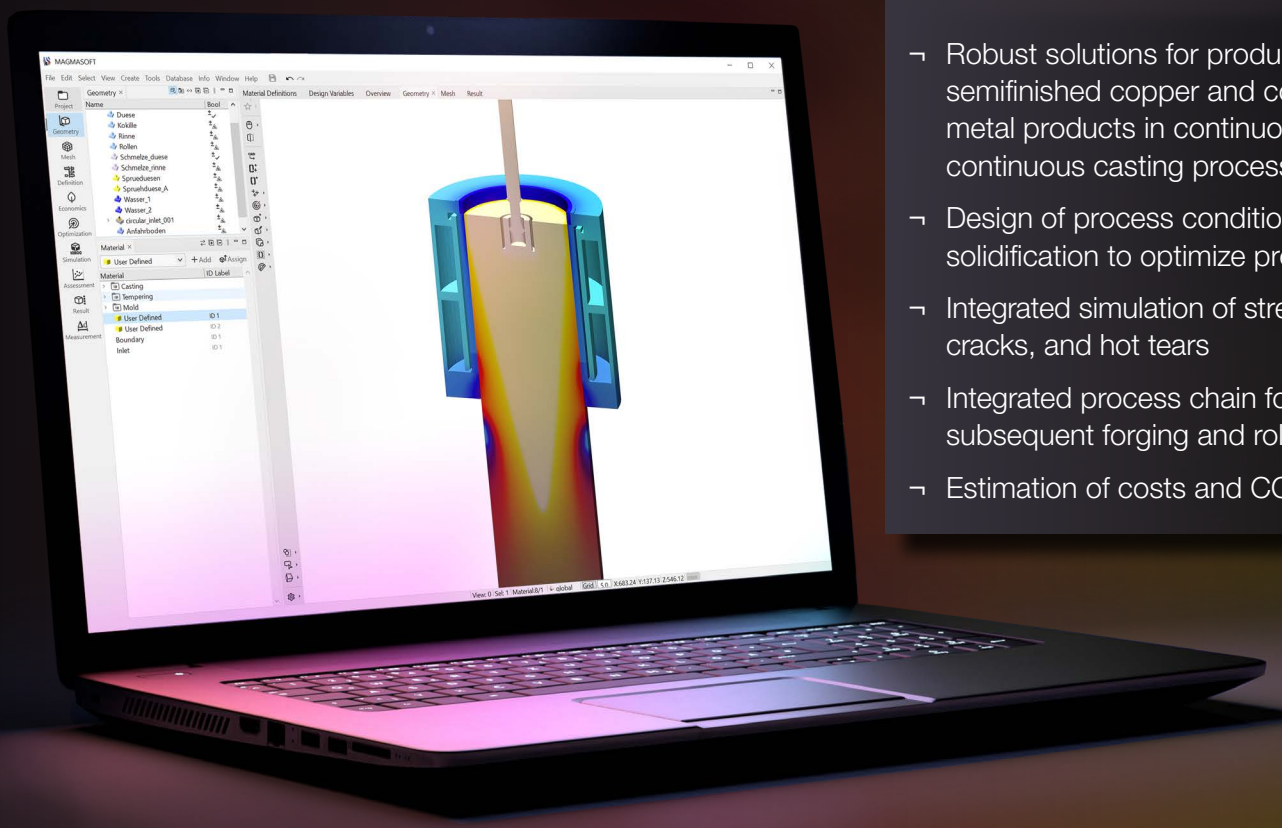
MAGMA CC

Autonomous Engineering

Copper Continuous and Semi-Continuous Casting Process



- Robust solutions for producing semifinished copper and copper-based metal products in continuous and semi-continuous casting processes
- Design of process conditions for flow and solidification to optimize product quality
- Integrated simulation of stress, cracks, and hot tears
- Integrated process chain for casting with subsequent forging and rolling processes
- Estimation of costs and CO_2 emissions

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.

