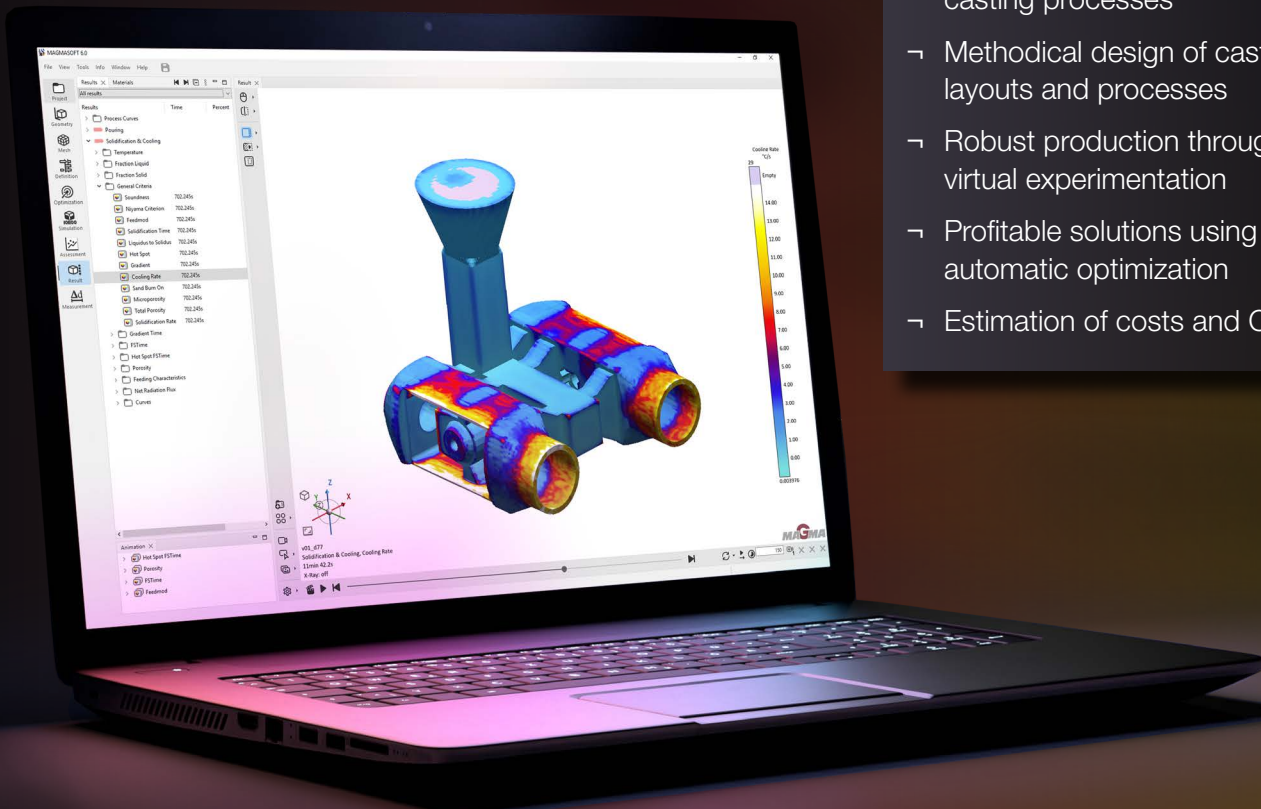


# MAGMA Investment Casting

# Autonomous Engineering



## Investment Casting



- Robust solutions for all investment casting processes
- Methodical design of casting layouts and processes
- Robust production through virtual experimentation
- Profitable solutions using automatic optimization
- Estimation of costs and CO<sub>2</sub> emissions

# Robust, Economical, Fast, **Optimized**

**Optimize all aspects of the production of investment castings and find the best solution for your requirements – with MAGMASOFT® autonomous engineering.**

MAGMASOFT® is a comprehensive and powerful simulation software for all aspects around designing and improving investment casting quality, pattern design and robust process conditions while ensuring optimal profitability. The focus is on your resources, time and costs.

With MAGMASOFT®, 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 pattern layouts and investment casting production conditions.

With Autonomous Engineering, you can simultaneously pursue different quality and cost objectives. From securing part quality and process robustness at the concept stage, through final pattern design and the continuous improvement of profitability in series production.

