



Cornille Havard Foundry improves its productivity and expands its bell-casting market thanks to QuikCAST

THE CHALLENGE

Cornille Havard Foundry wanted to implement never-done-before casting simulation on bronze alloy-based large bell castings, in order to reduce scrap rates and expand their business in this niche market. The major challenge was to cast these bell castings as large as 7 tons in weight, using a special bronze, with little available data on the material. To help in this effort, the foundry called on CTIF, a French research and development center specialized in metal casting.

THE BENEFITS

- To trade in empiricism for a more accurate numerical approach of the casting process;
- Better knowledge and control of the casting alloy and process;
- Higher quality of the cast bell;
- Early design for manufacturing.

“The simulation results obtained with QuikCAST along with the material characterization bring us to a better understanding of the fluid flow sequence, thermal exchanges and metallurgical phenomena which appear when casting bells. The principal outcomes were the validation and the optimization of our molding system as well as the possibility to consider the casting of bigger bells in order to enter new markets.”

Didier LINXE, Digital Engineering Manager, CTIF

Cornille Havard Foundry has cast bells in Normandy, France since the end of the middle ages. They produce mainly small and medium-sized bells up to a maximum of 7 tons in weight, using mostly copper-based bronze alloys. The foundry went for a complete overhaul in its manufacturing process in 2003 by generalizing a process named “inverted casting” which confers to the bell improved metallurgical and acoustic properties along with a better aspect.

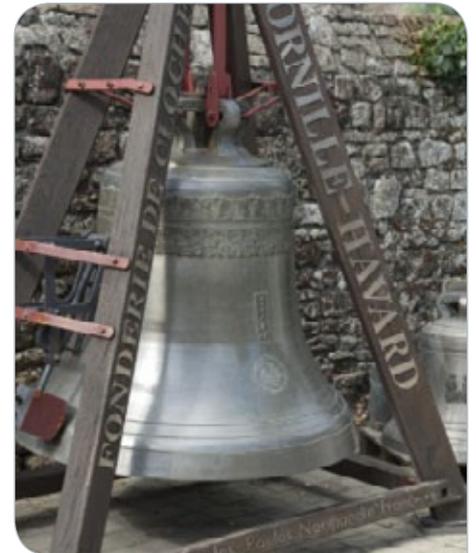
Wishing to expand their market to very large bells, the foundry sought to adopt simulation techniques to better understand the solidification behavior in such castings. Simulation meant being able to characterize the material properties of their alloy, in order to generate accurate predictions. Cornille Havard Foundry called upon CTIF, a French research and development center specialized in metal casting, to characterize their production process using numerical simulation tools and validate these using experimental methods and measurements. CTIF and Cornille Havard implemented a step-by-step process to finally achieve the goal of casting a high quality 7 tons bell casting.

Material characterization of CuSn22 bronze alloy



Adopted casting simulation process

The 7 tons bell casting had to be cast in CuSn22 bronze, a non-standard cast alloy. Not only was there little available information in literature regarding thermo-physical properties required for simulation



Medium-size bell casting

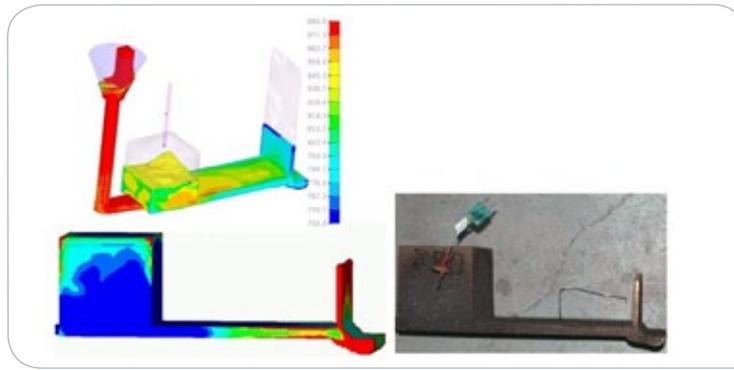
of this alloy, but the existing thermodynamic data was too approximate for use in simulation. Laboratory testing was therefore organized to characterize the material properties and to retrieve the necessary data usable for casting simulation, such as:

- Solidus, eutectic, and liquidus temperatures ($^{\circ}\text{C}$),
- Latent heat (J/kg),
- Specific heat ($\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$),
- Density (kg/m^3),
- Solid fraction,
- Thermal conductivity ($\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$),
- Dynamic viscosity ($\text{Pa}\cdot\text{s}$).

