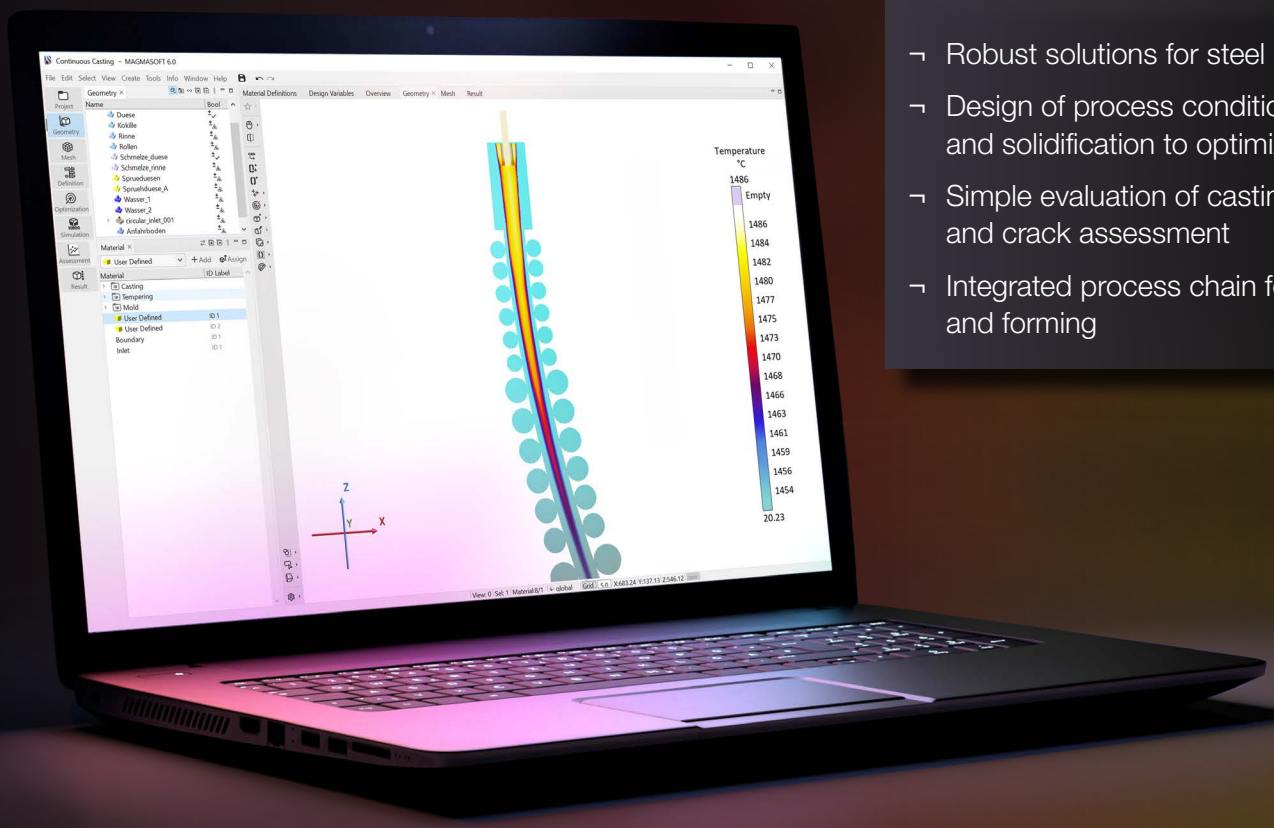
MAGMA CC 6.0

Autonomous Engineering

Continuous Casting of Steel Alloys



- Robust solutions for steel continuous casting
- Design of process conditions for flow and solidification to optimize product quality
- Simple evaluation of casting stresses and crack assessment
- Integrated process chain for casting and forming

Robust, Economical, Fast, **Optimized**

Optimize all aspects of continuous casting processes and find the best solution for your requirements — with MAGMASOFT® autonomous engineering and MAGMA CC.

