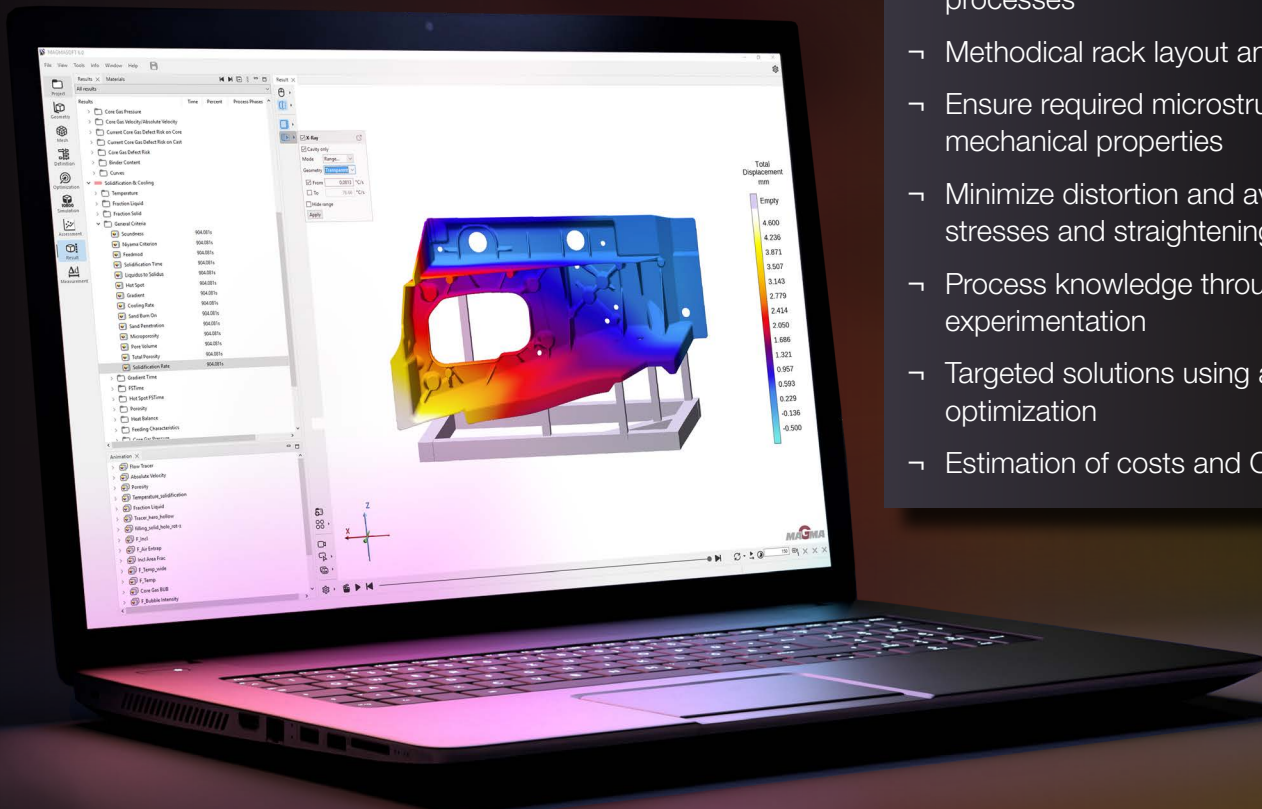**MAGMA Heat Treatment 6.1**

Autonomous Engineering

Heat Treatment

- ¬ Robust solutions for heat treatment processes
- ¬ Methodical rack layout and process design
- ¬ Ensure required microstructure and mechanical properties
- ¬ Minimize distortion and avoid high residual stresses and straightening processes
- ¬ Process knowledge through virtual experimentation
- ¬ Targeted solutions using automatic optimization
- ¬ Estimation of costs and CO_2 emissions

Robust, Economical, Fast, **Optimized**

Comprehensively optimize your heat treatment processes and find the best solution for your requirements — with MAGMASOFT® autonomous engineering.

MAGMASOFT® is the comprehensive and powerful simulation software for all aspects around designing and improving heat treatment processes while ensuring optimal part quality. 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 heat treatment process conditions based on the entire manufacturing process.