MAGMASOFT® autonomous engineering:

- Supports you in the comprehensive prediction of all process steps in the production of investment castings.
- Offers you a virtual test environment for the reduction of casting defects.
- Enables you to make quick decisions and saves time for all parties involved.
- Allows proactive quality management by understanding process fluctuations.
- Improves communication and cooperation within your organization and with customers.



## Targeted and Systematic Success

The MAGMA APPROACH, which is fully integrated in MAGMASOFT®, 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 investment casting process that is optimally designed for the desired objectives and allows realizing a stable production.

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

## Reliable Control of the Process

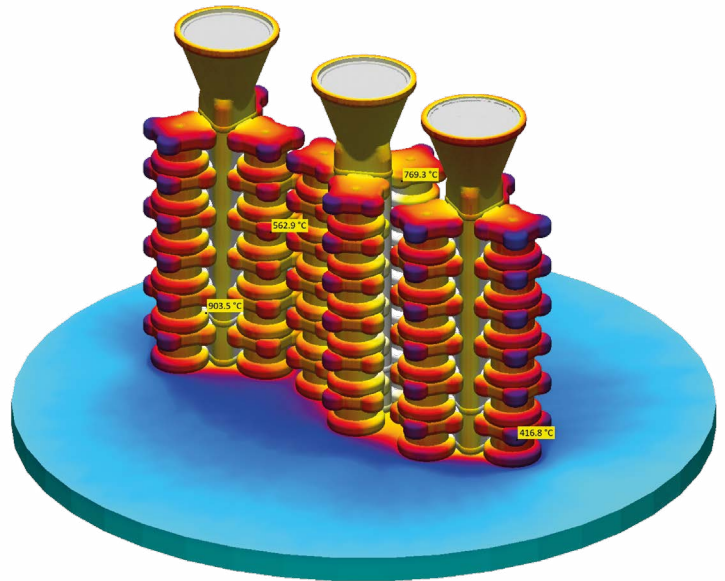
Robust and reproducible quality in investment casting is not achieved by chance. The management of the diverse and often individual process steps to achieve a successfully poured investment casting requires a high level of specialist

knowledge and experience. With MAGMASOFT®, you can quantify your process knowledge and methodically and sustainably improve profitability.

## Thermal Process Conditions in Investment Casting

MAGMASOFT® takes the special thermal conditions in investment casting during pouring, solidification and cooling of the metal into account. This includes:

- Exact consideration of thermal radiation from the hot shell
- Consideration of shading between adjacent surfaces and heat accumulation in pockets
- Cooling of the shell before casting
- Local thickening of the shell
- Consideration of insulating materials or chills
- Controlled cooling/immersion of the casting including the shell



Radiation between heated shell molds and to the environment

## Filling

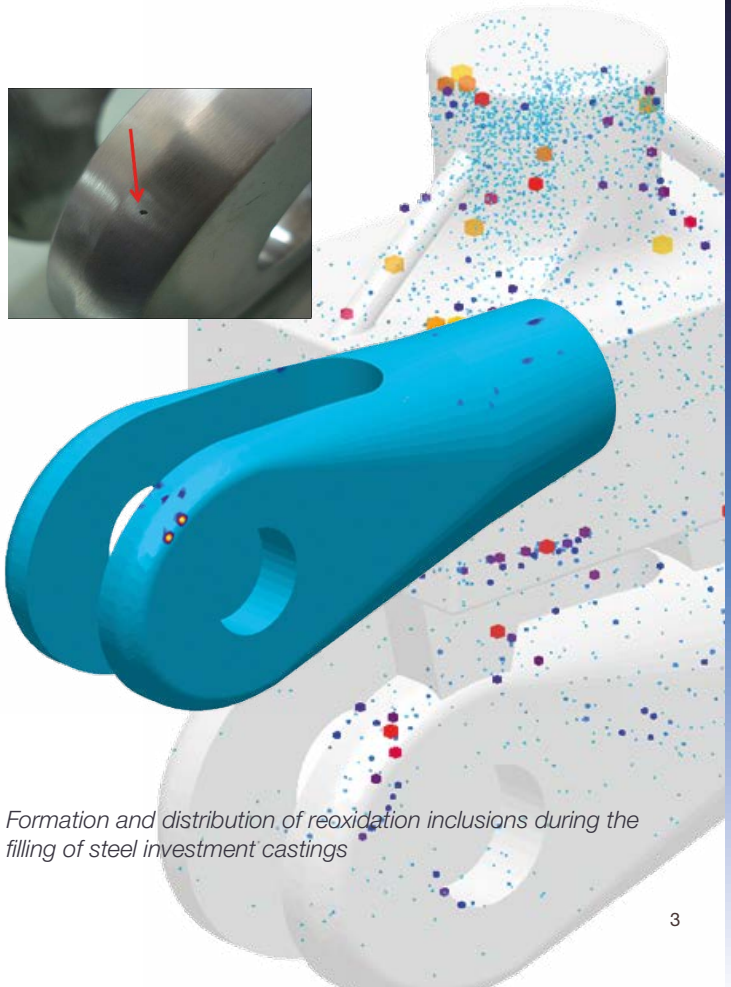
A reproducible filling of the mold is an important prerequisite for avoiding casting defects. The layout of the casting gating with MAGMASOFT® allows you to identify the root causes of possible defects, to understand them and eliminate them by systematically examining the relevant process variables.

