Influence of Die Evacuation on Mechanical Properties and Heat Treatability of HPD-Castings

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3rd International Forum on Vacuum Die Casting

May, 30th-31st 2018
Vevey, Switzerland

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- Show case: Squeeze-cup
- Show case: Engine torsion support
- Conclusions

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The ÖGI

- ÖGI is a joint research Institute of the Austrian foundry industry, established 1954, 42 employees
- Research facilities and competence in the whole field of casting technology is unique in Austria and ÖGI is one of the leading non university R&D–centers in Europe
- Accredited for 30 material test procedures according to EN ISO/IEC 17025
- Fully equipped pilot foundry for all casting processes and castalloys
- ÖGI is part and member of a technology network in Austria - ACR-Austrian Cooperative Research (second largest non university research organization in Austria, 650 employees)
- Close co-operation with the Montanuniversität Leoben, Casting Research Institute, connects fundamental and applied R&D

The ÖGI

Our competence is the hole field of casting technology

Raw material ➔ Casting processes/alloys ➔ Properties and use of castings

Business Areas

Applied Research and Development service	**Assessment of casting quality Failure analysis**
Material testing and Investigation	**Surface- and joining technology for Multi-material components**
Numerical Simulation of casting processes	**Engineering, Technology Transfer Special seminars and Education**

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- **Show case: Squeeze-cup**
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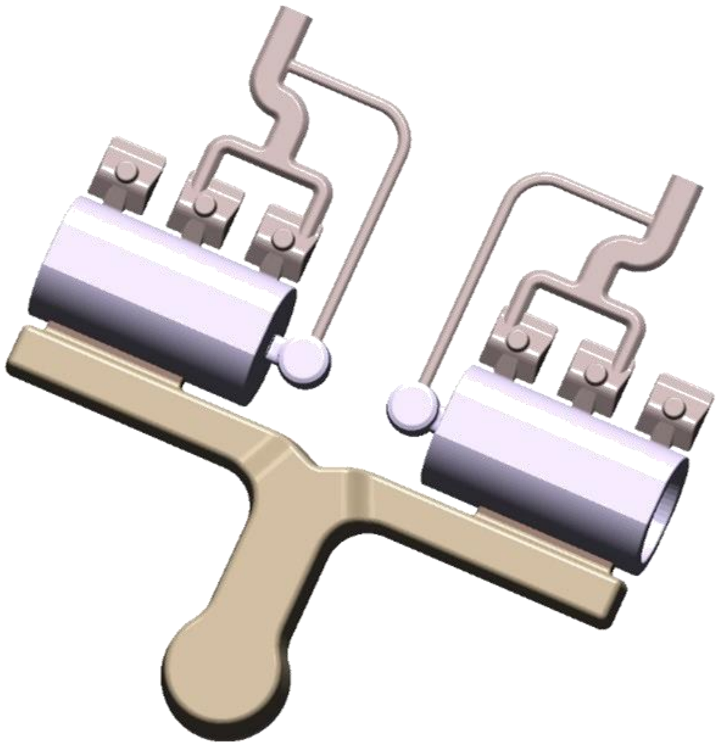
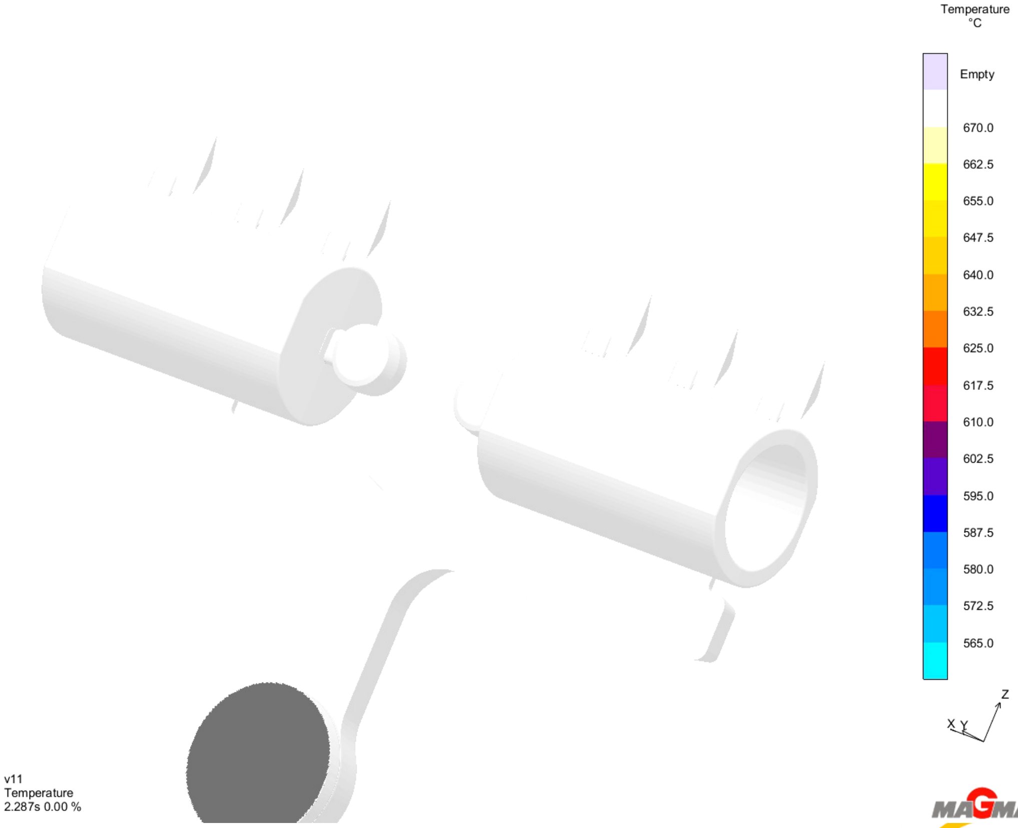
- Conclusions

Show case: Squeeze-cup

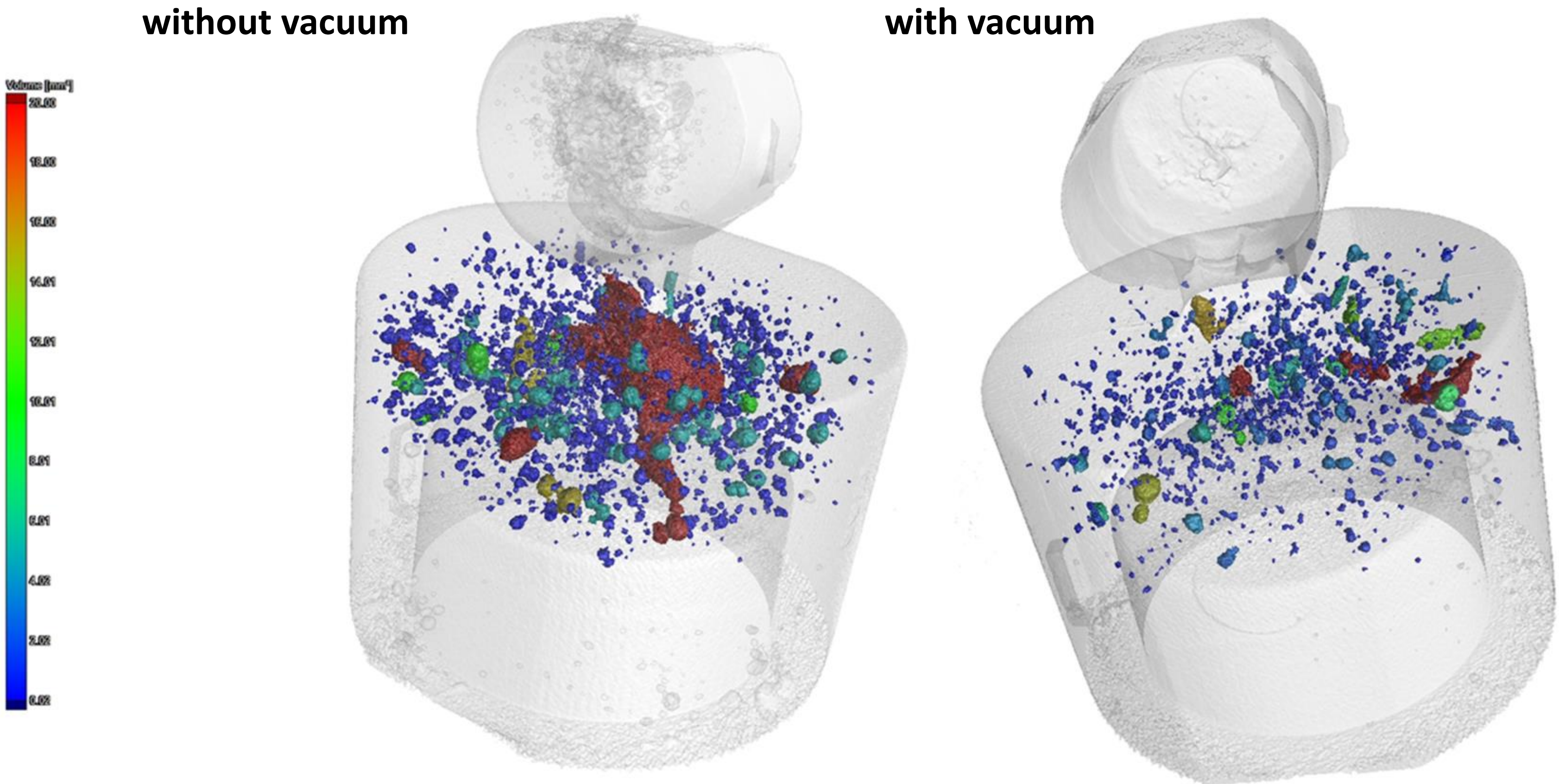
Massive walls and difficult venting leads to air entrapment