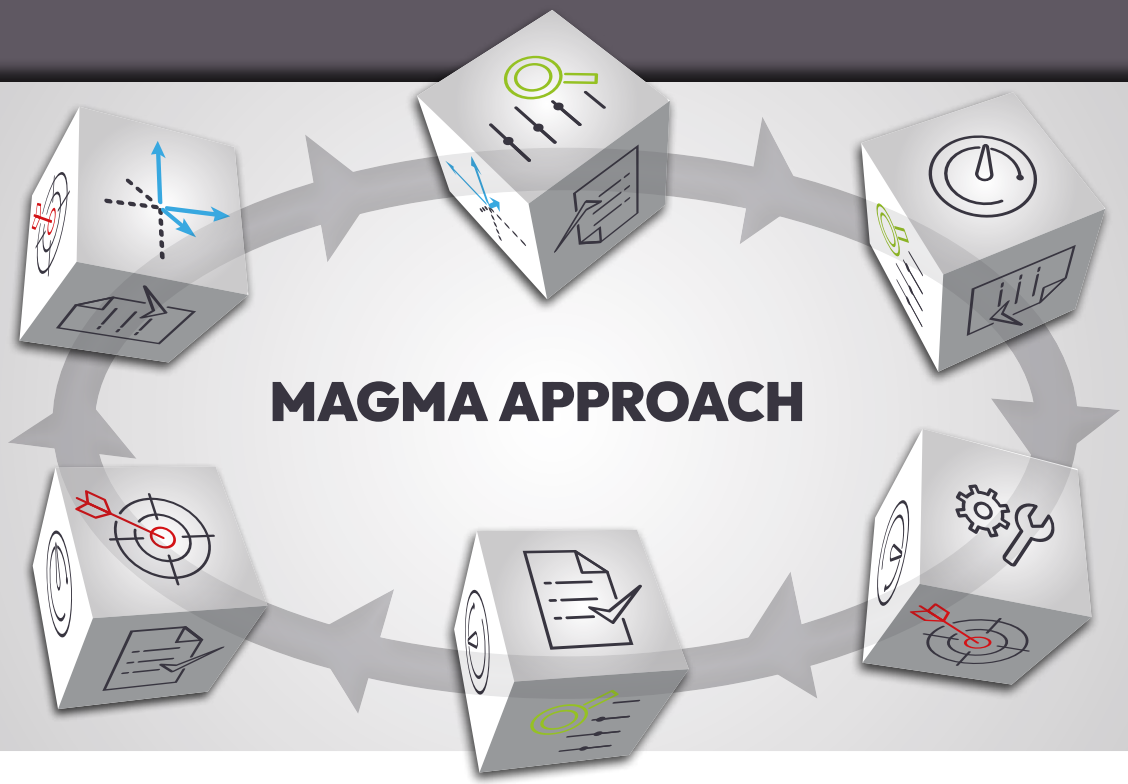
MAGMASOFT® and the dedicated turn-key solution MAGMA CC are comprehensive and powerful simulation tools for all aspects around designing and improving product quality. The focus is on establishing robust continuous casting processes while ensuring optimal profitability by saving resources, time, and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

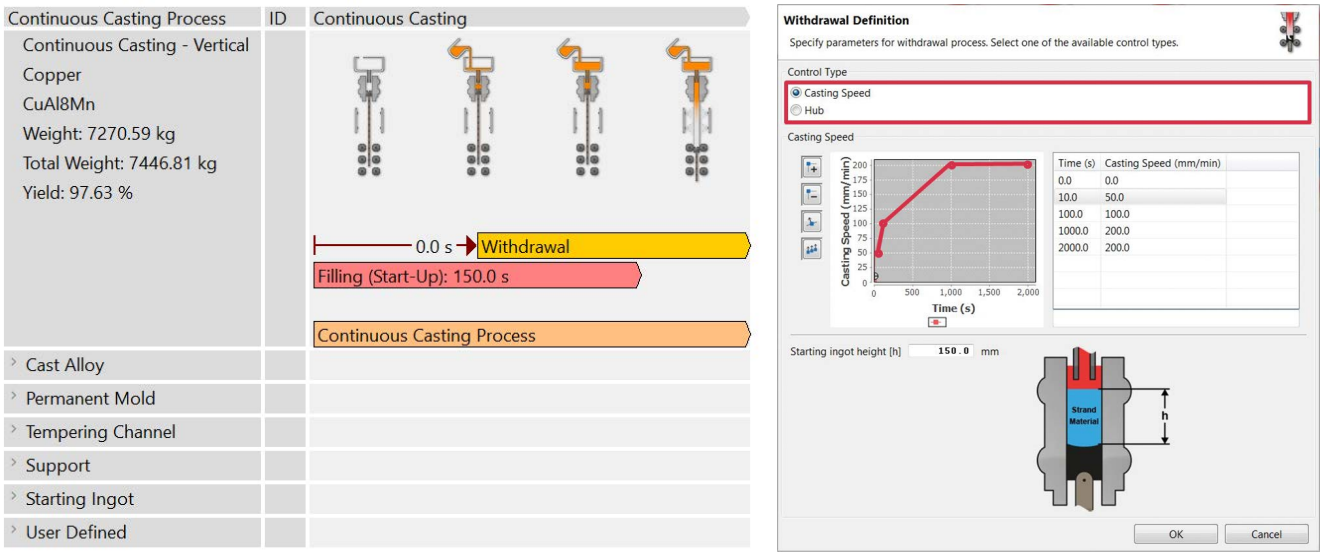
The MAGMA APPROACH supports you at every stage of the product development or improvement process, through a systematic methodology. The result is a robust process that is optimally designed for the desired objectives and prevents casting defects.

