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New Material Design Leads to an Other Casting Quality – Solidification, Stress, Mechanical Properties

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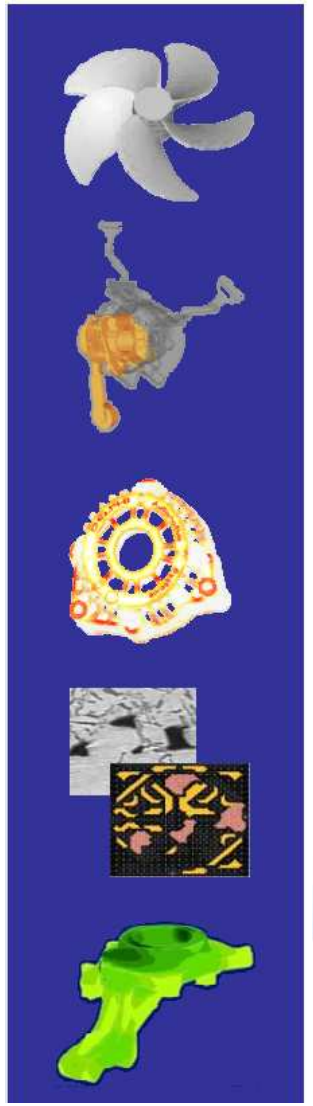
WinCast®
Finite Element
Simulation Software



October 1984
Foundation of RWP

Pioneer
in Simulation
of Casting Process

- **Introduction**
  - Facts of RWP
  - Increasing use of computer for the component development
  - The tendency of callback in the automotive industry is growing
- **Current Situation for the Development of Castings**
  - Using CAE-Tools
  - Using WinCast
- **Virtual component development- Possible results in the moment**
- **Improvement of the forecast of mechanical characteristics**
- **Micro FE**
  - Micro Tensile Test
  - Mono Materials
  - Tensile Test Synthetic
  - Rebuilding of a Real Micro Structure
- **Example Stub Axle**
- **Conclusion**

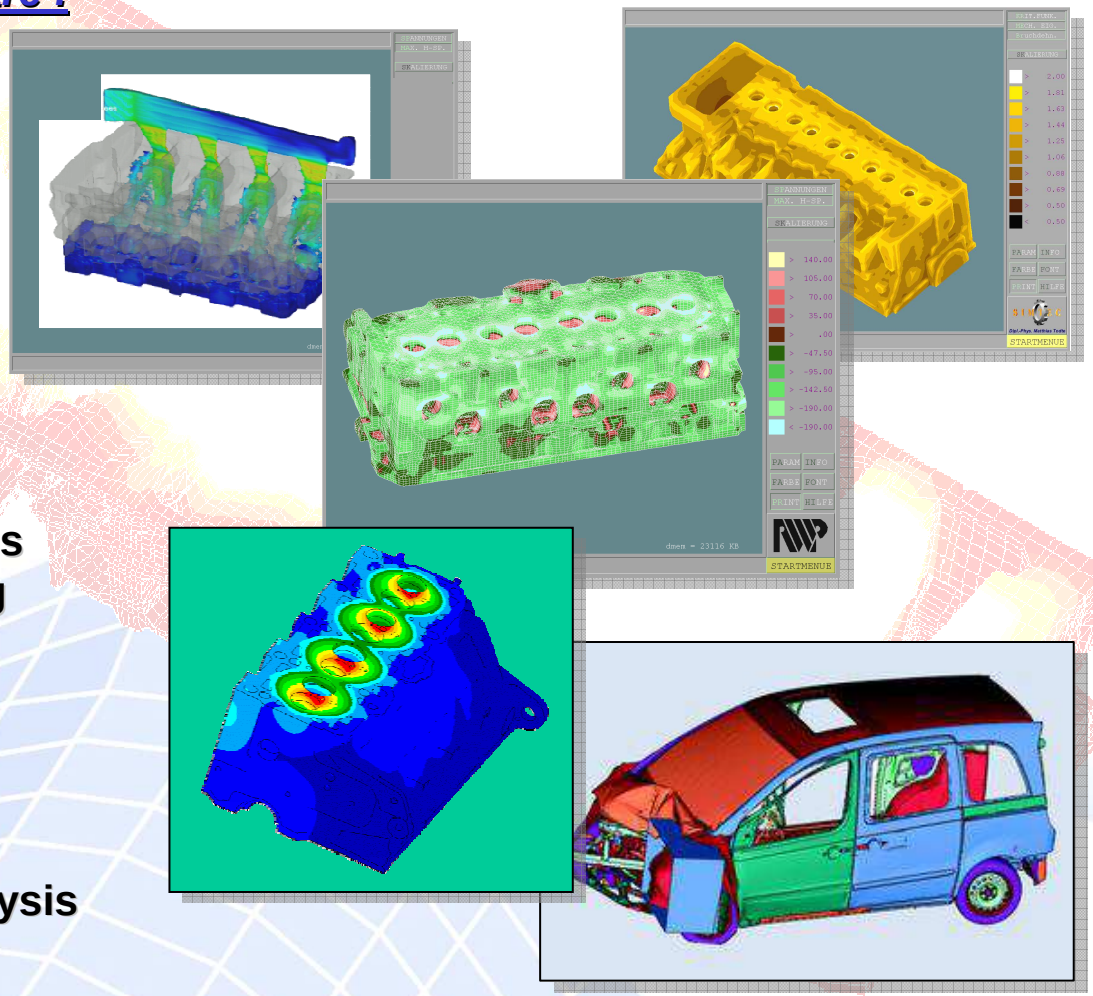
Facts of RWP

- **1984 RWP** was founded after basic developments at the RWTH Aachen done by Dr. Konrad Weiß
- **High experienced** software company developing casting simulation software
- **WinCast®** and **SIMTEC** are our software products for simulation of casting and cast processes
- **RWP** has become a **Global Company** with branch offices in USA, China, Russia, Spain, Czech Republic, Korea, India etc**.**
- **RWP** is an **expert** in **casting engineering** and supplies you with technical seminars, engineering services and software developments
- **RWP** works as a **partner of industry and universities** for external development and research projects on national and international level
- **Main industrial fields** of **RWP** are design and construction of optimized components, casting of metal and plastics, foundry process simulation and the simulation of welding, laser welding and process optimization

Increasing use of computer for component development

Possible application areas for software :

- CAD - construction
- Topology optimization
- Stability- and Structural analysis
- Life cycle calculation
- Production analysis
  - ⇨ mould fill simulation
  - ⇨ cast and solidification process
  - ⇨ heat treatment and machining
- Crash analysis
- Vibration- und Acoustic analysis
- Flow analysis
- Multiple component system analysis
- Electromagnetism analysis



The tendency of callback in the automotive industry is growing.

Different reasons :

- more hightech with higher risk of failure
- shorten model cycles as well as shorten development times
- tight calculated development and production costs

Possible way of solution :

- virtual Product development
  - ⇨ drastic reduction of development time
  - ⇨ saving on Prototypes
  - ⇨ efficient and faster introduction of serial production

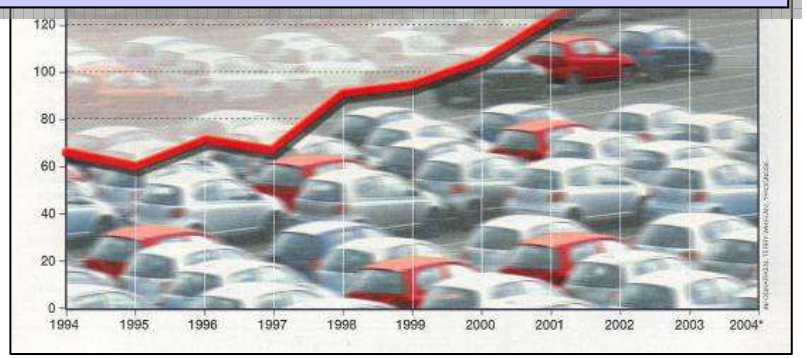
⇨ ***Saving of time, costs and material during the development process***

Toyota

Callback of 1,8 Million cars due to clamped gas pedals

„Sometimes it seems that the car driver will be misused as a test driver. “

A. DEMMEL (Leader automotive technique ADAC)



No. of callbacks during the last 10 years [Source: ADACmotorwelt 12 / 2004]

Current Situation for Development of Castings by using CAE

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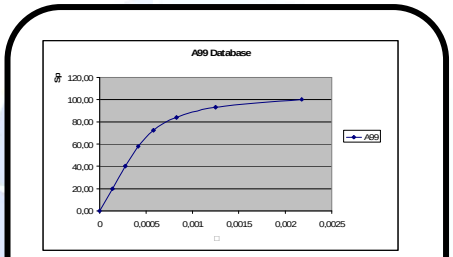
für Berechnung und rechnergestützte Simulation mbH



Stress- Elongation-Diagramm

The used physical properties are based on standard tensile tests
=> Homogenous Material

Design → CAE → Release 01/02/.. → Tests

Optimization

Optimization

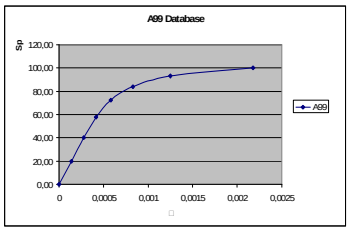
Final product

- High safety factor
- High weight
- High costs
- Quality level not easy to increase

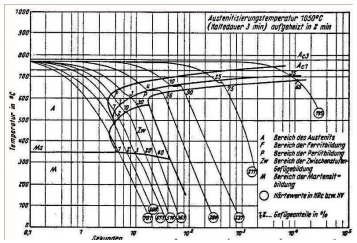
Conclusion

Due to the dependency of current material information no adequate forecast of the mechanical behaviour of the component

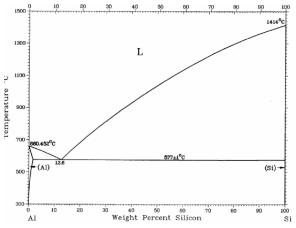
Current Situation for Development of Castings by using WinCast



Stress- Elongation-Diagramm

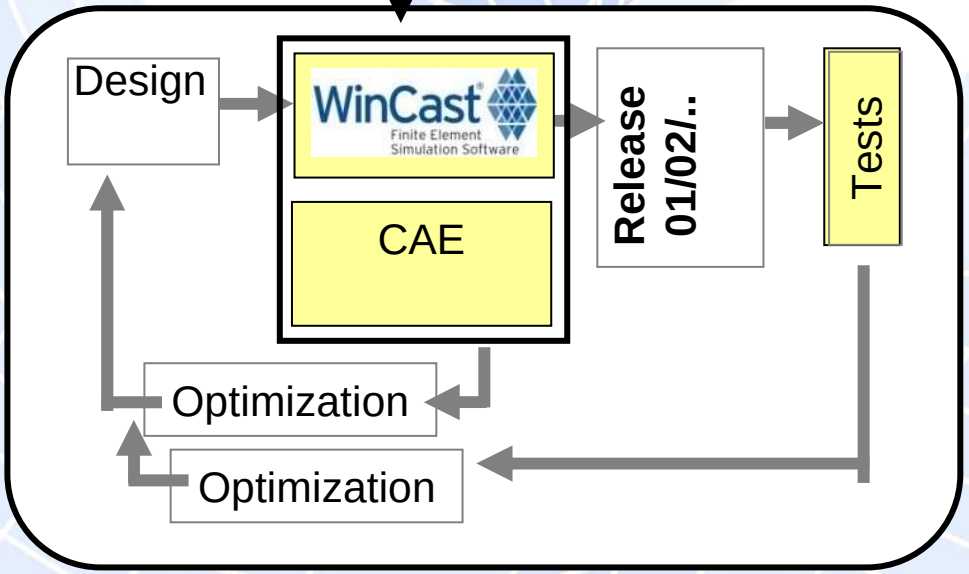


Carbon-Iron-Phase-Diagramm



Al-Si- Phase-Diagramm

Taking the material properties into account due to solidification time



Final product

- (Still) High safety factor
- Weight can be reduced
- High costs
- Quality level can be increased