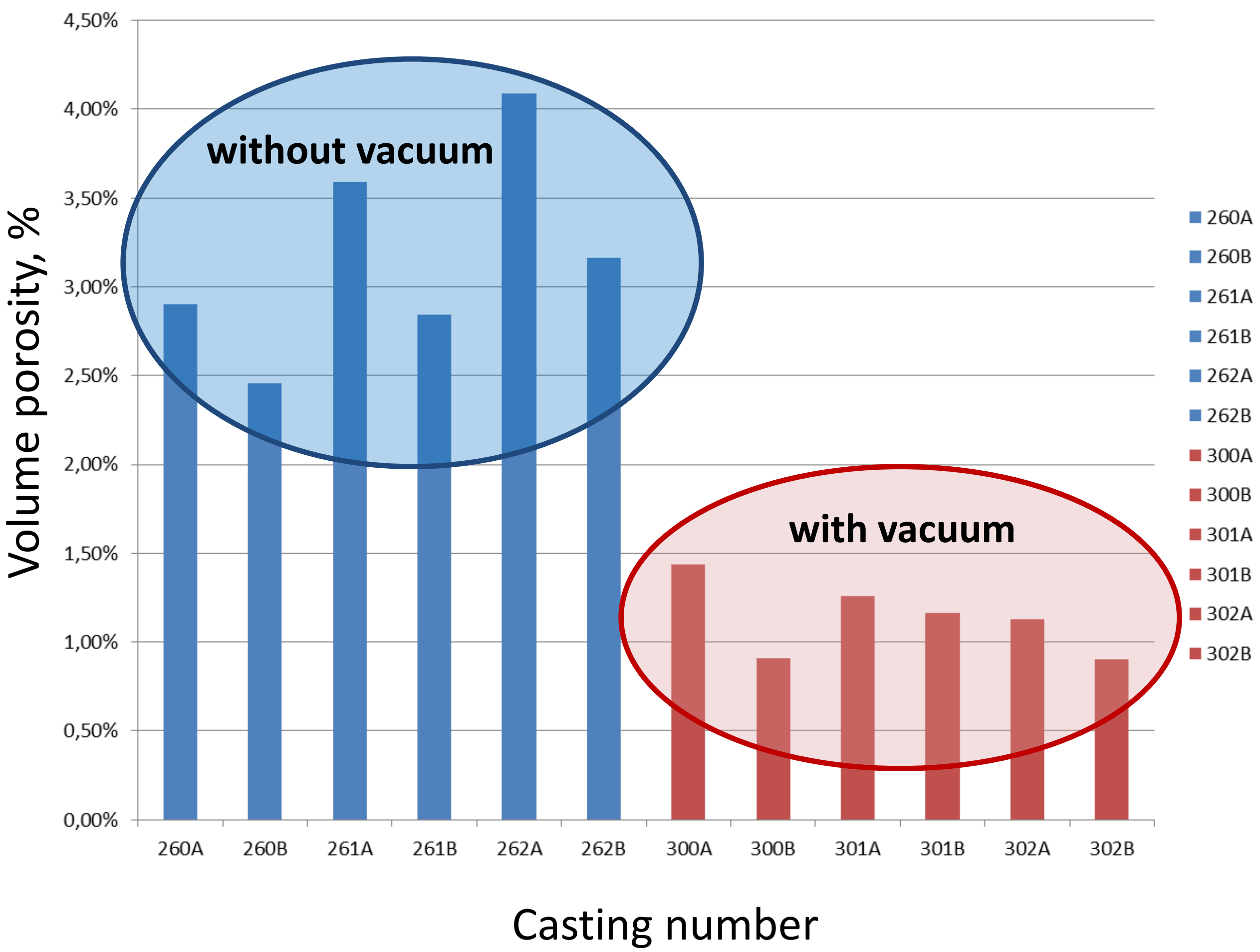
Two nests – reference and specimen

Show case: Squeeze-cup



Massive Porosity in both cases – no squeezing applied! Porosity is clearly influenced by die evacuation. Quantitative Evaluation of porosity by computed tomography