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 frame design and the continuous improvement of profitability in series production.

MAGMASOFT® autonomous engineering:

- Supports you in the comprehensive prediction of all process steps from casting through heat treatment.
- Offers you a virtual test environment for avoiding quality issues.
- 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.

MAGMA APPROACH

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 measures 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 manufacturing process that is optimally designed for the desired objectives and that enables stable production conditions, taking into account all manufacturing steps from casting to heat treatment to final machining of the cast part.

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

For many cast components, heat treatment after the casting process is a prerequisite for obtaining the desired microstructure and mechanical properties or for reducing existing residual stresses and distortion.

Comprehensive Process Description

The different heat treatment steps are specified according to the real process conditions to ensure accurate thermal results. Variations in furnace temperature, radiation and quench conditions can be taken into account based on the orientation of the part.
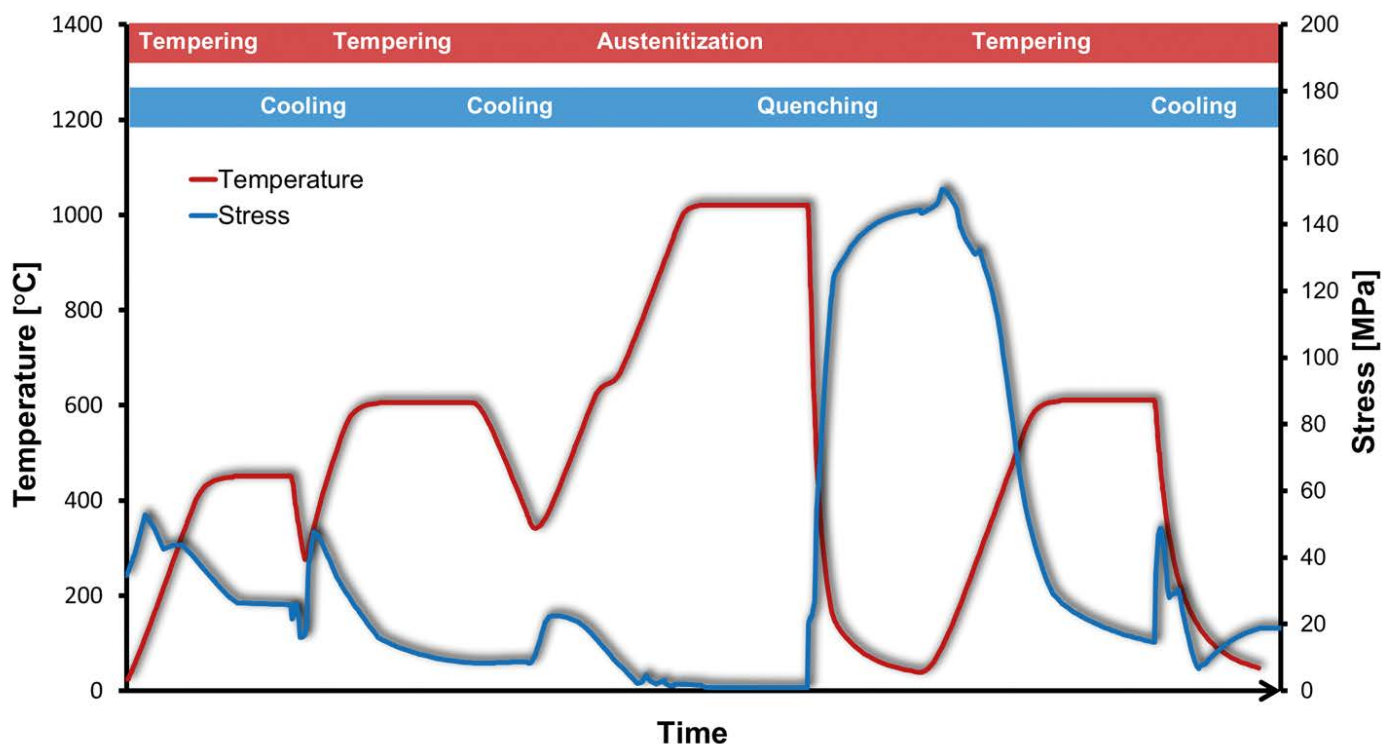

Characteristic temperature profile and associated stress evolution during heat treatment

Complete Rack Description

MAGMASOFT® enables modeling of the full support rack, to get accurate thermal and mechanical conditions for the part inside the furnace.