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

MAGMA CC is the fully integrated solution for the virtual design and optimization of semi-continuous and continuous casting processes for copper and copper-based alloys. 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 development of stresses in the inflowing metal, the solidifying strand, and the mold. The software is capable of simulating both vertical and horizontal continuous casting processes for any product shape.

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



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

Preparation

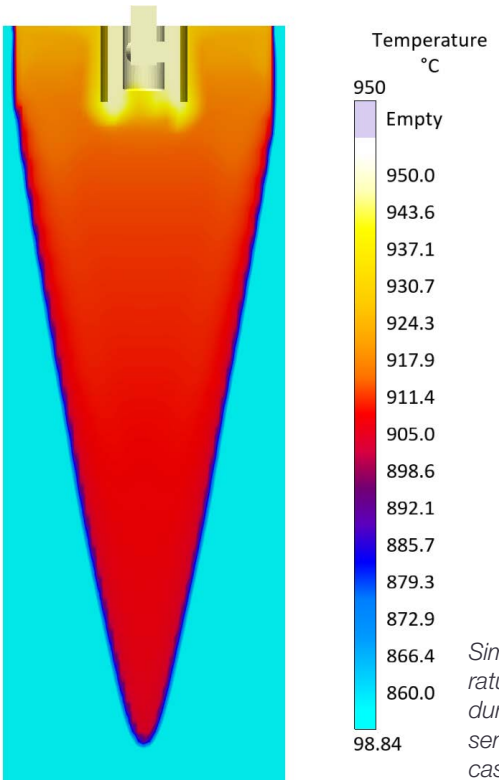
In addition to casting speed and casting temperature of the liquid metal, the cooling conditions in the mold (primary cooling) and in the secondary cooling zones are decisive process variables for the design of the continuous casting process.

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

Temperature

A transient numerical simulation models the temperature distribution from the nozzle to the end of secondary cooling, combining flow and solidification physics to predict shell growth and thermal gradients.

- Thermal conduction and convection
- Latent heat release during solidification

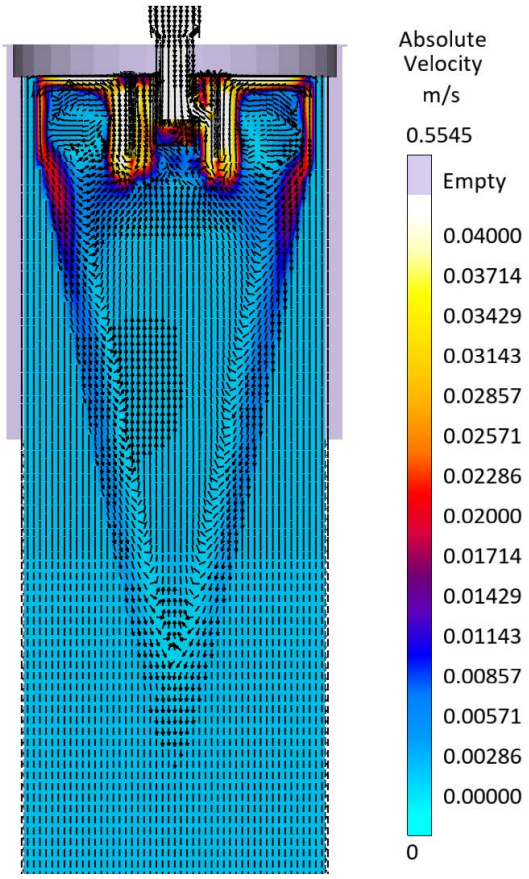


Simulated temperature distribution during copper semi-continuous casting

Velocity

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 control system optimization
- Insights into convective heat and mass transfer
- Adaptable nozzle design for optimal flow
- Electromagnetic stirring (EMS)