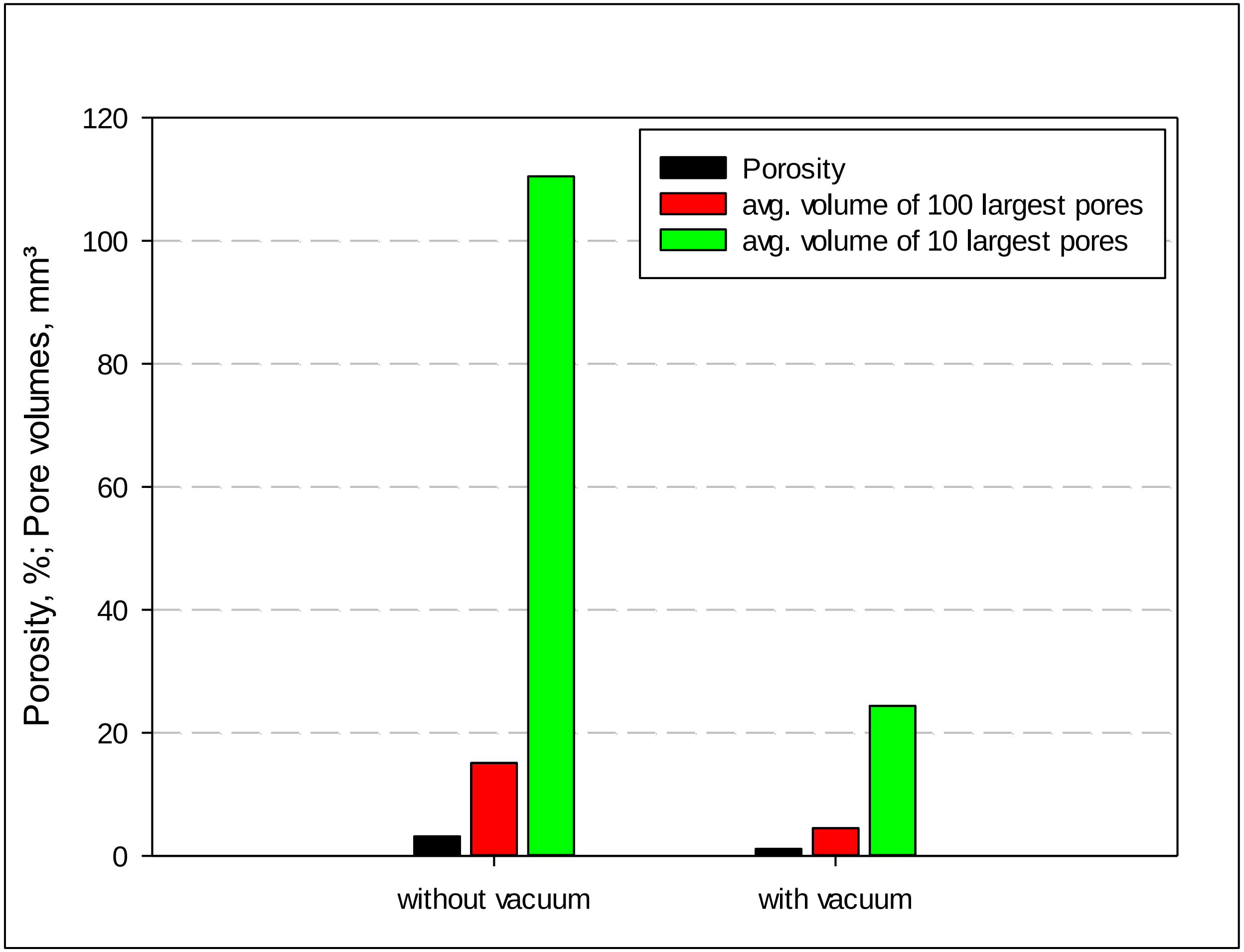
Show case: Squeeze-cup



Alloy: **Al226D**

Vacuum has a clear impact on overall volume porosity, by reducing it **approx. 60 %**

Show case: Squeeze-cup



Vacuum has a large impact on large pores which are mainly caused **by air bubble entrainment!**

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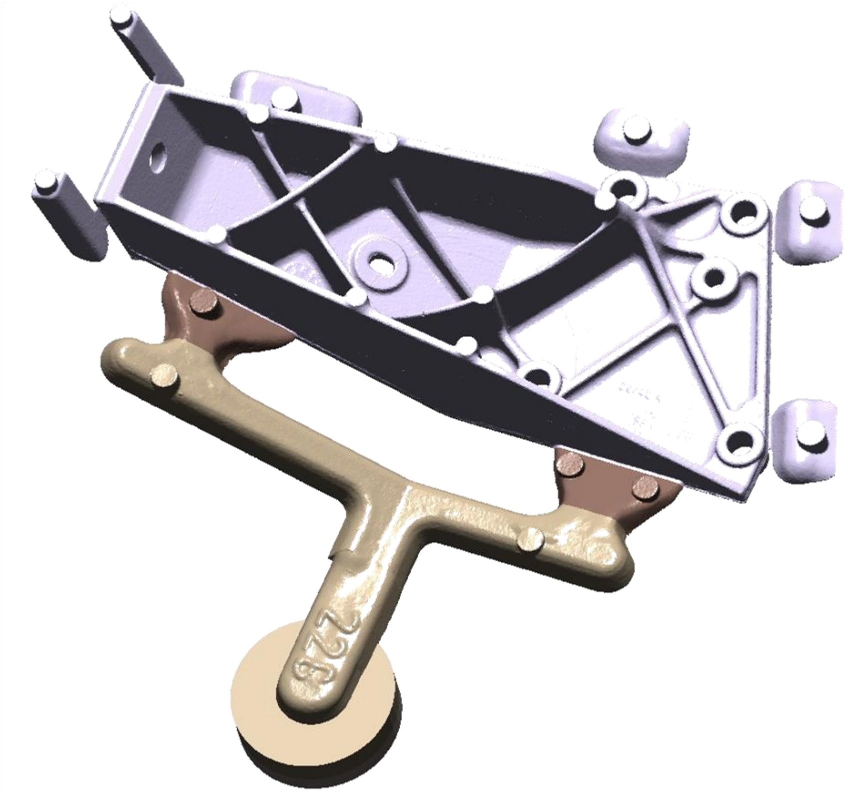
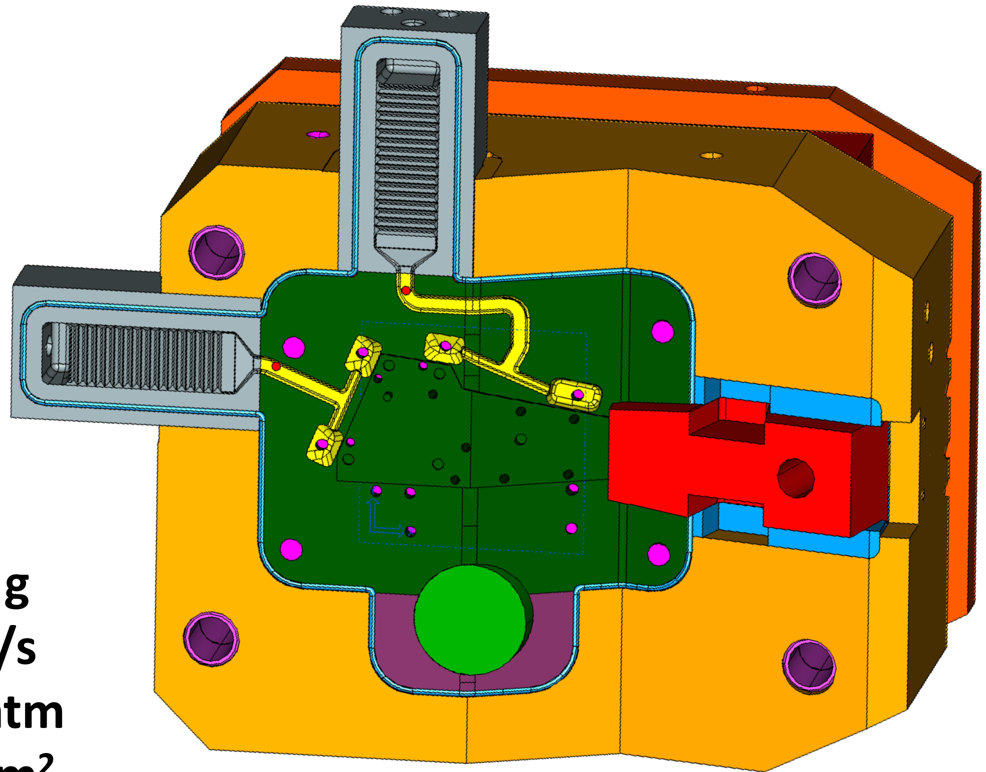
Show case: Engine torsion support