Conclusion

Still dependency of standard material information so the forecast of mechanical properties still are not adequate enough

Virtual Component development- Possible results in the moment

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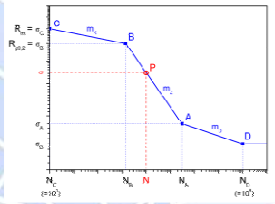
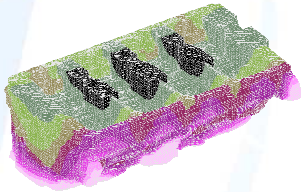
Virtual component development of a cylinder head

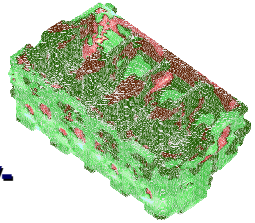
Prototype introduction of series production

Life cycle prediction

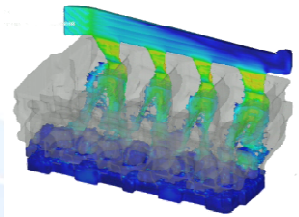


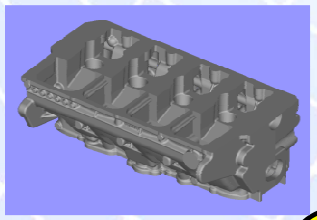


FEM-Stability-calculation



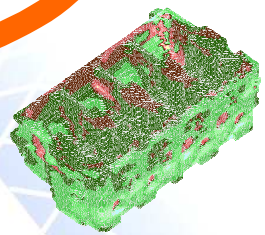
Stress simulation
- Casting process
- Heat treatment
- Machining





CAD-Construction
- Topology optimization
- Structural optimization

Mould fill- and solidification simulation



Determination of mechanical Properties

Basics

Virtual Component development- Possible results in the moment

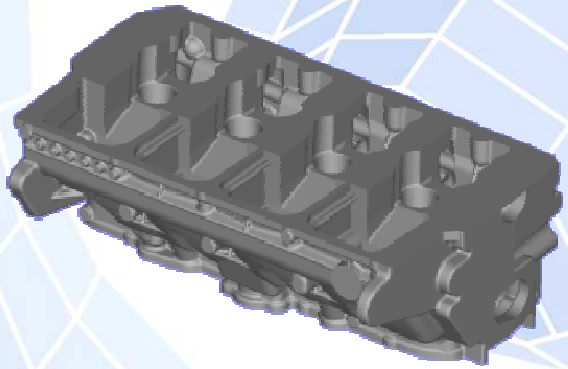
The CAD data are the starting point

The macroscopic simulation is used for form filling and solidification

The result of the macroscopic temperature calculation can be used for the prediction of macroscopic mechanical properties

Residual and load stress can be superimposed in order to evaluate the limits for strength fatique

The prototype building is the target

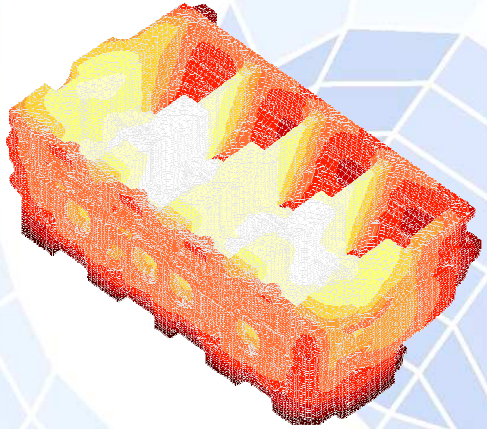


CAD Data is available as solid models and can be used for simulation after transformation into the STL-Format

CAD Data

CAD Data is generally already available during the various component development steps. Initial simulation results for the casting process chain can be achieved even with a low degree of detail of the component.

Virtual Component development- Possible results in the moment

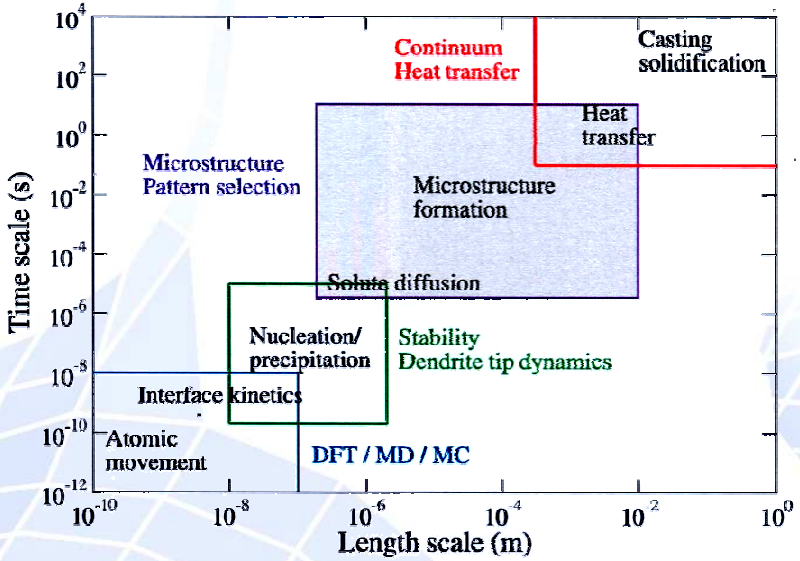


Calculation of form filling and solidification is achieved using differential equations
(Navier-Stokes, Fourier)

Physical data is necessary for the simulation.

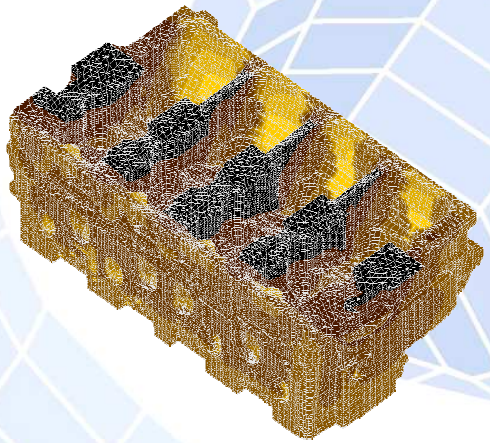
Form filling and solidification

Calculations can only be done in the area of 10^{-2} – 10^{-3} m.



Micro-models are necessary in order to determine solidification phenomina.

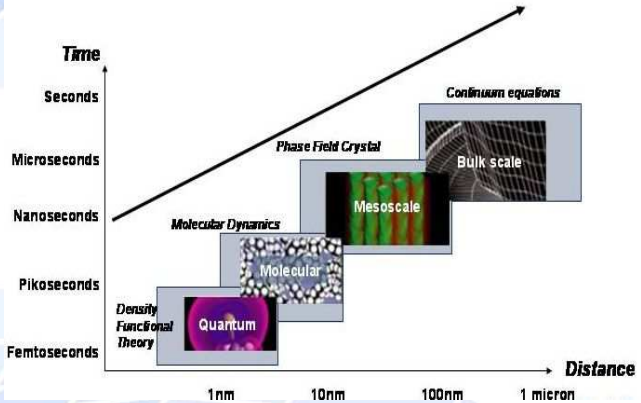
Virtual Component development- Possible results in the moment

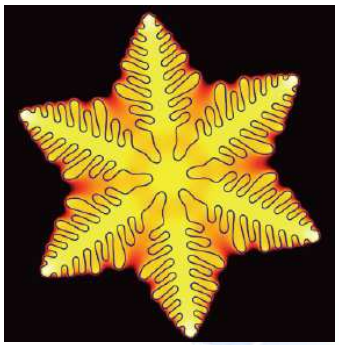


The macroscopical statements were developed using empirical investigations. The results are very close to those of investigations on real.

Structure/Microstructure

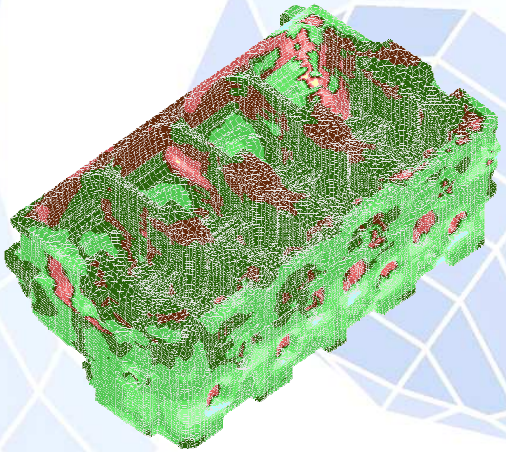
Initial calculation of structures and microstructures are carried out on various levels.





The various models are in development and need more effort in research and development.

Virtual Component development- Possible results in the moment



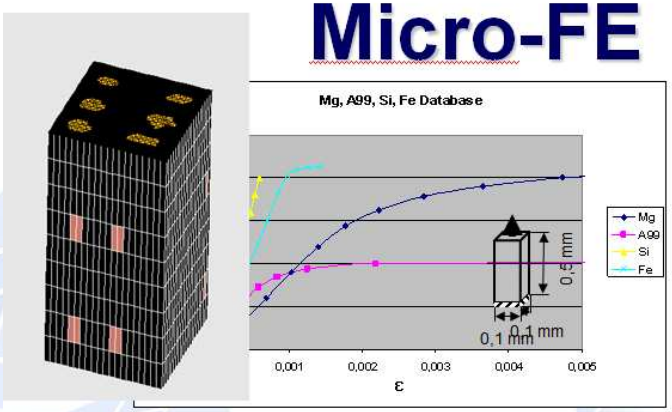
The residual stresses are the result of the cooling sequence during casting and solidification.

The load stresses result of the calculation of the various load situations.

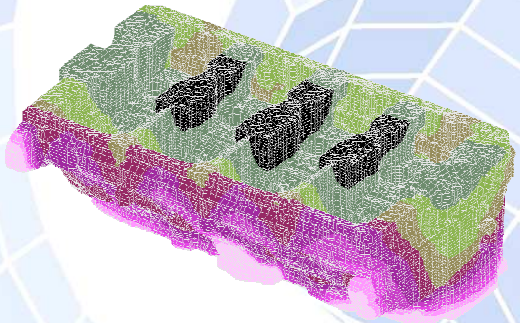
Residual- and Load stresses

Various physical/mechanical characteristic data are required for consideration of the local mechanical characteristics within the.

Micro-FE



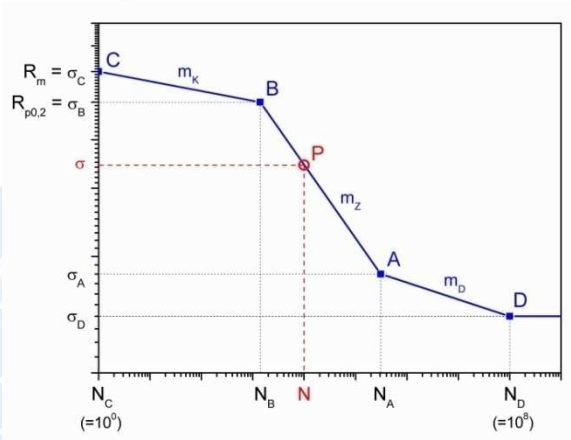
The calculation of these various data can be achieved via virtual material development.



The calculation of the local stress cycle diagrams is developed from the macroscopic temperature profile.

Life cycle definition

Life cycle definition is achieved by comparing the various load collectives with the local stress cycle diagram.



