Comprehensive optimization of insulating high temperature molding processes using COMSOL® Application Builder module

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Introduction: In the industry, high temperature is more and more common and controlling the heating efficiency and the temperature distribution at very high temperature requires a high understanding regarding the confinement of these elements using specific materials.

Typically these elements are heated from the ambient temperature to high temperature which could be higher than 1000℃ and this level of temperature can be kept for from few hours to few weeks.

The challenge of this application is to design a consistent solution to insulate this element at high temperature using a stack of different materials (*figure 1*)

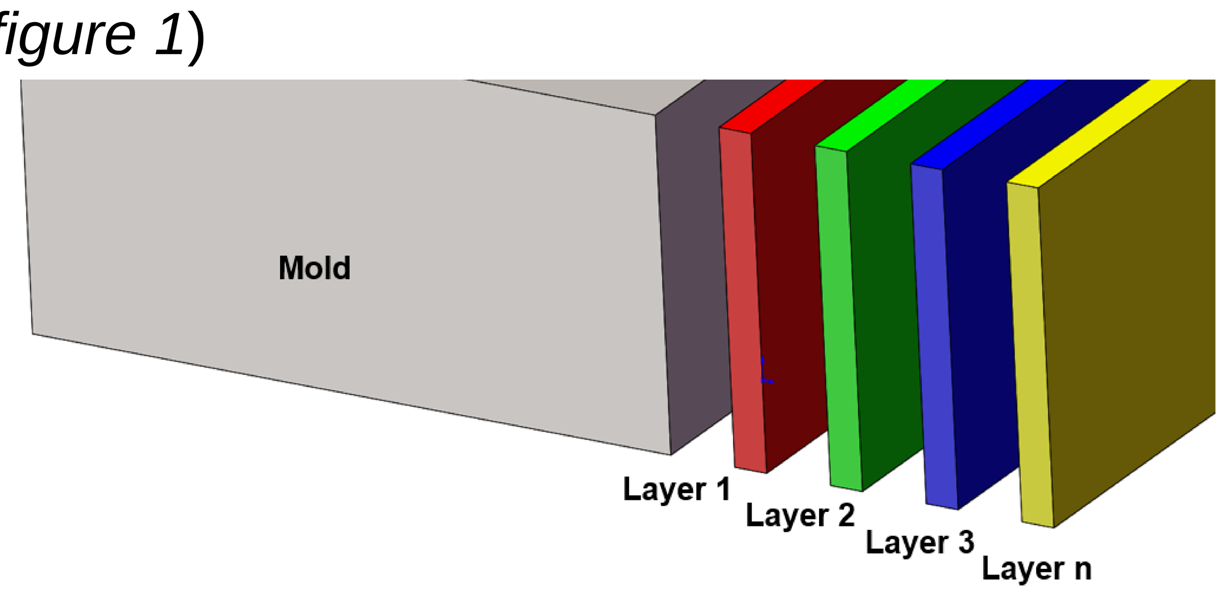


***Figure 1**. Considered geometry*

Computational Methods: A simplified 1D thermal model represents the multi-insulation-layer system, illustrated in *figure 2*. Heat transfer module and COMSOL® Application Builder module are used in this study.

