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HEAT TRANSFER MODELING INSIDE INDUSTRIAL FURNACES

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ABSTRACT

We consider in this paper the thermal modeling for an industrial oven. The main objective is to design an industrial software solution able to handle real complex furnaces configurations in terms of geometries, atmospheres, parts positioning, heat generators and physical thermal phenomena's. Using computational fluid dynamics (CFD) will probably not replace physical experiments completely but it can reduce the amount of experimental work.

We begin by considering a single 3D grid of this oven and then we use an immersion technique for the multi-domain problem. This technique will take into account different positions and forms of the heated parts inside *(Fig. 1)*. In other words, we apply a signed distance function χ to define the interface of the ingot. Via this function, we can turn different thermal properties of each component (air/solid: T, ρ, Cp, k) into homogeneous parameters to utilize during the resolution.

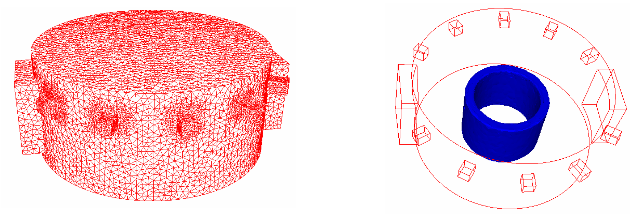

Figure 1: 3D geometry of the model problem

Moreover, to gain high precision at the interface, we used an anisotropic mesh adaptation technique based on variations of χ *(Fig. 2)*. This will allow a better capture of the discontinuities that characterize the strongly heterogeneous domain.

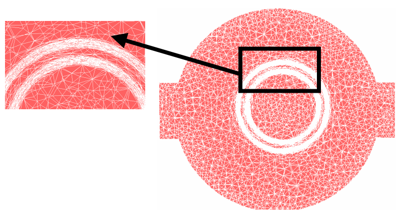

Figure 2: Mesh refinement at the interface level

At the burner's level and inside our domain, it is well known that for advection-dominated problems, spurious oscillations may appear in the standard finite element resolution of the advection-diffusion equations. In order to overcome this numerical difficulty, different stabilized finite element methods will be used, such as SUPG (Streamline Upwind Petrov-Galerkin) and SCPG (Shock Capturing Petrov-Galerkin).

At ingot's level, where diffusion is the sole mechanism for heat mass transfer, there are still some conditions for which the Galerkin method fails to solve unsteady diffusion problem. A new approach will be presented to obtain stabilized finite element formulation that ensures an oscillation-free solution and treats the thermal shocks. This method will be known as RFB-i (Residual-Free bubbles-i).

The velocity and the pressure fields are computed by solving the Navier-Stokes equations coupled to heat equations. This finite element solver is already implemented in our library CIMLIB. It uses the so called P1+/P1 or "MINI-element" formulation as a stabilization method.

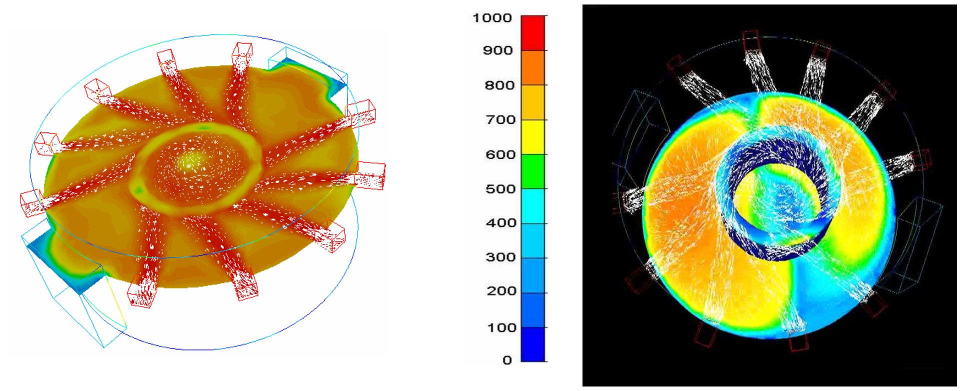

Figure 3: Temperature and velocity distribution

The Reynolds Averaging of Navier-Stokes (RANS) equation types of k-ε turbulence model are used.

REFERENCES

[1] L.P. Franca and C. Farhat, "Bubble functions prompt unusual stabilized finite element methods", Comput. Methods Appl. Mech. Engrg. 123 (1995) 299-308

[2] Anderson JD. "Computational fluid dynamics". International Edition. New York: McGraw-Hill; 1995

[3] T. Coupez, H. Digonnet and R. Ducloux, "Parallel meshing and remeshing", Comput. Methods Appl. Mech. Engrg. 25 (2000) 153-157

[4] E. Hachem, H. Digonnet, E. Massoni and T. Coupez, "Residual-Free Bubbles method applied to transient heat conduction transfer", Comput. Methods Appl. Mech. Engrg. (submitted in November 2007)

[5] E. Hachem, H. Digonnet, E. Massoni et T. Coupez, "Modélisation du procédé de chauffage de pièces dans un four industriel", 18èmeCongrès Français de Mécanique, (2007)