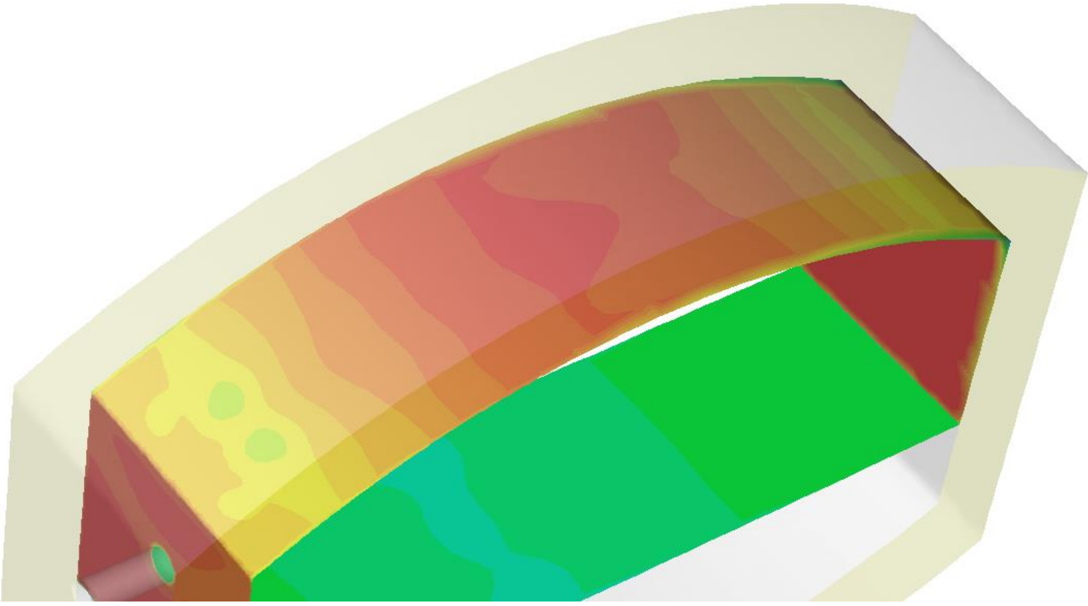
Computational fluid dynamics in metallurgy

# Heat distribution in a metallurgical furnace



## Introduction

Metallurgical furnaces can use different heat sources to enable a smelting process. The process itself may be exothermic (e.g. flash furnaces), the furnace may use electric heating (e.g. EAF), or fossil fuels may be used through burners. In all cases, finding an optimal heat distribution is relevant to:

- Optimize throughput by maximizing the active volume of the process
- Increase efficiency through the optimal use of heat from the off-gases
- Avoid hotspots and minimize wear of refractory
- Improve process control and reduce variability

In this article, we discuss the possibilities of computational fluid dynamics to study the heat distribution in a gas-fired melting furnace (reverberatory furnace). Similar calculations could be set-up for other gas-fired installations such as short rotary furnaces, muffle furnaces, kilns, or shaft furnaces.

## Challenges

The main challenge is to combine the large length scale of the full furnace, with the small length scale of the burner features. Indeed, the burner design will influence the flame shape, which influences the heat distribution by radiation, convection, and conduction. All these heat transfer phenomena interact and need to be taken into account simultaneously.

For many applications, calculations become too complex when all phenomena in the furnace are modelled, and simplifications are needed. The process itself is therefore approximated by a heat source or sink. Thermodynamic calculations, in which InsPyro has substantial experience, provide accurate data for the enthalpy changes of heating and melting, and reactions such as oxidation or reduction.

Many aspects of the furnace design can be varied. The amount of burners, and their location, orientation, and settings, are certainly relevant. Changes in furnace insulation, refractory properties, and fill level, also influence the heat distribution and can be modelled as well.

However, modifying the furnace is subject to several space and cost constraints. Therefore the project team will use metallurgical expertise and customer input to set-up targeted calculations in order to find an improved design with realizable modifications.

## Technology used

Computational Fluid Dynamics (CFD) software: ANSYS Fluent

Automation of workflow: ANSYS Workbench

## Engineering Solution

- Turbulence and combustion models are used
- Heat transfer models for conduction, convection and radiation are used
- In most cases, the geometry is simplified using shells for insulation layers, in order to speed up calculations.
- Actual gas, air or oxygen, and material flows are used to reach the thermal equilibrium as in reality.
- Variations are made to settings and designs based on automated workflows where possible.

## Results

The figures show some of the parameters which can be evaluated using a CFD model. The temperature distribution is the most important (Figure 1-2), but modelling allows to study detailed mechanisms such as the incident radiation on the bath surface (Figure 4). An accurate heat balance can be calculated for several scenarios based on heat losses to off-gas, through walls, and heat provided to the process (Figure 3).