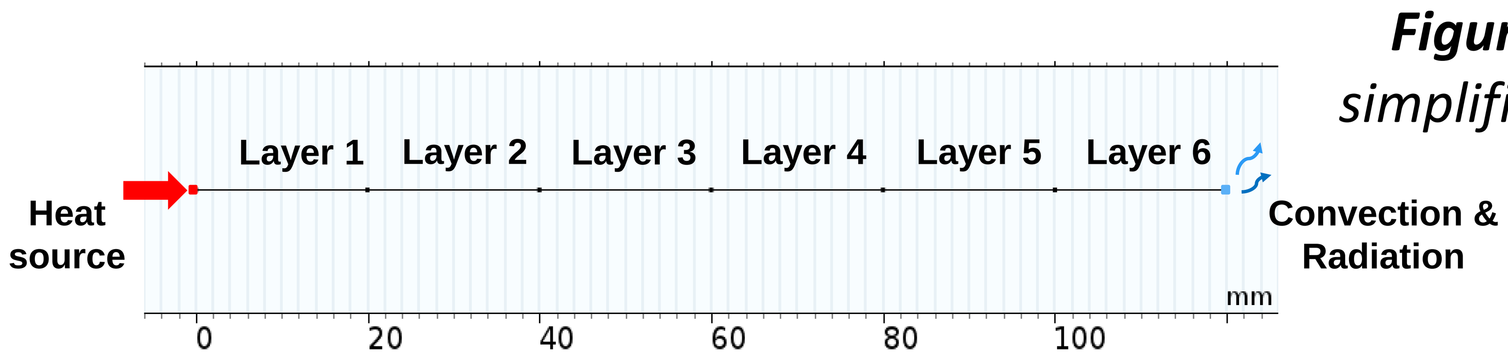


***Figure 2**. 1D simplified model*

In the model, the contact with the hot tool is represented by a heat flux controlled by a temperature evolution measured on the tool in reality. The last layer is affected by convection and radiation with the ambient environment. Time dependent study is considered.

The application shown below in figure 3 allows users to control the simulation through an user friendly interface, especially convenient to test combinations of different materials, number of layers and dimensions in the simulation to find the best solution.

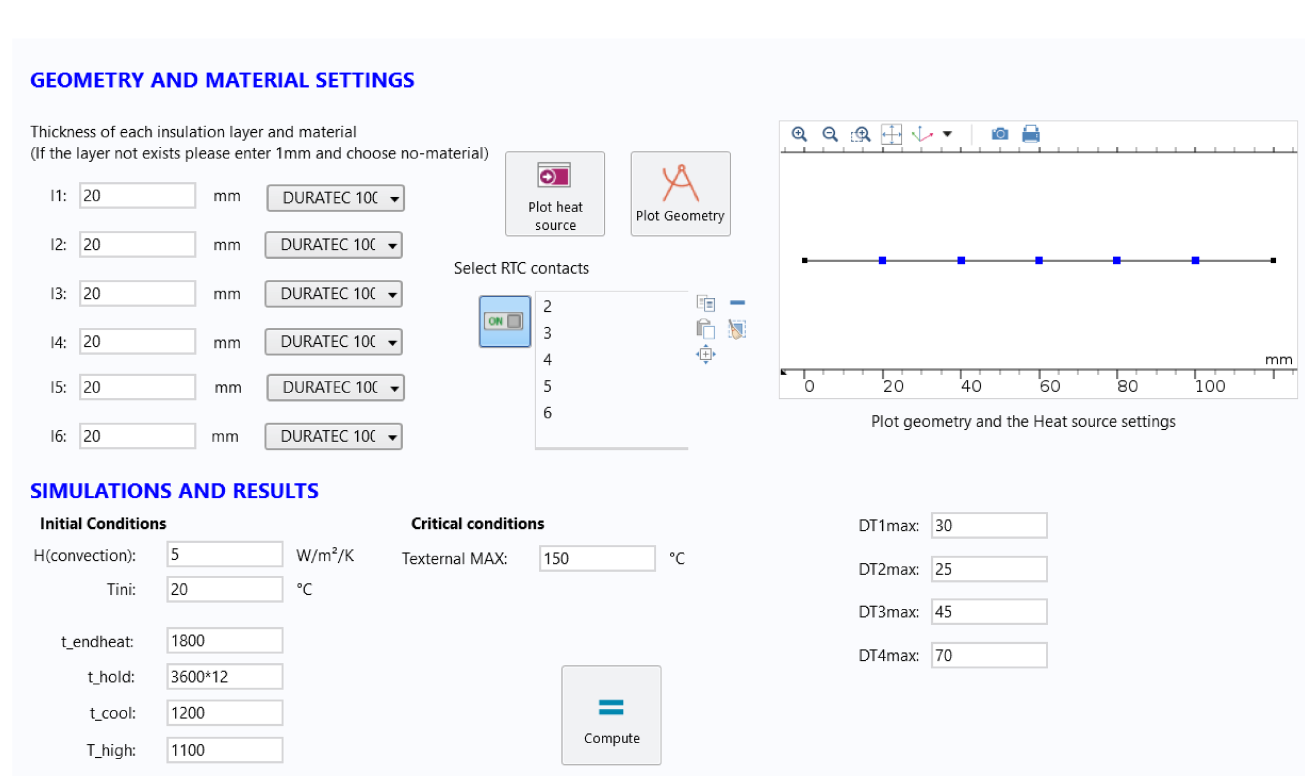


***Figure 3**. Application User control interface*

The goal of the application is to identify one of the best scenario accounting for the different optimization criteria which are: 1.The maximum temperature of each layer constituting the insulation elements to ensure the sustainability of the global system 2.The maximum temperature difference which pilots the internal stress 3.The external temperature for safety reasons towards any operator.

