Modeling of the Vacuum Arc Remelting process at Böhler Edelstahl GmbH

CALCOSOFT-2D provides for a better understanding of the coupled phenomena occuring in the remelting process

More than 250 steel grades from Böhler Edelstahl are used in the production of goods which we use every day. For example as moulds in the production of plastic goods, as cold work tool steels for punching, bending and cutting applications, as hot work tool steel in die casting or as special materials in turbines, automotive and aircraft industry, etc.

Advanced technology for high quality products

Böhler Edelstahl combines the latest vacuum-melting technologies and a range of Electro Slag Remelting facilities enabling the manufacture of materials with a high metallurgical degree of purity. Three VAR-furnaces capable of producing ingots up to 950mm in diameter, are mainly used for the production of special steels and nickel-based alloys.

"We have been using CALCOSOFT-2D for two years to simulate solidification and optimize the process," says Christof Sommitsch, Project Leader, Böhler Edelstahl GmbH. The company is considering CALCOSOFT-2D as an efficient tool providing:

- better process understanding,
- process optimization and parameter studies such as cooling, melt rate, geometry,
- increased material quality through analysis of macro and micro-segregations and non-metallic inclusions,
- better customer services thanks to detailed specifications and qualifications.

CALCOSOFT simulation of the VAR process

The difficulties involved in simulating Vacuum Arc Remelting (VAR) processes are directly linked to the wide range of physical and chemical phenomena which occur simultaneously and are often coupled in such remelting processes. "CALCOSOFT brings the necessary knowledge for a deep understanding of the VAR process," adds C. Sommitsch.

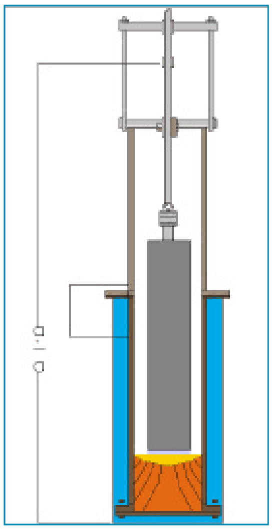
A comprehensive digital simulation should incorporate fluid flow, heat and mass transfer, electromagnetic effects, solidification (including microstructure prediction) and macro-segregation. The modeling of heat transfer, fluid flow, solidification including grain structure prediction, solid-state transformation, hot tears, porosity and macro-segregation is already available in CALCOSOFT-2D.

Moreover, the software also includes an induction heating model which allows magnetic stirring to be modeled. However, due to the geometry of the VAR furnace and its power supply, a new axisymmetric electromagnetic solver which takes into account both Lorentz's forces and Ohm's law heating, was developed to simulate the VAR process.

950mm diameter ingot

Analysis

The VAR process is characterized by an axisymmetric geometry, so all calculations are carried out in a 2D axisymmetric system. The model used



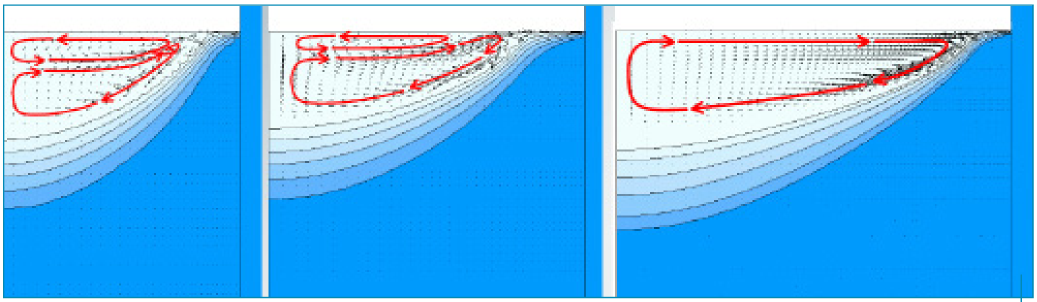
Vacuum Arc Furnace

in the simulation contains the ingot and the copper mould; the electrode and the electric arc are not directly considered. Heat flow, transport of the solid phase, fluid flow and the magneto-dynamic effects in the pool due to the melt current are taken into account by the calculations.