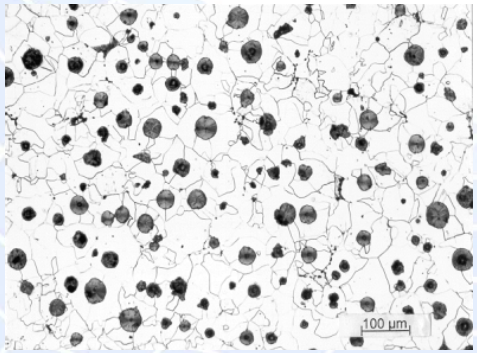
Solidification conditions and composition must be considered when calculating the local stress cycle diagrams.

Prototyping will continue to be necessary in the future, however, the number of components will be greatly reduced due to the capabilities of virtual component testing.

Prototype / Series production

The effort put into producing components after the casting process chain are not only usable for the development of prototypes. Simulation of the production chain, and therefore the influence on the appropriate component quality areas, deliver results which are used for the design of components, tools and processes.

Improvement of the forecast of mechanical characteristics



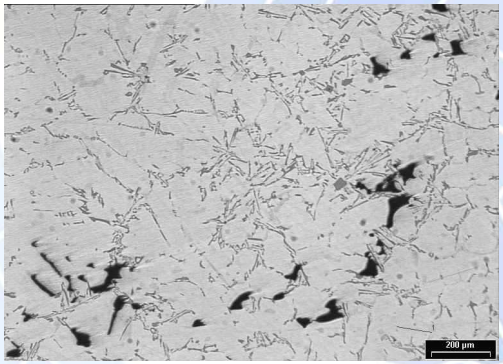
The consequence of different wall thicknesses and local conditions leads to different temperature gradients and solidifications times

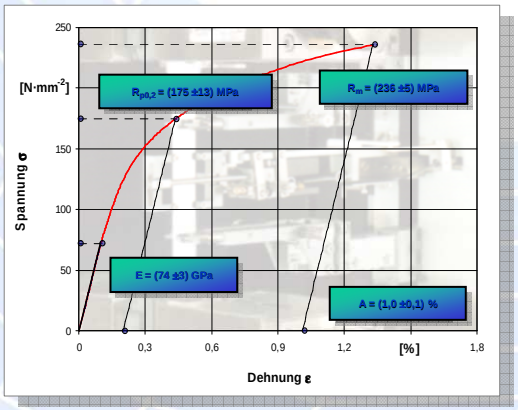
Micro structure is not homogenous
Distribution of Mechanical properties are within a range

What must be done?

The demand to get more and more information about the material properties already in the design stage of a new component leads to the necessity to know more about the building mechanism of the basic matrix. Here we give one important step to get more detailed information on the mechanism of building different mechanical properties.

Improvement of the forecast of mechanical characteristics



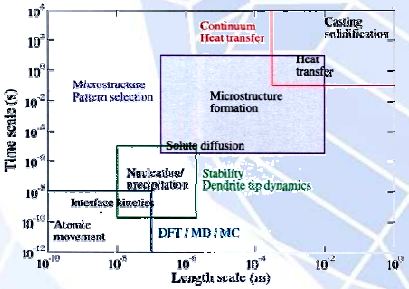


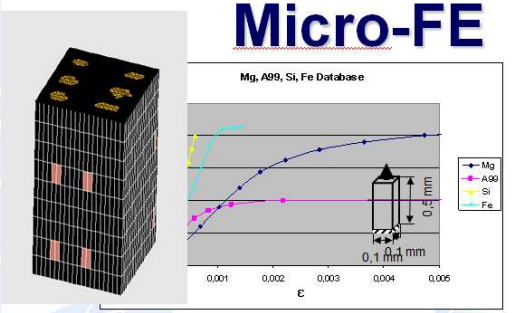
The classical approach for the evaluation of data ist time-consuming and strongly dependent on test conditions. New alternatives have to be found in order to be able to describe the various structures and the local conditions within the components.

Lets take a different route

- We create various virtual basic structures and test their characteristics.
- The characteristics are validated with targeted experiments.
- Constrution of synthetic structures
- Comparison of real and synthetic structures
- Creation of a correlation between solidification conditions and synthetic structures.
- Creation of a database for the calculation of the expected mechanical properties.

Improvement of the forecast of mechanical characteristics





Development of tools

Tool 1

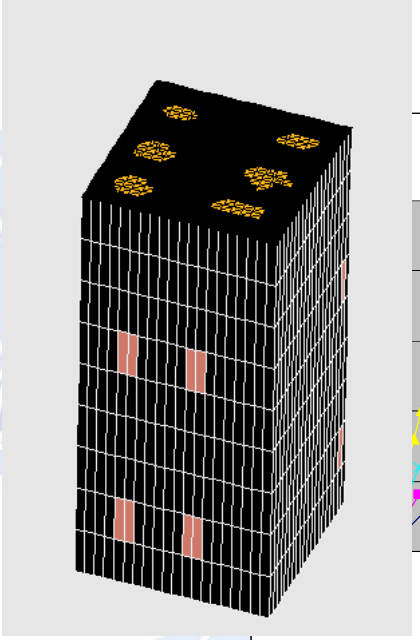
The coupling of micro- and macro-simulation with the consequences on the solidifiction sequences combines nucleation and growth as well as the release of latent heat with the expected structures.

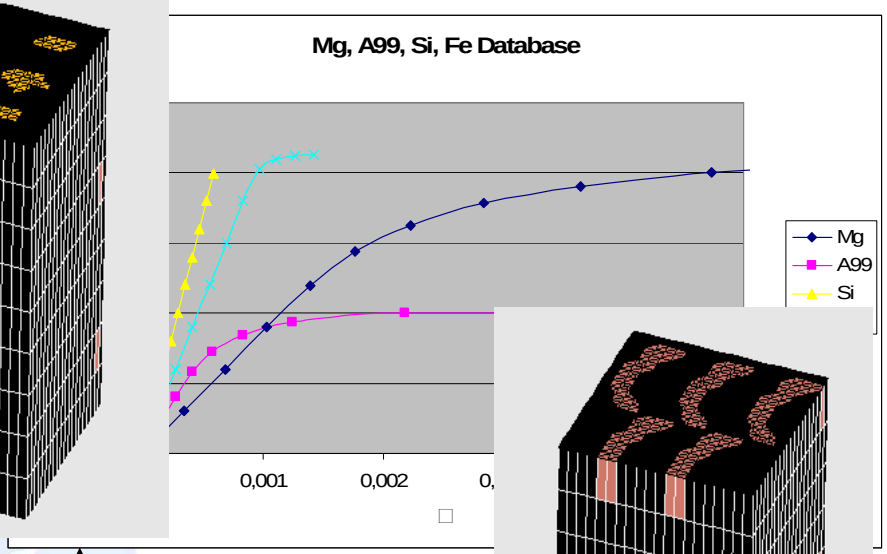
Tool 2

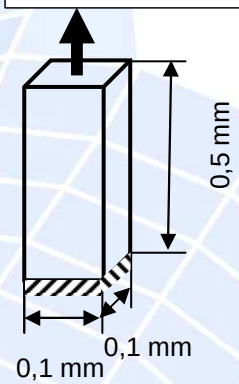
Micro-FE shows the possibilities and limits of the various materials and processes. This method can also be used to create missing physical and mechanical data.

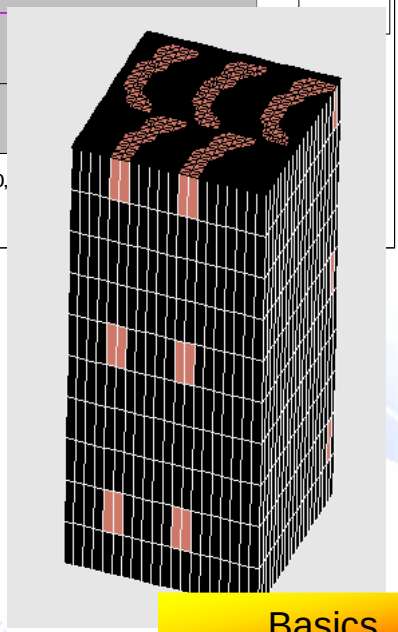
Micro-FE

With the cristal, eutectic, matrix calculation we can see what happens during solidification. The resulting mechanical properties can not be defined.
Therefore we will have a look at the micro FE analysis to get more information about the relationship between microstructure and mechanical properties.





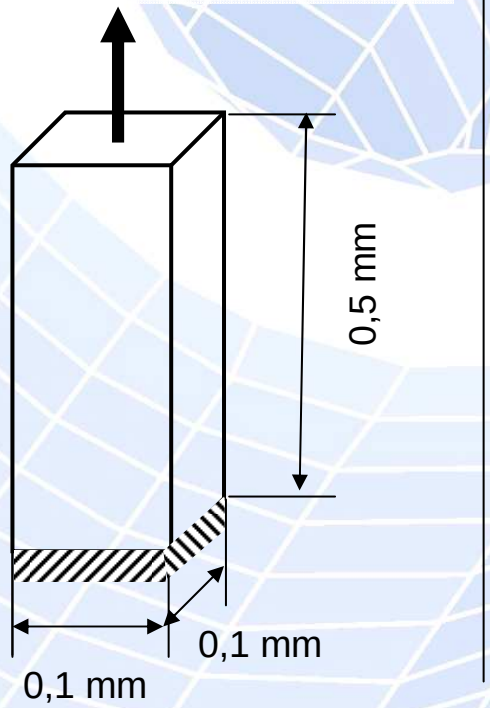


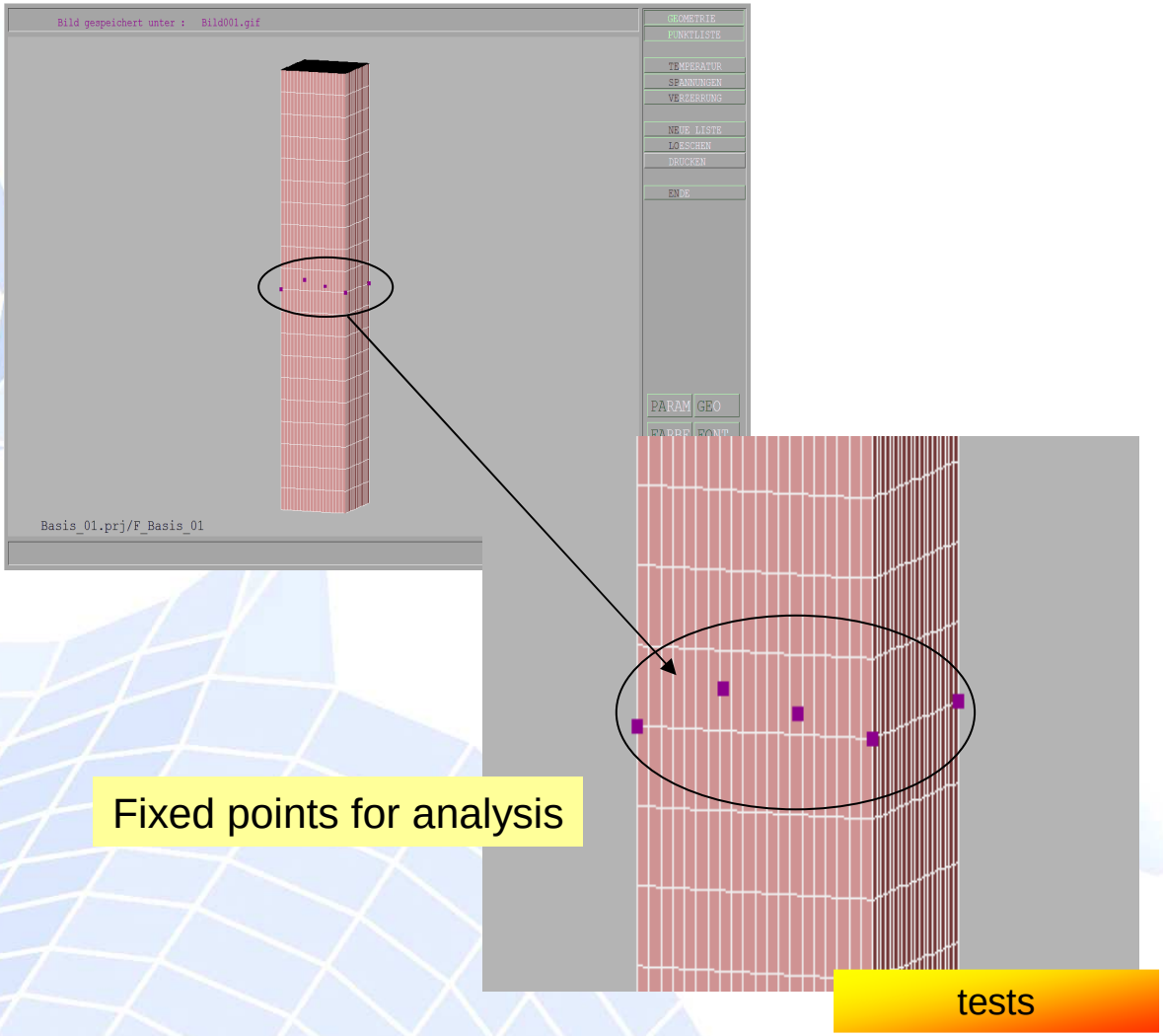


Basics

Micro Tensile Test

The tests of the mechanical properties are done with a micro tensile test .