This allows assessing of whether the design of the rack sufficiently supports the part at high temperatures, resulting in minimal deformations due to creep and thermal expansion.
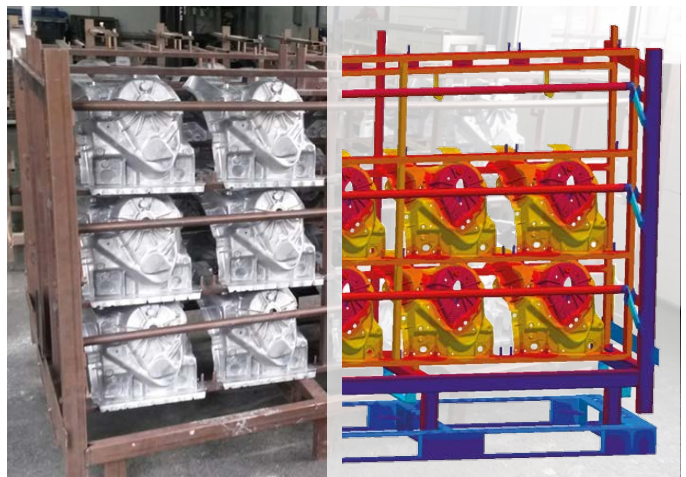
Simulation of cast parts positioned in a heat treatment rack as in the real process

Radiation and Thermal Conditions

Use MAGMASOFT®'s fast and efficient algorithm for radiative heat exchange to determine process parameters dependent on different furnace configurations and the required material properties.
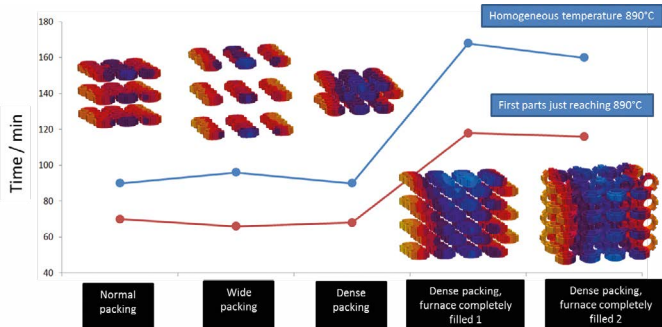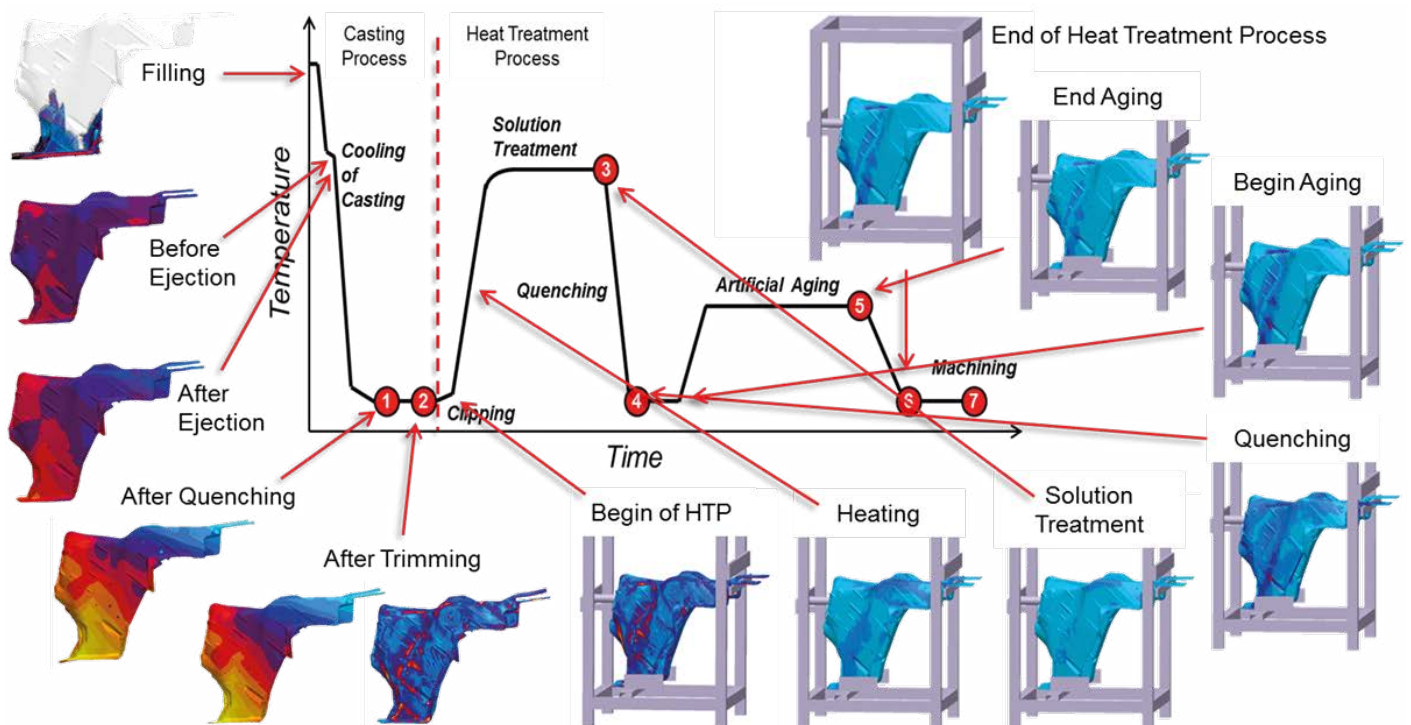

Austenitization times for different charges

From Casting to Heat Treatment

The simulation of the heat treatment process is seamlessly integrated into the virtual process sequence for casting production. All process steps from casting, trimming, heating, solution treatment, quenching, tempering, to ageing and finally cooling to room temperature can be considered.

This ensures a comprehensive evaluation of thermal fields, stress states and component distortion.

Virtual Experimentation and Process Optimization

MAGMASOFT® offers extensive possibilities for virtual designs of experiments and optimization. This enables a detailed analysis of the process window without economic risks or delays in production. Numerous process variables can be analyzed to set robust manufacturing conditions.

Comprehensive statistical evaluation methods enable you to determine optimal heat treatment conditions for:

¬ Process times, temperatures and material composition

¬ Temperature control in the furnace

¬ Microstructure and material properties

¬ Reduction of residual stresses, cold cracking risk and distortion of the cast component

Robust Processes

Determine the influence of process fluctuations on casting quality after heat treatment through systematic designs of experiments. With MAGMASOFT® autonomous engineering, you can quantitatively evaluate main effects and correlations, and determine concrete actions for your production even before the first trial has been carried out.

Using a main effect matrix you can reveal physical relationships and make your process easier to control.

Integrated modeling of the casting and heat treatment processes

Microstructure and Mechanical Properties

For many materials, MAGMASOFT® predicts local microstructures and mechanical properties in the component.
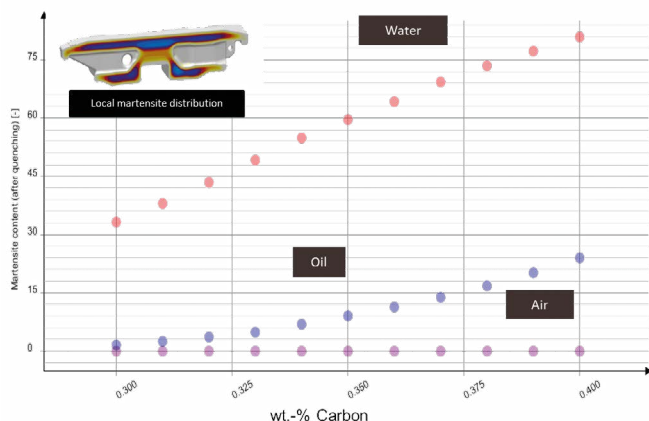
Martensite content as a function of the carbon content and quench medium

Microstructure and material properties are predicted for low-alloy steel grades. Both the chemical composition and the temperature history during heat treatment are taken into account.
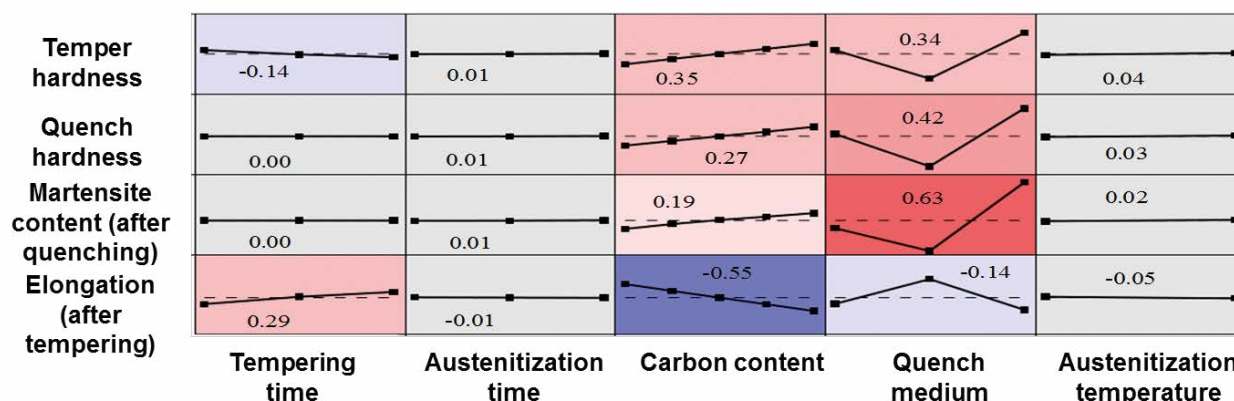
The program calculates the heat treatment of austempered ductile iron (ADI) as well as the ferritization and pearlitization of ductile iron.
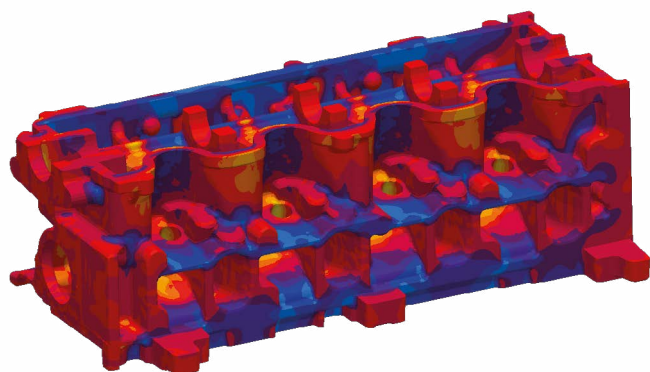
Residual stresses in a cylinder head after heat treatment

Residual Stresses and Cracks

During heat treatment, the stress state changes in the cast material. While stresses are relieved during solution treatment and tempering/ageing as a function of the temperature level and process time, stresses typically build up during quenching due to the thermal gradients and decreasing temperatures.

MAGMASOFT® allows the prediction of local stresses, deformation and the risk for crack formation in the component.

Support Rack Design

Calculate the distortion of your component during heat treatment with a state-of-the-art contact algorithm.
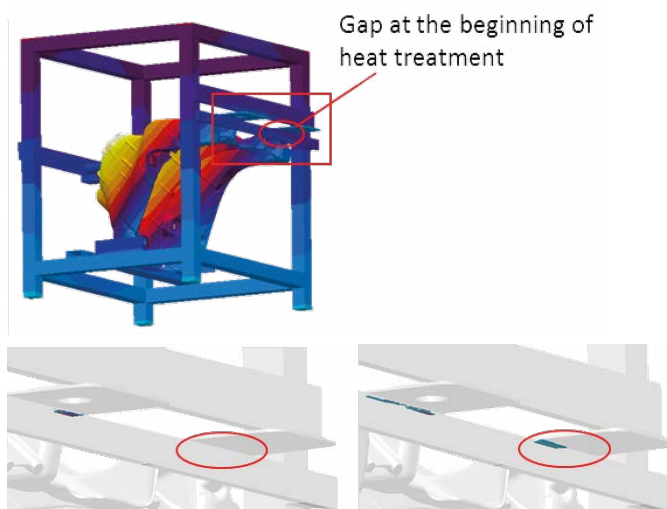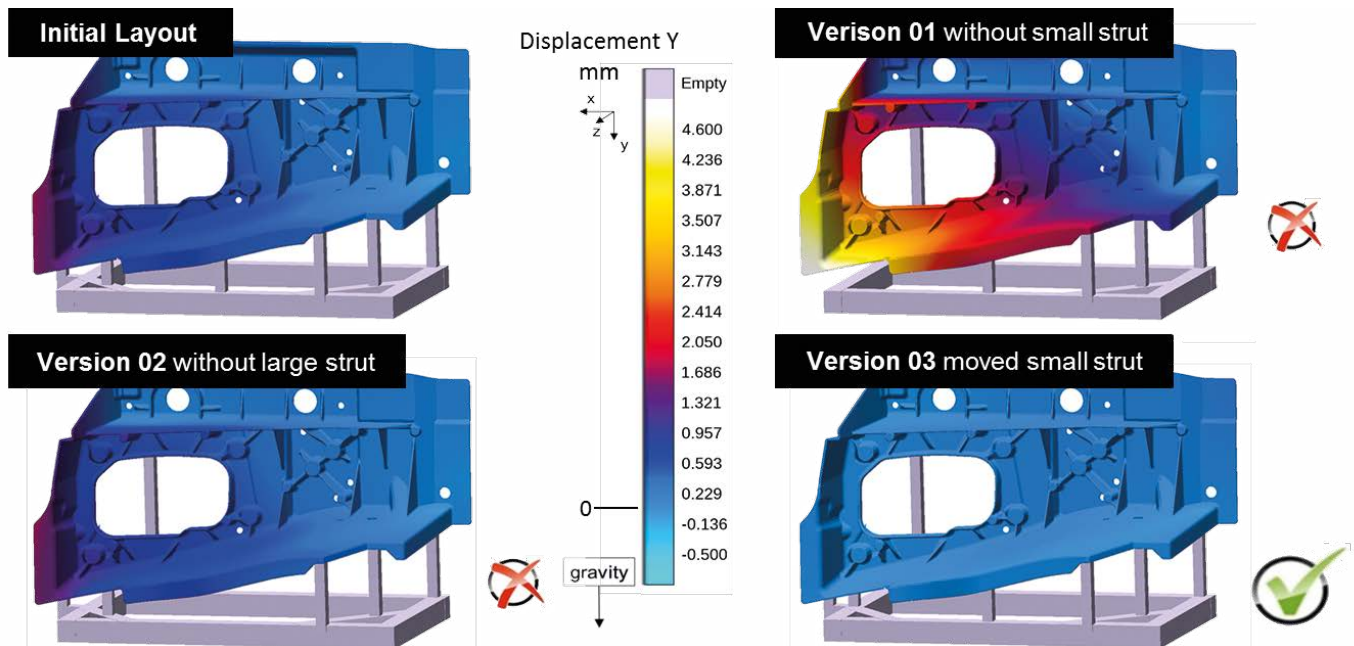

Automatically identified and continuously updated contact points

All contact pairings are automatically detected and updated at each calculation step, without the need for cumbersome contact definitions. Realistic contact conditions ensure that distortion results correspond with reality.

MAGMASOFT® gives you the ability to evaluate different process conditions at an early stage to minimize distortion during heat treatment. Alternatively, you can test different support rack designs to bring the component into the required dimensional tolerances.

Reduce or avoid costly straightening operations for your component. Show your customers the advantage of an almost stress-free component with a straightening-free production method.

	Tempering time	Austenitization time	Carbon content	Quench medium	Austenitization temperature
Temper hardness	-0.14	0.01	0.35	0.34	0.04
Quench hardness	0.00	0.01	0.27	0.42	0.03
Martensite content (after quenching)	0.00	0.01	0.19	0.63	0.02
Elongation (after tempering)	0.29	-0.01	-0.55	-0.14	-0.05

Main effect matrix – statistical assessment of results

Initial Layout

Verison 01 without small strut

Version 02 without large strut

Version 03 moved small strut

Displacement Y
mm

Empty	
4.600	
4.236	
3.871	
3.507	
3.143	
2.779	
2.414	
2.050	
1.686	
1.321	
0.957	
0.593	
0.229	
0 —	
-0.136	
-0.500	

gravity

Evaluation of different rack designs

Pre-Shaping the Mold

Throughout the entire casting and heat treatment process chain, it is possible to check compliance with the required manufacturing tolerances. MAGMASOFT® simulations are used to pre-shape the tooling so that expensive machining or repair of the part can be avoided.


Deviation [mm]

+25

-25
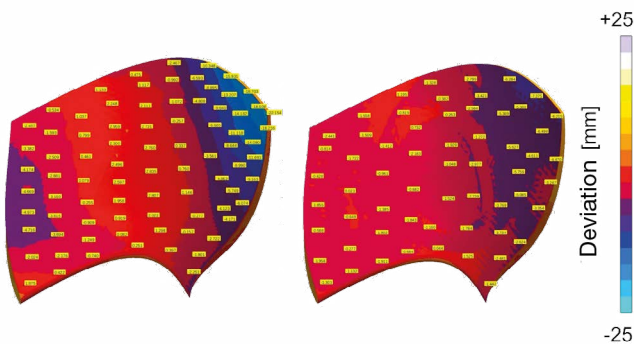
Reduction of distortion after the complete process using pre-compensation in the tooling in comparison with the original shape (left)

Evaluation of Dimensional Tolerances

Evaluate the distortion of the component after each process step directly in MAGMASOFT® (3-point, 6-point or best-fit methods) and evaluate the most critical phases of your process in terms of distortion.

-1.5	+1.5	-1.5	+1.5
Simulation		Measuring result	
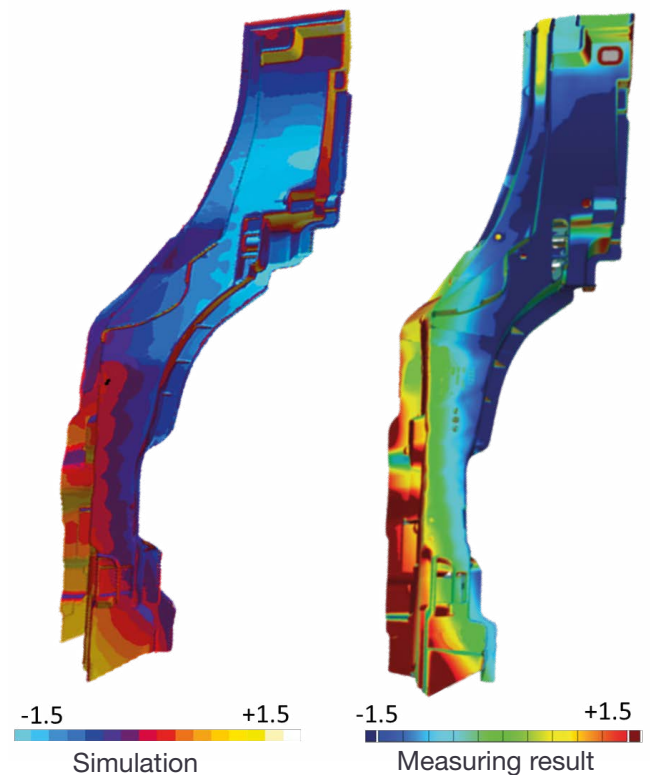
Evaluation of the predicted distortion using the 6-point method (simulation vs. measuring result)
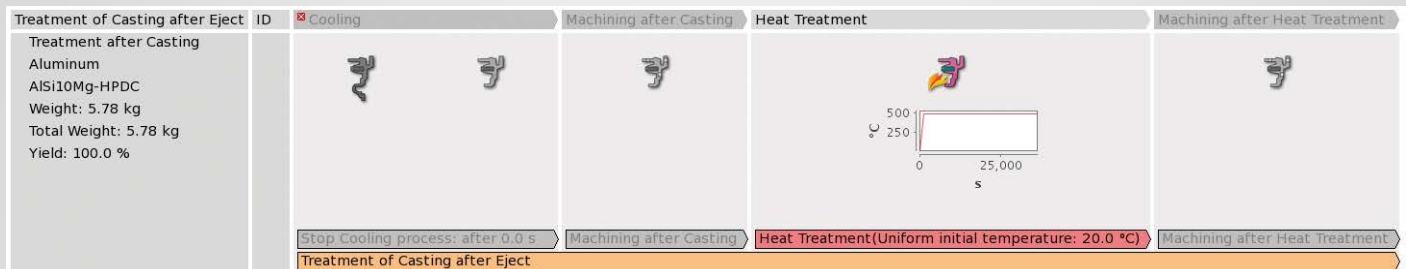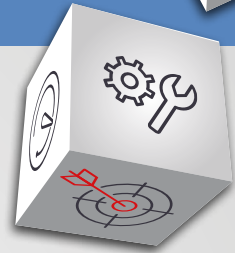
Work **Efficiently** and **Systematically**

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.
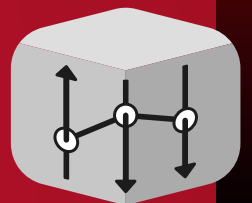
Intuitive Process Control

Use MAGMASOFT® to optimize all relevant process steps. From furnace design and rack construction to treatment times and temperatures, virtual experiments can lead you to a robust optimum.

Treatment of Casting after Eject	ID	⊠ Cooling		Machining after Casting	Heat Treatment		Machining after Heat Treatment

Treatment after Casting
Aluminum
AlSi10Mg-HPDC
Weight: 5.78 kg
Total Weight: 5.78 kg
Yield: 100.0 %

500
°C 250
0   25,000
s

Stop Cooling process: after 0.0 s   Machining after Casting   Heat Treatment(Uniform initial temperature: 20.0 °C)   Machining after Heat Treatment
Treatment of Casting after Eject

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 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 addition simulation time

¬ **Autonomous Engineering:** seamless integration with optimization and virtual design of experiments
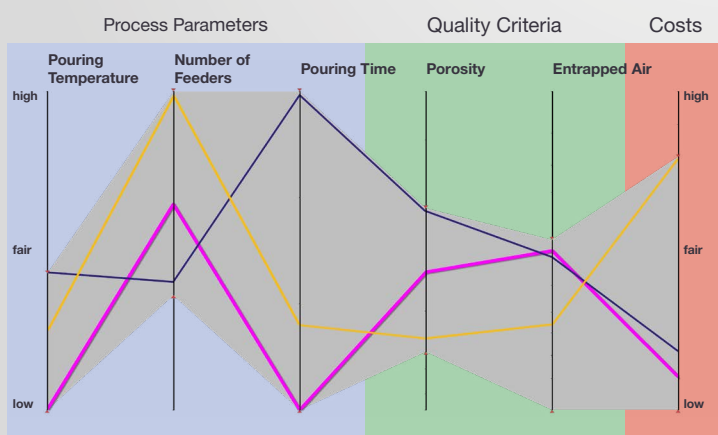
With MAGMA ECONOMICS, the parallel coordinate diagram as established, interactive tool for analyzing process variations and quality criteria is complemented by corporate criteria such as costs, energy/resource consumption and sustainability.

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).

Process Parameters   Quality Criteria   Costs

Pouring   Number of   Pouring Time   Porosity   Entrapped Air
Temperature   Feeders

high   high

fair   fair

low   low

7

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.
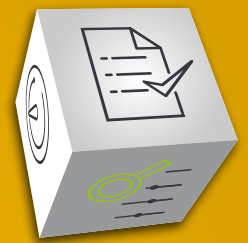
Implementation

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.
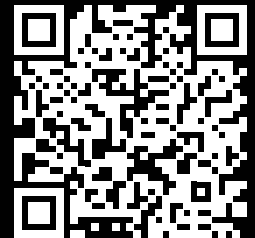
MAGMAengineering

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:

6.1
MAGMASOFT®