Alloy property validation on a sample test casting

The material properties obtained from the characterization exercise were first validated on a representative casting sample using a sand mold with well known material properties (chemically bonded sand). Few iterations were carried out to refine the physical properties involved in filling and solidification simulation.

The geometry of the sample casting was deliberately heterogeneous in thickness, and the testing was performed at a lower temperature in order to assess the reliability of the software response. The simulation results concerning the filling behavior and the solidification pattern showed to be in good agreement with the experimental results. This correlation confirmed the material property characterization done for the CuSn22 alloy.



Simulation of test casting compared to experimental measurements

Process validation on a medium-sized bell casting

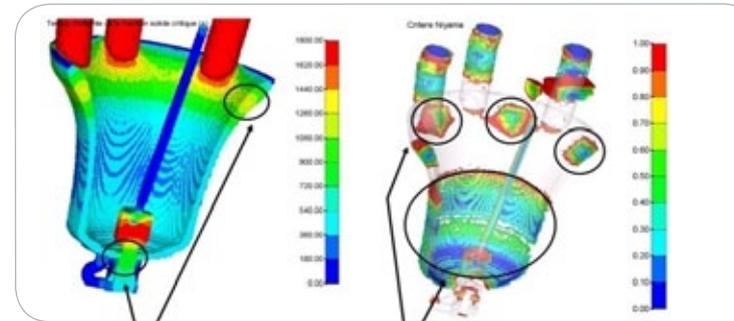
The next step was to validate the entire process on an instrumented casting, similar in design to the actual casting, but of medium-size and weighing about 600kg. Manufacturing conditions remained similar to the sample test casting, and a comparison was made with the corresponding simulation results.

The mold was equipped with thermocouples in order to measure and analyze:

- Filling temperature variations,
- Stages of solidification,
- Cooling temperatures in the cast part and mold,
- Thermal exchanges between casting alloy and mold constituents.

In parallel, numerical simulations of filling and solidification were performed using QuikCAST based on:

- Material data from the characterization phase,
- 3D CAD model of the entire mold cavity set-up,
- Calculation hypotheses reflecting the actual casting conditions, including instrumentation (measurements obtained from the thermocouples).



Risk of shrinkage porosity: The feeding path is cut off prematurely between the risers

Niyama criterium: With the criterium we can highlight the problem of feeding distance which can cause shrinkage porosities in the part

QuikCAST simulation predictions on the medium-sized bell casting

The output of the filling simulation revealed a choke in the filling system design, the evolution of the metal front (temperatures, velocities, pressures) indicating potential areas of air entrapment and cold laps, as well as the regions filled last inside the cavity.

The casting solidification study provided cooling curves, the evolution of the liquid fraction across the entire solidification range, as well as temperature gradients across different casting sections, and solidification time on the entire casting part.

By comparing experimental and simulated results using QuikCAST, CTIF was able to finalize the calibration exercise and have well set simulation parameters, suited to such a casting process.

Results & Conclusion

Cornille Havard Foundry implemented QuikCAST numerical simulation to help manufacture bigger bronze bell casting than with their traditional bell castings process. The methodology featured advanced techniques enabling them to acquire knowledge on the thermal and fluid properties of CuSn22 bronze alloy and on the behavior of the mold materials during solidification. This opens the way for predictive numerical simulation studies for the production of very large bell castings over new markets.

To find out more about ESI's solutions for Casting simulation, please visit : www.esi-group.com/casting

ABOUT CORNILLE HARVARD

Cornille Havard Bell Foundry is settled in Normandy (France) since 1830. In this niche market, the company is one of the leader by producing top quality church bells in terms of tuning and appearance. The foundry exports each year between 20 to 50% of its production to Viet Nam, Japan, New Caledonia, Nigeria, USA, Malta, Lebanon and Rwanda. Human values and quality work have been its main foundations over the past 20 years of development. Today, with 18 employees, the company attained a turnover of 1.200.000 €.

ABOUT ESI GROUP

ESI is a pioneer and world-leading provider in virtual prototyping for manufacturing industries that takes into account the physics of materials. ESI has developed an extensive suite of coherent, industry-oriented applications to realistically simulate a product's behavior during testing, to fine-tune manufacturing processes in accordance with desired product performance, and to evaluate the environment's impact on performance. ESI's solutions fit into a single collaborative and open environment for End-to-End Virtual Prototyping, thus eliminating the need for physical prototypes during product development. The company employs about 850 high-level specialists worldwide covering more than 30 countries. ESI Group is listed in compartment C of NYSE Euronext Paris. For further information, visit www.esi-group.com.



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