MAGMASOFT® and the dedicated turn-key solution MAGMA CC are comprehensive and powerful simulation tools for all aspects around designing and improving product quality. The focus is on establishing robust continuous casting processes while ensuring optimal profitability by saving resources, time and costs.

With both MAGMASOFT® and MAGMA CC, you use simulations in an automated virtual design of experiments or genetic optimization. The result is Autonomous Engineering – systematic and fully automated decision-making for reliable product quality and optimal operating points.

With Autonomous Engineering, you can simultaneously pursue different quality and cost objectives. From securing product quality and process robustness at the concept stage, through continuous improvement of profitability during production.

MAGMASOFT® and MAGMA CC autonomous engineering:

- Support you in the comprehensive prediction of all process steps in continuous casting.
- Offer you a virtual test environment for optimizing productivity.
- Enable you to make quick decisions and save time for all parties involved.
- Allow proactive quality management by understanding process fluctuations.
- Improve communication and cooperation within your organization and with customers.

Targeted and Systematic Success

The MAGMA APPROACH, which is fully integrated in MAGMASOFT® and MAGMA CC, is a systematic methodology for achieving your objectives using virtual experiments. In combination with MAGMASOFT® autonomous engineering, secured actions can be identified and implemented to achieve continuous improvements, without economic risks.

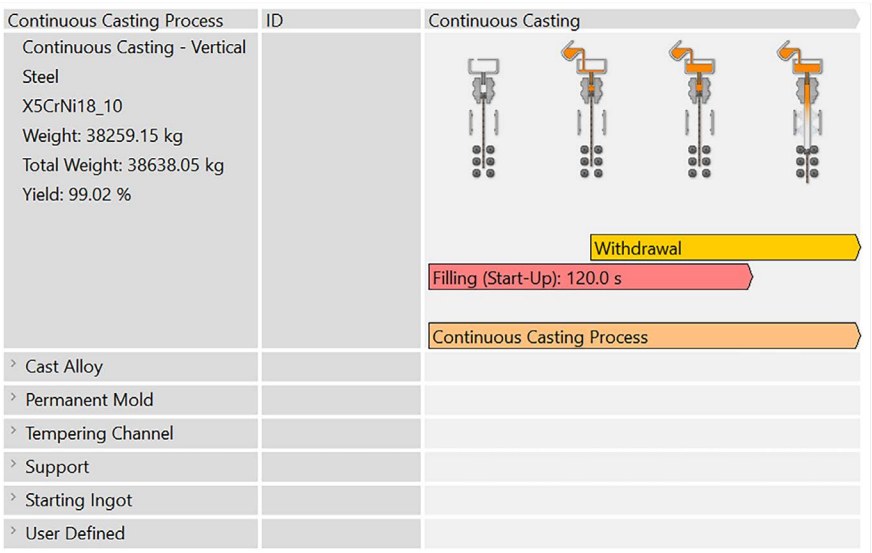
The MAGMA APPROACH supports you at every stage of the product development or improvement process through a systematic methodology. The result is a robust process that is optimally designed for the desired objectives and prevents casting defects.

Set Your **Objectives**, Define Your **Variables**, Specify Your **Criteria**

MAGMA CC is the fully integrated solution for the virtual design and optimization of continuous casting processes for aluminum, copper and steel materials. MAGMA CC offers parametric geometry modeling, automatic meshing, an extensive database and comprehensive tools for evaluation and statistical assessment of results.

MAGMA CC considers the flow, heat transfer, solidification and stress generation in the inflowing metal, the solidifying strand and the mold. The software is capable of simulating vertical and horizontal casting processes for any product shape.

MAGMA CC supports you in process design through integrated capabilities for virtual designs of experiments. This allows robust process windows to be identified or operating points to be optimized autonomously, guaranteeing high product quality with process stability.