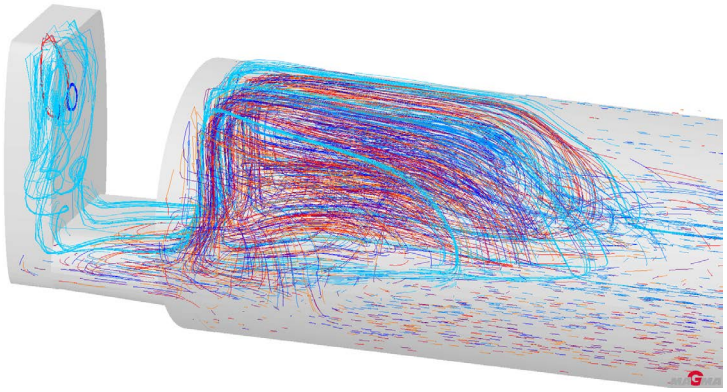
Flow pattern in nozzle and liquid metal during casting

Accurate prediction of flow patterns in both nozzle and mold ensures uniform filling and reduces turbulence-driven inclusions, which is essential for quality in both **horizontal** and **vertical** casting set-ups.

Horizontal Bar Casting

Accurate prediction of flow patterns in the tundish, nozzle, and mold region is key to achieving uniform filling and minimizing turbulence-induced inclusions. Understanding thermal convection effects is especially critical in horizontal set-ups, where buoyancy can create asymmetries.

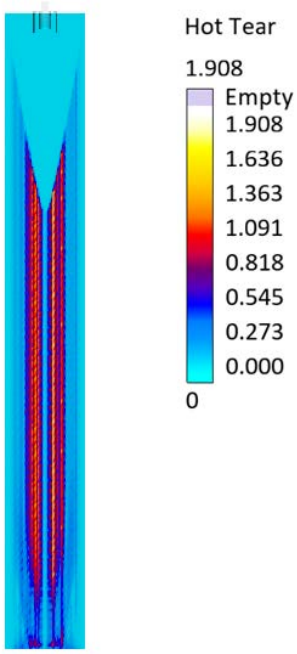
- Identification of flow asymmetry due to thermal convection



Flow dynamics in horizontally cast rod, including thermal convection

Stress & Defect Mechanism

During solidification, non-uniform contraction and mechanical constraints may lead to hot tears. Simulations help localize and identify such risk areas by evaluating strain rate and thermal evolution.

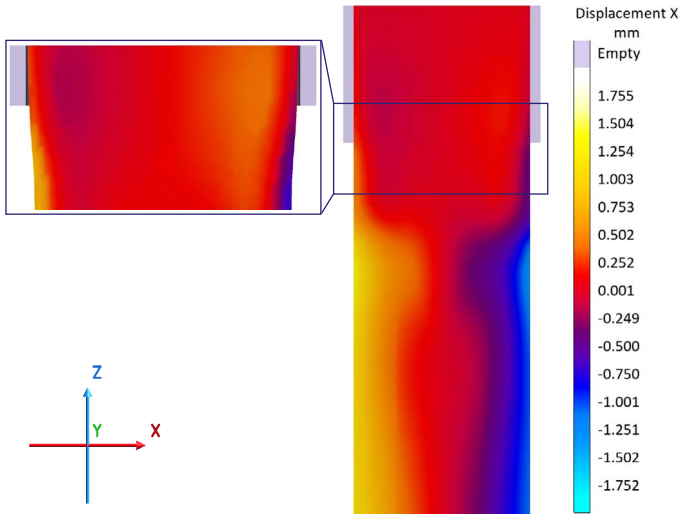


Predicted hot tear risk zones in the mid-section of the cast bar

Deformation

The interaction between cooling rate and mechanical resistance is visualized through strand deformation and mold gap formation – key indicators of dimensional stability.