Take advantage of specific investment casting capabilities such as automatic control of the fill level in the pouring basin, pouring rate control through automated pouring or the influence of a vacuum. You can tilt the shell, rotate it or use a low-pressure process to fill it.

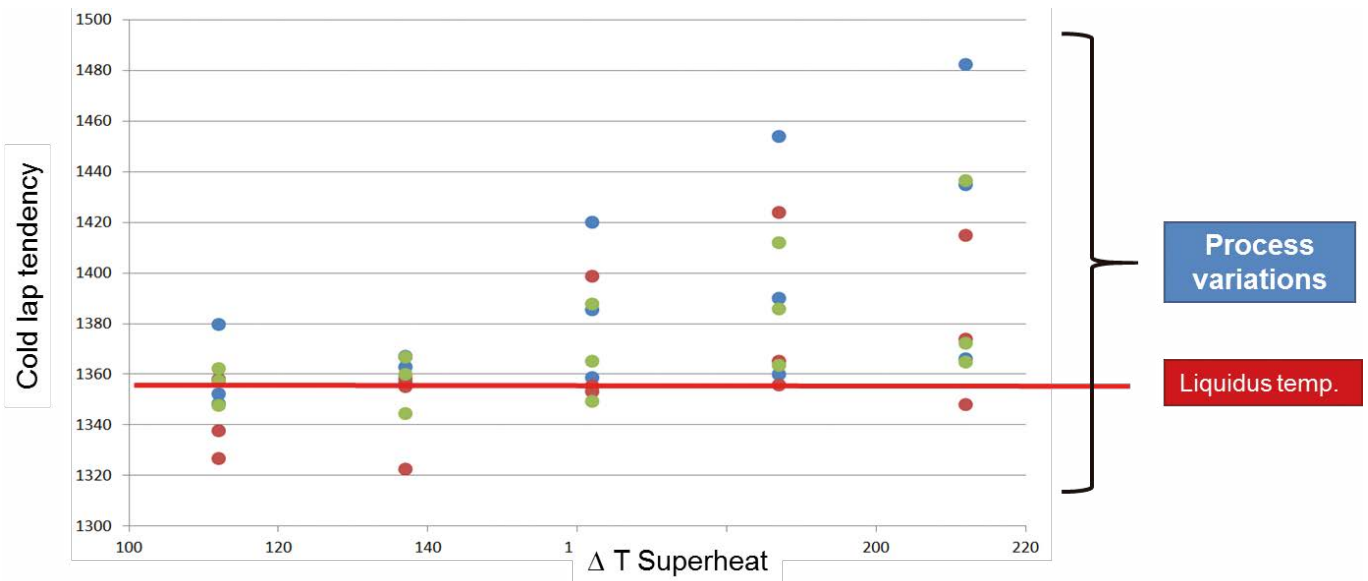
Evaluate quality criteria such as: inclusions (oxides, shell erosion), entrapped air, misruns, incomplete filling or cold shuts, as well as the uniformity of filling for all parts.