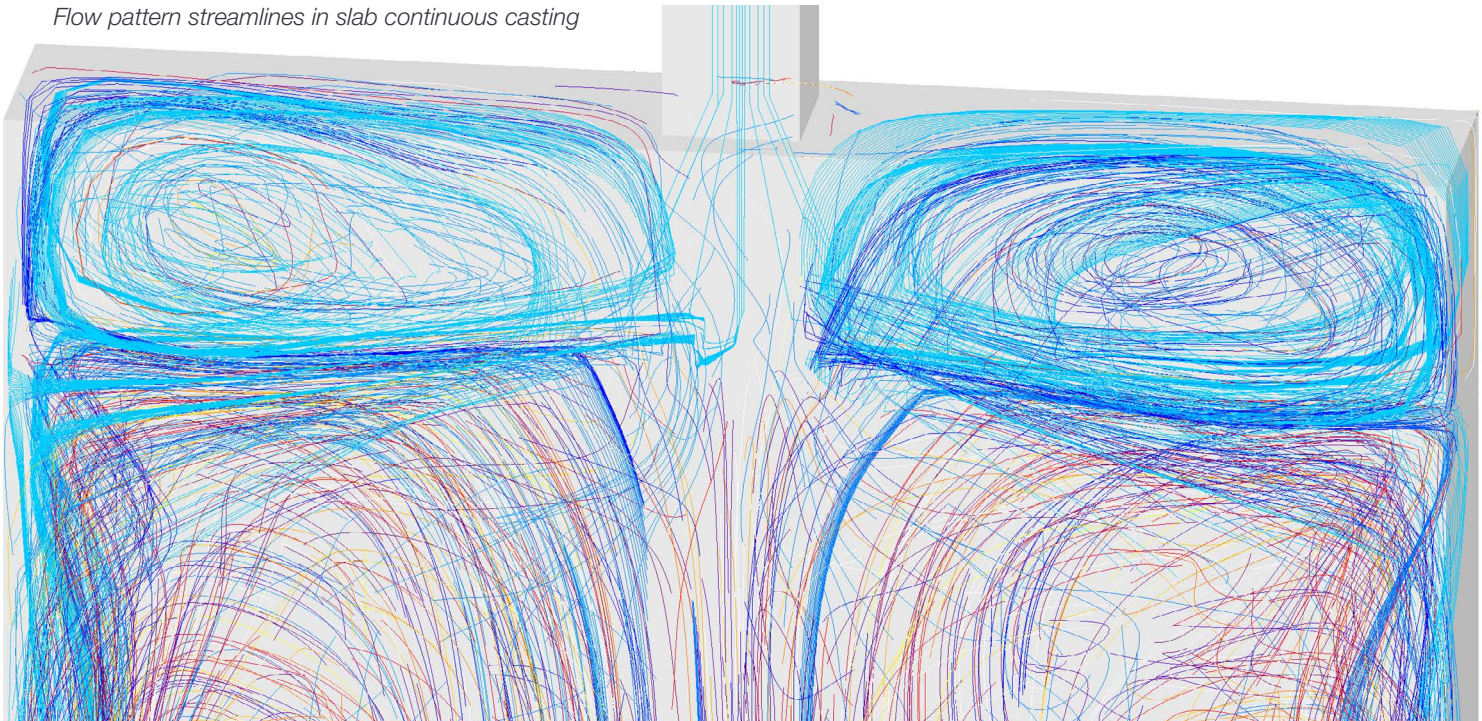
Comprehensive description of the continuous casting process and determination of the casting speed

Preparation

In addition to casting speed and casting temperature of the liquid metal, the cooling conditions in the mold (primary cooling) and in the secondary cooling zones are decisive process variables for the design of the continuous casting process.

The realistic representation of the entire process allows the assessment of the flow conditions during start-up and subsequent strand withdrawal. Optionally, the flow conditions in the tundish can also be taken into account.