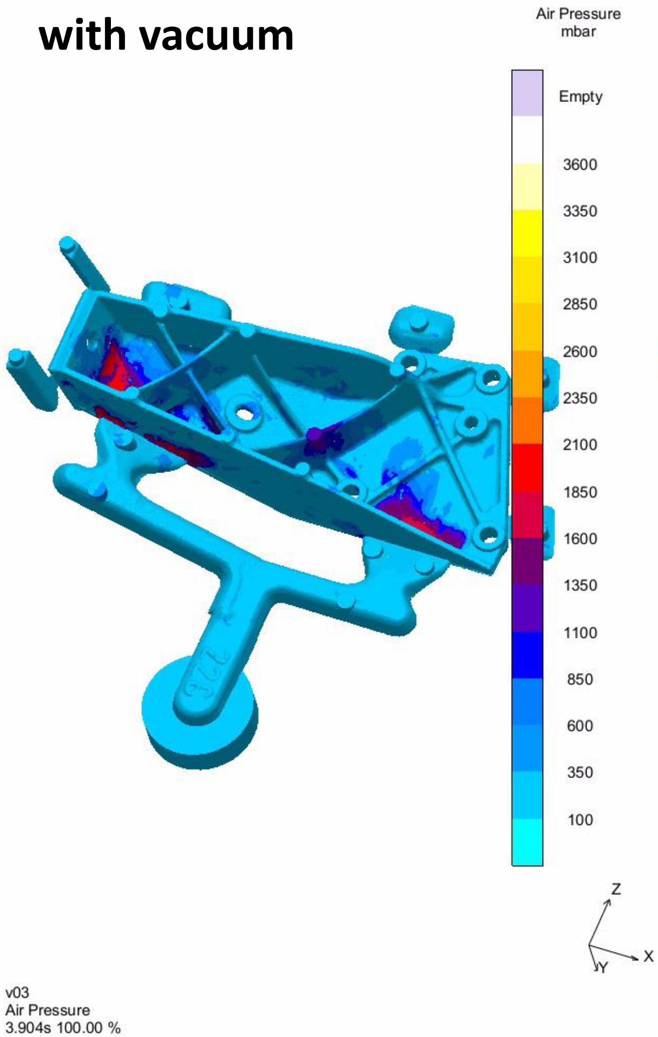


total shot weight:	**1240 g**
velocity of metal at gate:	**35 m/s**
intensification pressure:	**850 atm**
cross section of vents:	**32 mm²**

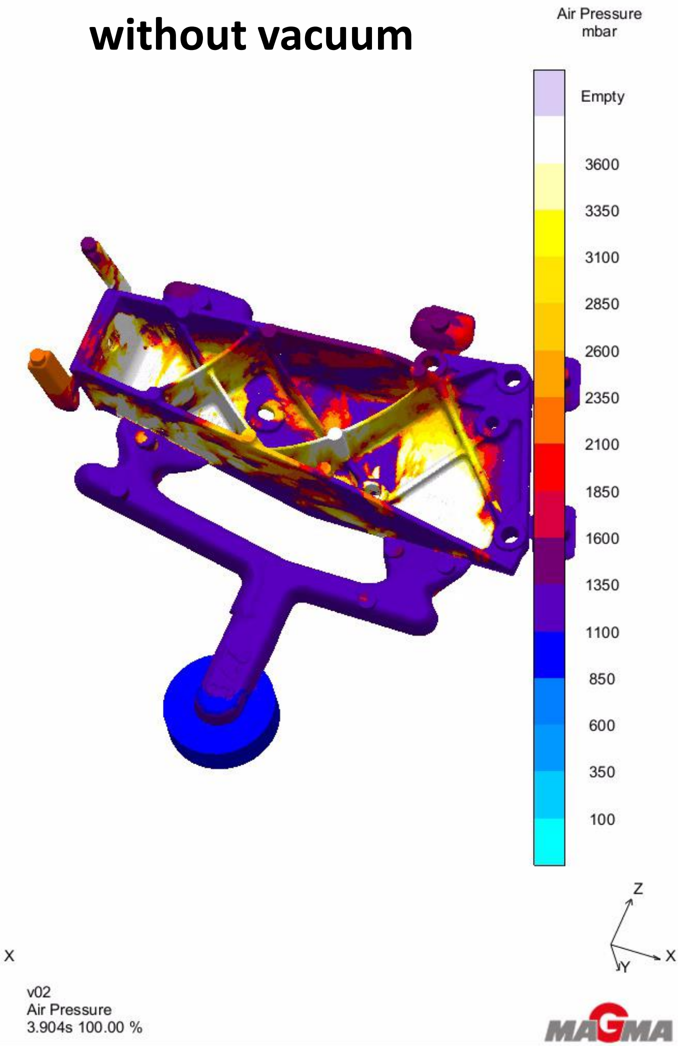
Show case: Engine torsion support

Pressure of trapped air:

with vacuum



without vacuum



Show case: Engine torsion support

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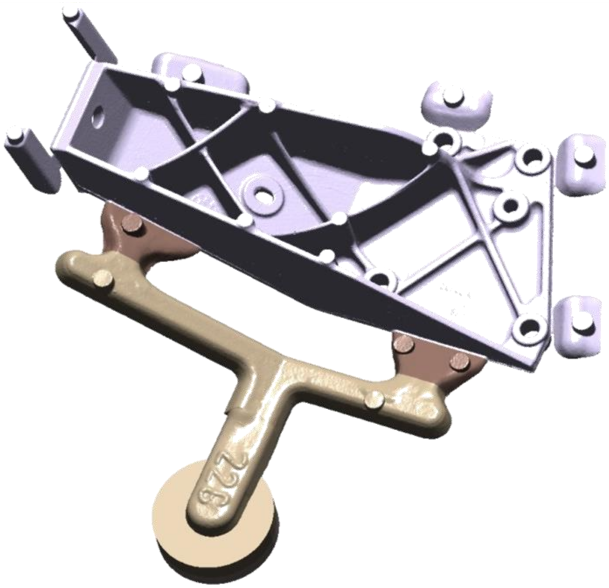


Trial series:

Alloy:	**AlSi10MgMn(Sr)**
Mg-contents:	**0,10/0,32/0,50 %**
Intensif. pressure:	**850 atm**
Vacuum pressures:	**ambient/<0,1 atm**
Heat treatment:	**none/sol.: 470°C/sol.: 510°C**
Pore classification:	**Computed tomography**
Force/elongation:	**Structural testing**

Show case: Engine torsion support

The odds with heat treatment in HPDC:

Blisters after Heat Treatment with high solution temperatures

Equation of ideal gases:

$$p \cdot V = n \cdot R \cdot T$$

p…Pressure [Pa]
V…Volume [m³]
n…Amount of substance [mol]
R…Ideal gas constant [J/Kmol]
*T…Temperature [**K!**]*

$$V = \frac{n \cdot R \cdot T}{p}$$

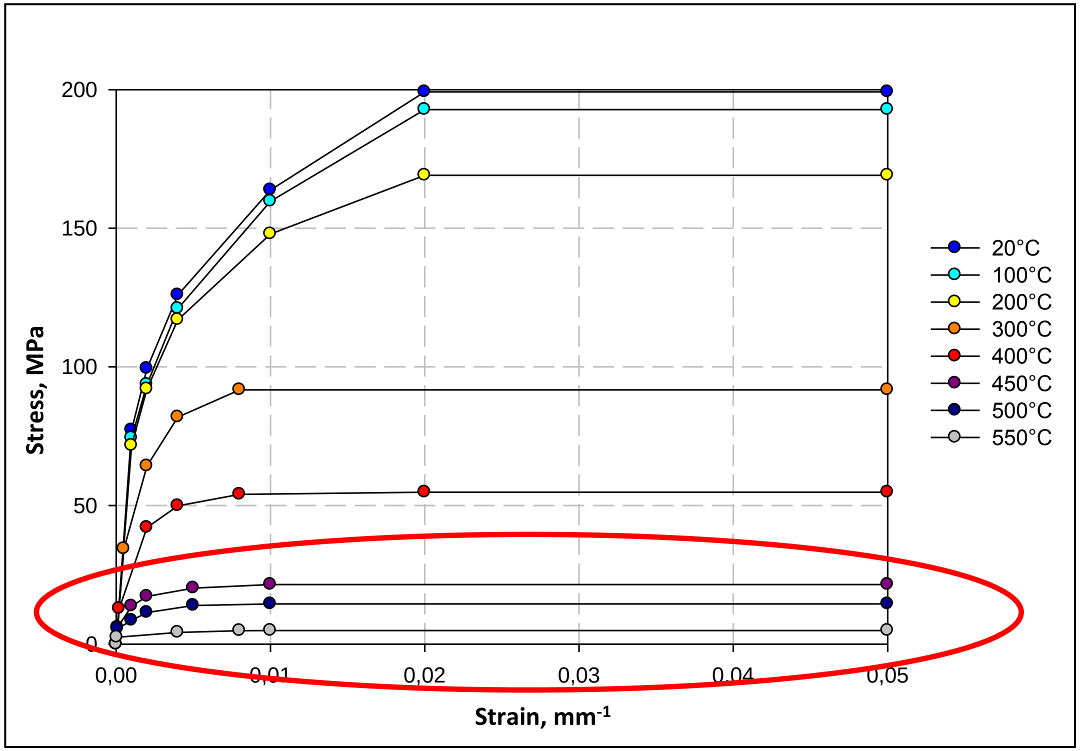
$$V(300\ K) = \frac{1 \cdot 8{,}314 \cdot 300}{8 * 10^7} = 0{,}03\ litres \qquad V(800\ K) = \frac{1 \cdot 8{,}314 \cdot 800}{8 * 10^7} = 0{,}08\ litres$$