**Benefits**

- **Fast feedback on many possible variations in furnace lay-out and burner settings.**
- **Understanding the relations between burner parameters and efficiency of the full furnace**
- **Optimizing refractory inner surface temperature in order to avoid hotspots and accelerated degradation**
- **Experimenting on the production installation can be avoided**
- **Design recommendations can be turned into reality at the next standstill**

Sander Arnout, PhD
Modelling expert
InsPyro NV
Leuven, Belgium
www.inspyro.be

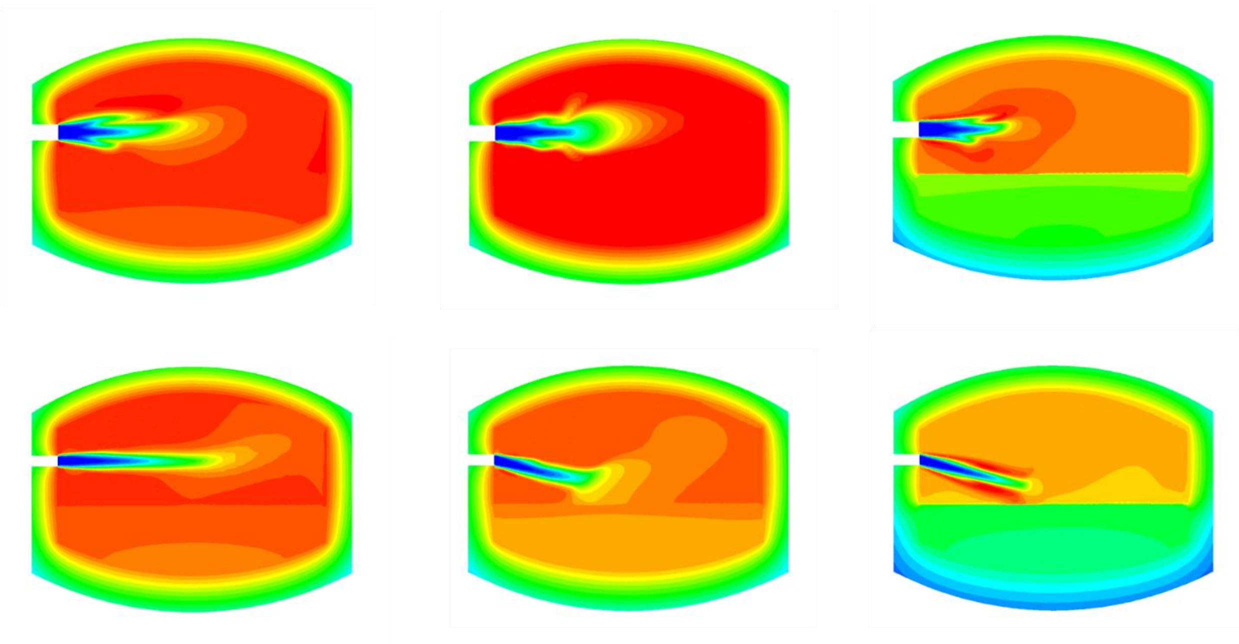


Figure 1: Temperature distribution result for different burner designs, settings, and process conditions*