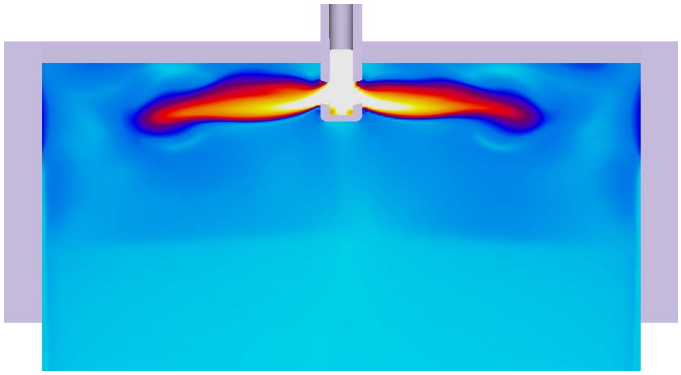
Flow pattern streamlines in slab continuous casting



Shroud and Submerged Entry Nozzle Layout

In MAGMA CC, you can fully consider the start-up process, from the filling of the mold with liquid metal to the start of strand withdrawal:

- During start-up, the shroud and submerged entry nozzle can be optimized for the flow.
- The starting point for the subsequent simulation of strand withdrawal are the temperatures and flow during start-up.
- The flow and heat balance in the tundish and launder can be analyzed separately or coupled with the casting process.
- Optimized tundish furniture design helps to achieve a high level of metal purity.



Flow trough SEN during withdrawal

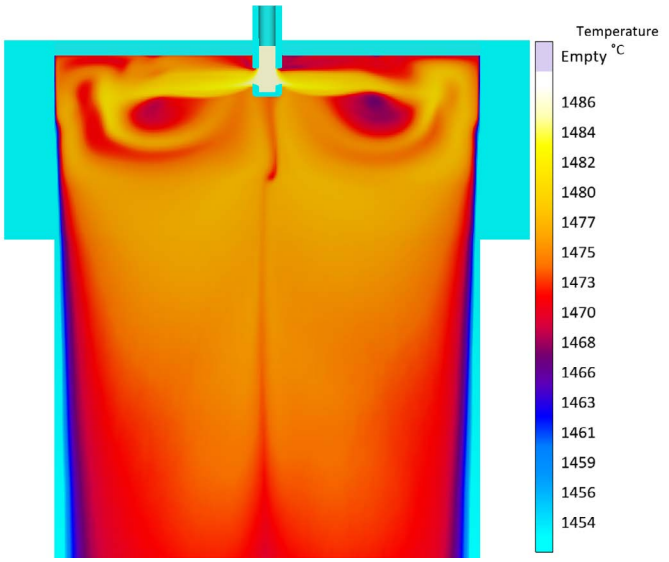
Forced and Natural Convection

MAGMA CC allows the combined consideration of forced and natural convection in the liquid metal and in the mushy zone. Both the inflow and the temperature gradients in the metal are taken into account.

Prediction of Inclusions

MAGMA CC considers the flow-related transport of particles with a defined size and density in the liquid metal. This allows the evaluation of inclusions in the flow at start-up and reoxidation inclusions due to convection during solidification.

- Calculation of formation, growth, transport and agglomeration of reoxidation inclusions in steel, taking into account the potential for oxidation in the tundish, during casting and in the mold

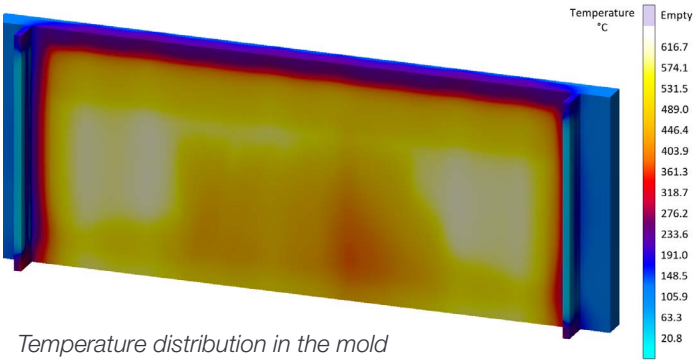


Temperature

Primary Cooling

The thermal conditions in the mold are decisive for the solidification and cooling of the strand. MAGMA CC allows:

- Setting of process-specific parameters such as water flow rates in cooling channels, fluxes and graphite inserts in the mold
- Prediction of temperatures in the strand and mold with quantitative evaluation of the thermal balance for the entire process

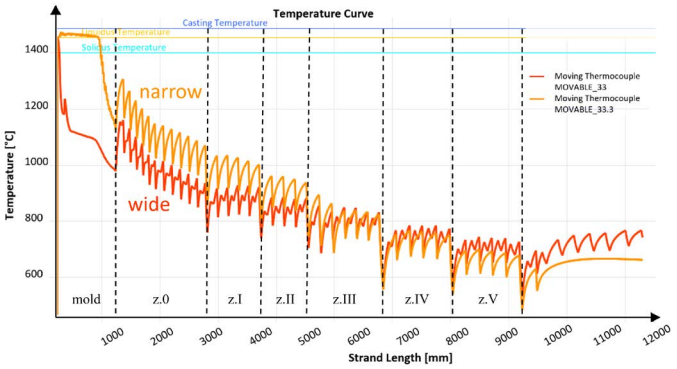


Temperature distribution in the mold

Secondary Cooling

The secondary cooling can be defined for various cooling zones using recommended heat transfer coefficients from the database. Currently, the program supports three different types of heat transfer coefficients:

- Radiation and/or convection
- Spray cooling
- Film cooling after spraying
- Support rolls contact

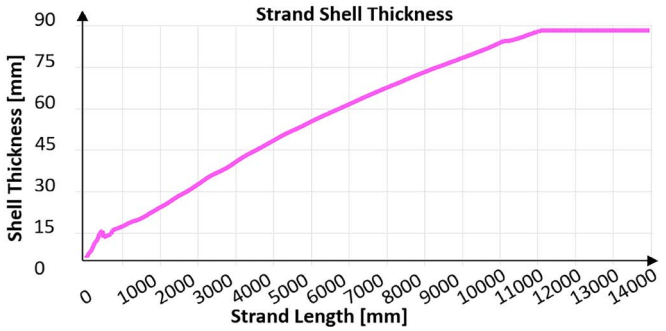


Strand-surface temperature prediction at the narrow and wide faces

Stationary Temperature Distribution

MAGMA CC determines the stationary temperature distribution in the strand and the mold and evaluates the importance of the influencing parameters through statistical design of experiments and autonomous optimization.

- Determination of the influence of process variables on the heat balance, contact conditions between strand and mold, metal flow, primary and secondary cooling, withdrawal speed as a function of time
- Accurate prediction of the metallurgical length
- Evaluation of optimal process parameters for improving the energy efficiency of the process



Averaged solid shell thickness over the strand length

Stress Distribution in the Strand

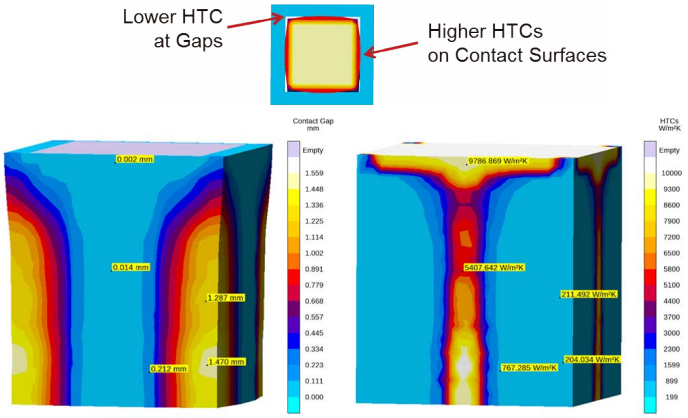
The temperature distribution and residual stresses of the metal in the mold are decisively influenced by the contact and heat transfer between the strand and the mold surface.
MAGMA CC supports an accurate process design through:

- Consideration of the air gap between the strand and mold including reduced heat transfer due to thermal contraction
- Coupled simulation of temperatures and stresses in the strand and mold
- Support of mold design, e.g., through optimization of the conicity
- Layout of the primary and secondary cooling, ensuring the required cooling of the strand to avoid defects such as cracking

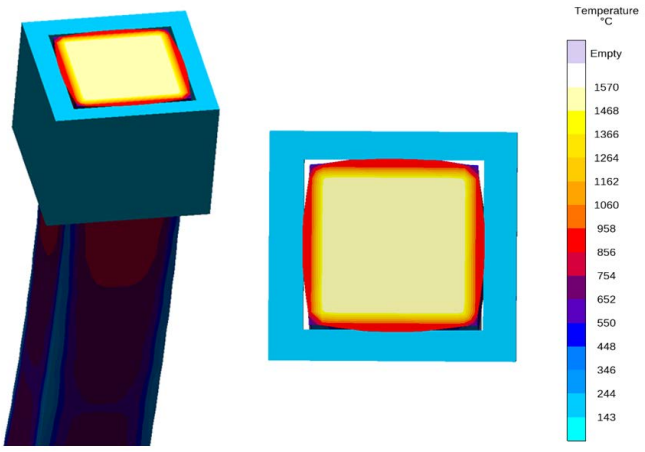
Thermomechanical Coupling

Considering air gaps to update heat transfer coefficients:

- 3D air gap formation data allows using an accurate heat transfer coefficient for strand-to-mold heat transport calculation
- Determination of strand deformation with an integrated stress calculation
- More accurate prediction of thermomechanical-based defects (hot tears, cold cracks, etc.)
- Calculation of stresses and deformation in strand as well as in mold material
- Distortion function for visualizing actual air gap formation



Considering air gaps to update heat transfer coefficients



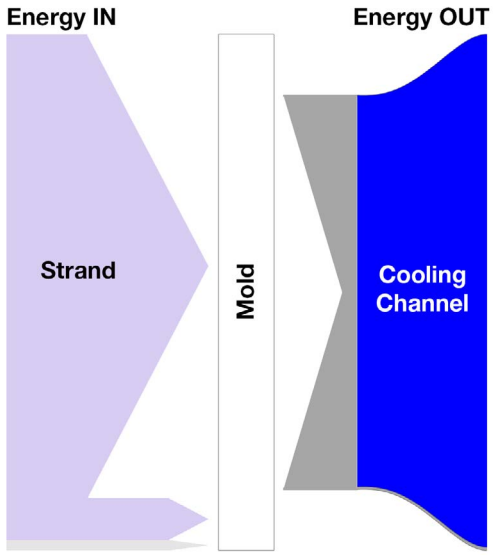
Air gap formation in square billet casting

Improved Solidification

- Evaluation of centerline shrinkage and porosity to evaluate varying process conditions
- Prediction of macrosegregation

Heat Balance

In MAGMA CC, the efficiency of the mold can be used, e.g., as a quality criterion for a stable casting process. The efficiency is calculated as the ratio of the total heat input and removal.



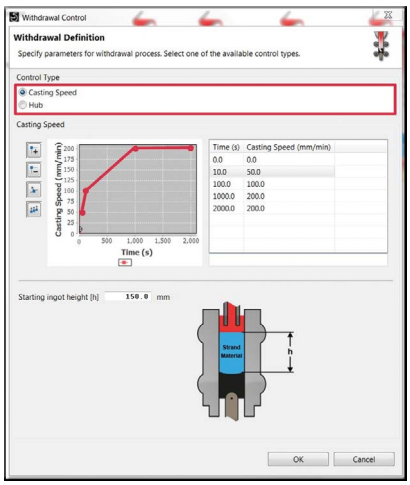
Sankey chart showing the heat balance in the mold

Secure Processes with Designs of Experiments

In MAGMA CC, you can freely vary your process systematically, to understand the influence of different production conditions on quality and productivity quantitatively.

