Annealing Furnaces Modelisation for Photovoltaïc Applications

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Introduction: Comsol is used to calculate the power feeding of Kanthal heaters for new annealing furnaces in EMIX for temperature higher than 1200°C. A simplified radiation model is presented. Is it possible to neglect natural convection ?

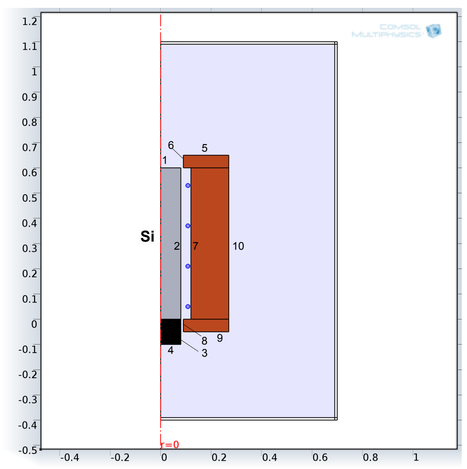

Figure 1. Annealing furnace around Silicon charge on graphite plate

Computational Methods: A full model of an enclosure furnace, including fluids dynamic transient computation is compared to pure radiation stationary models with analytic losses terms for free convection. Magnetic fields (mf) is used to feed heaters with a voltage coil group domain feature. Electromagnetic heating serves as a term source for heat equation including surface to surface calculation, wich is coupled with turbulent NS equation (k-e). Boussinesq approximation is used to calculate the natural convection in NS equation.

A spiral Kanthal filament brings to the furnace an incoming electric power of 11,5 kW. Initial temperature in the system is 25°C, transient computation is made on 5,5 hours where a quasi- stationary state is reached.

The average temperature of the silicon domain serves as comparison between full and simplified radiative models.

Results: Figures 1, 2 & 3 show the full model results. Temperature of silicon reaches 1578°C after 5,5 hours. 2,04 kW are lost due free convection on silicon and plate boundaries. Heat transfert coefficients are calculated from full modelisation. Analytical heat transfert coefficient are estimated from Grashoff and Nusselts numbers.

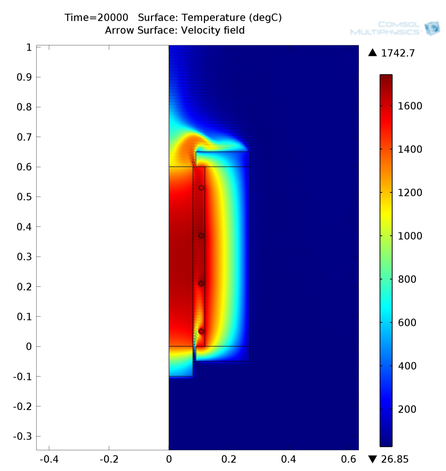

Figure 3. temperature Field in full model

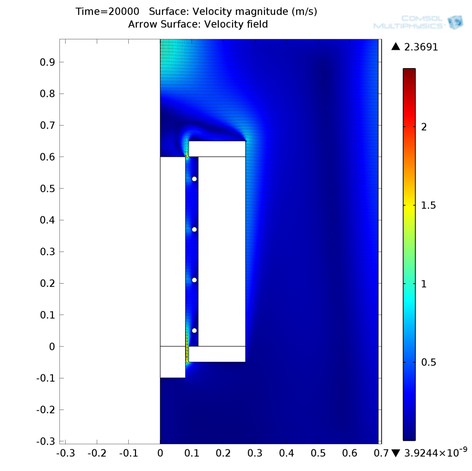

Figure 4. Velocity magnitude

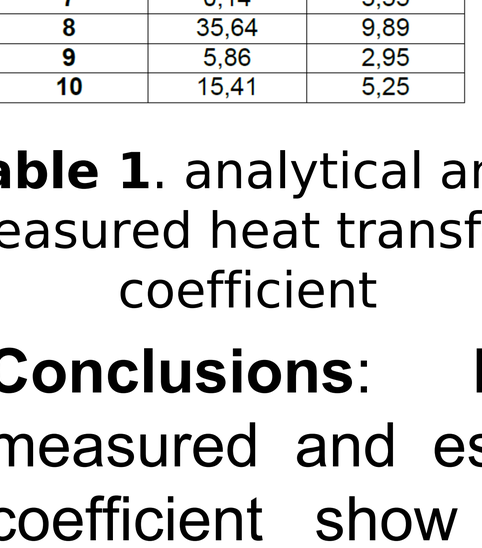

Figure 5. Average silicon domain temperature

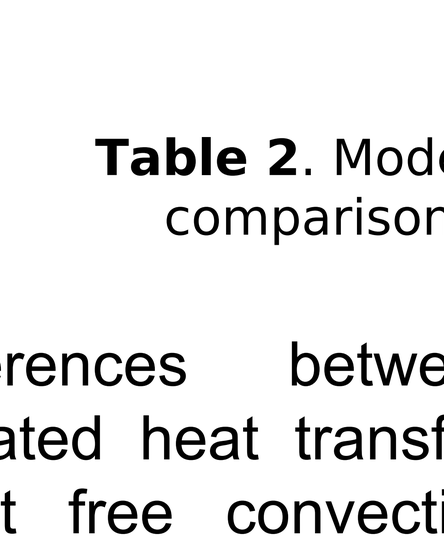

Figure 6.temperature Field in radiative model

surfaces	h_measured [W/(m.K)]	h_analytical [W/(m.K)]
1	-0,195	6,67
2	1,38	4,61
3	40,95	6,85
4	15,17	3,32
5	-13,07	6,99
6	-4,54	9,86
7	0,14	3,55
8	35,64	9,89
9	5,86	2,95
10	15,41	5,25

Table 1. analytical and measured heat transfert coefficient

models	Si temperature [°C]
full model	1578
Radiative + h_measured	1593
Radiative + h_analytical	1401
Radiative + without losses	1737

Table 2. Models comparison

Conclusions: Differences between measured and estimated heat transfert coefficient show that free convection must be calculated in a numerical way in complex geometries. Comsol permits a power sizing of heaters elements in fonction of characteristics of isolation materials for a real world application.

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