Ugitech Optimizes Steel Casting Process Using COMSOL Multiphysics®

BY CHRISTIAN DEVILLE-CAVELLIN, UGITECH S.A., UGINE, FRANCE

In any industrial process, one key goal is to optimize speed. For Ugitech S.A., a manufacturer of stainless steel in France, that means running its continuing casting machines as fast as possible while maintaining quality. Yet, if you cut off individual pieces from the square bloom coming out of the casts prematurely, the inside of the steel section will not completely solidify, and a molten metal well with as much as 1.5 tons of liquid steel can empty into the bottom sections of the vertical concast machine, causing major damage. Through modeling, Ugitech is optimizing the proper temperatures and process speeds for each of the 150 different steel grades the company produces.

A Solidified Shell Forms First

In our casting process, molten steel enters a tapered copper tube mold that is intensely cooled by external water circulation. During this stage, a solidified shell forms that can withstand the ferrostatic pressure from the molten metal well inside the strand. After the mold, three series of water sprays keep on increasing the strength of the shell, while rollers prevent it from bulging. The strand is finally cooled through radiation; see Figure 1.

One modeling investigation concerns early solidification, which can lead to cracks, segregations near the product's skin, depressions and oscillation marks (the mold oscillates vertically to help the mold effect lubrication). As the shell cools, it shrinks and an air gap forms at certain points; see Figure 2. That gap's location has a big impact on the final product, and controlling its proper level is a delicate process. If the gap opens too early, insufficient heat is removed from this part of the shell, the solid skin remains thin, and internal defects appear in the product. If the air gap is too thin, the mold becomes too conical and friction arises between the strand and the copper mold, which may cause a shell breakout below the mold, due to excessive friction during the extraction process.

Only with multiphysics modeling is it possible to understand what is happening inside the steel bloom as it passes through the concast machine. Using COMSOL Multiphysics® along with the Heat Transfer Module and the Structural Mechanics Module, to compute the skin deformation during the solidification process, it took us roughly 6 months of time to develop the model and verify it against experimental data.

Author Biography:

Dr. Ing. Christian Deville-Cavellin is the Head of Liquid Metal Metallurgy/Solidification Dept. at Ugitech S.A.'s Research Center in Ugine, France.

Contact Conditions and Phase Changes

The model actually consists of two parts. Firstly, a pure heat-transfer model that can predict temperatures and phases within the bloom and then a thermomechanical model that will help us better understand the mold/steel interface and explain certain defects on the bloom surface in order to correct them; see Figure 2.

Part of the challenge in setting up the model is due to the strong nonlinearity of the contact condition between the steel and the mold. In addition, the steel undergoes phase changes. For this, it is necessary to find thermo-physical data about each steel grade and include it in the models. For example, we can directly include in COMSOL a description of thermal conductivity using a 3rd-order polynomial,