Investigate impacts on the quality of filling through the systematic variation of:

- Pouring rates and filling times
- Runner and gate cross-sections
- Number of mold cavities

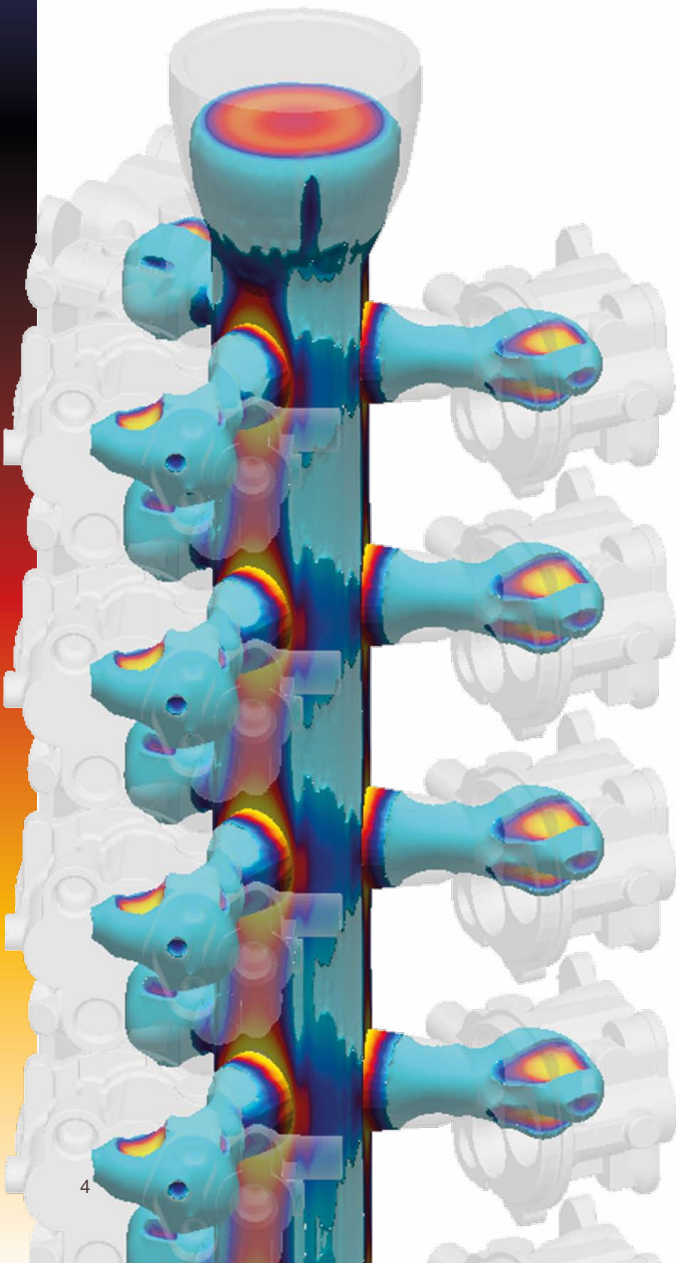


Formation and distribution of reoxidation inclusions during the filling of steel investment castings



Determination of the risk for cold shuts as a function of process variables and fluctuations

## Design of the Rigging

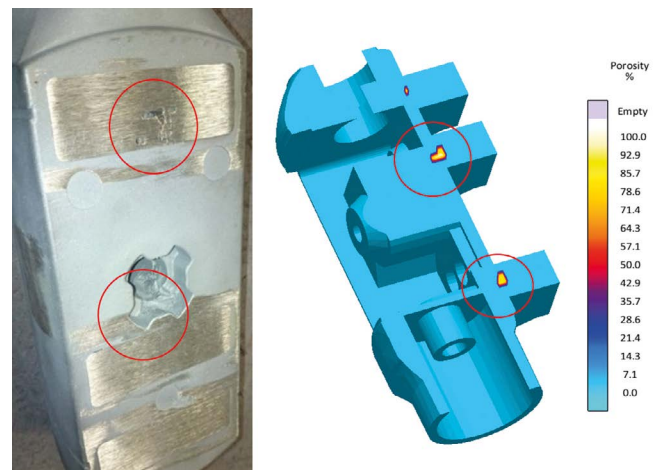


During the solidification, MAGMASOFT® considers important process variables that influence the casting quality. Use different capabilities for automatic variation of geometry to:

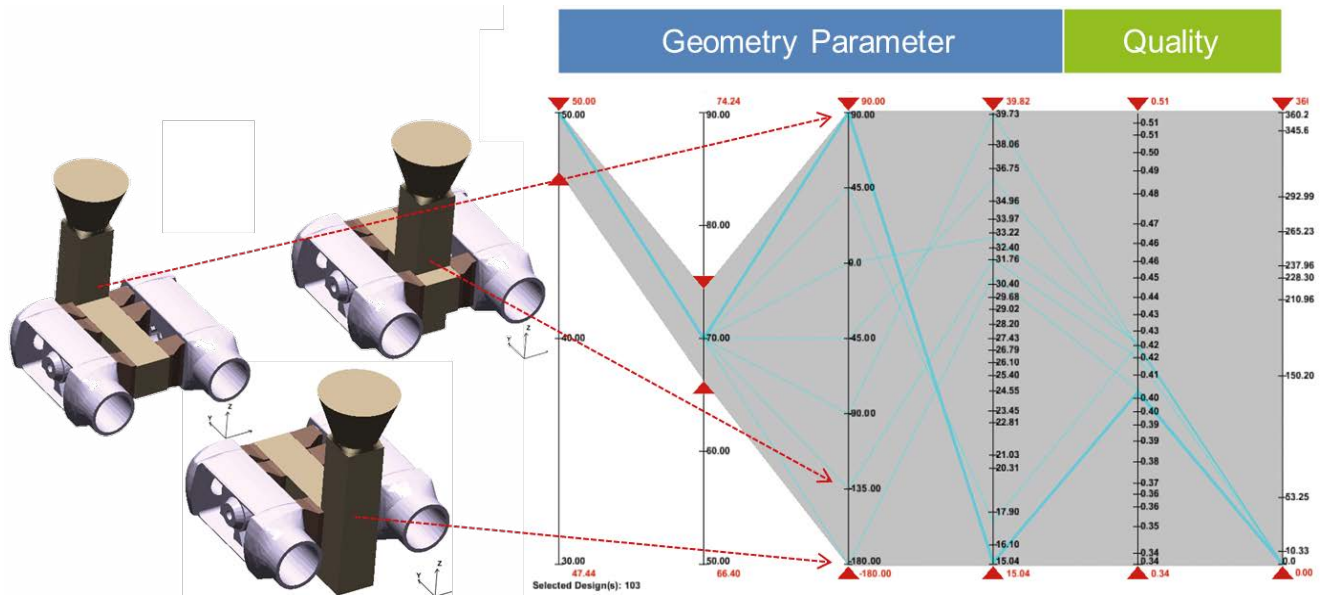
- ↪ Exchange imported CAD geometries
- ↪ Use parametric geometries from the MAGMASOFT® database
- ↪ Move geometries on surfaces or along trajectories

Optimize:

- ↪ Local thermal modulus
- ↪ Solidification pattern and hot spots
- ↪ Feeding behavior of the casting
- ↪ Macro- and microporosity



Different holding times lead to scrap.



Parallel coordinate diagram: evaluation of different geometries on the selected quality criterion (porosity) in a design of experiments

## Secure Processes With Virtual Designs of Experiments

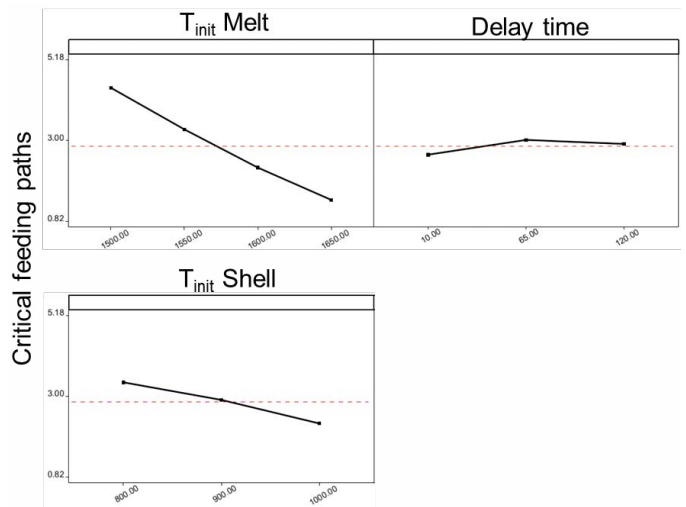
In MAGMASOFT®, you can freely vary your process systematically, to understand the influence of different production conditions on quality before you even start manufacturing.