Results: The case of a tool applying specific temperature cycle between 20℃ to 1100℃ and works on this high temperature over more than 12 hours is an example with the extreme working conditions.

In this simulation the material will be chosen from *table 1*, a list of insulation materials existing on the market.

Material	A	B	C	D
Conductivity ***k*** (W/m.K)	0.4	0.064	0.1	2
Density ***ρ*** (kg/m³)	1400	430	300	900
Thermal capacity ***Cp*** (W/kg.K)	1040	1100	1050	1200
Maximum working temperature T_{max}(℃)	1200	1200	1100	600
Thermal shock resistance ***TSR*** (K/mm)[1]	30	25	45	70

1.Values in research and in development

***Table 1**. Details of material*

The original insulation system is a simple stack containing two layers of high-temperature insulation material and one layer of standard material. (*figure 4*) This solution will cause important thermal shock during cooling step on the first layer, which may break the material during the process, results shown in graph 1..

A best combination has been chosen after testing serval times on the app (*figure 5*). The max temperature gradient per length on each layer respects the TSR correspond to the material, and the two other criteria are also satisfied.

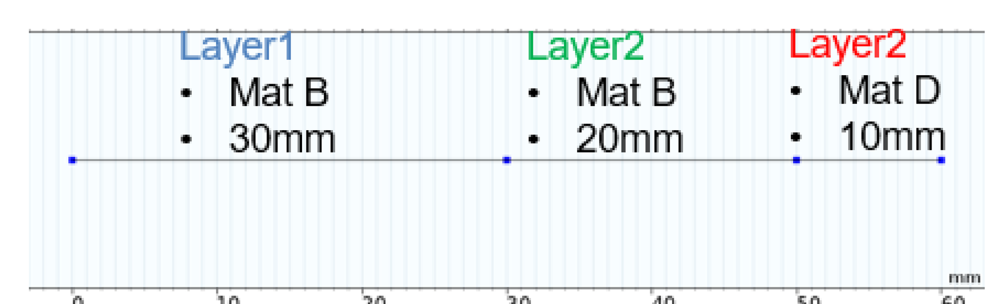
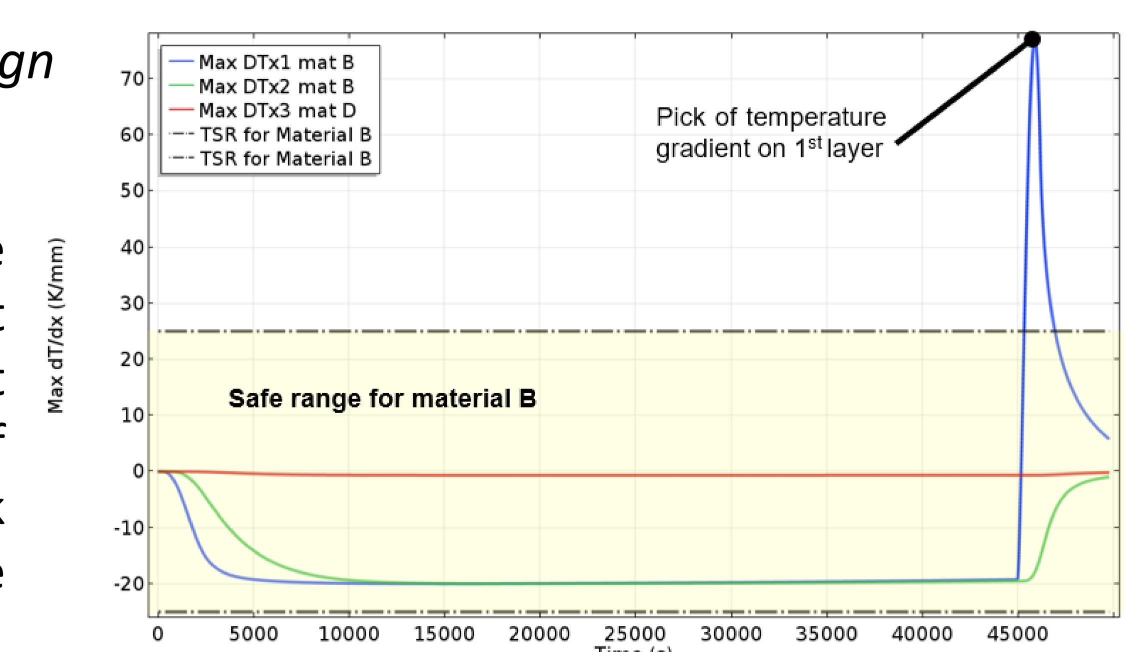