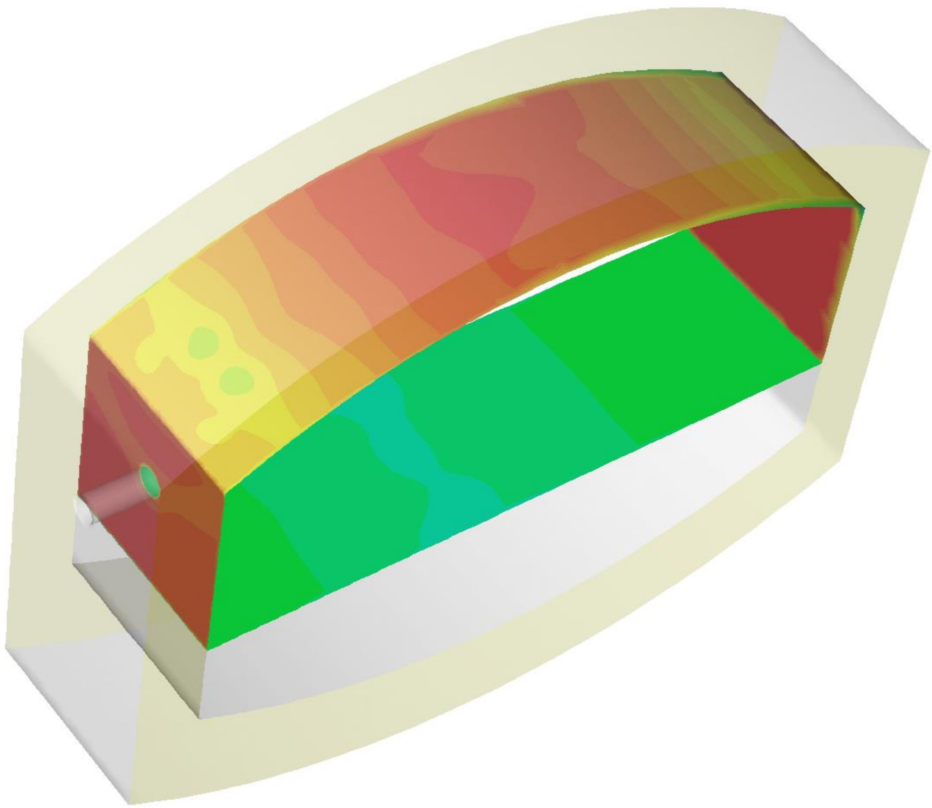


Figure 4: Radiation inner wall temperature on melt surface in a furnace section

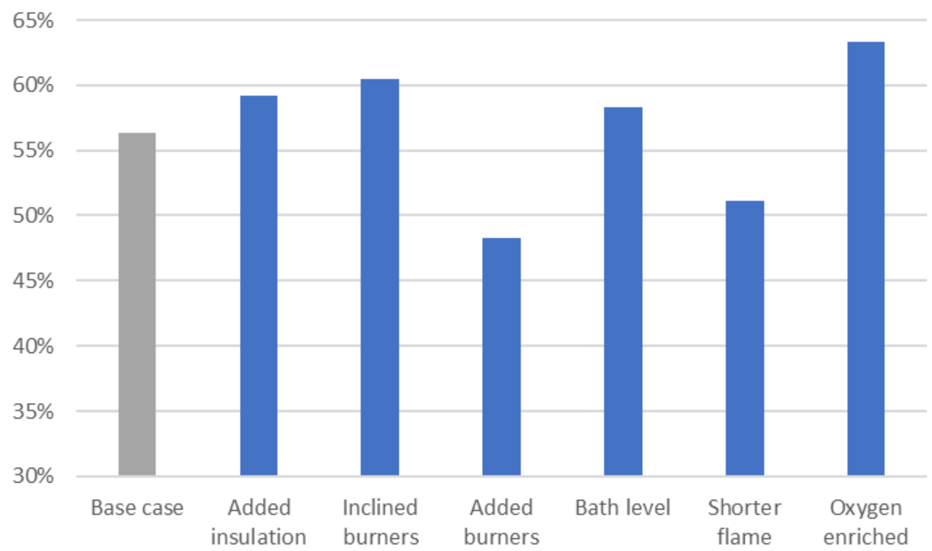



Figure 3: Furnace efficiency for different scenarios. Note: efficiency optimization also requires staying within constraints such as maximal service temperatures.

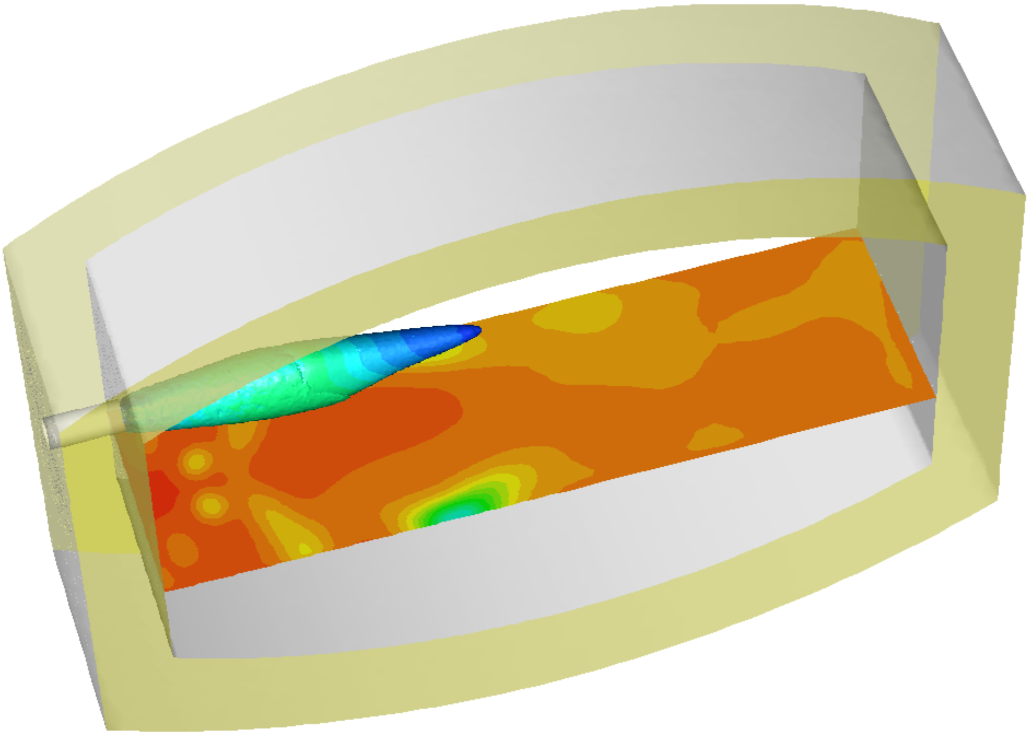


Figure 4: Radiation intensity map on melt surface in a gas-fired furnace section

*These graphs are based on a simplified hypothetical furnace design. Several similar but confidential projects on full furnaces have been run by InsPyro.