Answer questions such as:

- Which casting parameters are optimal for the selected casting layout?
- How does a different temperature of the shell before pouring affect the mold filling behavior?
- Do fluctuations in the following production parameters have an influence?
  - Shell thickness and properties
  - Alloy composition
  - Pouring rate
  - Shakeout time
  - Removal of the rigging

## Robust Processes

Determine the influence of process fluctuations on the solidification behavior of your casting through systematic virtual experimentation. With MAGMASOFT®, you can quantitatively identify main effects and correlations, and determine concrete actions for your production before the first casting has been made.



Main effect diagram: influence of process parameters on the feeding behavior in the component

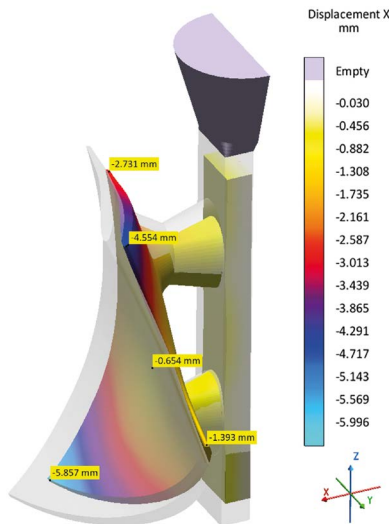


Cooling of the shell mold for different holding times

## Stresses, Cracks and Distortion

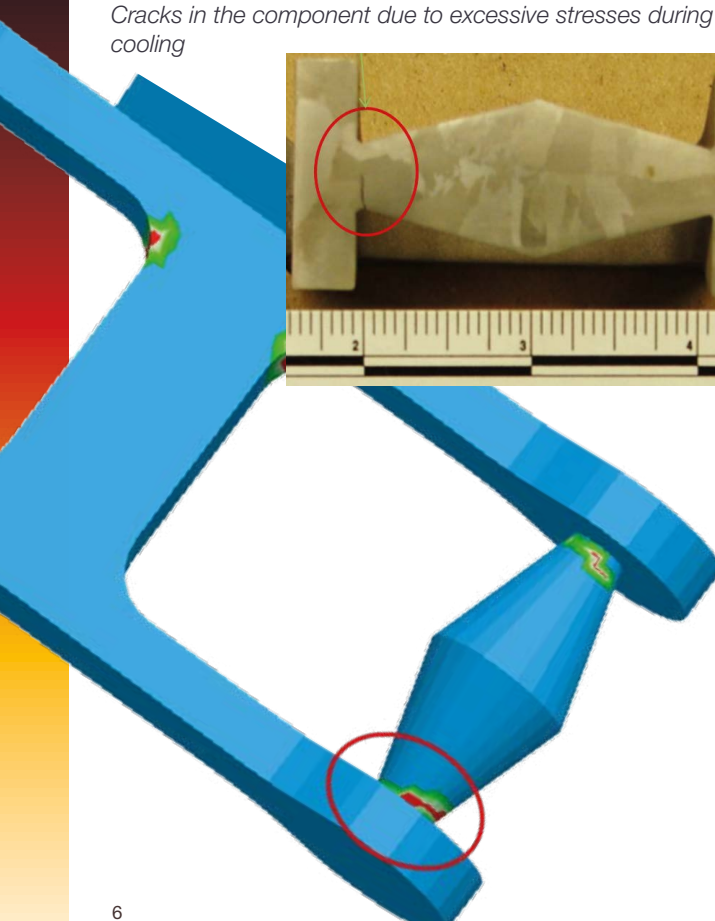
The casting shrinks during cooling. Depending on the component geometry and the resistance of the shell, residual stresses may build up in the casting.

Examine the influence of parameters such as the shakeout time, the removal of the rigging or machining on crack tendencies and the dimensional accuracy of the casting.