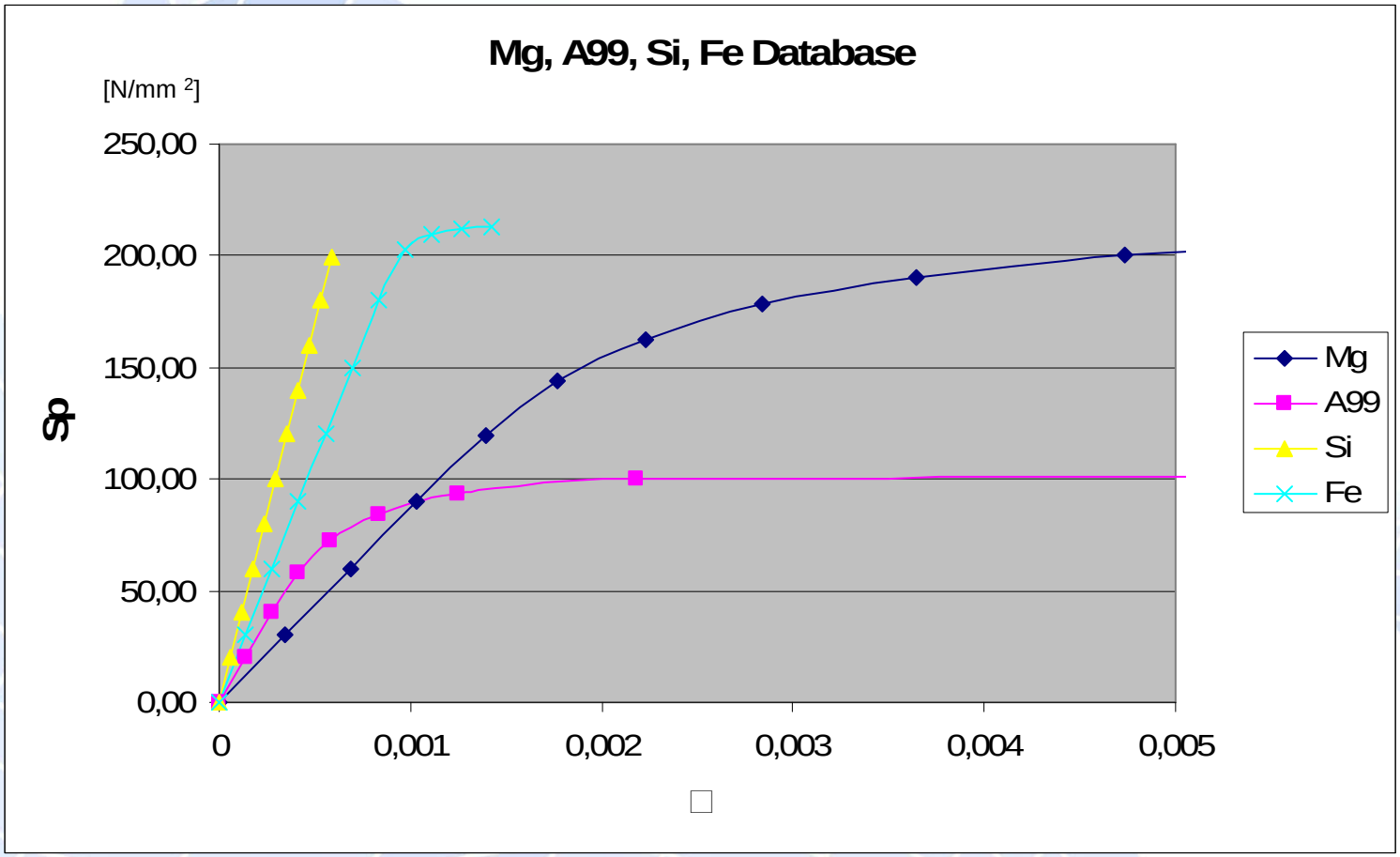




Fixed points for analysis

tests

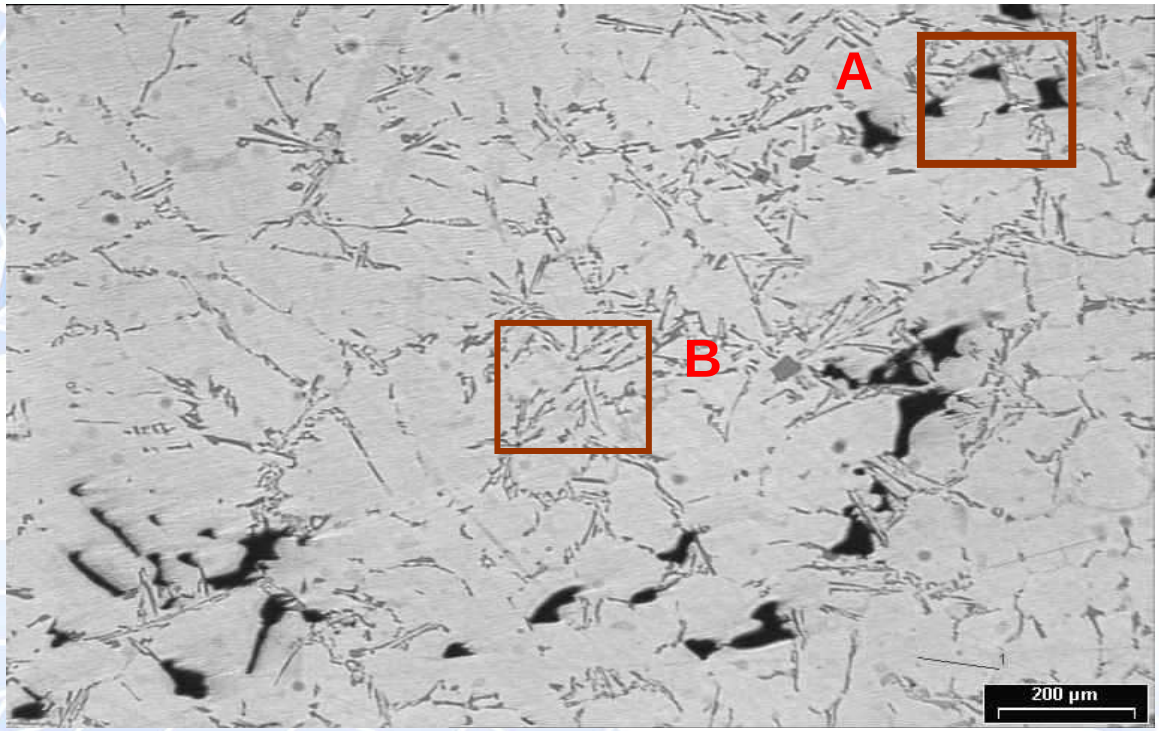
Mono Materials



tests

Rebuilding of Real Micro Structure

We are interested in the mechanical properties in specific areas of a real microstructure.
We need to know how the influence of the silica in the Alpha phase will be(A), also we would like the influence of the porosities(B).

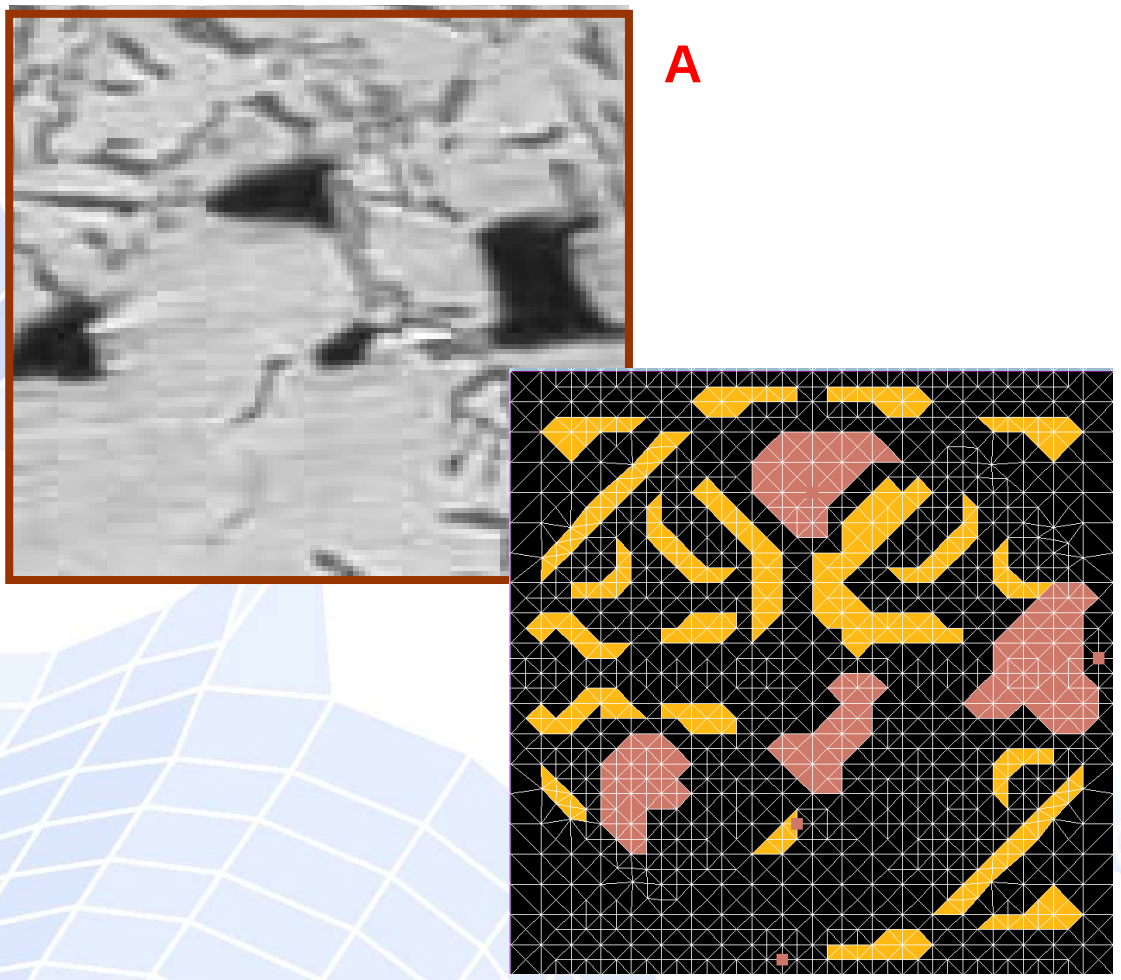


Model building

Rebuilding of Real Micro Structure

We build the finite Element mesh to have a description of the matrix. The red areas represent the pores.