- Quantification of mold-strand gap growth
- Updating of local heat-transfer coefficients as contact changes
- Pinpointing of zones prone to surface cracks or dimensional deviation

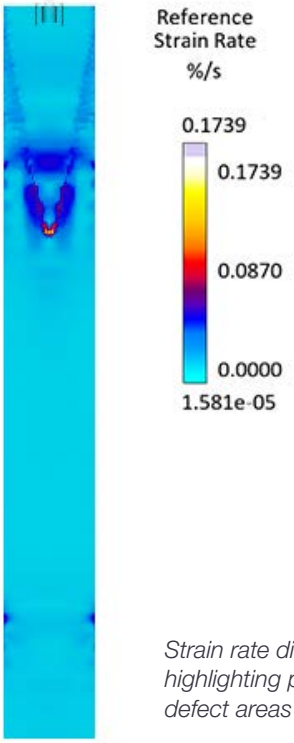


Strand deformation and gap formation at the mold interface

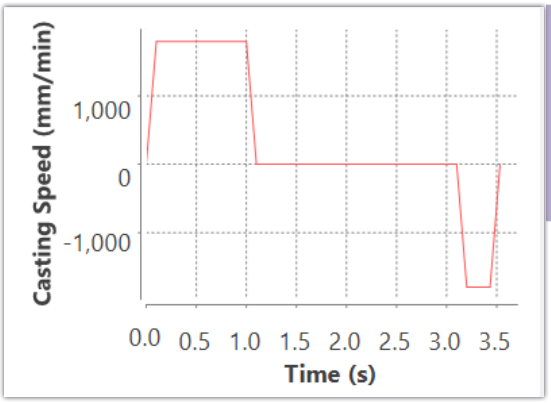
Strain Rate

Finite element coupling of temperature field and solid mechanics provides local strain rate fields for both horizontal and vertical strands. Peaks correlate with mismatches between shell and contraction and are reliable indicators of hot tear or surface crack susceptibility.

- Locating zones prone to cracks and hot tears
- Supporting both withdrawal speed and cooling zone optimization

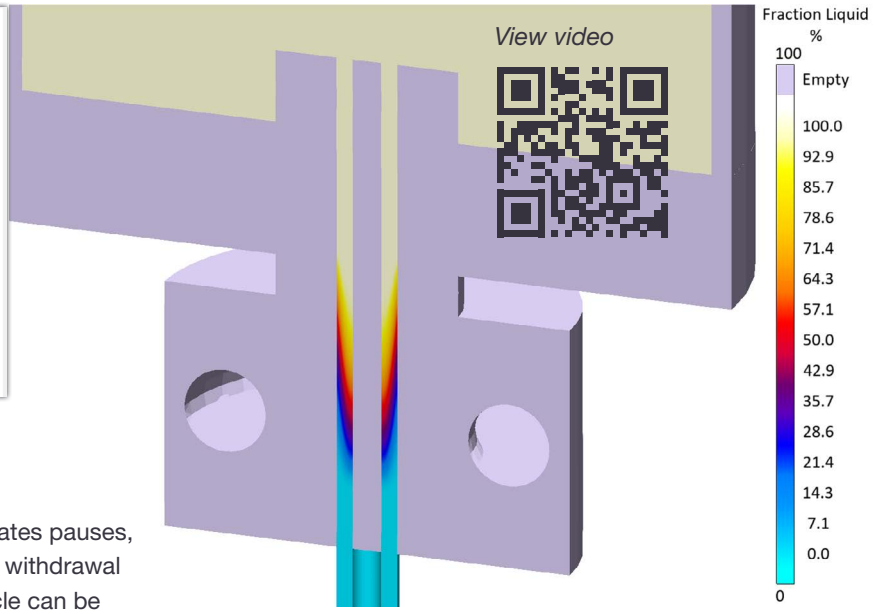


Strain rate distribution highlighting potential defect areas



"Stop & Go"

A flexible design of the casting speed accommodates pauses, return strokes, and cyclical movements within the withdrawal process and simulates them. This "stop & go" cycle can be mapped across the entire withdrawal process, thus simplifying the analysis of complex process sequences.

