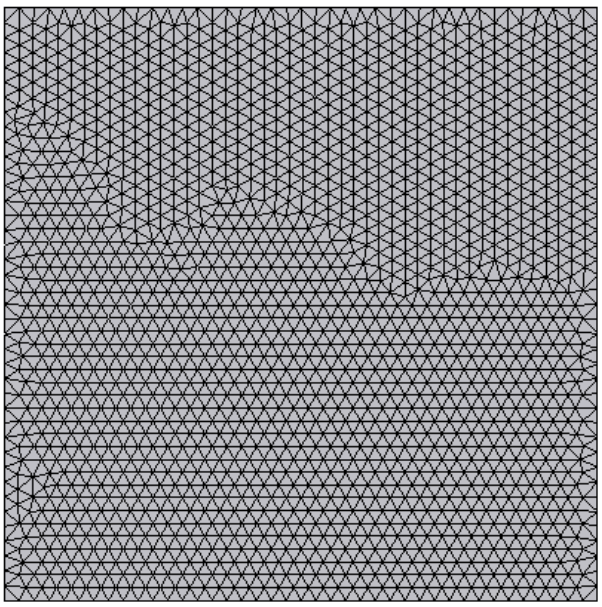
Radiation flux solids 2: the bottom bounding plate (Γ_2) has assigned an emissivity ε = 1.0 and a wall temperature T_{w1} = 200 K.

Mesh

Mesh properties for the present analysis are summarized in the following table:

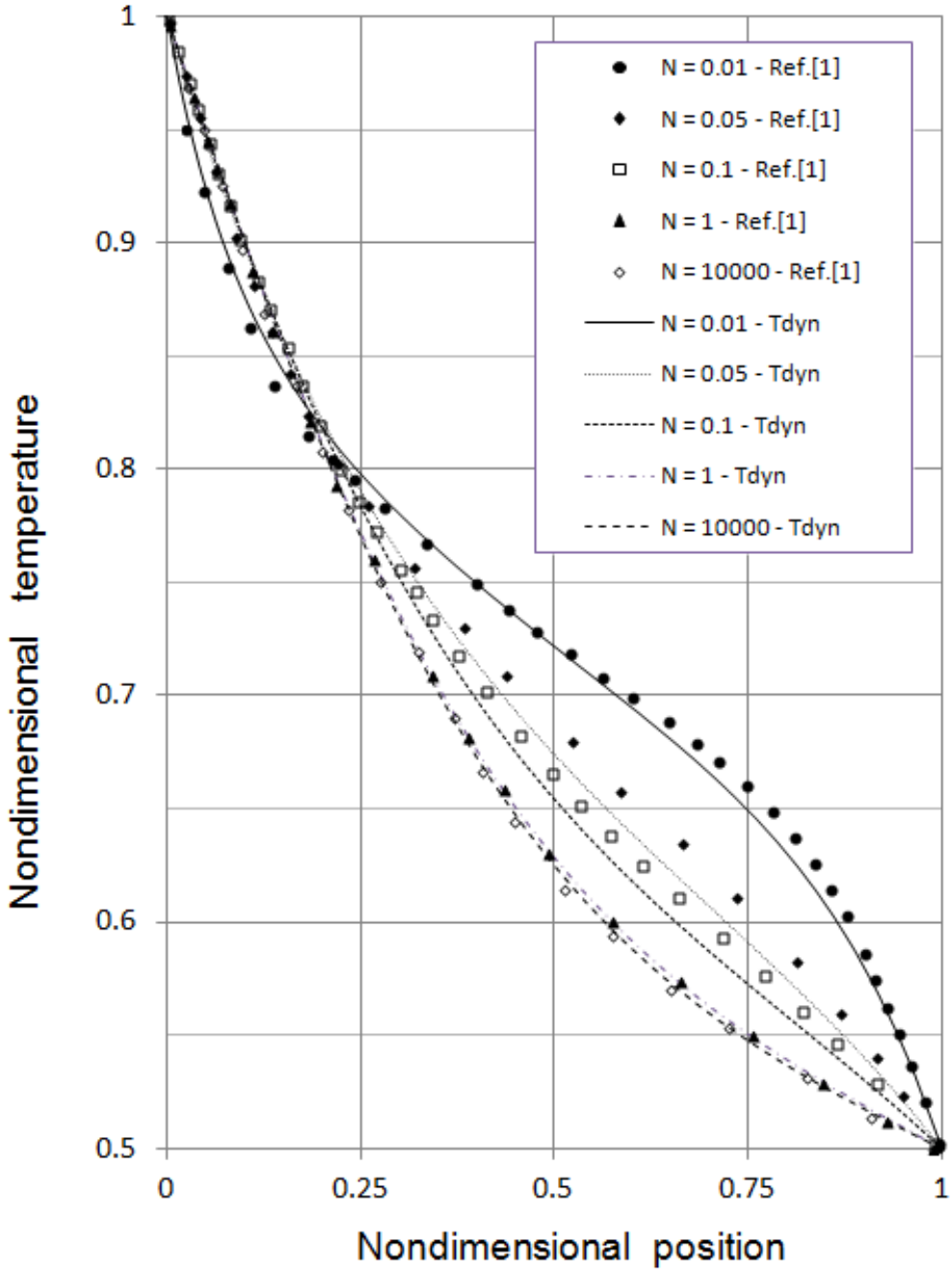
Mesh properties	
Min. element size	--
Max element size	0.025
Mesh size transition	0.6
Number of elements	3760
Number of nodes	1881

The resulting unstructured mesh is shown in the figure below.



Results

For the sake of validation, the temperature profiles along the midside plane of the squared enclosure are compared against the results reported in [1]. The graph below shows that the results are in quite good agreement with reference values for a wide range of the dimensionless conduction/radiation number N.



References

[1] Siegel R. and Howell J.R., Thermal radiation heat transfer, 3rd edition, Hemisphere publishing corporation, Washington DC, 1992.

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