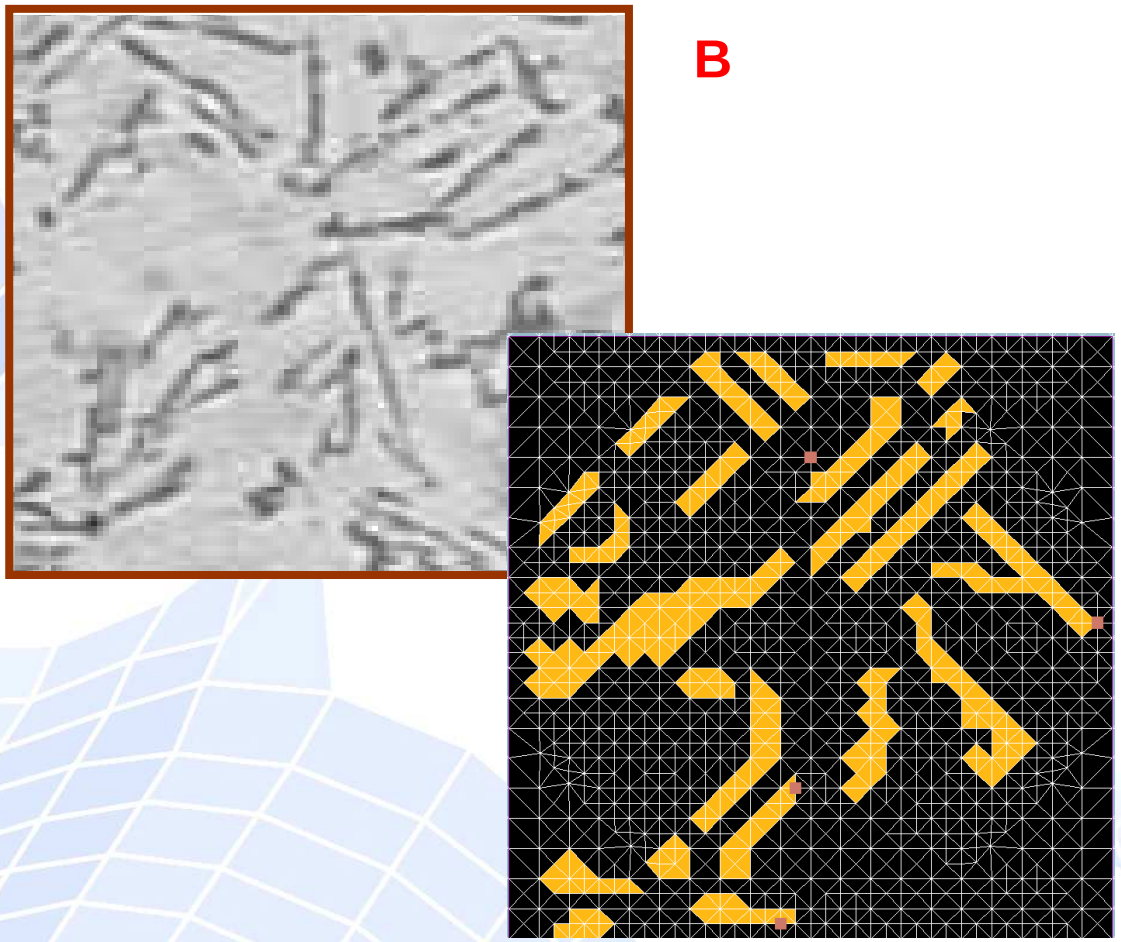
With this method it is possible to see the influence of the shape of porosities.



Model building

Rebuilding of Real Micro Structure

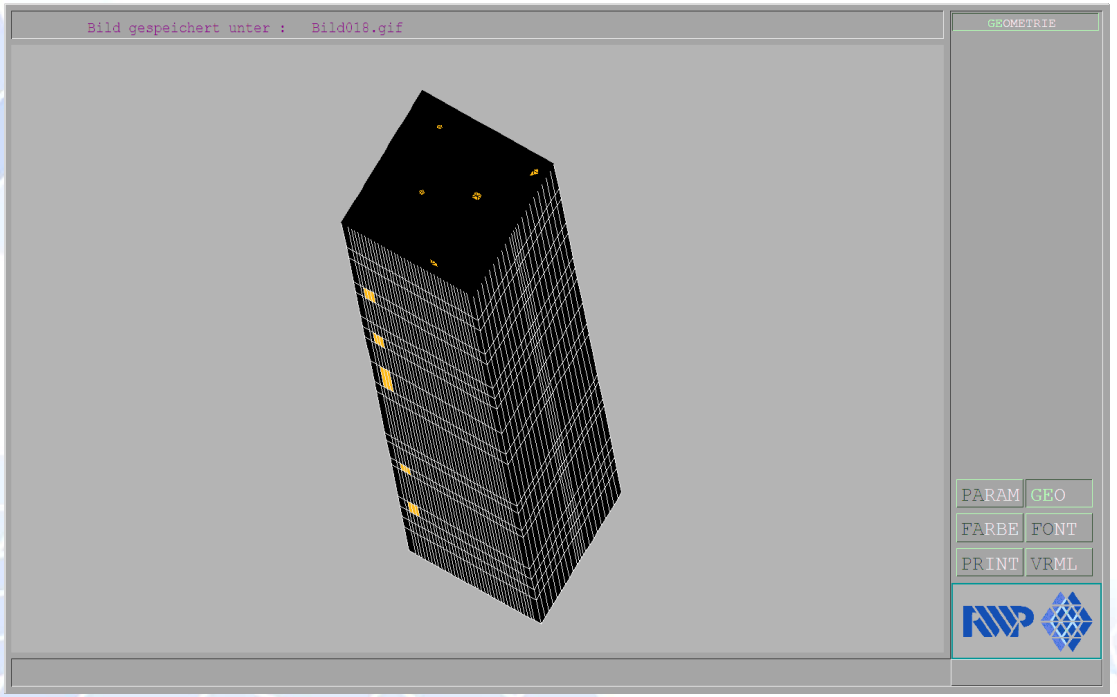
Here we just bring in the silica distribution into the Alpha matrix. Different shapes and sizes can be built.



Model building

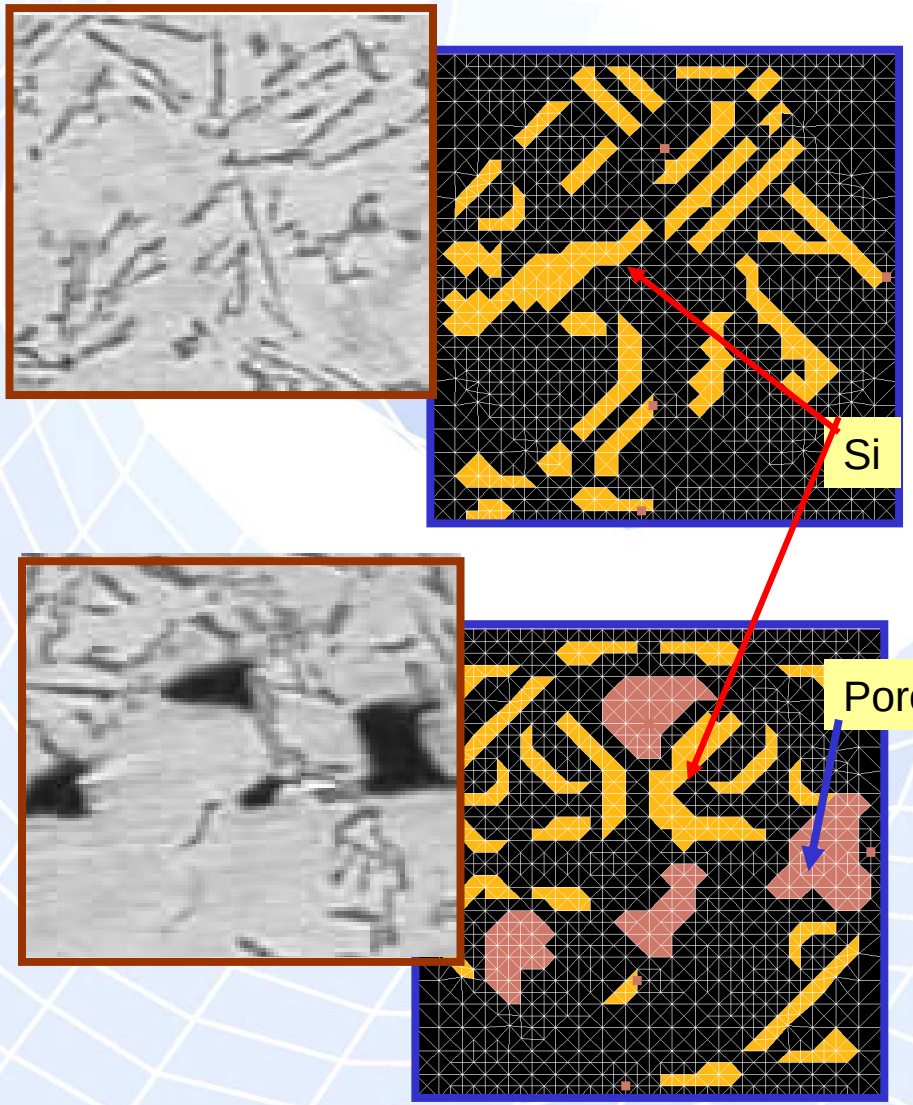
Rebuilding of Real Micro Structure

The view through the testing part shows the distribution of the different „disturbants“. This is possible In all directions.