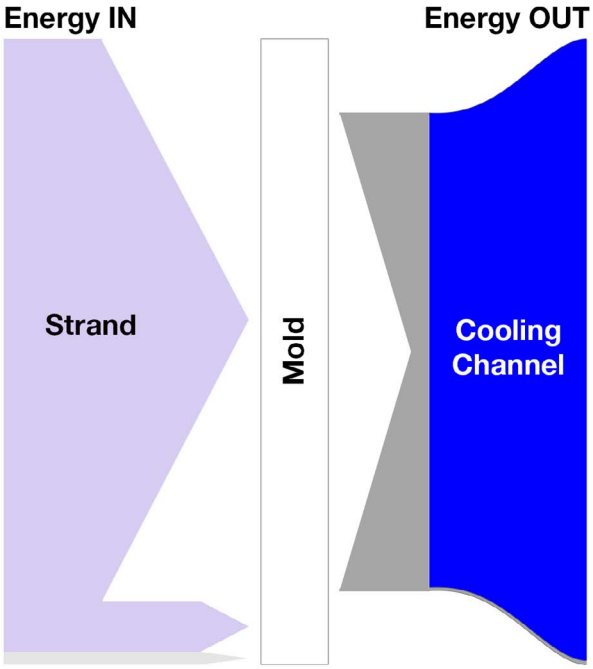


Consideration of "stop & go" cycles during withdrawal

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 output.

With the heat balance calculation, it is also possible to analyze the efficiency of the secondary cooling. Finally, you can balance the desired heat extraction between primary and secondary cooling.



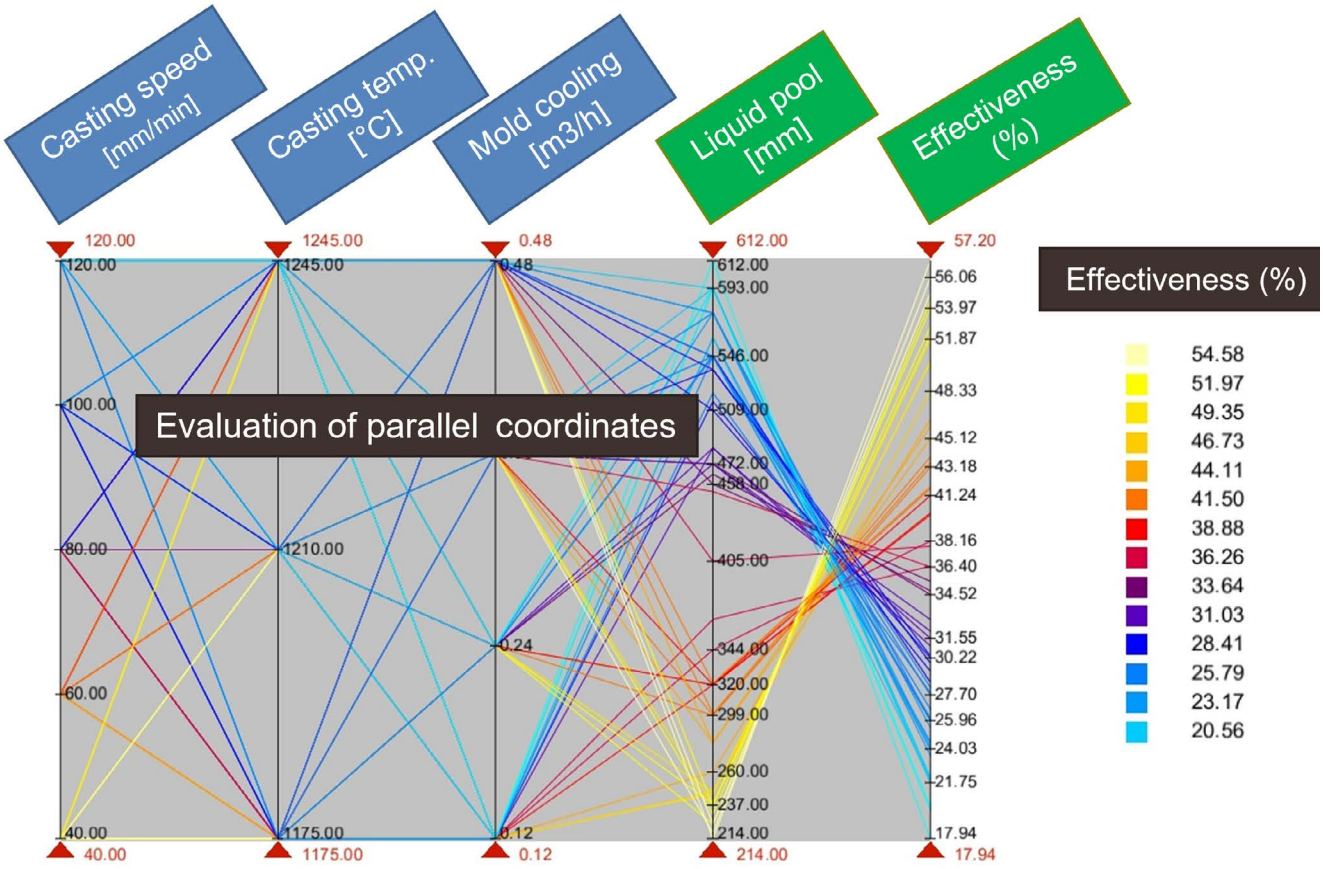
Secure Processes With Designs of Experiments