Trials are carried out for three different dimensions, a 310mm, a 410mm and a 510mm diameter ingot, all made of Alloy 718. The geometry of the mould, the electrode dimension and process parameters such as melt rate and melt current correlate to those used for industrial production. The total energy coming from the droplets and from the radiation of the electric arc is represented by a constant temperature at the pool surface (given by the liquidus temperature and superheat), and a constant flow of material according to the melt rate. The superheat is estimated by multiplying the fraction of arc energy that goes into the melt by the power of the arc per electrode cross-section.

Starting from fictitious initial conditions, the heat balance of the system is calculated until stationary conditions are reached with a sufficiently high number of time steps. Transient process phases such as changes in the melt rate and phases of the process which are transient by nature, for example hot topping or the start phase, are not taken into consideration.

Because of the shrinkage of the solidifying material, a gap appears between the ingot and the mould. The gap formation as a function of the ingot height can be calculated and equivalent heat transfer coefficients between the ingot and cooling water are derived as a function of the gap width.



Flow distribution for various ingot diameters (from 310 on the left to 410, then 510mm on the right)

Results

The main results obtained with CALCOSOFT-2D are: the temperature distribution, the distribution of the fraction of solid in the ingot and the fluid flow in the liquid pool.
The comparison between measured and simulated pool profiles shows good correlation for the pool profile of the 510mm ingot.

The different flow regimes obtained for various ingot diameters can be related to the different acting forces. At the top of the pool, where the current density is very high, the flow is mainly driven by Lorentz forces which lead to the flow pattern observed. Further below the surface, the current density decreases and the flow regime is mainly driven by buoyancy forces.

Based on these promising initial results, Böhler Edelstahl GmbH now plans to extend its simulation activities to microstructure and segregation predictions. CALCOSOFT will be used also to analyze the simulation of the solidification behavior of other alloys. Finally, the possibility of simulating other production processes, in particular the Electro Slag Remelting process, is also being investigated.

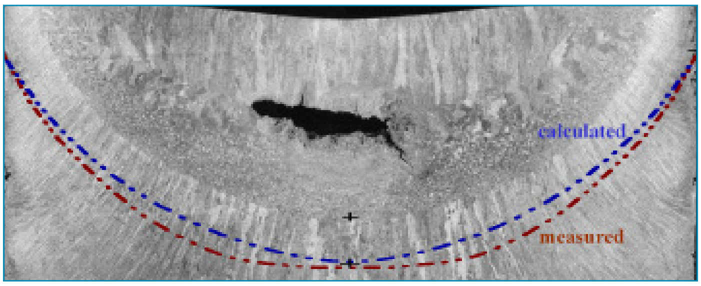
“Using CALCOSOFT-2D we will be able to improve the quality of our remelted ingots by an optimization of the melt rate, the fill ratio, the cooling system and the current and voltage definitions”

BÖHLER Edelstahl GmbH

BÖHLER Edelstahl GmbH is one of the most important suppliers of high speed steel, tool steel and special materials worldwide. The company was founded in 1991 and is a 100% subsidiary of the BÖHLER UDDEHOLM AG group in Vienna.

Yearly producing 126,000 tons of special steels, BÖHLER Edelstahl concentrates on materials for highly demanding applications in the aeronautics and aerospace sectors, automotive, energy, medicine, or in oil and chemical industries. Finally, the Austrian Mint but a lot of other renowned mints around the world are using the hardest BÖHLER steel to produce billions of coins.

The latest vacuum-melting technology and an ever-increasing metallurgical expertise guarantee the highest standard of quality – from melting to delivery.
More information on: http://www.bohler-edelstahl.at/



Validation of pool profile: comparison of simulated and measured pool profile.