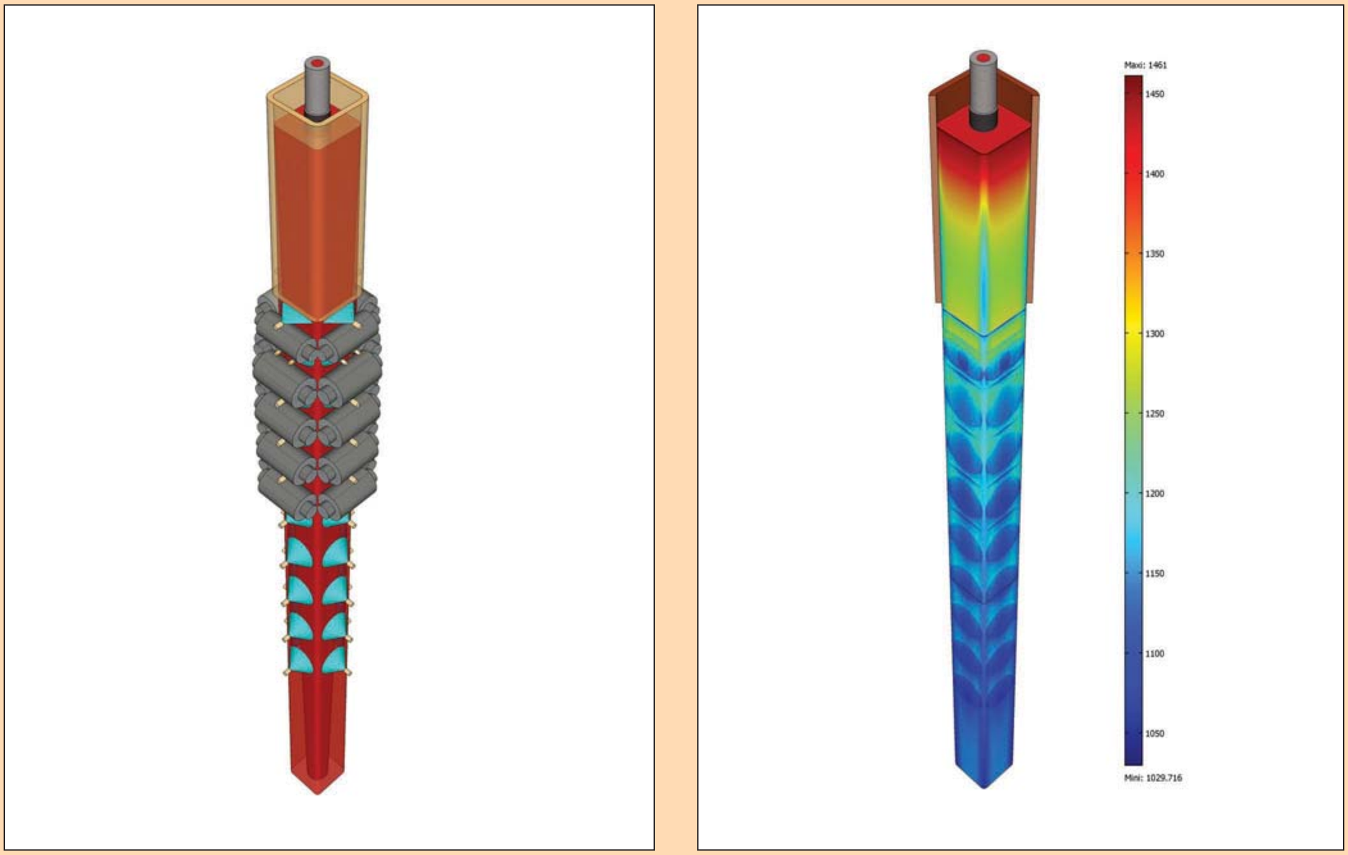

Figure 1: Depiction of the casting process. Liquid metal enters a water cooled mold where cooling and solidification occurs through convection and conduction. Once a solid shell (the skin) has developed, this is cooled through a series of water sprays before cooling is allowed to occur naturally through radiation. The length of the liquid well is critical to the point where the cast can be torch-cut. The temperature profile is also shown.

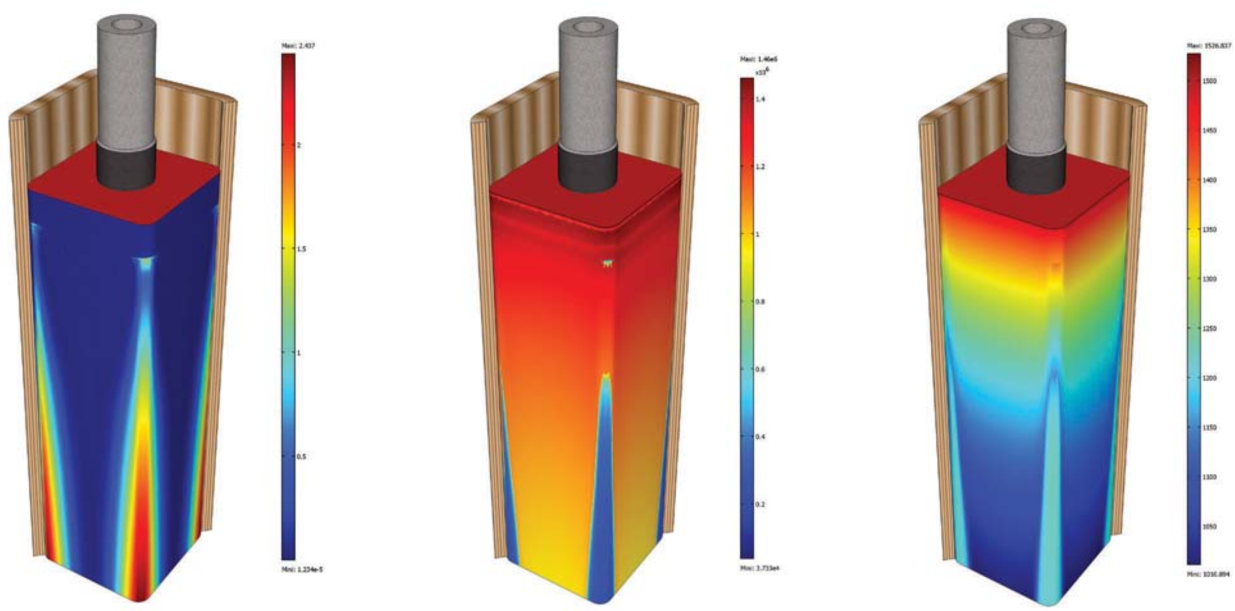

Figure 2: The model is used to examine the development of the air gap (left), the heat flux inside the bloom (middle) and the temperature in the bloom (right). The air gap not only affects the heat flux and cooling of the cast, which is to be expected, but also has a significant effect on the product surface quality.