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

Robust Processes

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

- High productivity (maximum casting speed)
- Cost and energy efficiency
- Reduction of porosity and shrinkage
- Reduction of the risk for bleedout
- Reduction of residual stresses and cracking tendency
- Design optimization of both tundish and nozzle



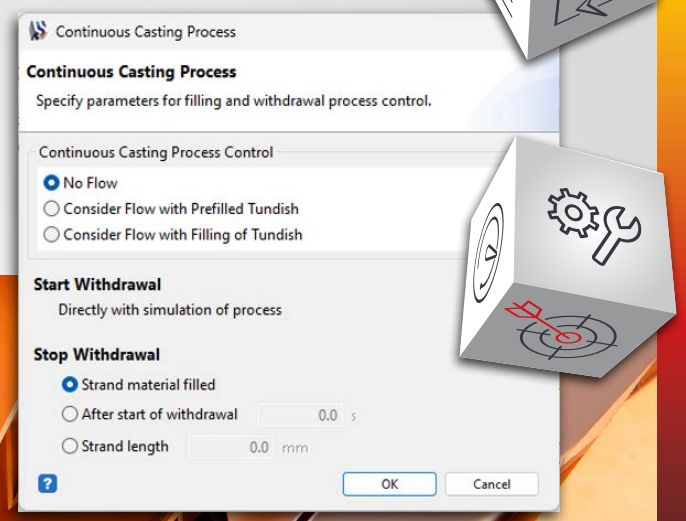
Parallel coordinate diagram for analyzing the effectiveness of the primary cooling in the mold

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.

Intuitive Process Control

Use the control of all relevant process steps to optimize continuous casting processes, beginning with the metal flow in 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.



MAGMA ECONOMICS Technology & Profitability

MAGMA ECONOMICS expands technical optimization with MAGMASOFT® to include economic decision-making criteria. This allows identifying savings potentials that are often overlooked in purely technical simulations.
The information provided by MAGMASOFT® thus creates additional opportunities as a management tool within the company.

Optimize Your Casting Quality, Cost & Carbon Footprint

MAGMA ECONOMICS calculates and compares costs, energy consumption, and CO_2 emissions of different scenarios. The perspective draws on existing geometry, material and process data as well as simulation results.

Customizable templates for common materials and processes contain specific cost and emission factors, enabling a detailed analysis of resource consumption and production costs along the entire casting process – from tooling preparation to actual casting and possible machining steps.

Key Features

- **New perspective:** comprehensive quantitative analysis of costs, energy, and resource consumption, and CO_2 emissions, coupled with quality criteria in MAGMASOFT®

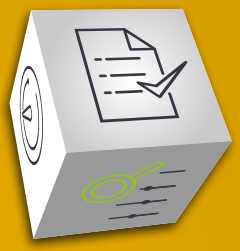
  Intuitive evaluation of quality, productivity, project costs, and sustainability as key tool for your competitiveness
- **Database:** evaluation based on existing geometries, materials, processes, and simulation results
- **Customizable templates:** templates for materials and processes with specific cost and emission factors
- **Scenario comparison:** individual variation of process parameters and comparison of different scenarios – thanks to intuitive control – without additional simulation time
- **Autonomous Engineering:** seamless integration with optimization and virtual design of experiments

With MAGMA ECONOMICS, the parallel coordinate diagram as established, interactive tool for analyzing process variations and quality criteria is complemented by corporate criteria such as costs, energy/resource consumption, and sustainability.

Systematically and quickly find the best compromise between quality and costs (violet line) and the limits of your robust manufacturing process (process window, marked in gray).

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, to 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 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.

More Information:

MAGMASOFT®

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