Model building

Rebuilding of Real Micro Structure



Tensile Test synthetic

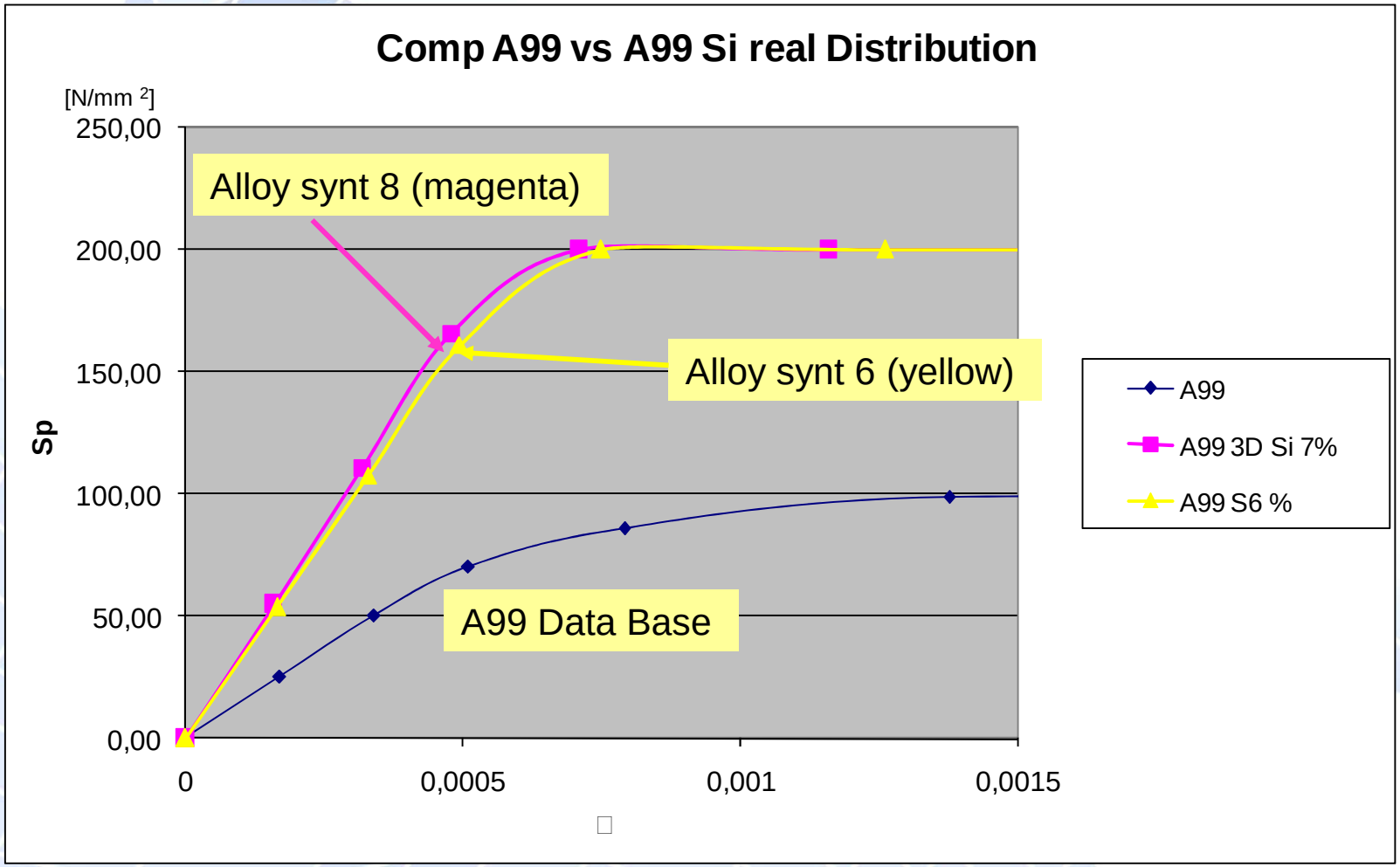
Alloy synt 6 with real distribution
A99 Si 6 %

Alloy synt 7 with real distribution
A99 Si 6 % and porosities

Alloy synt 8 with real distribution
A99 Si 7 %

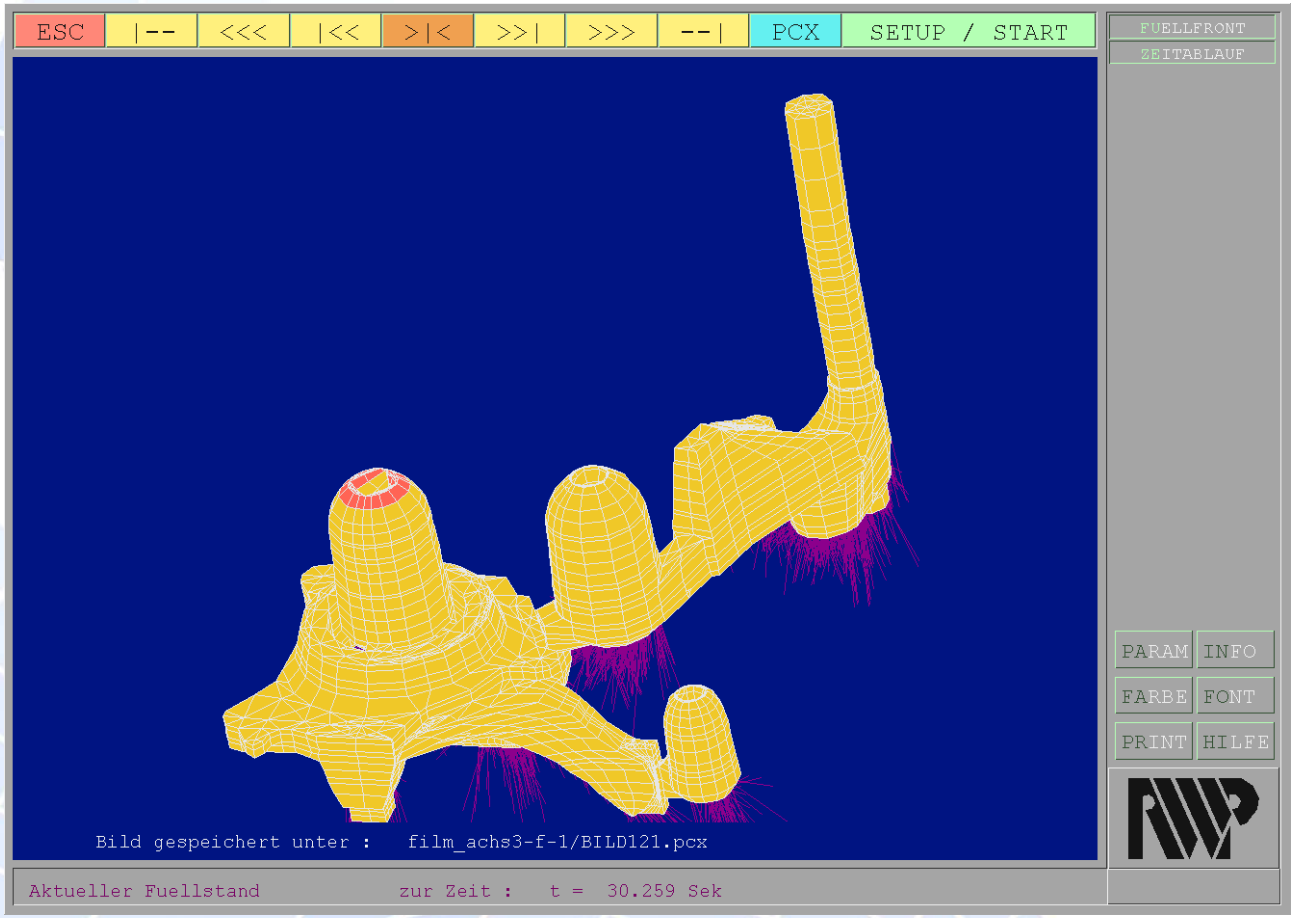
Tensile test alloy synt no 6 -8 to compare real distribution of alloying elements