Intuitive Process Control

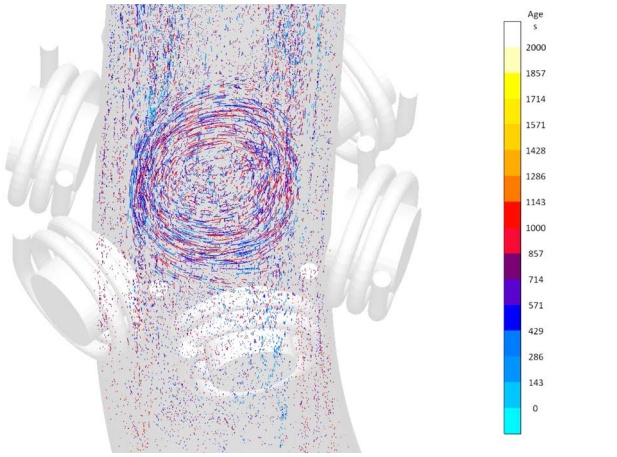
Use the control of all relevant process steps to optimize the continuous casting process. Beginning with the casting spout through the tundish and nozzle and into the mold to describe the start-up process, to the withdrawal and continuous operation including consideration of the secondary cooling.



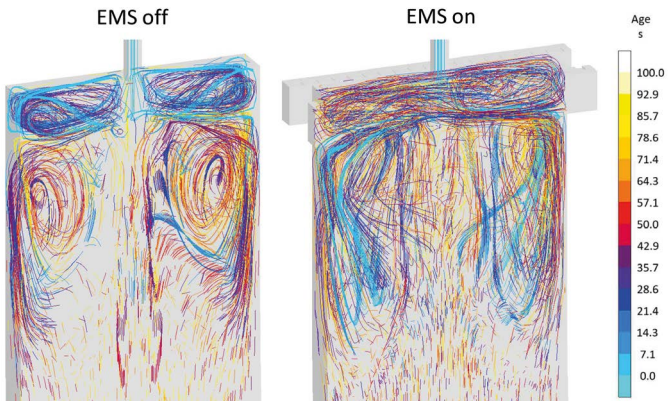
Electromagnetic Stirring

Electromagnetic stirring (EMS) are widely used to optimize the product quality in continuous casting processes of steel:

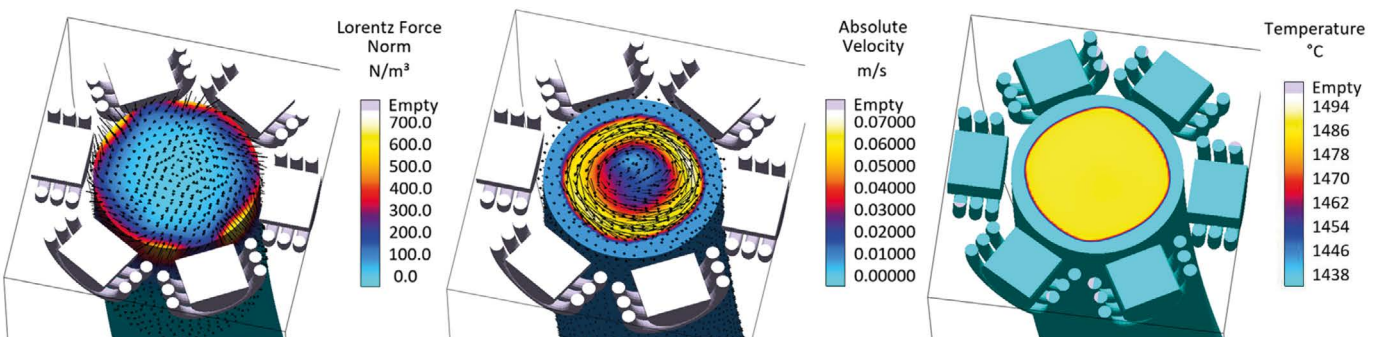
- Finding robust processes by optimizing flow conditions influenced through EMS
- 3D electromagnetic field and calculation of Lorentz forces
- Liquid metal flow calculation under the EMS and thermal convection
- Effect of EMS on the temperature distribution
- Assessment of the shell thickness growth and solidification under the impact of EMS
- Prediction of the metallurgical length and optimal EMS equipment placement
- Optimal stirrer position and control parameters



