LINGOPTI PROJECT : SEMI-CONTINUOUS CASTING PROCESS OF COPPER-NICKEL ALLOYS

Etienne Pecquet [1], Ralf Volles [2], Jacqueline Lecomte-Beckers [3], Anne Marie Habraken [1]
[1]*ULg, Department of Mechanic of Materials and Structures, B-4000 Liege, Belgium*
[2]*RWTH, Institut für Bildsame Formgebung, 52056 Aachen, Germany*
[3]*ULg, Department ASMA, sector Special Metallic Materials, B-4000 Liege, Belgium*

Summary The following text deals with casting of copper-nickel alloys. They are high added values materials. The research contains two main parts. Laboratory tests (completed with bibliography) that provide thermal and mechanical properties of the ingot and the mould but also heat transfer coefficients between the ingot and its environment (mould, air and water). These parameters are required in the second part : development and validation of numerical modelizations by the finite element method to optimise the industrial process.

INTRODUCTION

The Lingopti project, performed in the University of Liege, is a first Europe research co-financed by the European Social Funds and the Walloon Region. The studied industrial process is the one of LBP factory. It consists in a vertical semi-continuous casting of copper-nickel alloys. The dimensions of an ingot are 7m in height and the section is 960x310mm. After a mould cooling, ingot is submitted to air cooling, water sprays and finally water tank cooling. LBP society makes several alloys. The principle component is the copper, and the content of nickel is between some percents to thirty percents. Sometimes, it can be added some iron or other components. Cupronickels are high added values materials used in very different domains from Euros money to tubes of brakes by Volvo.
The final goal of this research is the optimisation of the mould and the whole casting process of the enterprise to obtain better cast products. In fact, cast products sometimes present long oscillations marks ($\lambda \approx 500$mm) and some ingots have many internal cracks. It will also be examined the influence of the content in Nickel on the thermo mechanical evolution of the ingot during whole the casting process.

LABORATORY TESTS

Laboratory tests have been carried out in several domains. In fact, cupronickel alloys are not so common than steel and we do not dispose in the bibliography of enough data to characterise thermal and mechanical properties up to high temperatures and for the right alloys. Tests allow to determine thermal and mechanical properties of the solid, but in addition, heat transfer coefficients have also been determined for different environment conditions.

Mechanical tests
In casting process, it is essential to know the mechanical behaviour, up to the liquid state. Because of the viscosity is also an important parameter, tests of uniaxial compression has been carried out at different high temperatures and different speeds of deformation. Currently, we dispose of stress-strain curves for two alloys for three temperatures (500,900 and 1100°C) and three speeds of deformation (10^{-2}, 10^{-3} and 10^{-4} s^{-1}) : CuNi 75/25 and CuNi 70/30 with some Iron.

Thermal tests
With these tests, we determine, up to the solidus temperature, four parameters : the specific heat C_p, the thermal expansion coefficient α, the specific mass ρ and the heat conductivity λ. So that, we characterise the thermal behaviour and also dispose of these measurements for the two alloys mentioned here above. Thermal properties are also determined and can be used if we decide to modelize the mould in the numerical simulations.

Heat transfer coefficients
Finally, to be able to simulate numerically whole the casting process, heat transfer coefficient between the ingot and its environment are also necessary. We studied as well exchanges between the mould and the ingot (in case of contact or not) as heat transfer after that, with air, water sprays and water tank. For that purpose, some tests developments have been realised in collaboration with the department IBF of the University of Aachen (RWTH).

NUMERICAL CALCULATIONS

All the parameters determined here above are used in the numerical calculations by the finite element method with the Lagamine code, developed at the department M&S of the University of Liege since 1982. Currently, two 2D models are used and developed. A vertical slice has been first used only in thermal analysis. It allows to see the field of temperatures, but also to check, by a parametric study, the influence of several parameters. So, we verify that the latent heat of fusion or the exchanges with the mould influence a lot the field temperature. Another important point is that the vertical heat flux is small in comparison with the horizontal one. That allows to consider an horizontal slice (see after). Figure 1 presents the field of temperatures for this vertical slice for whole the cooling process.

1: 1275°C > T > 1180°C
2: 1180°C > T > 1100°C
3: 1100°C > T > 1020°C
4: 1020°C > T > 940°C
5: 940°C > T > 870°C
6: 870°C > T > 790°C
7: 790°C > T > 550°C
8: 550°C > T

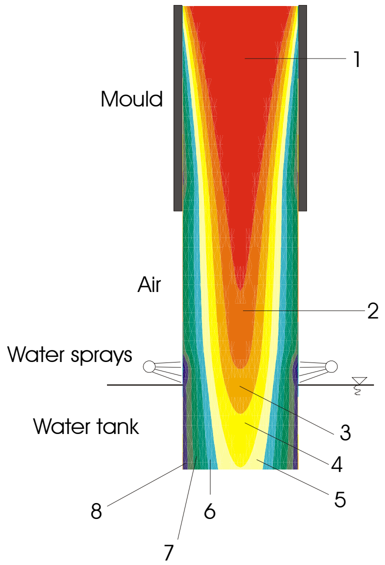

Figure 1 : Field temperature with the vertical slice model

With an horizontal slice model, we perform thermo mechanical analysis. The slice, by progression in the casting process, gives a 3D view of the ingot in stationary situation by a 2D modelization. This model, already developed and used by F.Pascon for continuous casting of steel [1], takes into account, in a simplified way by the concept of generalised plane state, stresses in the casting direction.
For the thermo mechanical analysis, for having convergence, mechanic requires small steps of time and themal behaviour big ones. So, we perform alternatively thermal and mechanical analysis transferring information from one to the other.
Figure 2 gives a view of the different material states obtained by this horizontal slice.

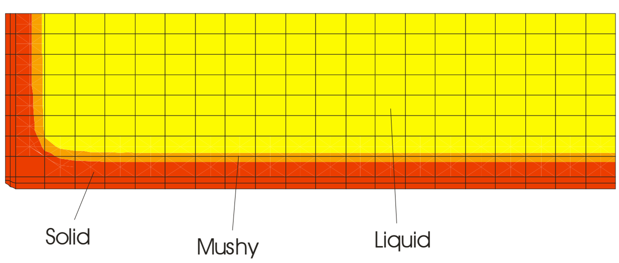

Figure 2 : Material state with the horizontal slice

PERSPECTIVES OF THE RESEARCH

Currently, models continue to be developed and validation has started. In order to compare numerical calculations and experimental measurements on the industrial process, following measurements have to be performed : heat flux extracted with the mould, geometry of the final ingot and surface temperatures just after the mould cooling.
We will also try to explain numerically long oscillation marks obtained on a lot of ingots and examine the ability of the available model to predict ingot shape.
The final goal is the optimisation of the casting process, when alloys composition is modified.

References

[1] Pascon F.: 2D1/2 Thermal-Mechanical model of Continuous Casting of Steel Using Finite Element Method *PhD Thesis*, Department M&S, ULg, 2003.