Influence of real distribution of Si and porosities



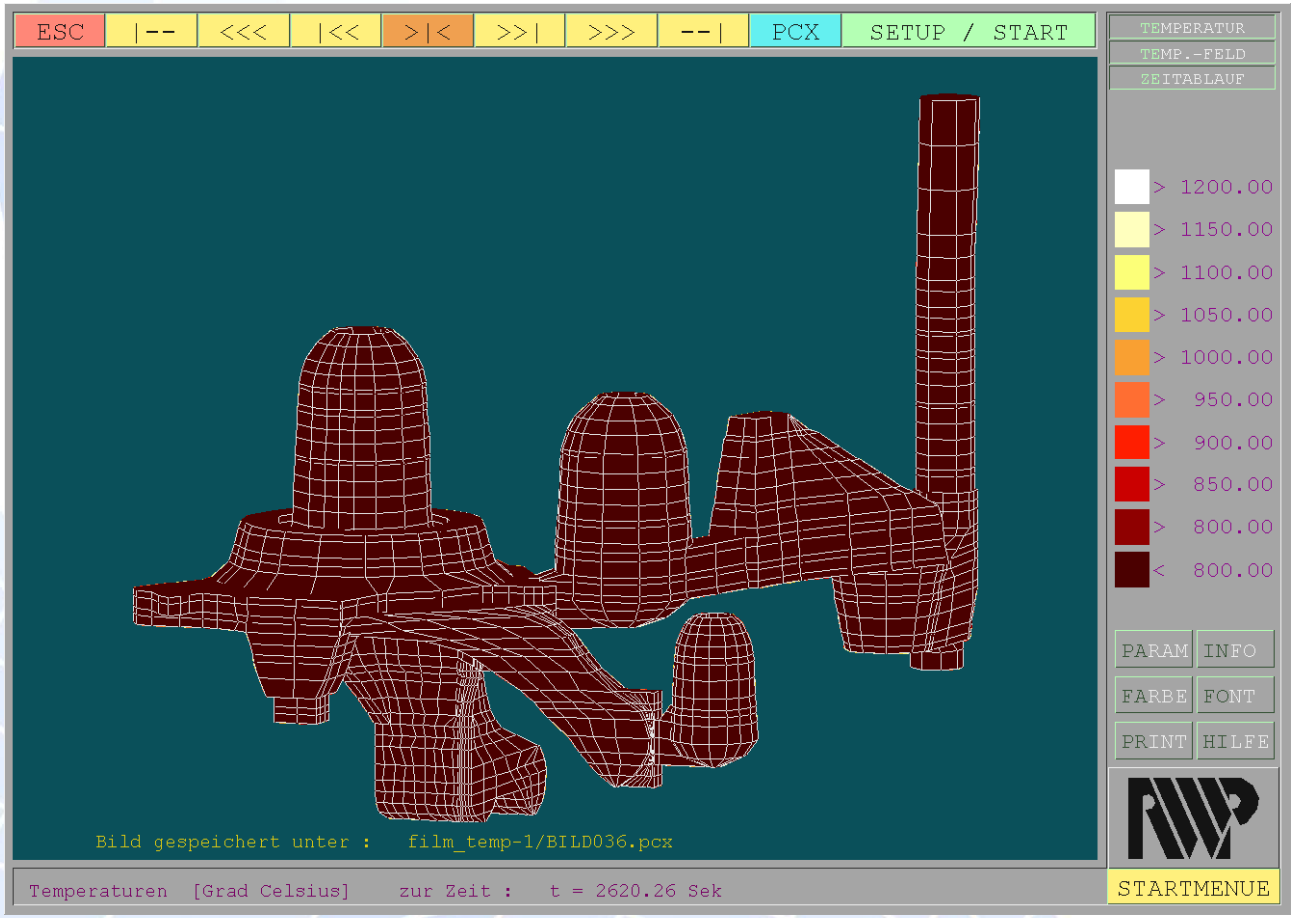
Example Stub Axle

Example Stub Axle



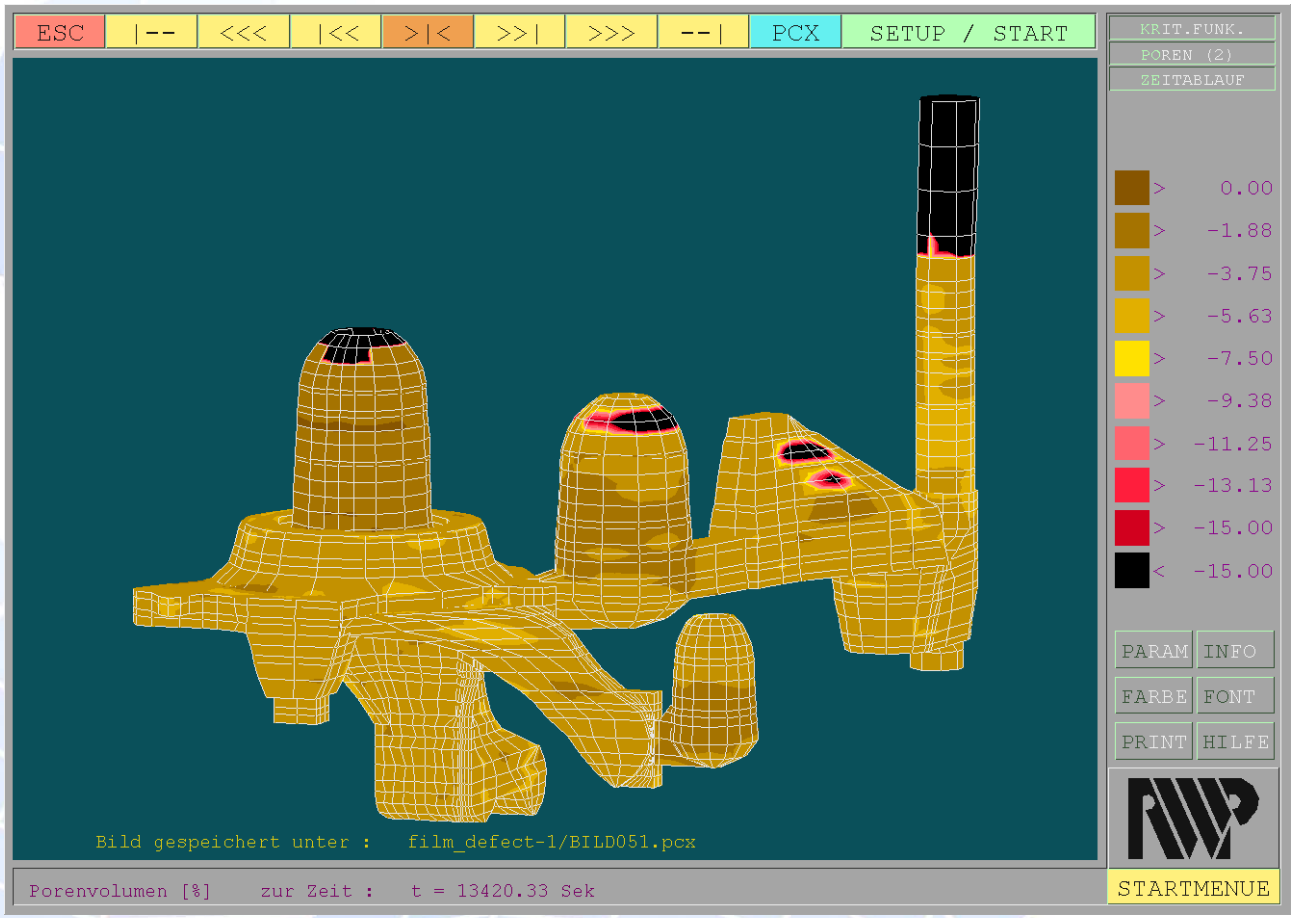
Mould filling animation

Example Stub Axle



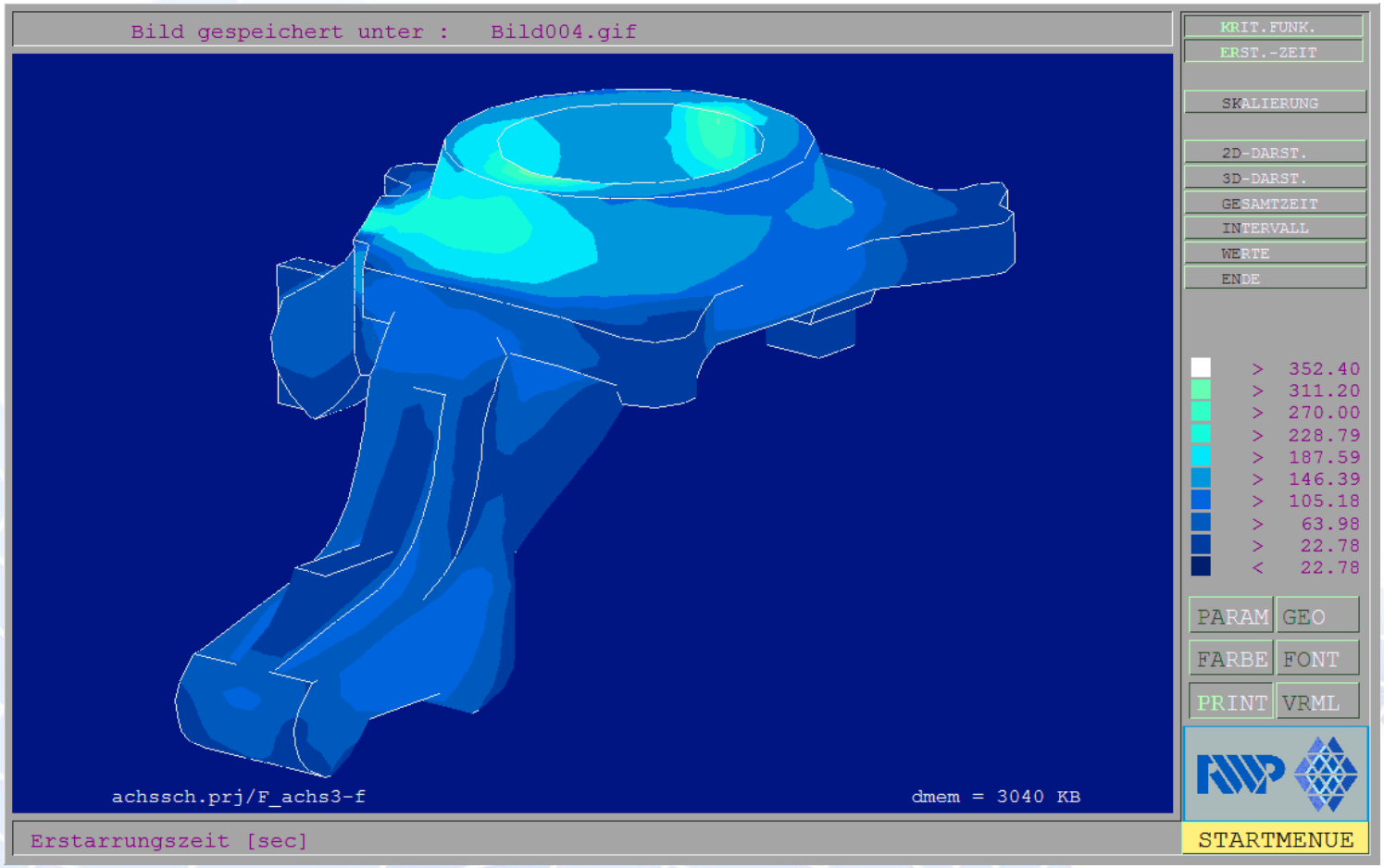
Temperature field animation

Example Stub Axle



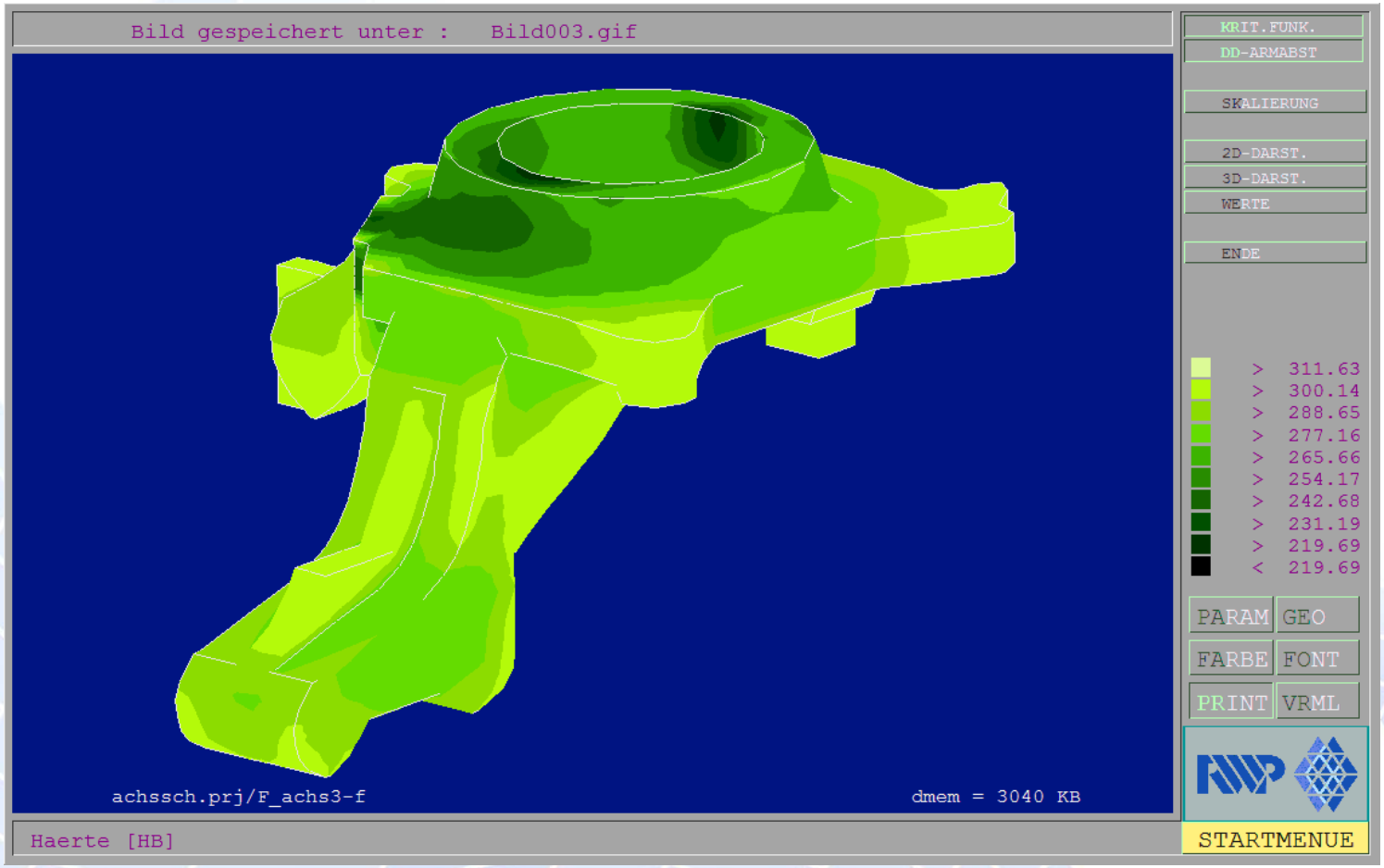
Defect building animation

Example Stub Axle



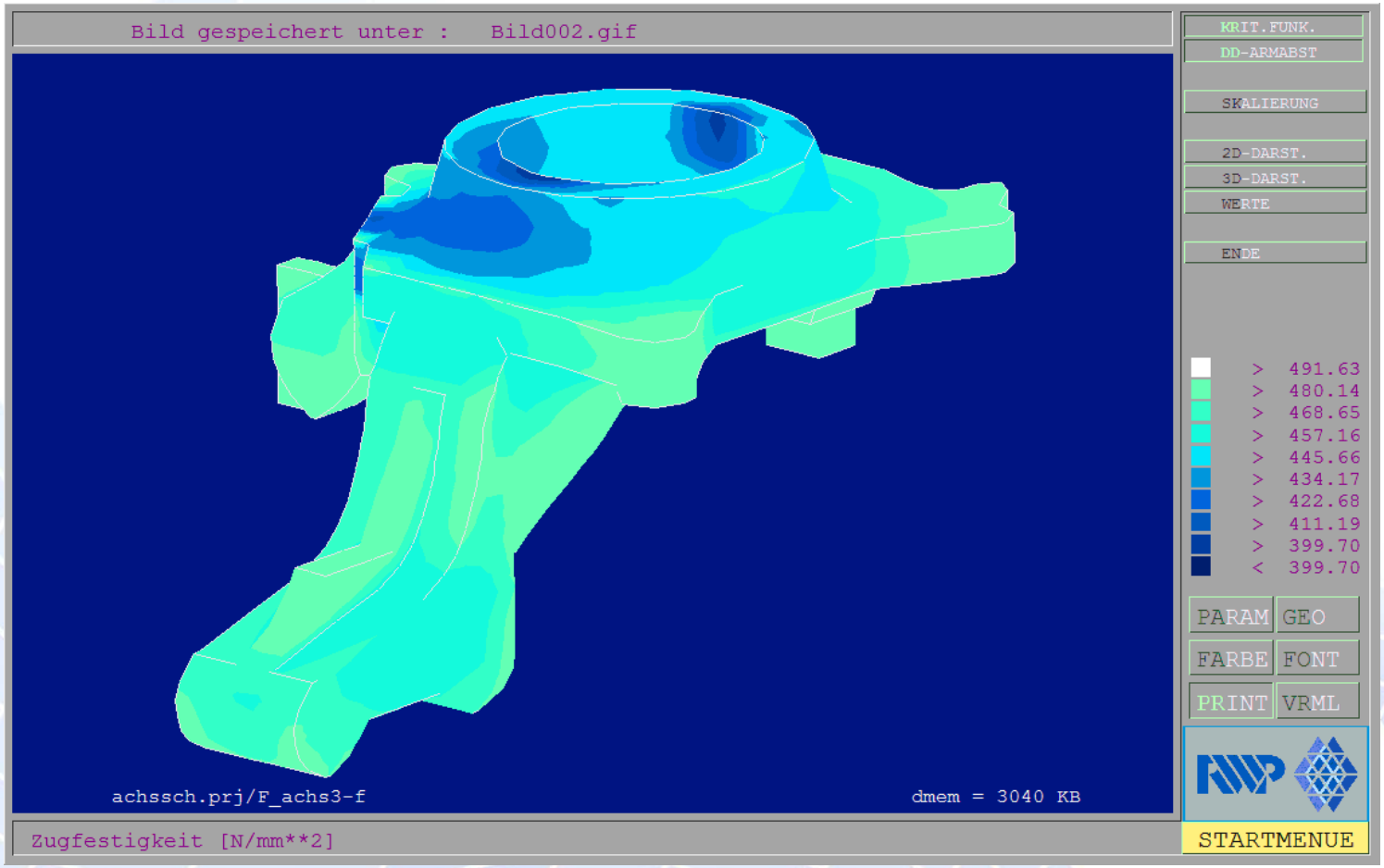
Solidification time

Example Stub Axle



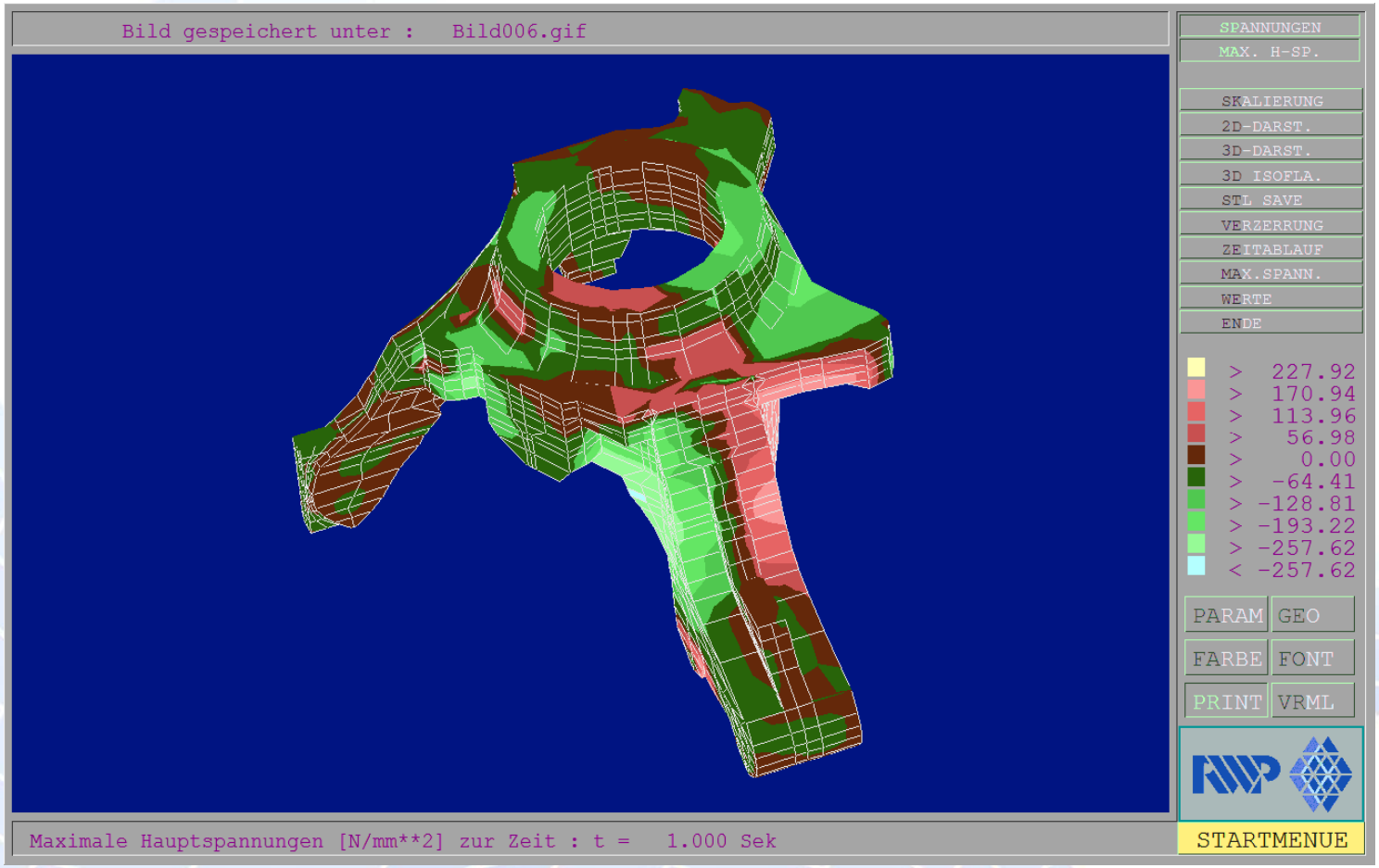
Hardness distribution

Example Stub Axle



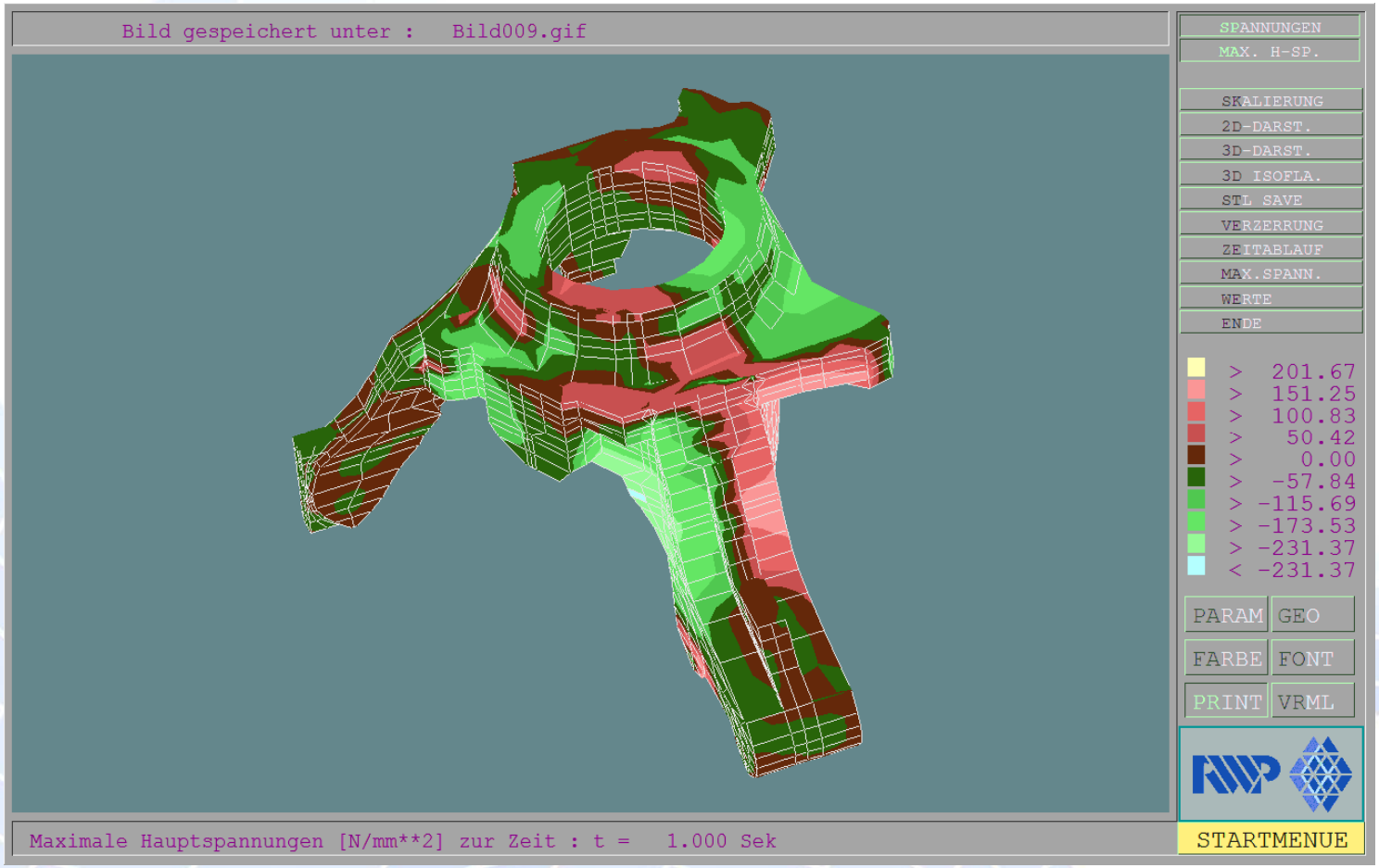
Tensile strength distribution

Example Stub Axle



Principle stress distribution with respect to classical mech. properties

Example Stub Axle

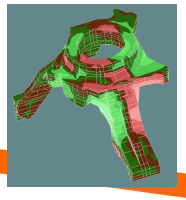


Principle stress distribution with respect to synthetical mech. properties