***Figure 4**.Original design: 3-layer stack system*



***Graph 1**. In the original design Max dT/dx of each layer.*

Result shows that during the cooling step, an important max temperature gradient will pass the security TSR of the material, which may risk to break this layer during the process

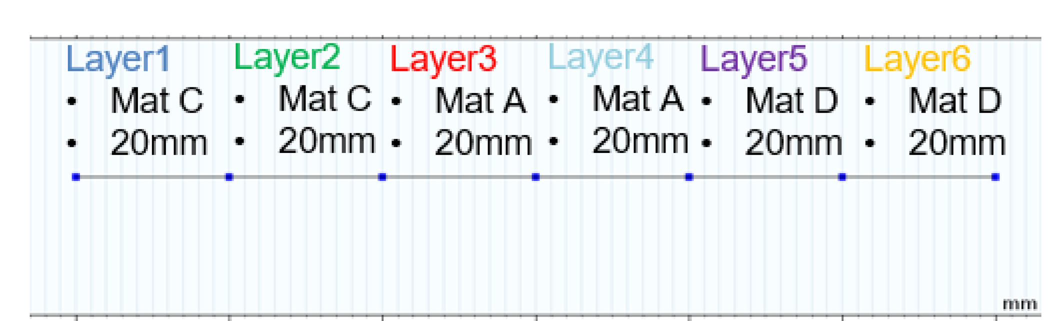
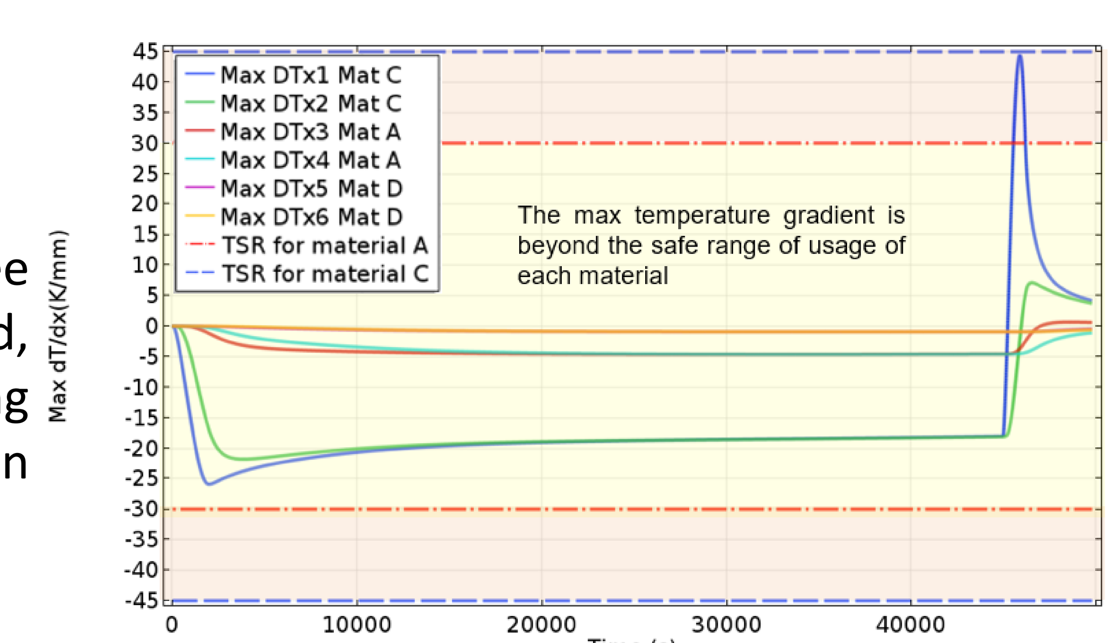


***Figure 5**.New design: 6-layer stack system*



***Graph 2**. New design Max dT/dx of each layer.*

In the new design the three criteria set are well respected, it will ensure the working condition of every layers in the insulation system

Conclusions: Using COMSOL allows to cover a large spectrum of criteria and to develop simple and consistent applications aimed at answering industrial challenges.

The application here allows to identify one of the best solution to insulate high temperature systems from the external environment aiming at increasing the sustainability and the cost effectiveness of the global system.

Perspective:

- Account for other dimensions (geometrical)
- Couple the thermomechanical aspects
- Use of specific optimization algorithms to fully automate the decision making process

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