Flow tracers in the strand liquid pool under the rotating magnetic field impact



3D streamlines of melt flow during the slab casting with and without EMS



EMS of the round bloom casting: Lorentz forces (left), velocity field in the strand liquid metal pool (center) and solid liquid interface (right)

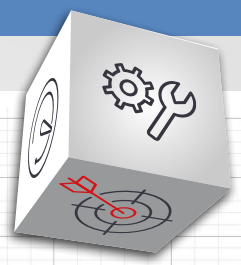
Work **Efficiently** and **Systematically**

Your time is limited! To achieve your goals, it is crucial to systematically and efficiently utilize all the available possibilities in MAGMASOFT®'s comprehensive toolbox.

Robust Processes

Determine the influence of process fluctuations on the solidification behavior of your product through systematic virtual experimentation. With MAGMA CC autonomous engineering, you can quantitatively identify main effects and correlations, and determine concrete actions to control your production.

- High productivity (maximum casting speed)
- Cost and energy efficiency
- Reducing centerline porosity and macrosegregation
- Reducing the risk for strand breakout
- Reducing residual stresses and cracking tendency
- Design optimization of tundish and nozzle



Strand breakout risk as a function of starting ingot position and casting speed

Act & Check Your **Improvements**

Success is more than software and hardware. MAGMA's professional team is ready to comprehensively support you in realizing your goals. You can take advantage of the services of our MAGMAacademy, engineering and support teams when and how it suits you, and all from a single source.

Implementation

All MAGMASOFT® programs are more than just software. They offer a methodology for optimizing engineering, communication and profitability in your organization.

Even before starting with our software, we will take the time to discuss with you the most important factors to ensure an effective and secured use of our tools based on your situation: from the required computer hardware through the qualification and training of users, to jointly defining objectives regarding where you want to be in the next year.

Whether you are a new customer or a long-time user of our software: We have plans with you!

MAGMAsupport

MAGMAsupport stands for the competent, methodical and fast support of our customers worldwide regarding all questions in the application of and problem-solving with our products. With the MAGMA APPROACH, our qualified support staff will help you to make better use of our software every day.

MAGMAacademy

The MAGMAacademy systematically supports you in the implementation of both casting process and virtual optimization, from the initial rollout to the comprehensive application of Autonomous Engineering throughout the entire organization.

In our training courses, workshops and seminars, we convey interdisciplinary understanding across all processes and departments for the best possible use of MAGMASOFT® – conducted at our offices or through a customized solution on-site.

MAGMAengineering

As an independent and competent partner, MAGMAengineering supports a successful virtual product development, tooling design and optimization of your robust foundry processes within the framework of engineering projects.

An interdisciplinary and international team of experts, with numerous years of casting expertise, is available to work with you using MAGMASOFT® autonomous engineering to address your challenges.

Casting Knowledge.
In a Software.

MAGMASOFT® 6.0

MAGMASOFT®
autonomous engineering

More Information:

MAGMA Gießereitechnologie GmbH
Kackertstr. 16-18 | 52072 Aachen, Germany | Phone: +49 241 88 90 1-0 | info@magmasoft.de | www.magmasoft.de

MAGMA