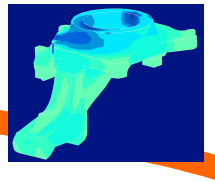
Virtual componetdevelopment with Micro FE

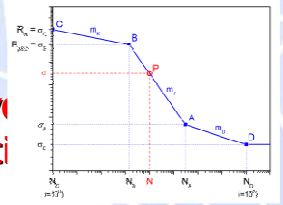
Prototype introduction of Series production

FEM-Stability-calculation



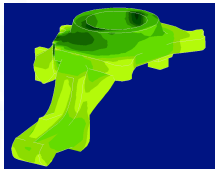
Determination of mechanical properties

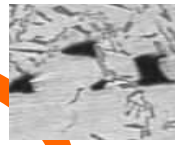




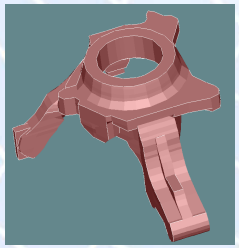
Life cy
predicti

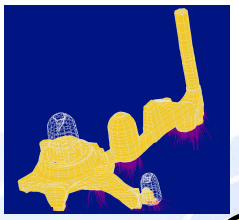
Stress simulation

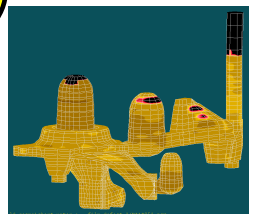




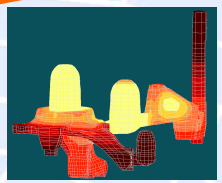
Matrix determination Micro FE







CAD-Construction



Mould fill- and solidification simulation

Defect calculation and graphit expansion

Conclusion

Further work to do

Determination of real matrix distribution

Determination of real mech. properties

Determination of matrix solidification time relationship

Creation of a building set for different alloys

Etc.

Thank You