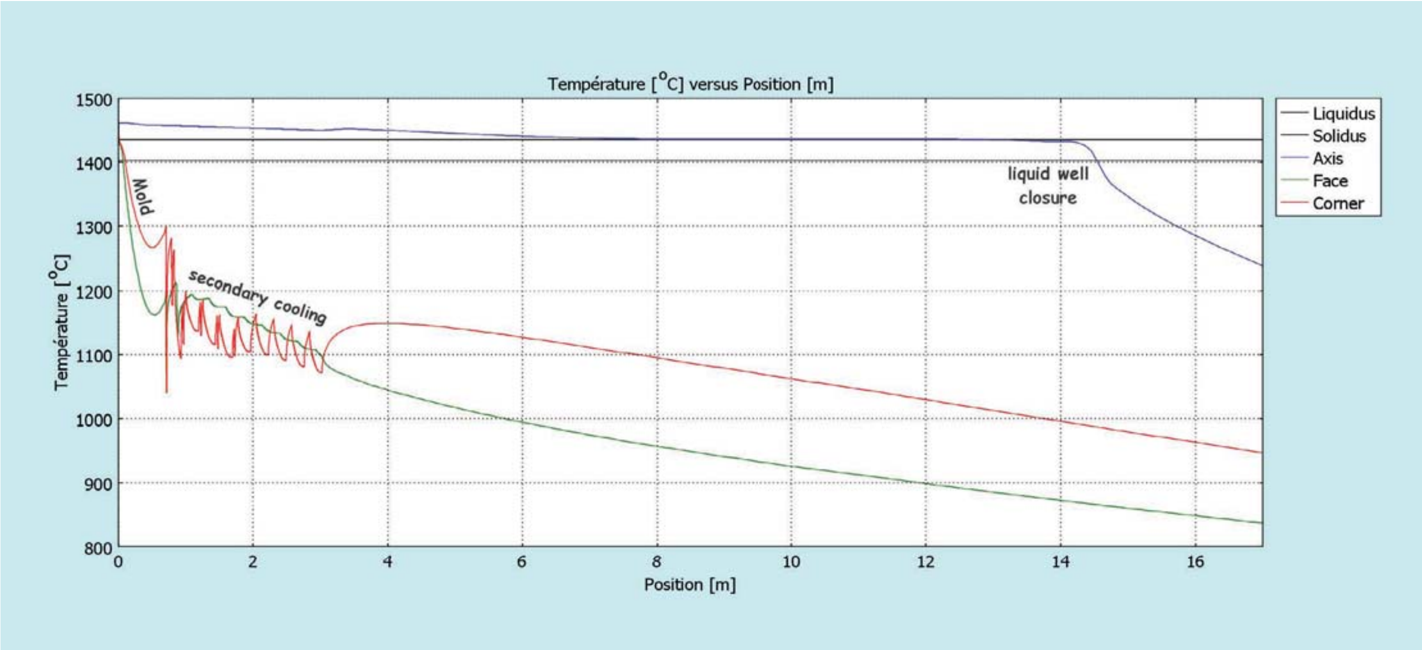

Figure 3: Torch cutting of the strand can take place only after the metal in the center of the bloom has solidified.

based on years of experimental data, but where in one critical temperature range, we instead include a table of 40 to 100 data points and let COMSOL extrapolate between them.

We spend a great deal of time with the model studying various cooling aspects, again to increase process speed without impacting product quality or to change the properties of the end product. This is a delicate matter, and we don't want to experiment with our customers. In some markets, such as the automotive and nuclear industries, end users run their own trials and certifications on the steel. Thus, making a process change takes considerable thought and planning, and the model is extremely helpful in giving us understanding and revealing possibilities.

With the model we can also assess modifications to the machine. One time, the production engineers asked us to study the secondary cooling section, which they wanted to move just a few centimeters for accessibility and maintenance purposes. Even a small change could have a major impact on the process, and it's not something you want to experiment with on such expensive machinery. With the model we were able to confirm that it was OK for the process team to move the cooling section without any serious consequences.

In another case, the model helped avert a major problem. The production staff wanted to make the torch-cut with what they thought was over a 1 m security limit for solidification. Our model showed that this would actually result in a premature cut and would open up a molten metal well, with the catastrophic consequences that this would entail. We ran the simulation with COMSOL, and we are now able to readjust the security limits much more accurately; see Figure 3.

Choosing COMSOL Multiphysics®

We selected COMSOL after a review of other simulation products and found that it provides the leading performance for a third of the price. We already have specialized software for mechanical engineering, and had to convince management that it would be a good investment for a multiphysics tool. We wanted a general-purpose tool that we could apply to a variety of problems. The initial project involved finding the temperature profile of a moving wire inside a heated tube. Using COMSOL Multiphysics, we found this profile and were able to convince management that we could perform such modeling easily and in a short time.

We have meanwhile found new ways of implementing and solving problems with this package, mostly due to the power it provides through us being able to add any physics to our models. With this approach we have become much more productive than with any other simulation software. These first results have given our process engineers some new ideas, as well as creating new questions, and it has encouraged them to imagine new ways for solving problems.

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More and more people at Ugitech are considering the benefits of increasing our simulation effort. People are not asking me questions of the type "can you calculate that?", but rather "what happens when… or if…?" We have also found COMSOL Multiphysics very useful in communicating ideas and concepts to our customers. ■

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