*Distortion of the component after shakeout and cooling (magnified representation)*

*Cracks in the component due to excessive stresses during cooling*



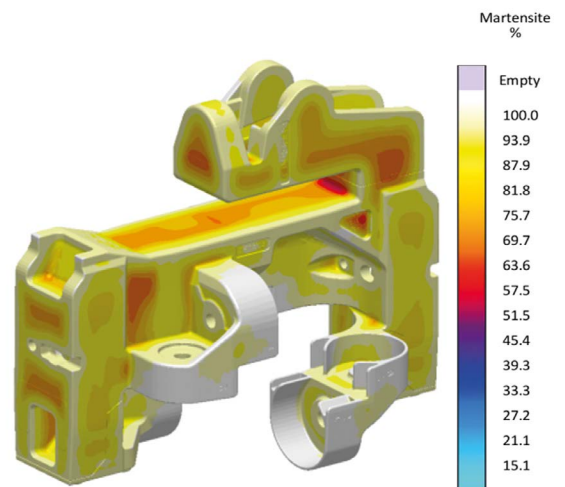
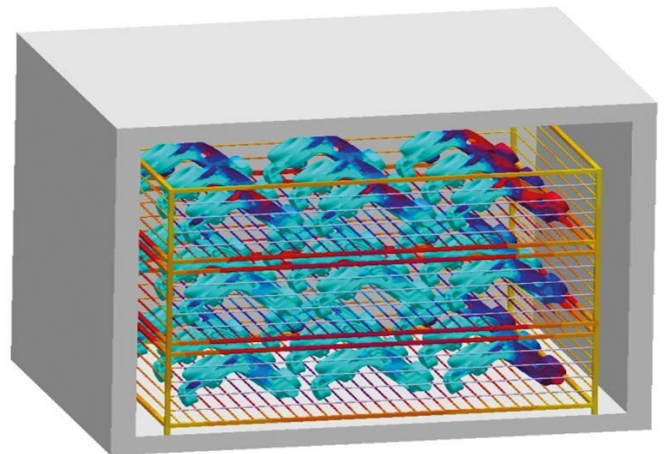
## Heat Treatment and Microstructure

The simulation of heat treatment is seamlessly integrated into the virtual process chain for investment castings. Use pre-defined process conditions and common quenching media to optimize the heating sequence, solution treatment times and temperatures, quenching behavior as well as tempering and cooling to room temperature.

For cast steel and non-ferrous alloys, local microstructures and mechanical properties can be predicted.

During solution treatment and ageing, the reduction in residual stresses due to creep as well as component distortion due to gravity are accounted for.

Evaluate local residual stresses and component distortion after heat treatment for precompensation of your pattern geometry.



*Heat treatment of cast steel: martensite distribution after quenching and tempering*

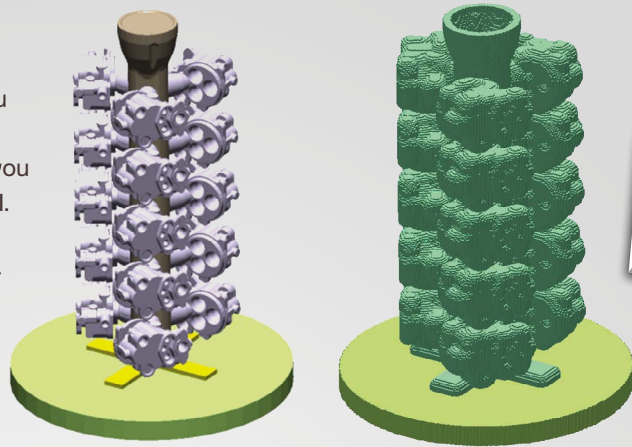
# Work **Efficiently** and **Systematically**

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.



## Assisted Modeling

Versatile wizards and convenient CAD capabilities support you in targeted and effective model preparation and enable short response times with minimum effort. For investment casting, you benefit from an automatic, user-defined generation of the shell. Use parametric geometries from the extensive geometry database or take advantage of the simple preparation of complex CAD models.

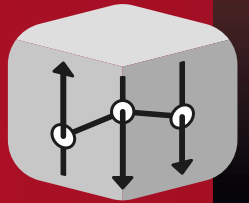


Complete wax model and automatically generated shell mold



# 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<sub>2</sub> 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<sub>2</sub> 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

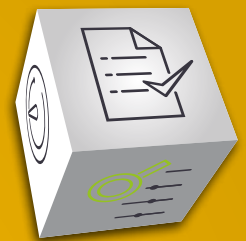


With MAGMA ECONOMICS, the parallel coordinate diagram as established, interactive tool for analyzing process variations and quality criteria is complemented by corporate criteria such as costs, energy/resource consumption and sustainability.

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 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.



More Information:

