Application of a Genetic Algorithm in Casting Process Simulation

Volker Kokot, Peter Bernbeck
MAGMA Giessereitechnologie GmbH, Germany

Introduction

Coupling of Simulation and Optimization Tool

Examples

Parts with support of
Heidelberger Druckmaschinen, Gießerei Amstetten

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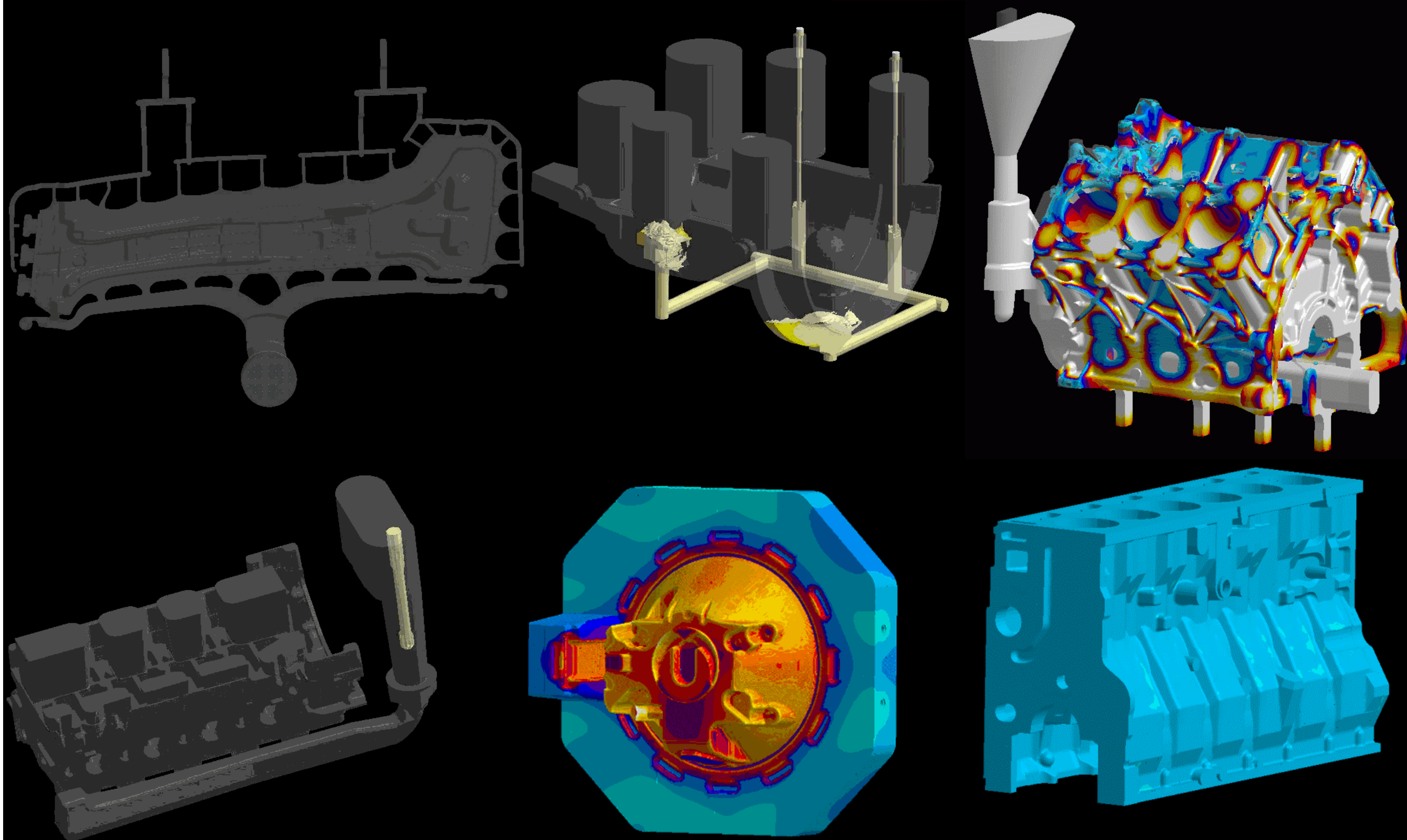
Casting Process Simulation

an established technology



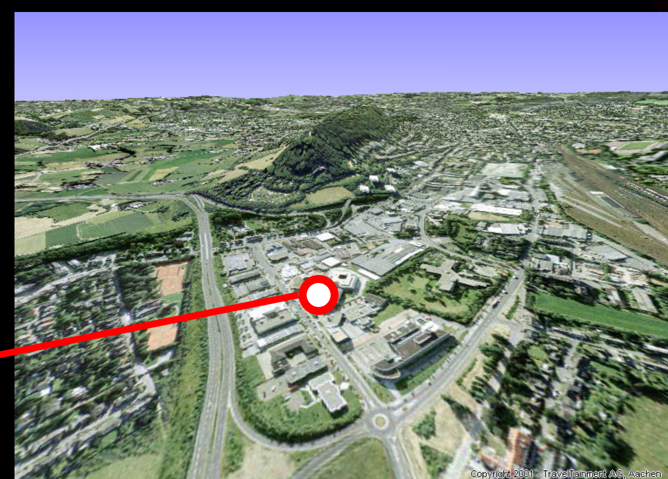
… the MAGMA concept:

“committed to Casting Excellence”

- Customer Satisfaction
  - Provide comprehensive engineering solutions to solve foundry problems
- Technology leadership
  - Use empirical foundry expertise coupled with physical based fundamentals
- Comprehensive approach and global focus
  - Considering the optimization of the entire manufacturing route of castings
- Worldwide Customer Base

  More than 600 Industrial Installations

MAGMA GmbH, Aachen



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MAGMA World-Wide

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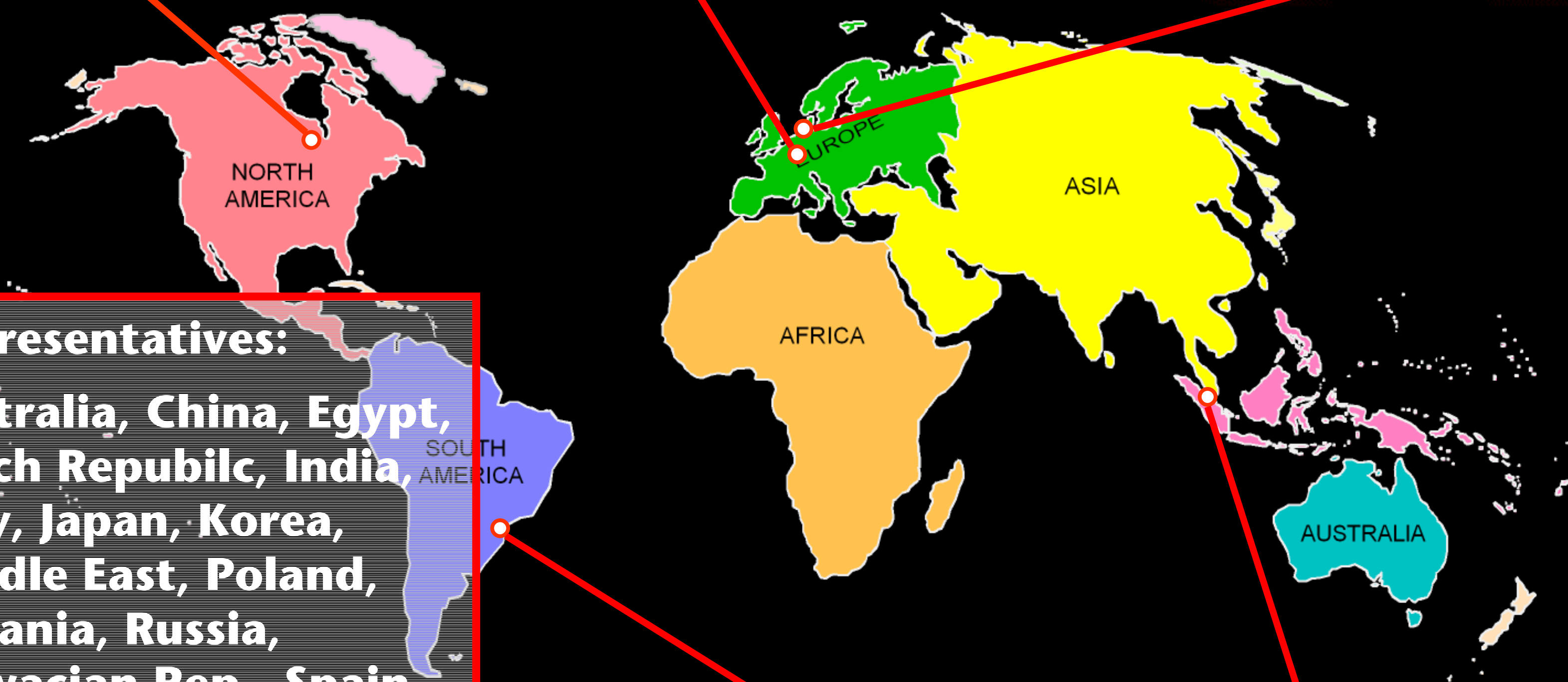
MAGMA Giessereitechnologie GmbH, Aachen, Germany

MAGMA Technologies A/S, Kopenhagen, Denmark



Representatives:

Australia, China, Egypt, Czech Repubilc, India, Italy, Japan, Korea, Middle East, Poland, Ronania, Russia, Slowacian Rep., Spain, Slowenia, South Africa, Taiwan, Turkey, France, UK,...

MAGMA Engenharia do Brasil Ltda., Sao Paulo, Brazil

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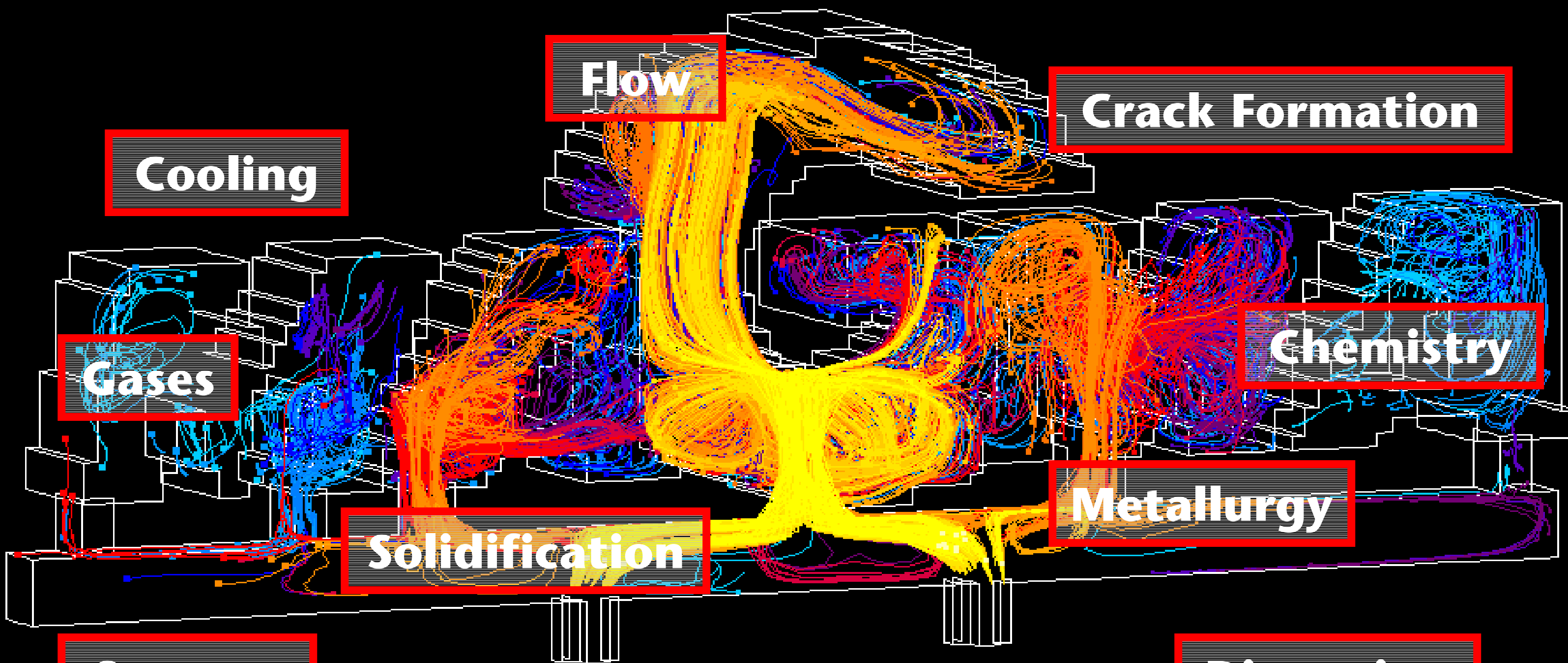
Casting -
The most complex manufacturing process



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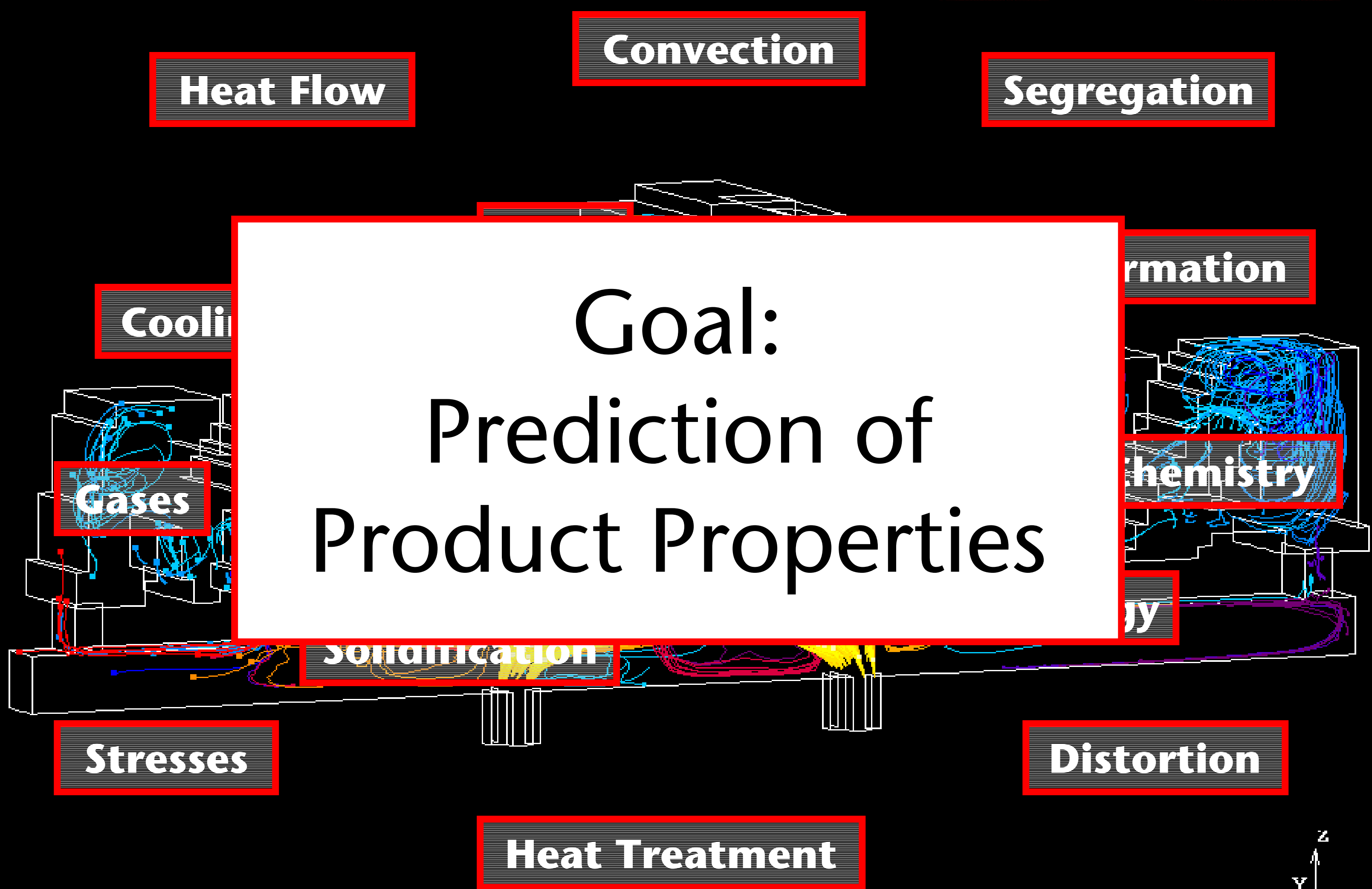
Casting -
The most complex manufacturing process



Goal:
Prediction of
Product Properties

Introduction

- In this presentation we will show what can be achieved by coupling a casting process simulation and a universal mathematical optimization tool.
- Basically there are two procedures how to solve optimization problems: analytic methods and black box methods.
- Here we want to concentrate on the black box method.

MAGMAfrontier

- MAGMAfrontier is the coupling of *mode*FRONTIER and MAGMASOFT in order to obtain a (semi)automatic procedure for design optimization.
- MAGMAfrontier allows the input of an optimization task for *mode*FRONTIER from the point of view of a MAGMASOFT user.
- GUI-concept for MAGMAfrontier: Simple definition of an optimization task using <u>predefined</u> and <u>preconfigured</u> templates.

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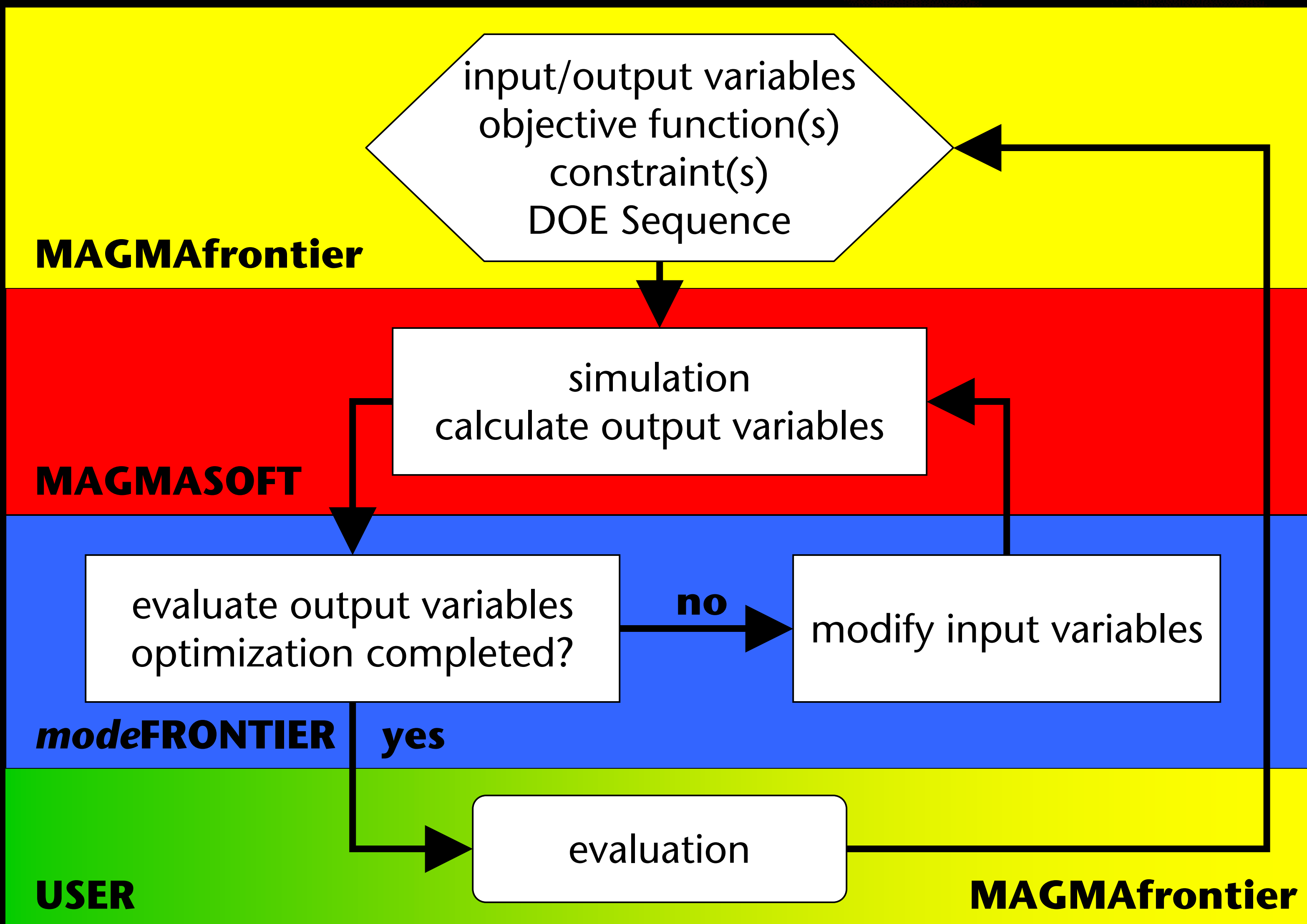
Coupling Simulation/Optimization



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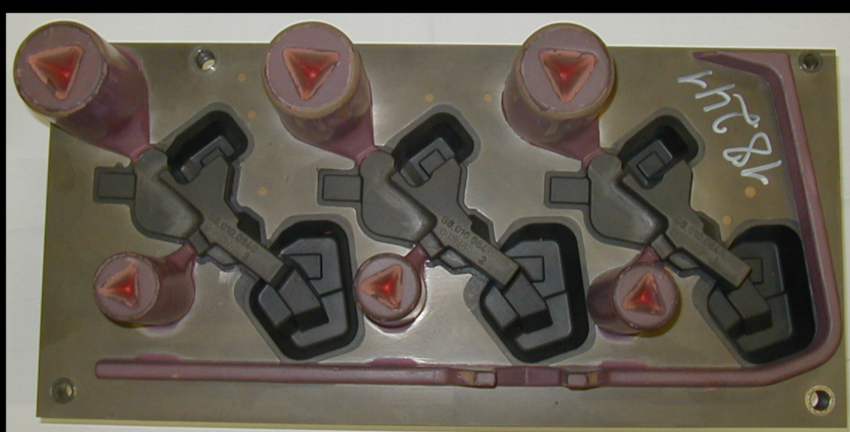
Examples: Feeder Optimization

- In this example we take a look at the problem how to place an exothermic micro feeder on a cast iron part in order to get a **sound casting** with a **minimal feeder volume**.

- Further the pattern lay-out should be optimized to **increase the yield** and to realize **certain material properties**.

Examples: Feeder Optimization

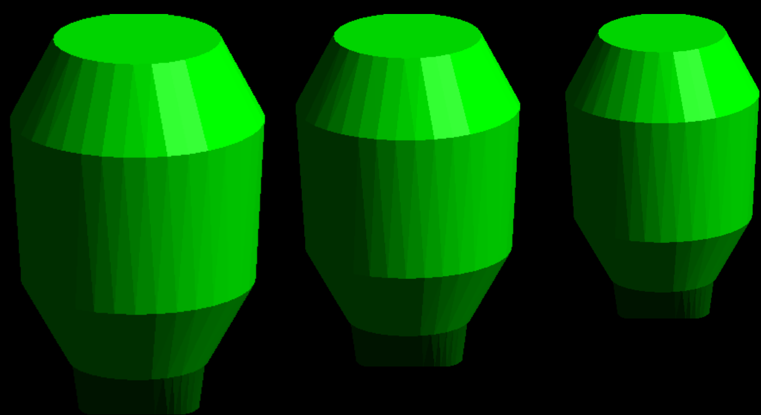
- **Situation before the Optimization:**
  - Material: GJS700 (gravity casting)
  - Weight: 1,55kg per part
  - 3 parts in pattern lay-out
  - 2 sand feeder per part
  - **Yield 16%**
  - **6,24** € per part



Examples: Feeder Optimization

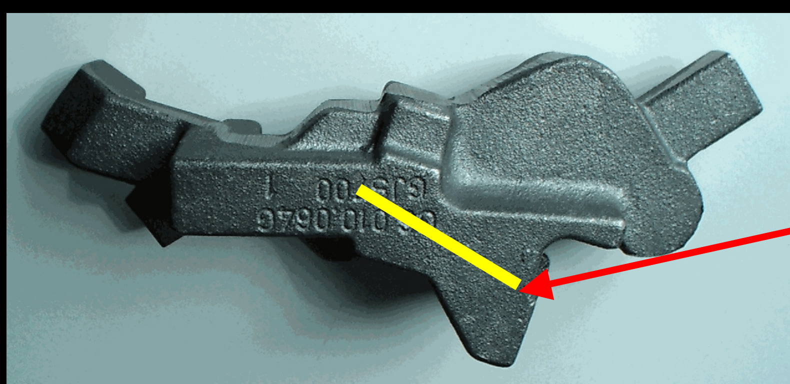
- **Wishes for Improvement:**
  - Min. Tensile Strength around 700MPa
  - Sound Casting
  - Maximize Yield
    (Minimize Feeder Volume)
  - More than 3 parts in pattern lay-out
  - Only one exothermic feeder, if possible

Examples: Feeder Optimization



Degrees of Freedom:

- Exothermic Sleeves: FOSECO V22/40, V28/40 and V38/40
- Possible locations of the feeder on the part



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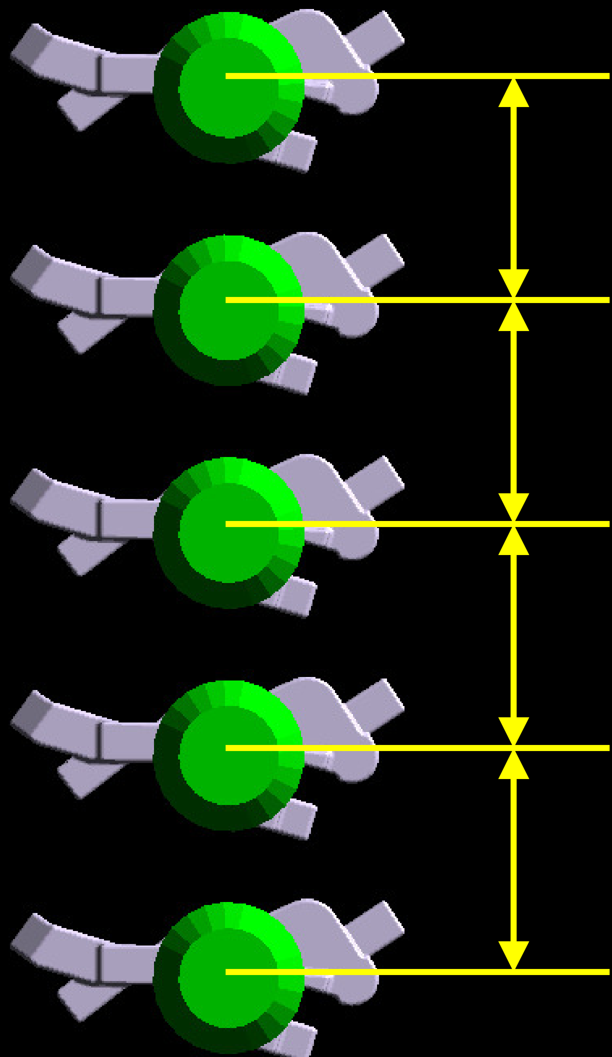
Examples: Feeder Optimization



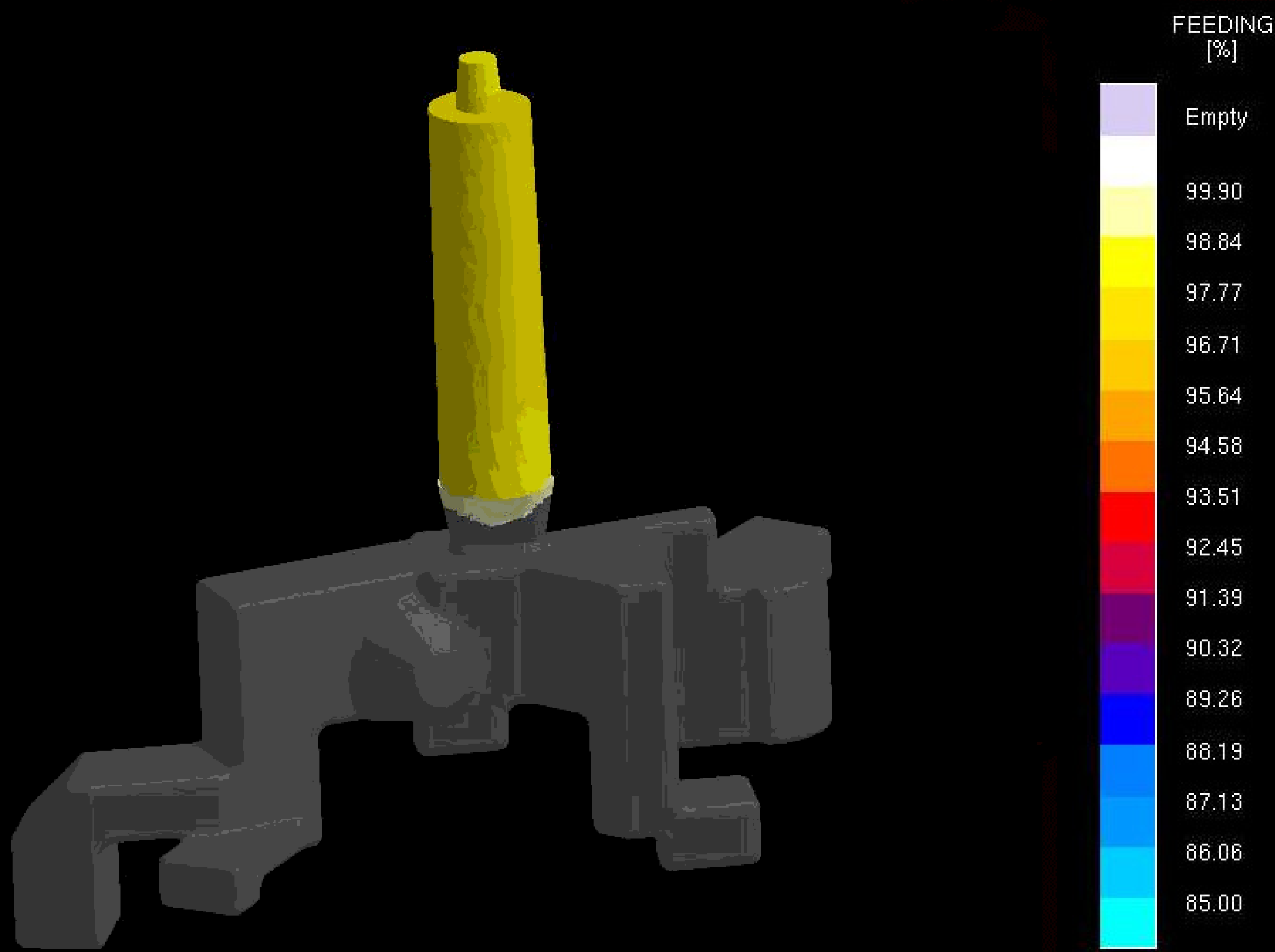
- **Degrees of Freedom**
- Distance between parts

Examples: Feeder Optimization

- Objectives taken into account:
  - Get Sound Casting...
    i.e. **Minimize (Porosity in cast)**
  - ...with Smallest possible exothermic feeder
    i.e. **Minimize (Volume of Feeder)**
  - Maximize number of parts in pattern lay-out
    i.e. **Minimize (Space between parts)**
  - At least 20mm of sand between the sleeves
    i.e. **Distance > 20mm**
  - Tensile Strength at least 660MPa
    i.e. **Maximize (Min. Tensile Strength)**

Examples: Feeder Optimization

- Calculated Variants



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Examples: Feeder Optimization

- Distribution of Tensile Strength

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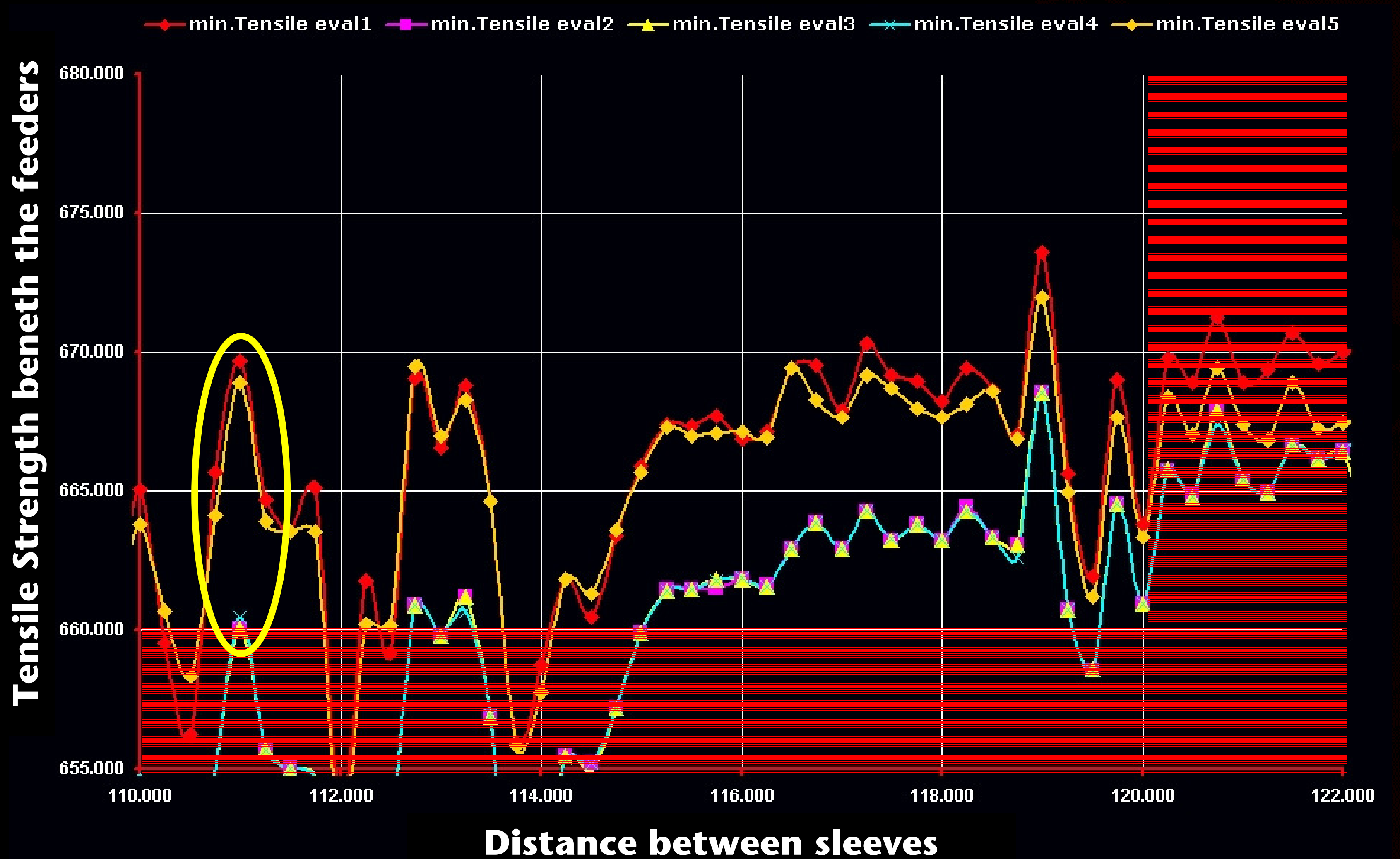
Examples: Feeder Optimization



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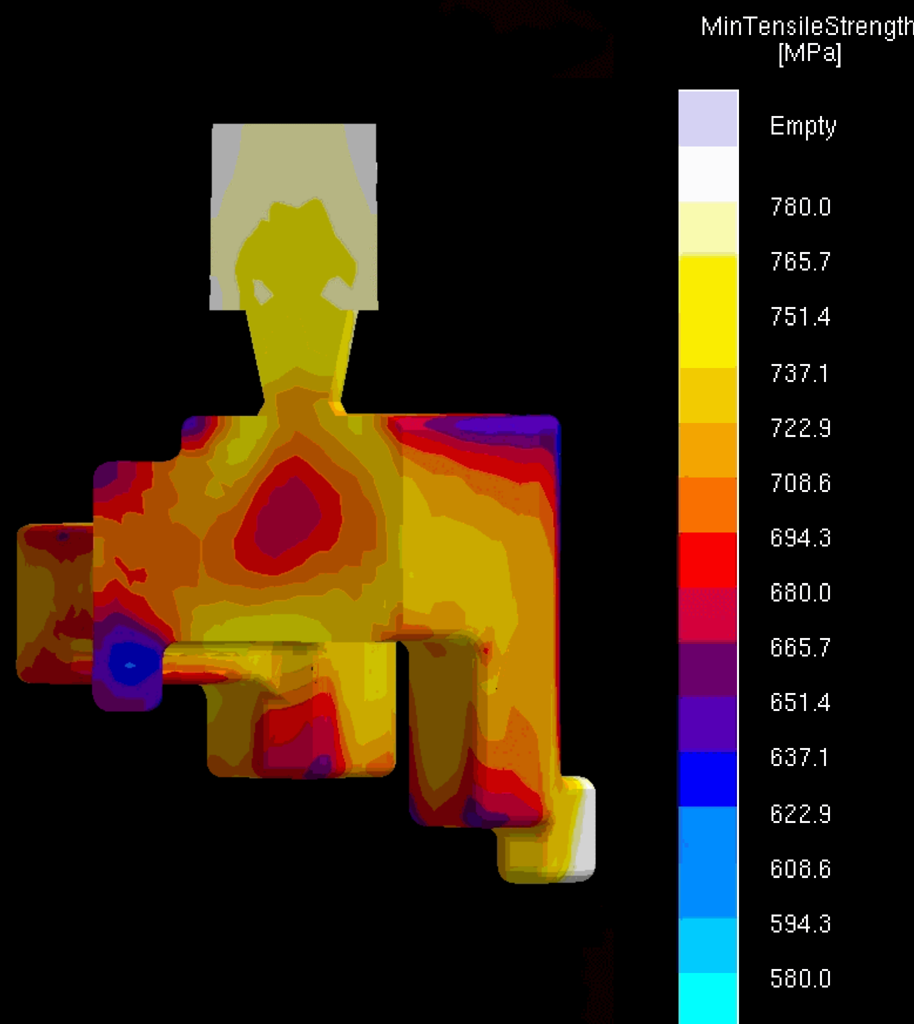
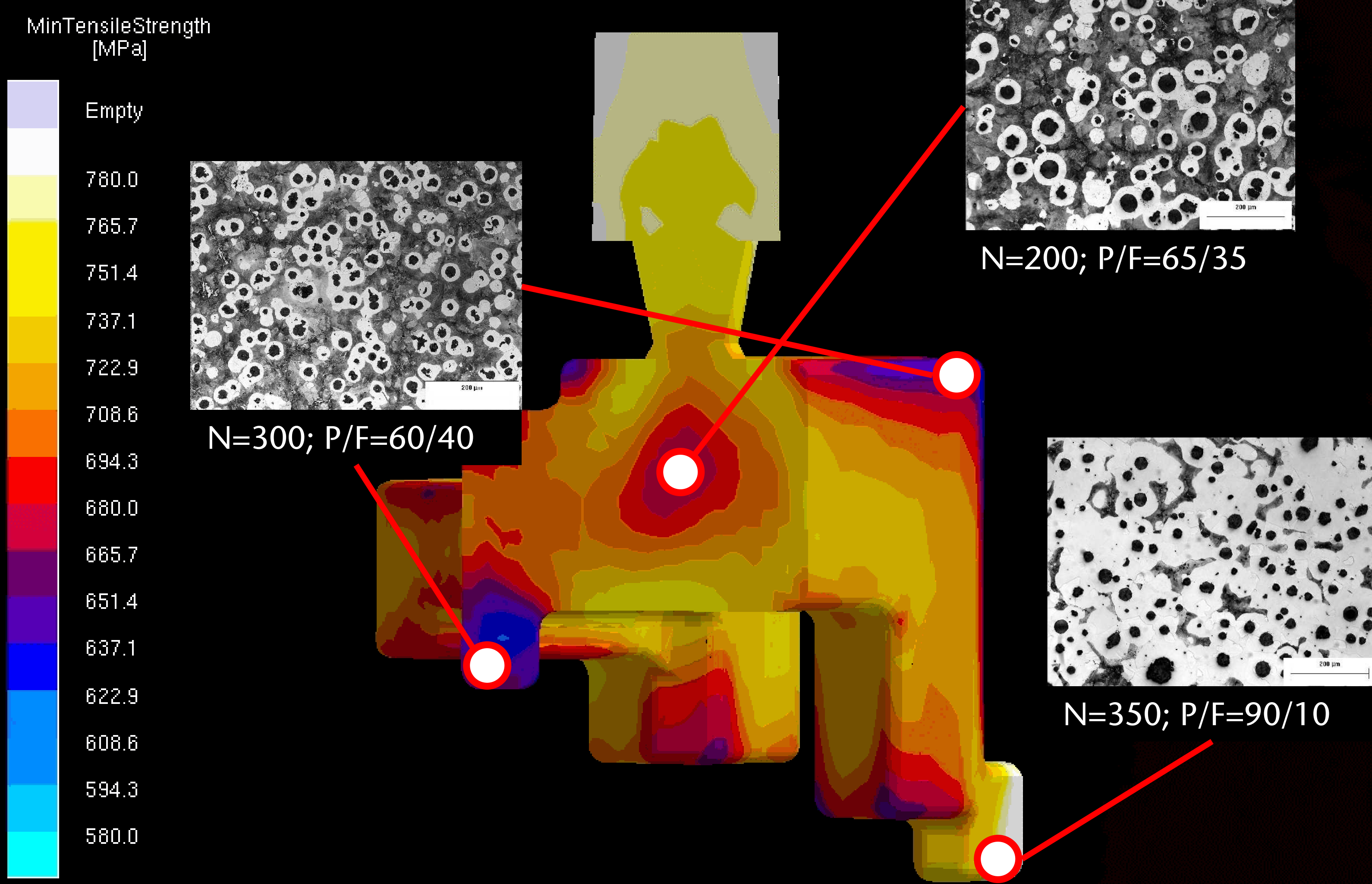
Examples: Feeder Optimization

- Statistics:
  - 200 simulations, each ca. 22min
  - Total calculation time: 3 days
  - Used computer: PC, Two Pentium 4 CPUs, 3.0 GHz, Red Hat Enterprise 3



Examples: Feeder Optimization

- Microstructure and Tensile Strength



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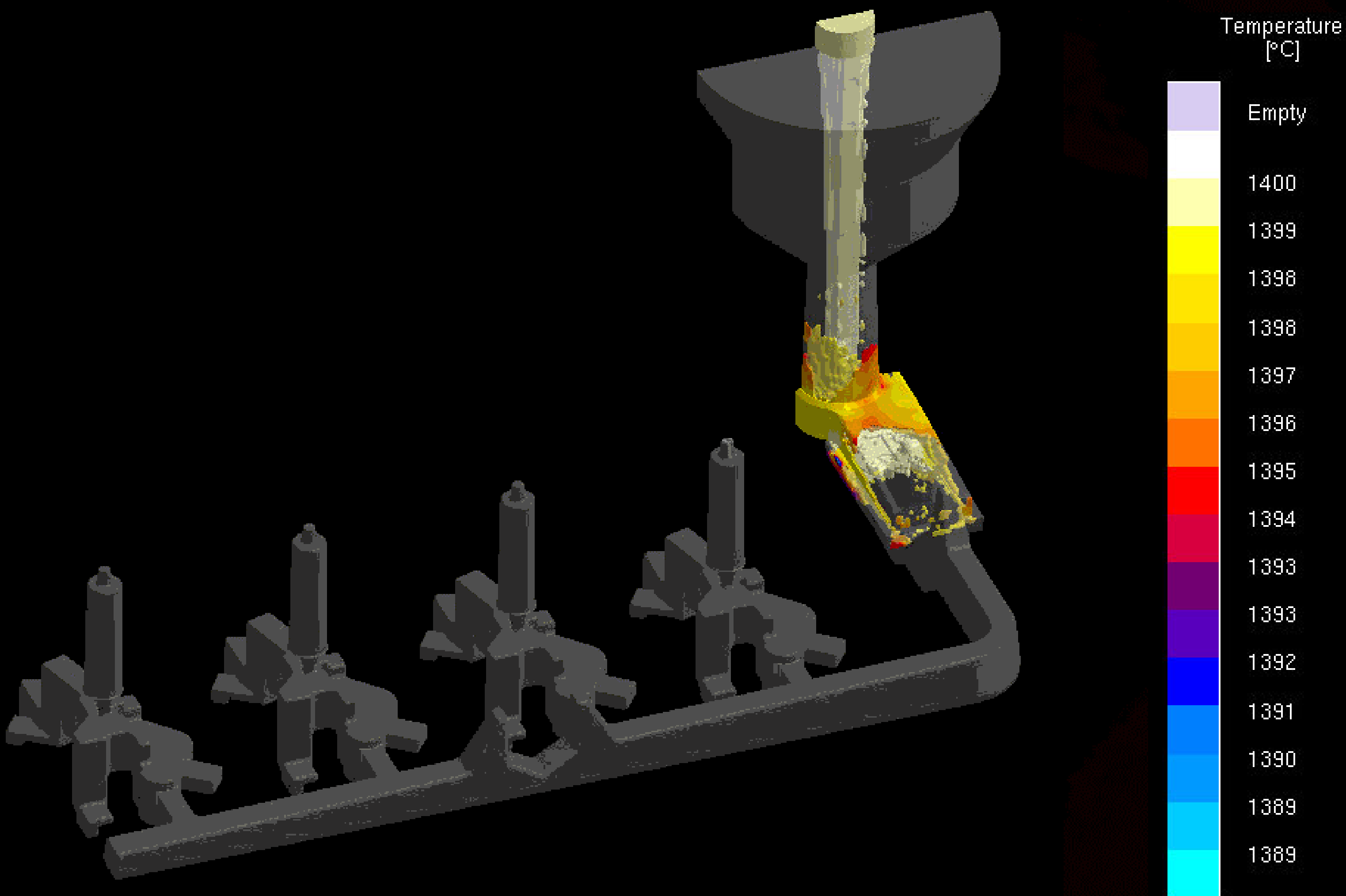
Examples: Feeder Optimization



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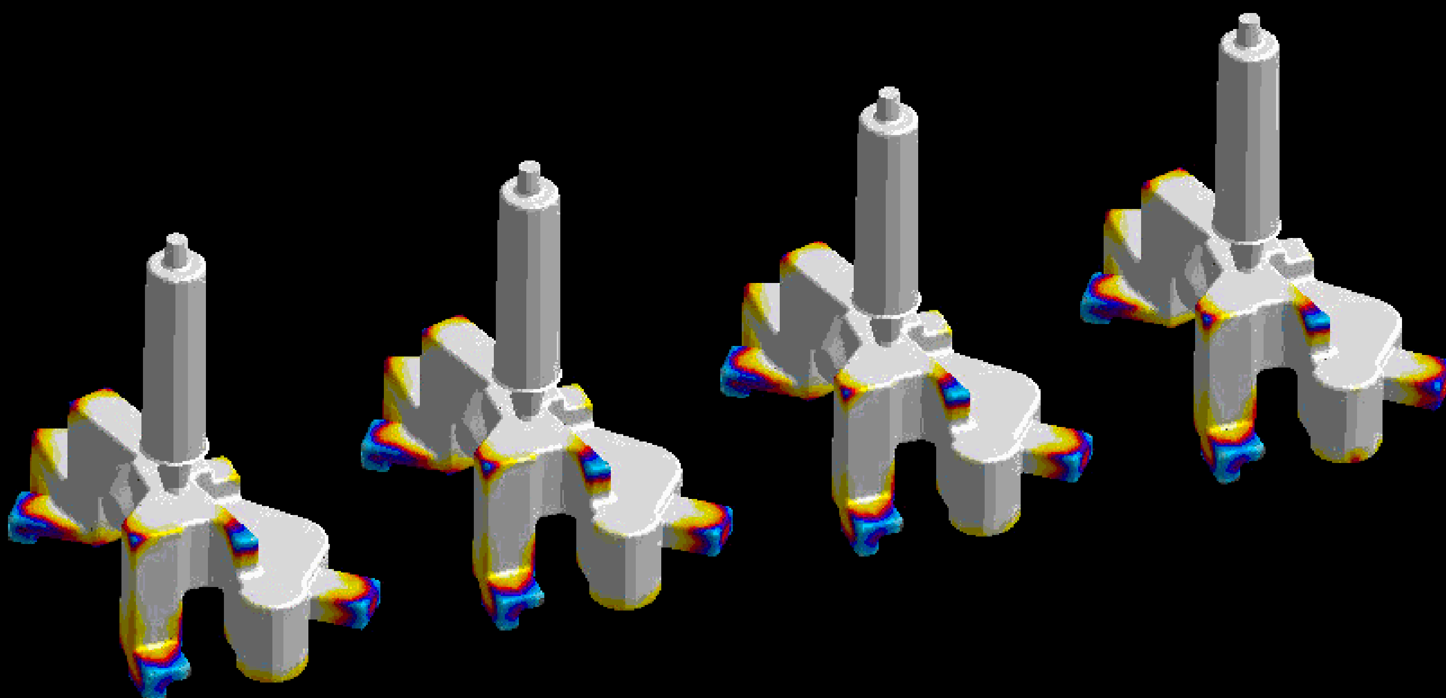
Examples: Feeder Optimization

- Soldification



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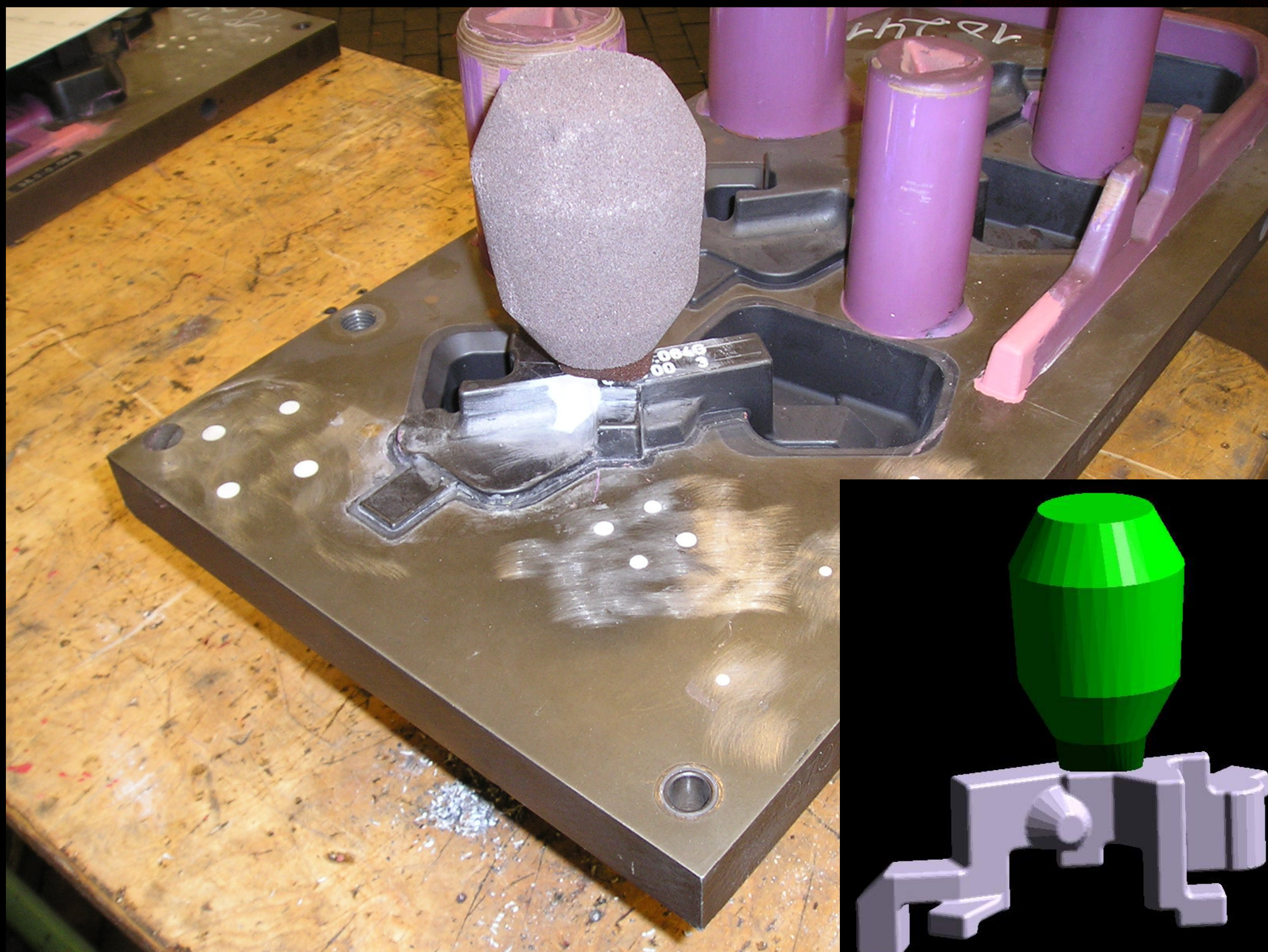
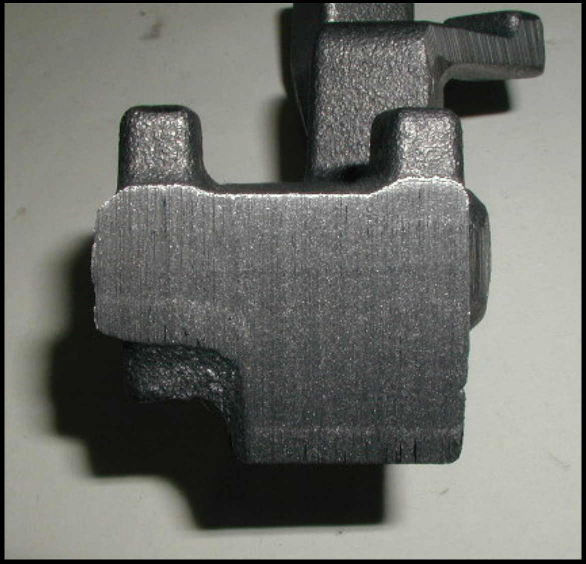
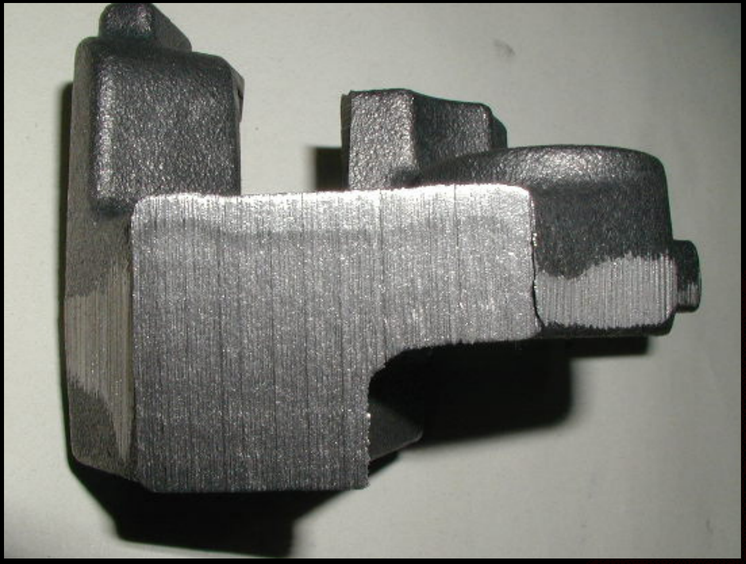
Examples: Feeder Optimization



Examples: Feeder Optimization





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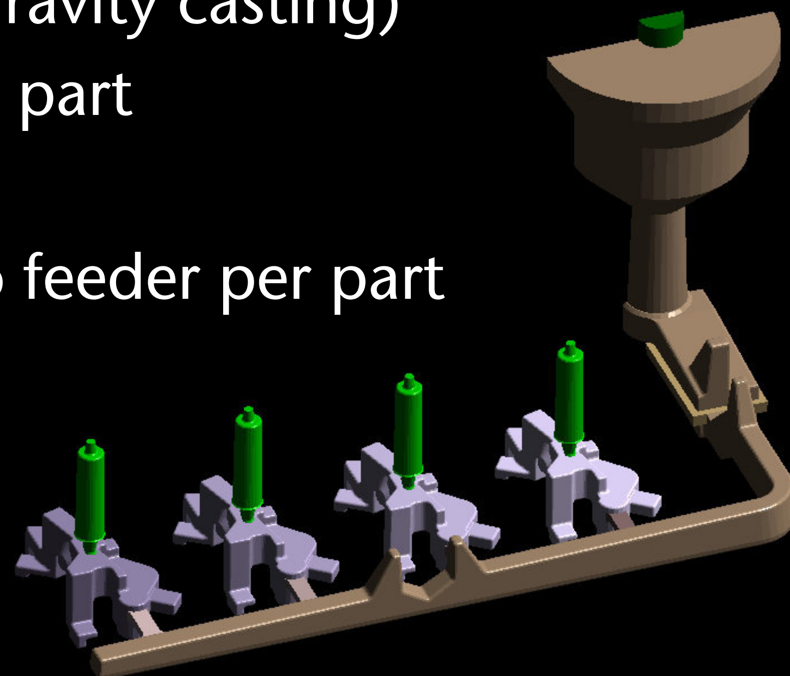
Examples: Feeder Optimization

- **Situation after the Optimization:**
  - Material: GJS700 (gravity casting)
  - Weight: 1,55kg per part
  - 4 parts per lay-out
  - 1 exothermic micro feeder per part
  - **Yield 46%**
  - **4,06** € per part



- **35% Reduction of Costs!**

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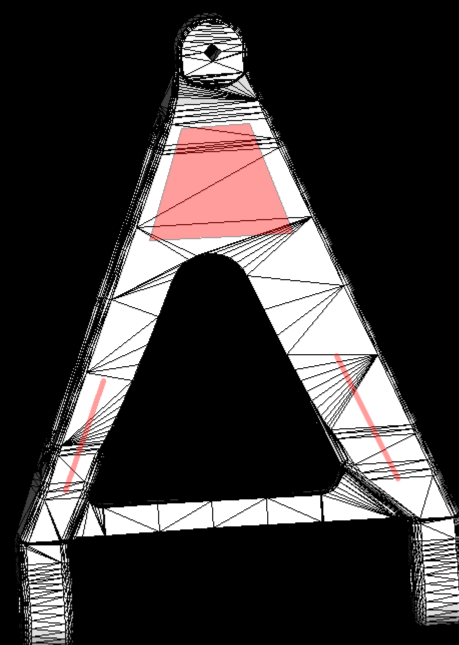
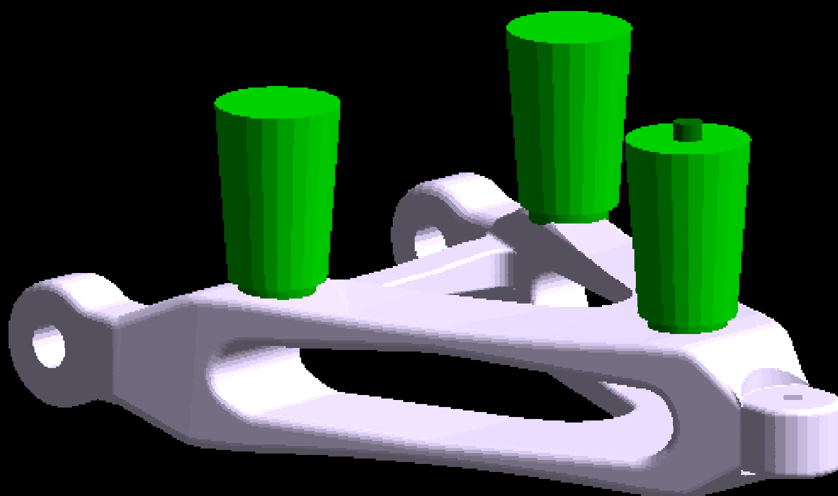
Examples: Feeder Optimization

- In this example three well sized insulated feeders should be placed on an aluminum suspension part in order to get a **sound casting** with a **minimal feeder volume**.
- The positions of the feeders were free to move:
  - two feeders are placed along the red lines,
  - the third inside the red area (see sketch)



Examples: Feeder Optimization



- Feeder Volume
  before: about 0.93 ℓ
  after: about 0.46 ℓ
- 126 calculated designs
- Calculation time 3½h

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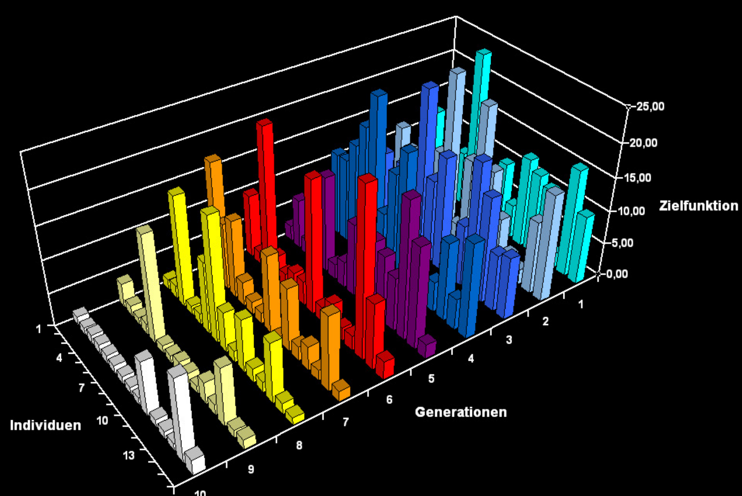
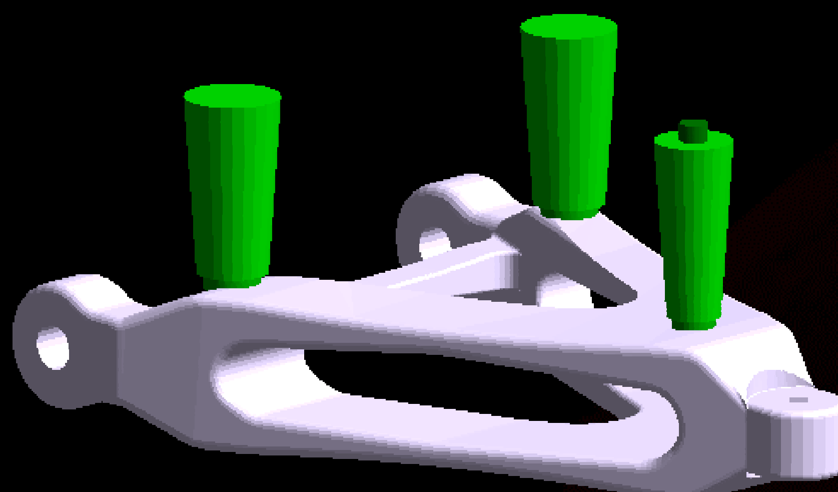
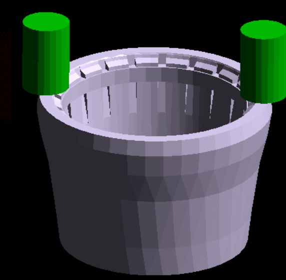
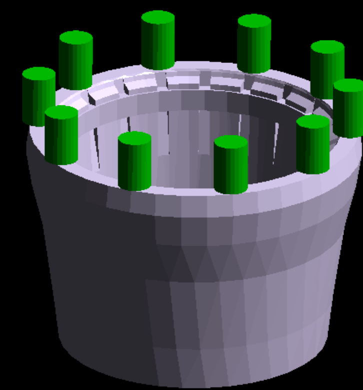




Examples: Feeder Optimization

- Sometimes the position of the feeders is quite obvious but the number of feeders is critical
- Let’s look at an upright aluminum flange in sand mold. Between 2 to 12 insulated feeders shall be placed on the top. The size and the number is to be varied. Once again we want a **sound casting** with a **minimal total feeder volume**.

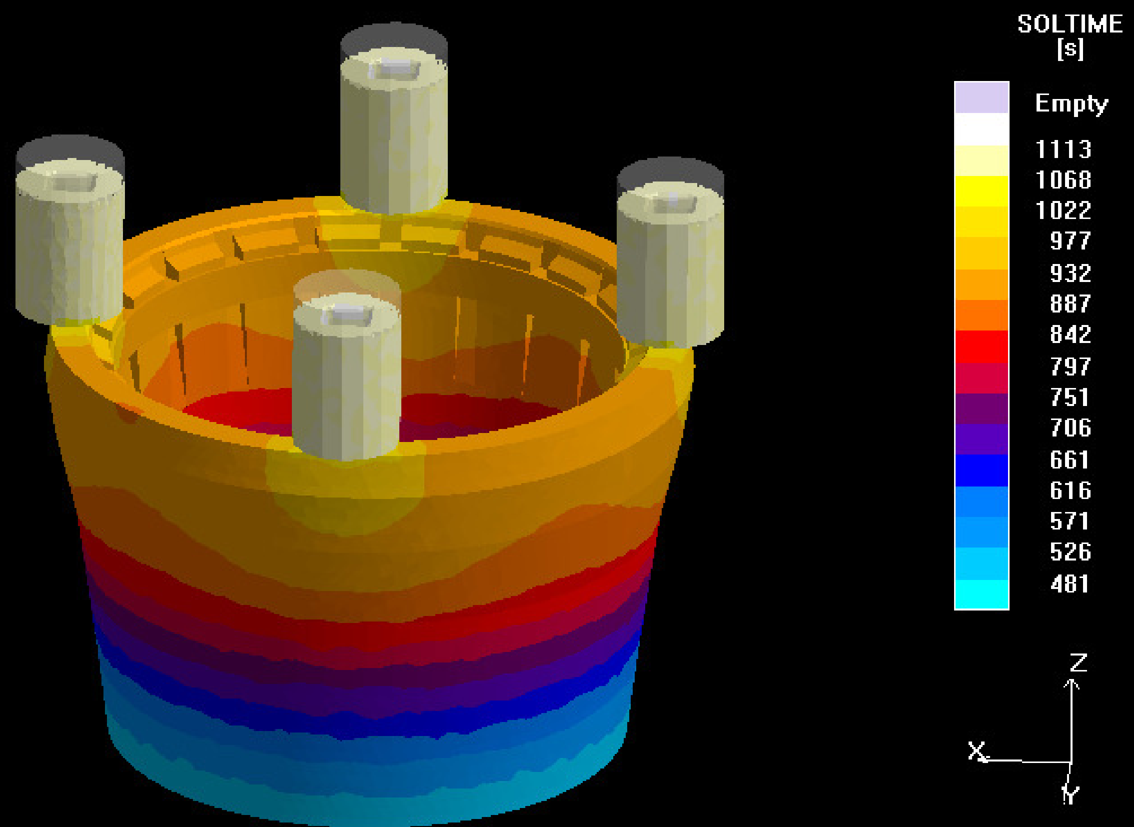




Examples: Feeder Optimization

Optimized Design:

100% sound material, feeder volume about 0.6l



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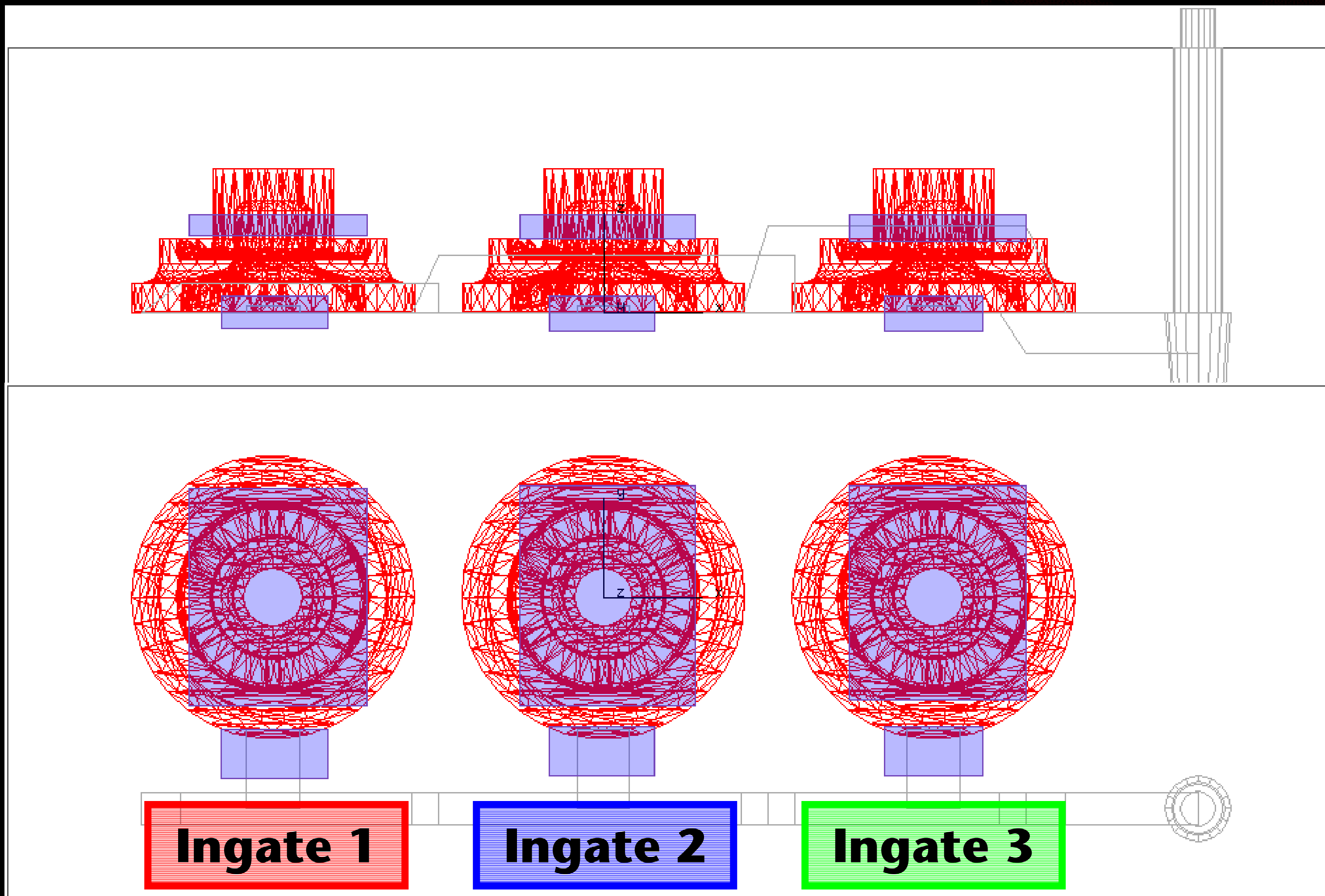
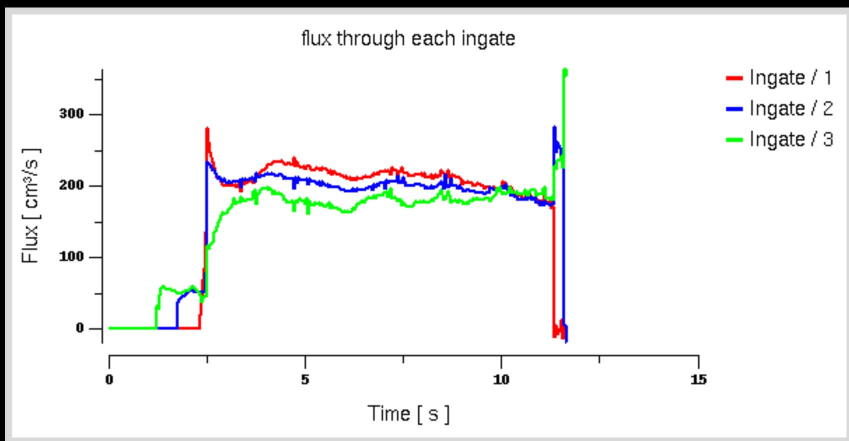
Examples: Gating Optimization

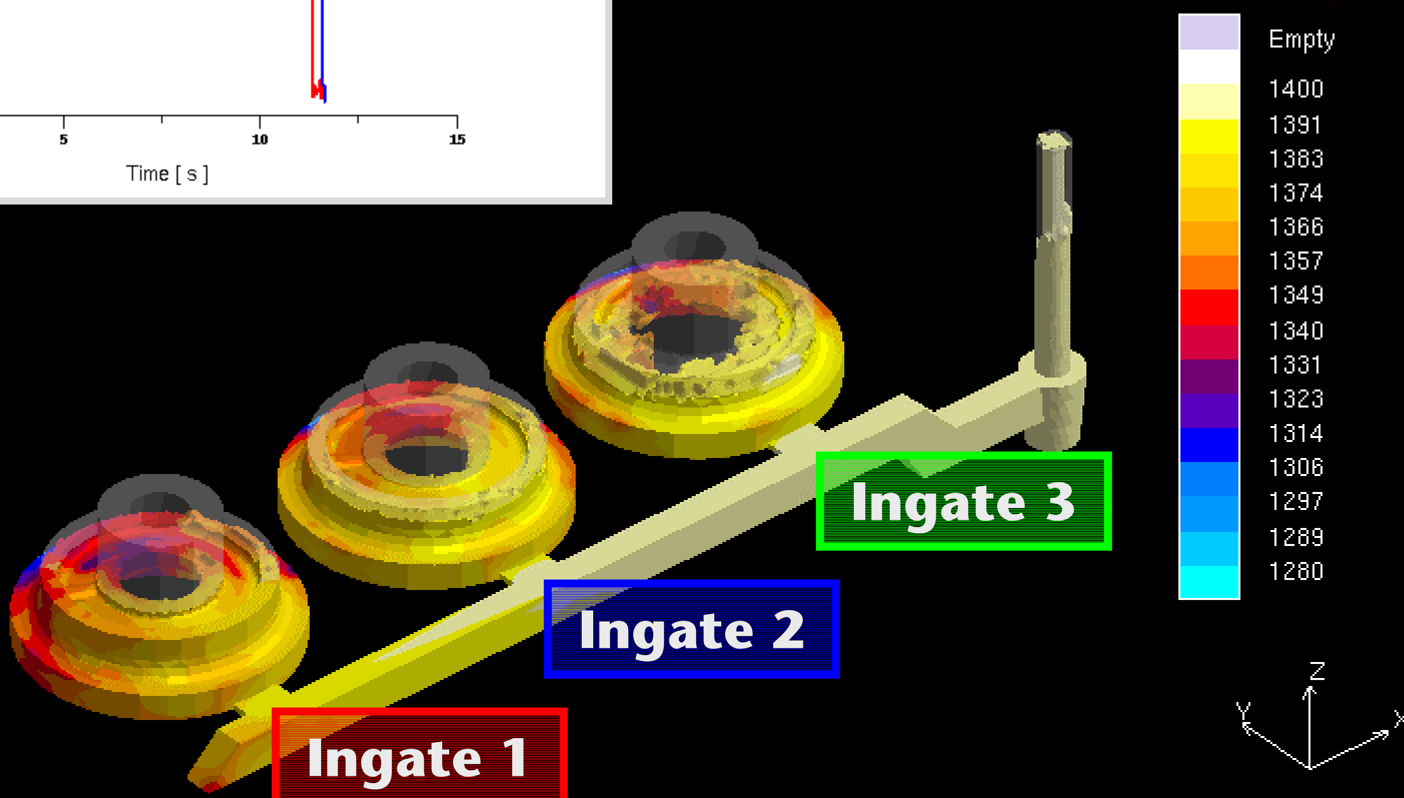
- In sand casting frequently several small parts are cast simultaneously in a simple pattern.
- The running system should contain only standard geometries and at the same time assure an identical filling behaviour for the different parts. Otherwise, the final quality could depend on the position of the part on the pattern.

Examples: Gating Optimization



Examples: Gating Optimization





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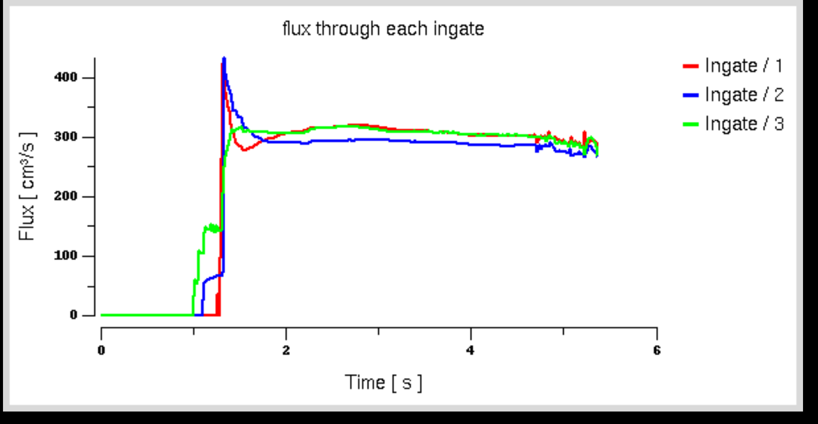
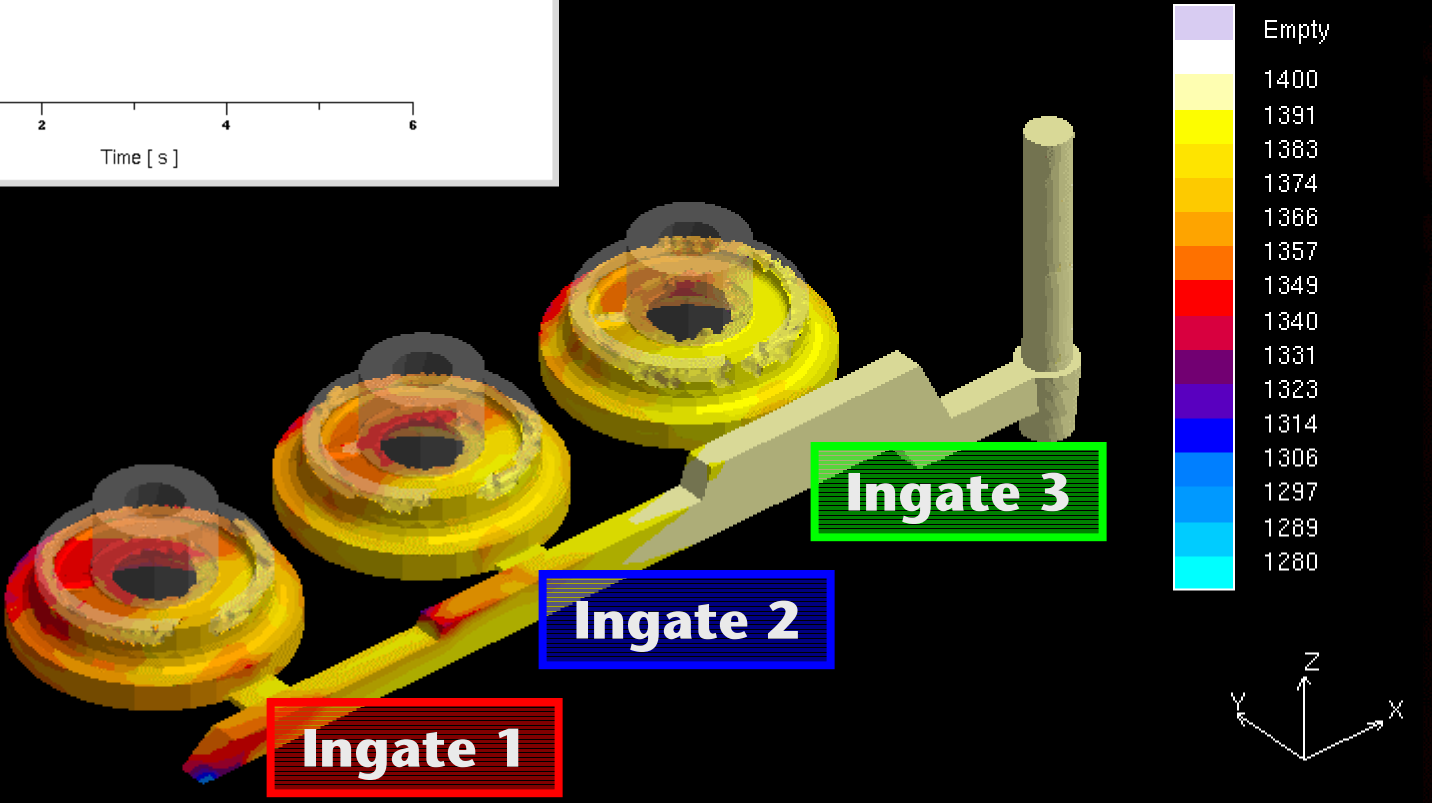
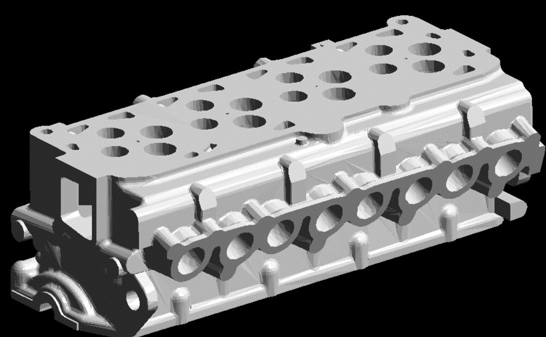
Examples: Gating Optimization

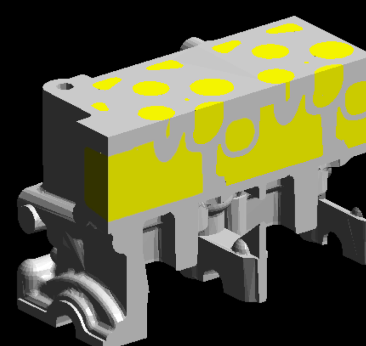




Examples: Inverse Problem

- In this example we have adapted the HTCs for the quenching of a cylinder head. This is an inverse problem, because here we want to improve the datasets of the simulation not the casting itself.
- The input variables in this case are the approximation parameters which describe the used heat transfer coefficients (temperature dependent).
- The objective is to minimize the differences between measured and calculated curves.





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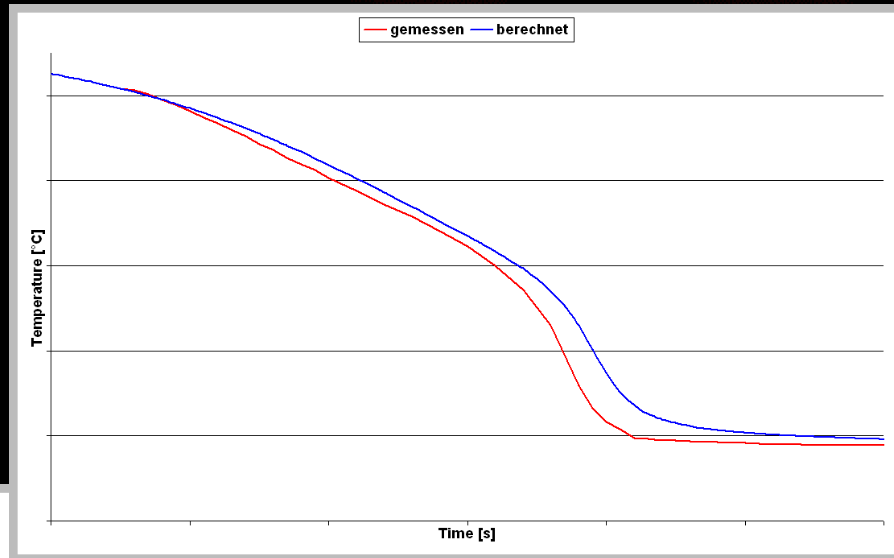
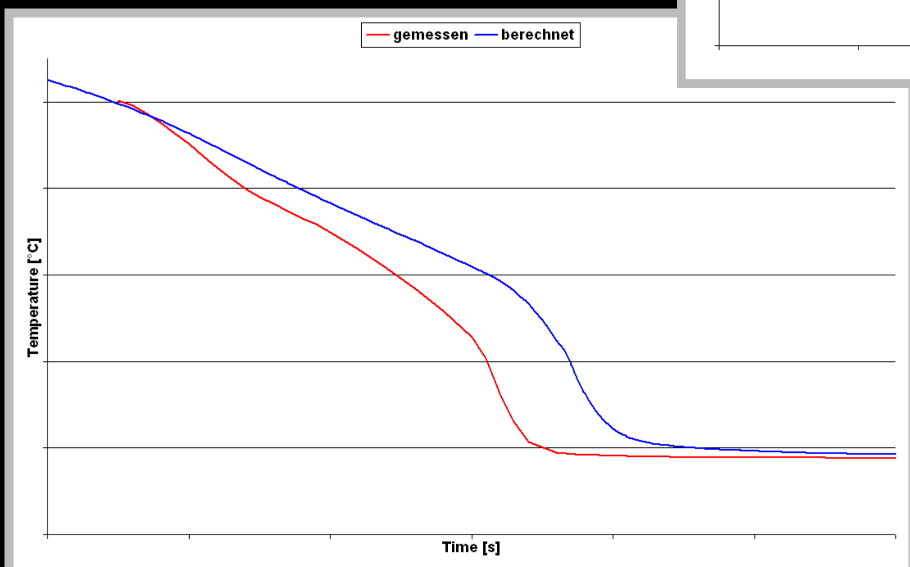
Examples: Inverse Problem

Differences between measured and simulated curves before the optimization





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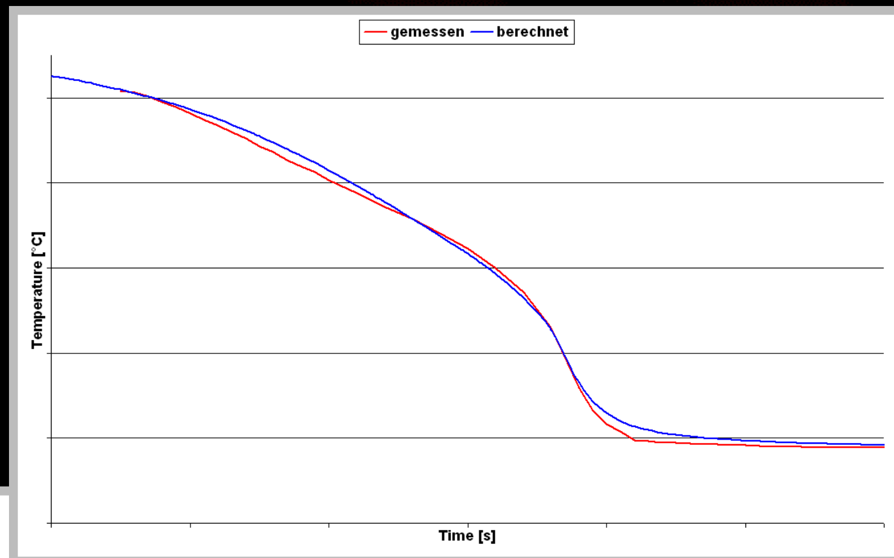
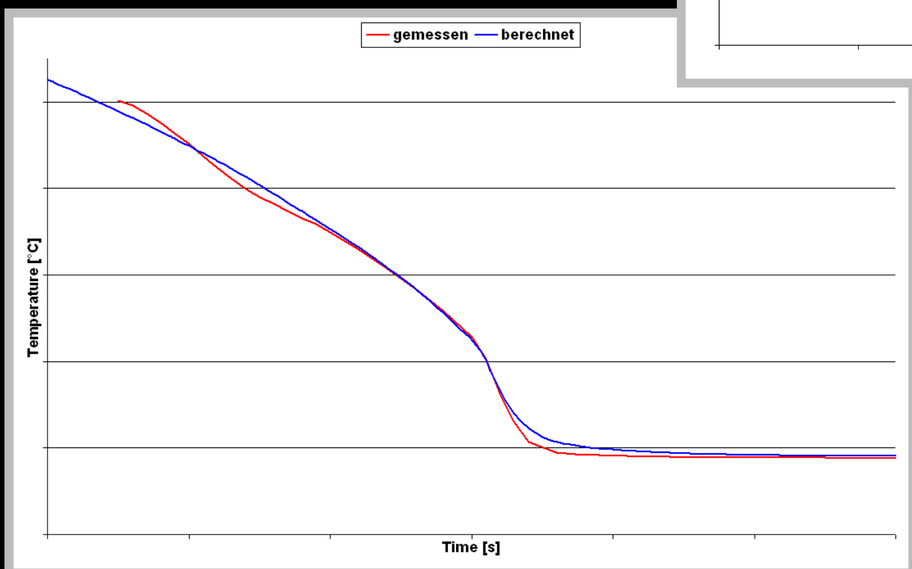
Examples: Inverse Problem

Differences after the optimization





Number of calculated Designs: 1231

Total calculation time: 25h

Conclusion & Outlook

- With the established optimization tool it is possible to solve many problems of casting process simulation using a genetic algorithm.
- Parameters of almost any type, e.g. casting temperature, heat transfer coefficients, wall thickness or quenching times, can be optimized or at least improved, if they have some influence on the output criteria.

Conclusion & Outlook

- But the application of a general genetic optimization strategy has also its (well known) limitations:
  If the problems become more and more complex — increasing degrees of freedom and/or larger number of objectives — the calculation times can explode even with massive parallelization.
- For that reason specialized, more efficient optimization strategies have been developed at least for some categories of optimization problems.
- But the development of such algorithms can be very time consuming and therefore cost-intensive.

Conclusion & Outlook

- In many interesting cases the application of a genetic algorithm in a general manner using the existing simulation program as a black box is efficient enough to solve casting process related problems in an acceptable time.
- Hence the genetic algorithm has won its place in the area of casting process simulation and optimization.