Results at constant pressure! In a gas pore the pressure is not constant during heating, leading to a rise of pressure, material softening and an increase of mechanical load

Show case: Engine torsion support

Solution treatment leads to material softening

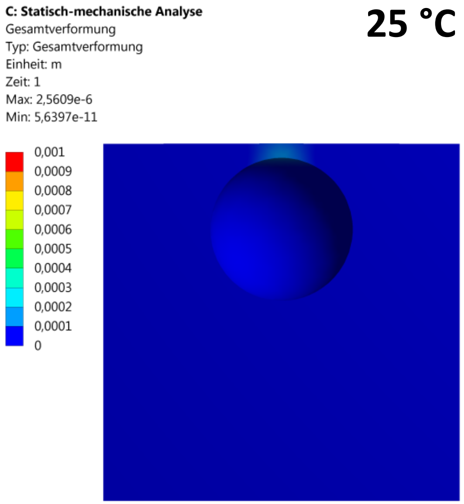
Stress-strain-curves for the alloy **AlSi10MgMn** at RT and elevated temperatures

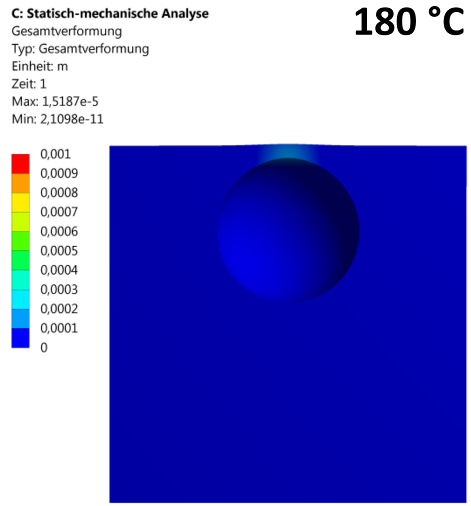


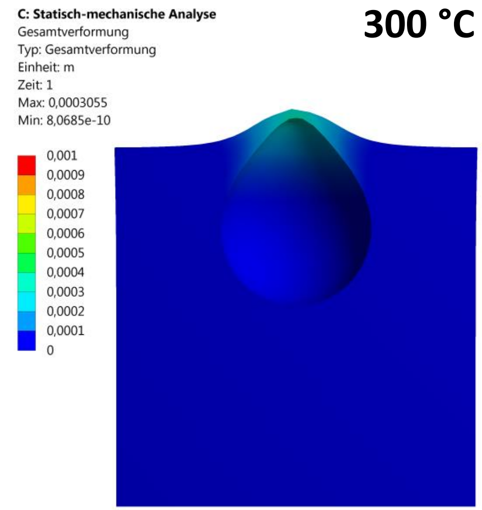
typical temperature range für solution treatment

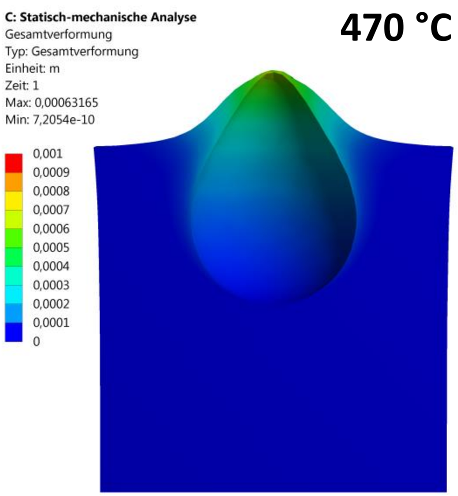
Show case: Engine torsion support

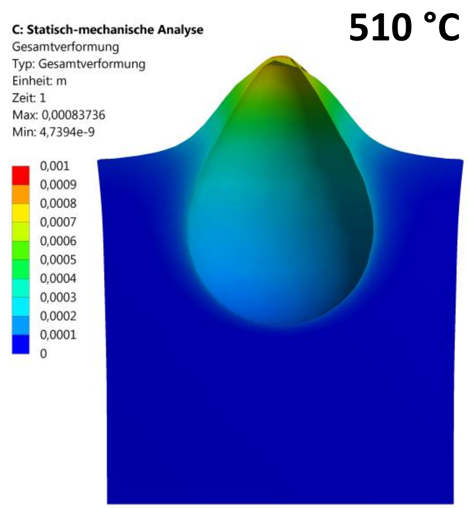
Material softening leads to blistering





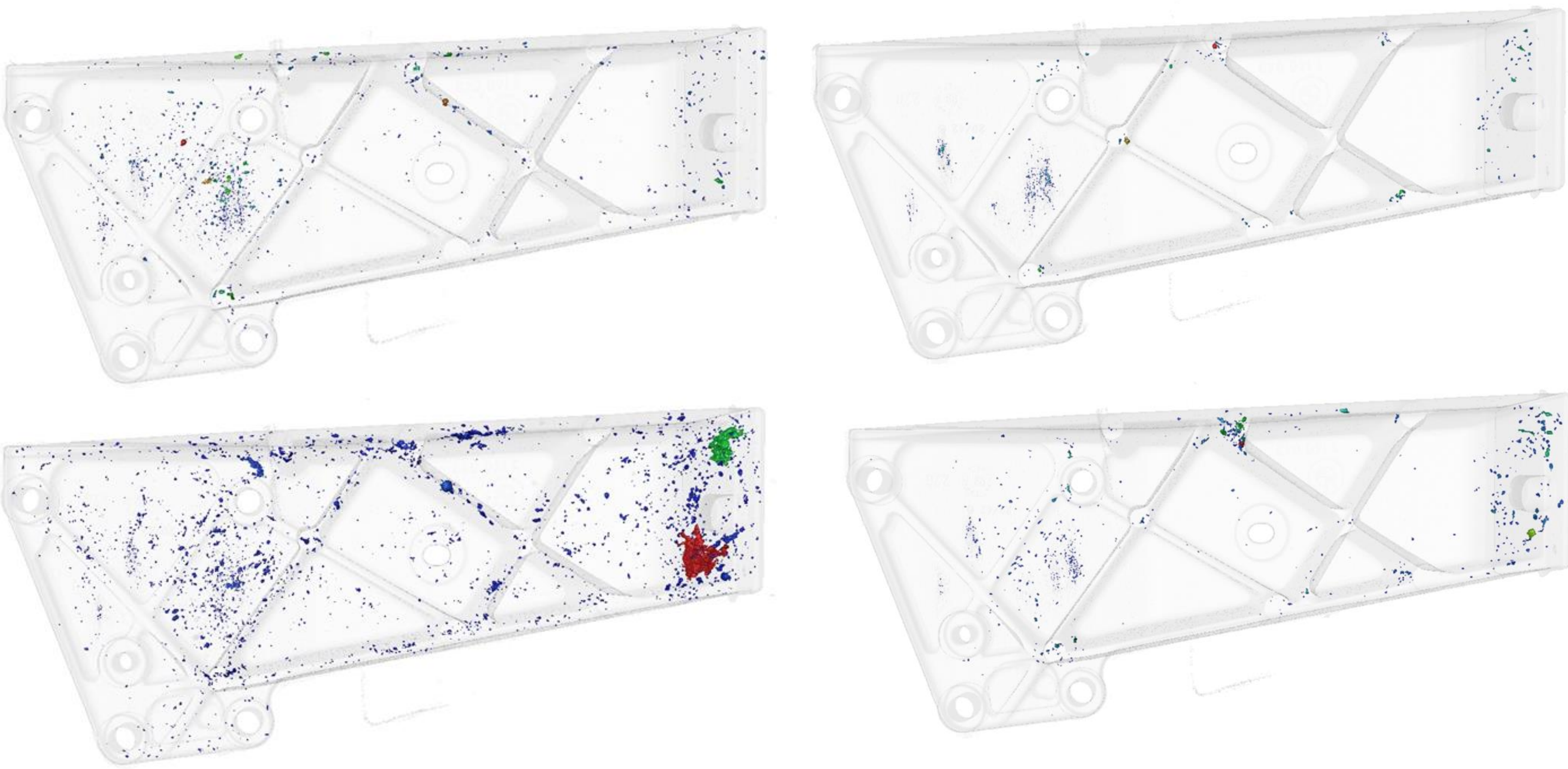






Load situation: Pore diameter is 1 mm, trapped air is intensified with a pressure of 800 atm and remains in the pore; simulation with generic AlSi10MgMn-data; **no creep model applied, strain is rather underestimated!**

Show case: Engine torsion support



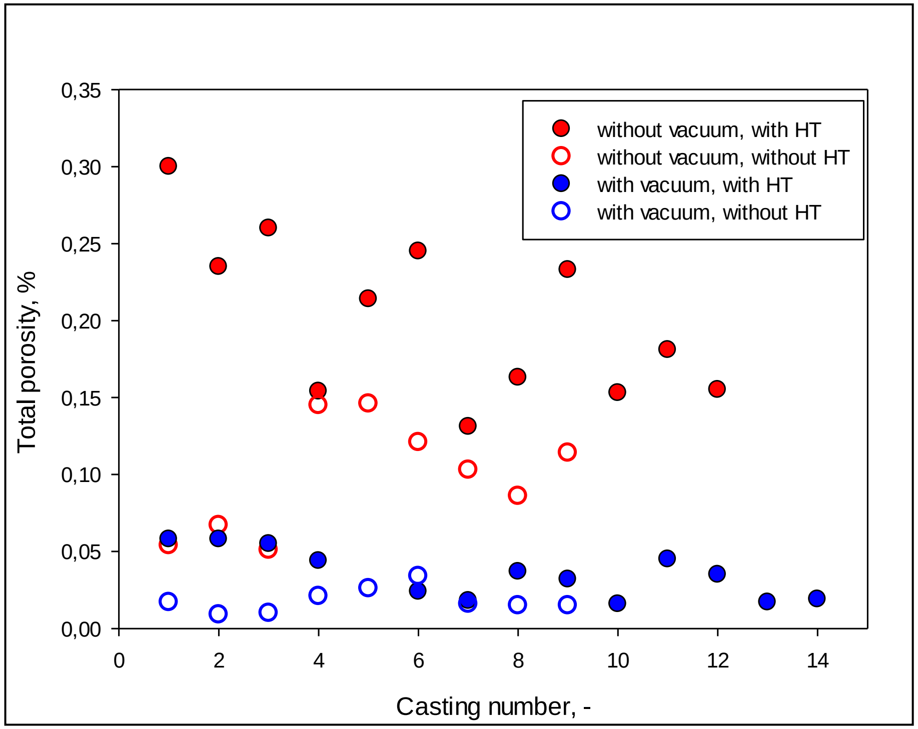
top: **without** vacuum, without HT

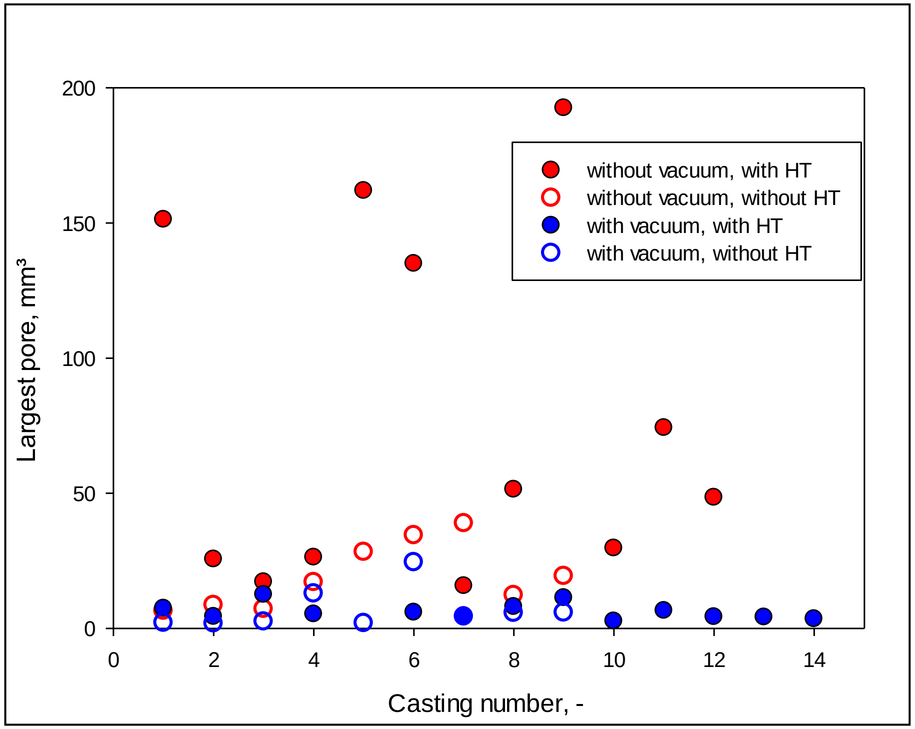
bottom: **without** vacuum, with HT

top: **with** vacuum, without HT

bottom: **with** vacuum, with HT

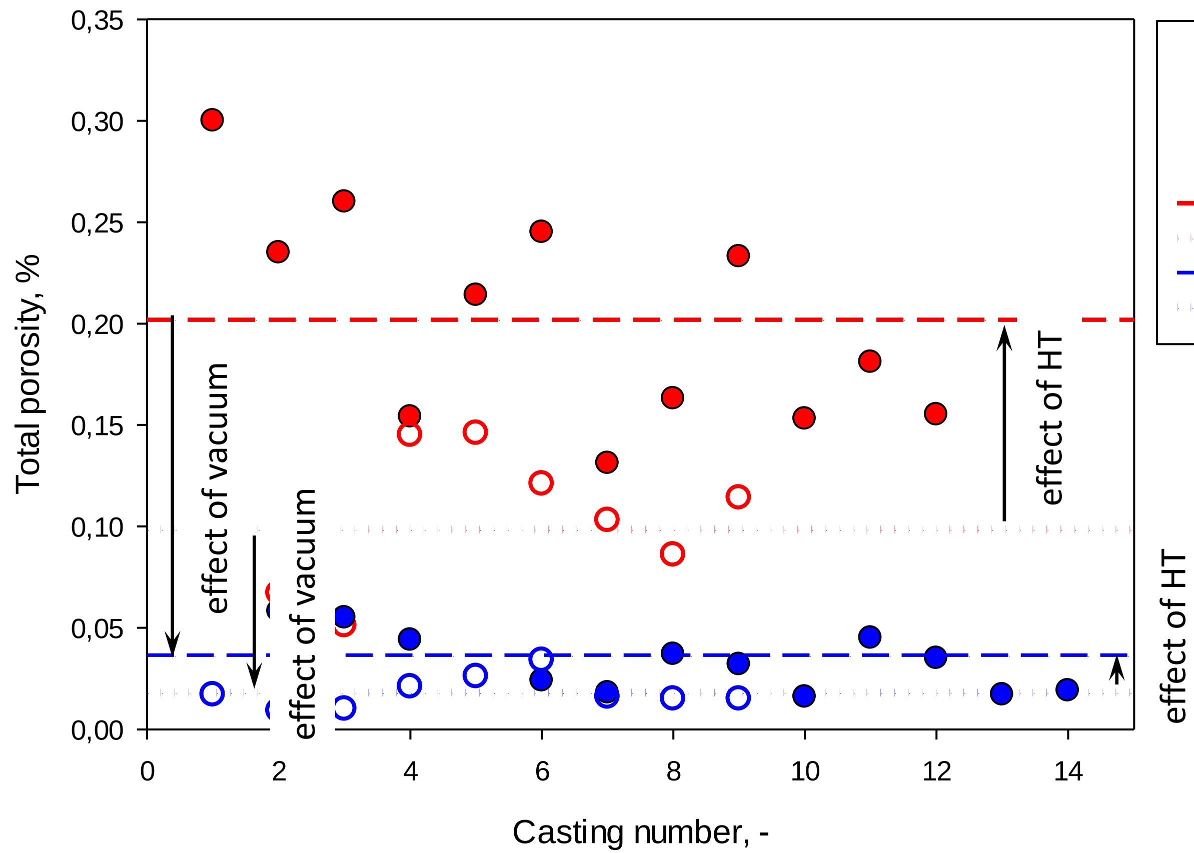
Show case: Engine torsion support





One can observe the same effect as in the squeeze-cup: very large pores are eliminated by the vacuum, leading to a **better heat treatability without massive blistering** of the parts, even at high solution treatment temperatures.

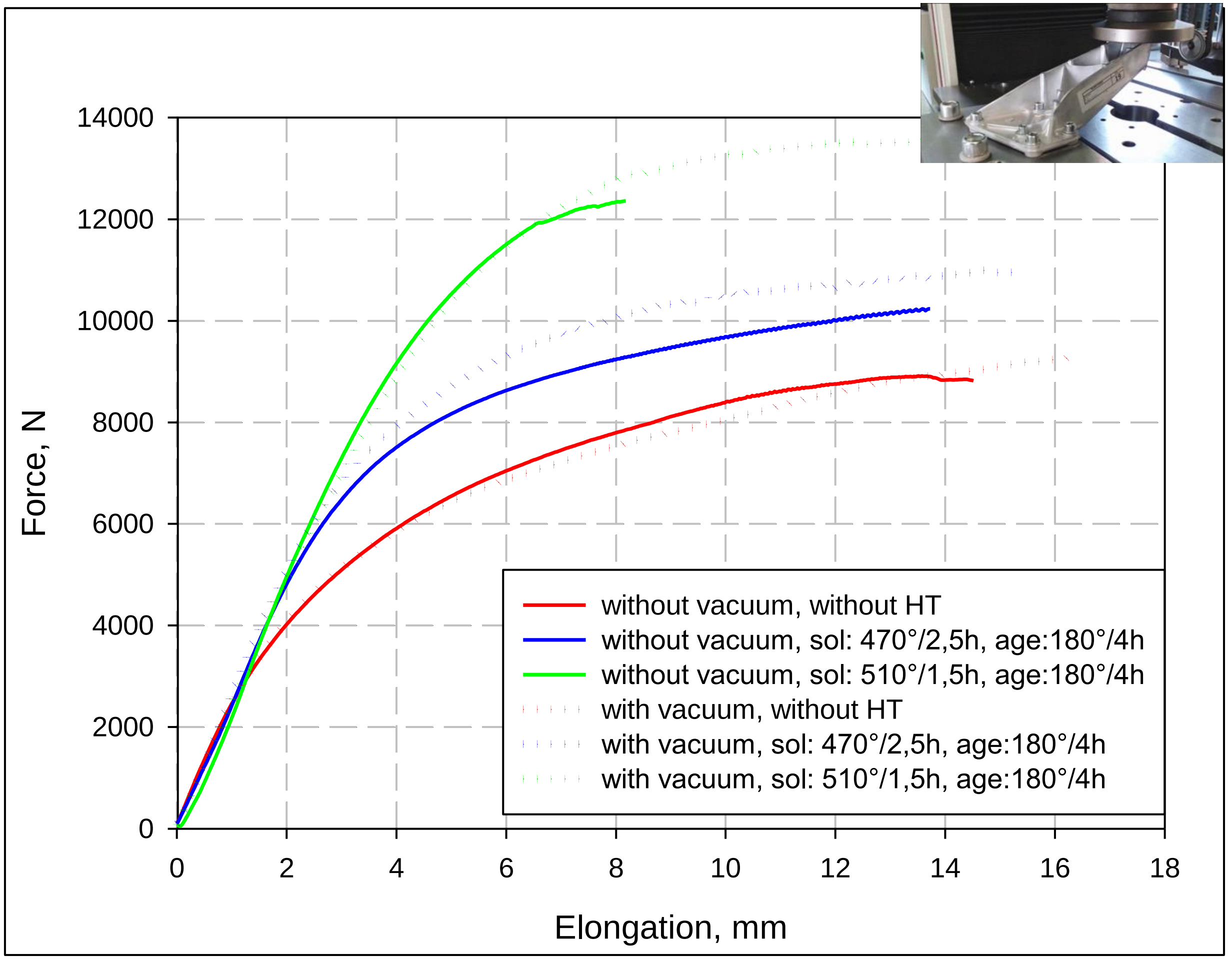
Show case: Engine torsion support



Effect of die evacuation is greater than the effect of HT without solution treatment at high temperatures (T5 instead of T6/T64/T7)

Why not use low temperatures for solution treatment?

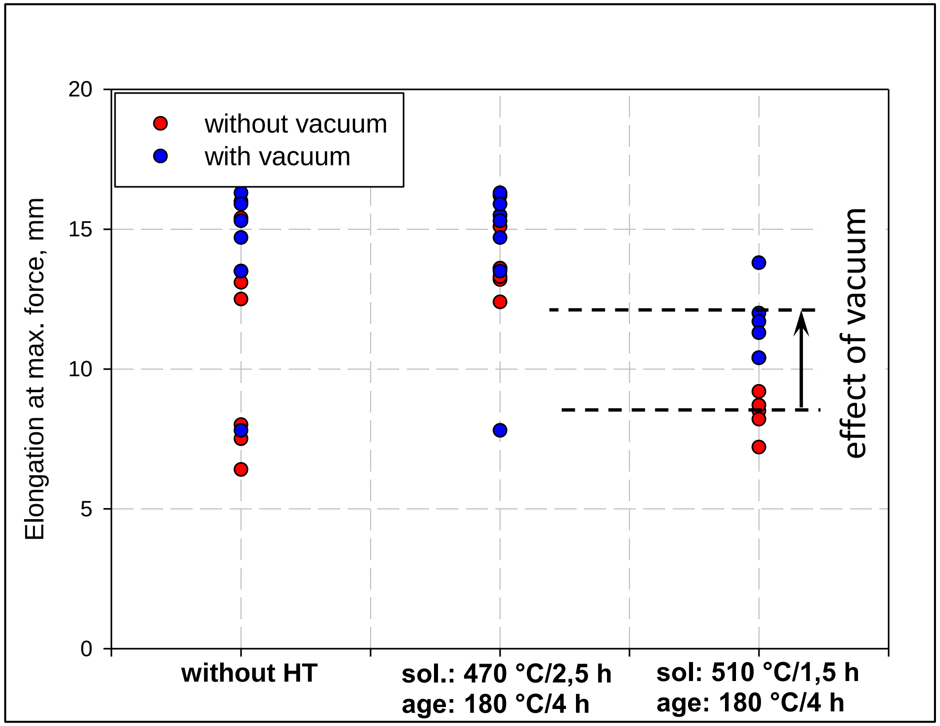
Show case: Engine torsion support

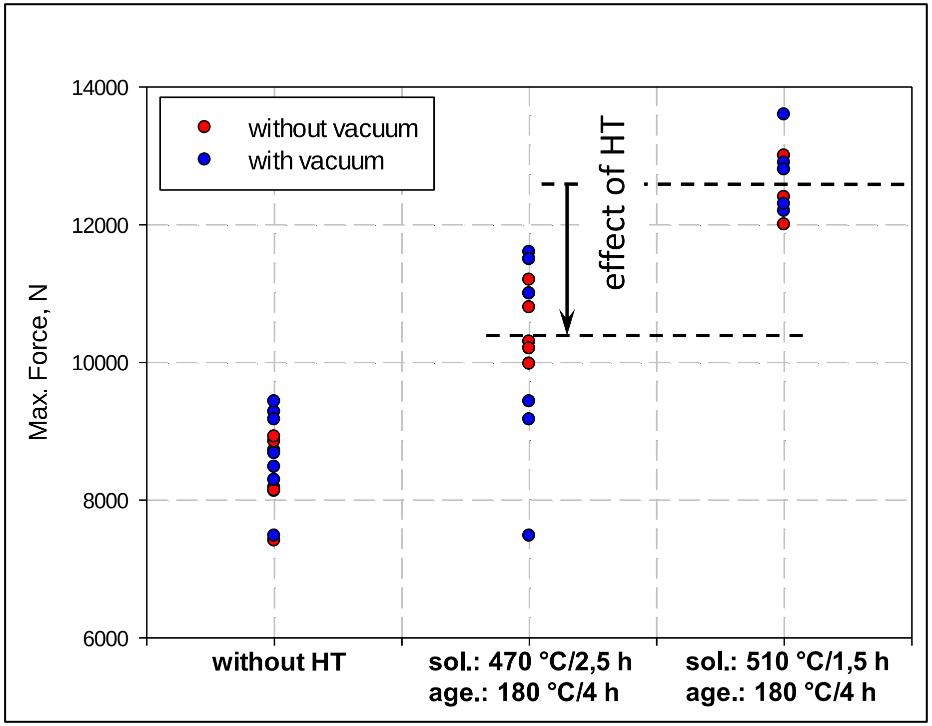


Mg-content: 0,32 %

Effect of die evacuation leads to more elongation in the test, differences become more clearly **with high solution treatment temperatures!**

Show case: Engine torsion support

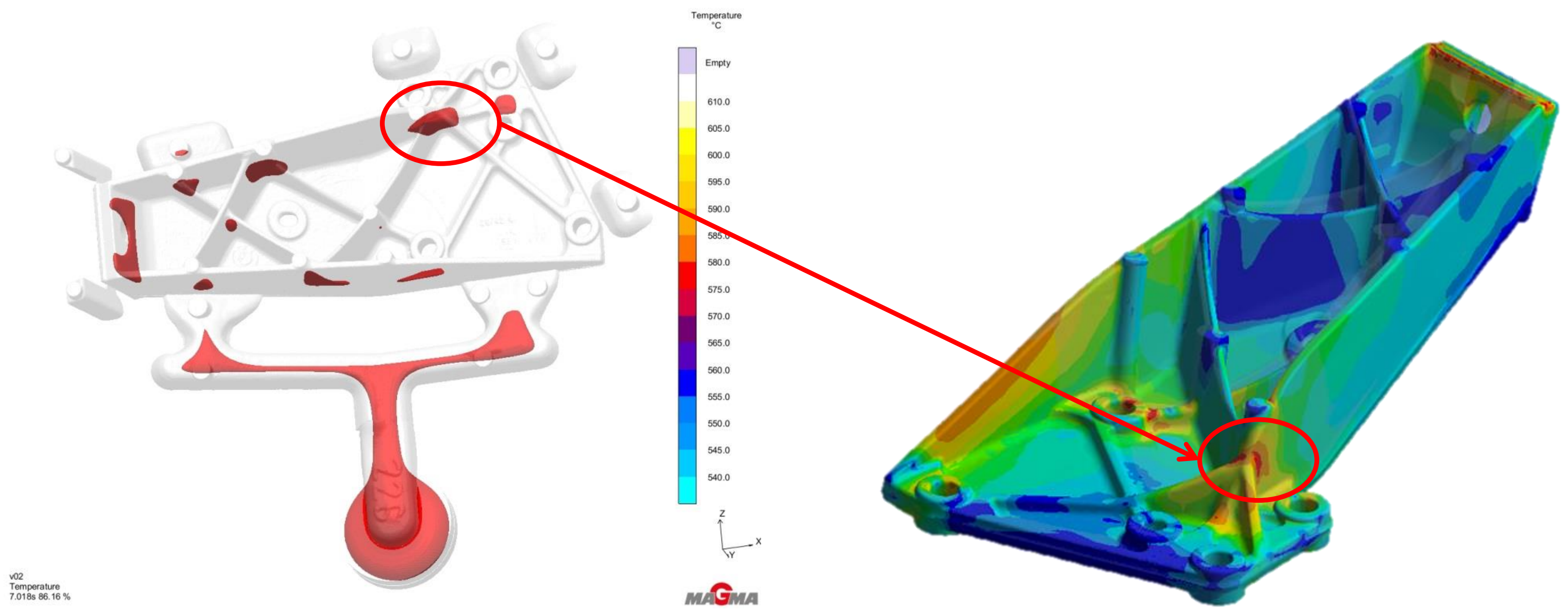




Mg-content: 0,32 %

At a solution treatment temperature of 510 °C blistering becomes dominant for the elongation of the structure, **reducing the temperature of solution treatment controls the blistering but leads to lower max. forces!**

Show case: Engine torsion support

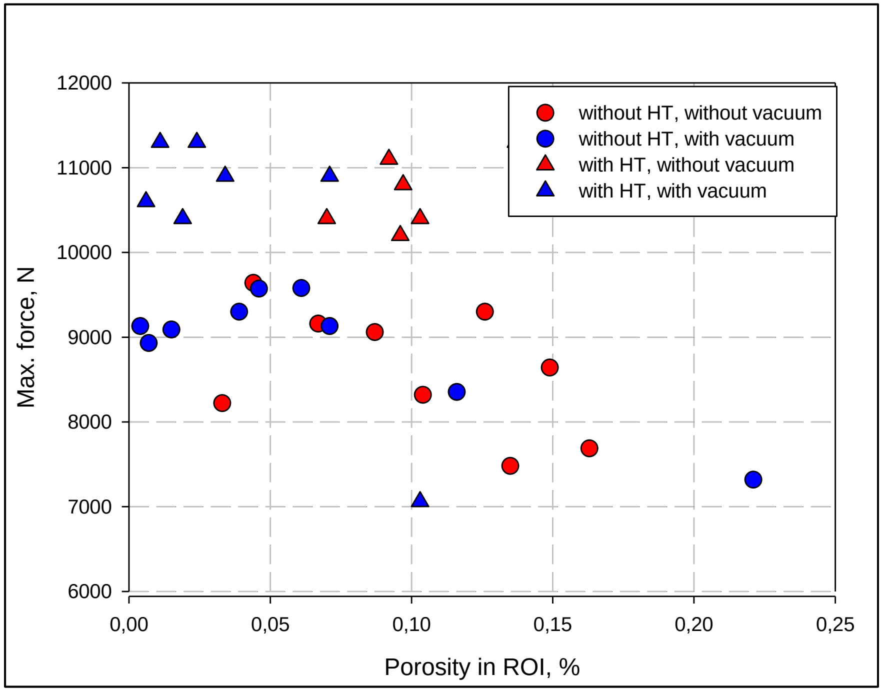


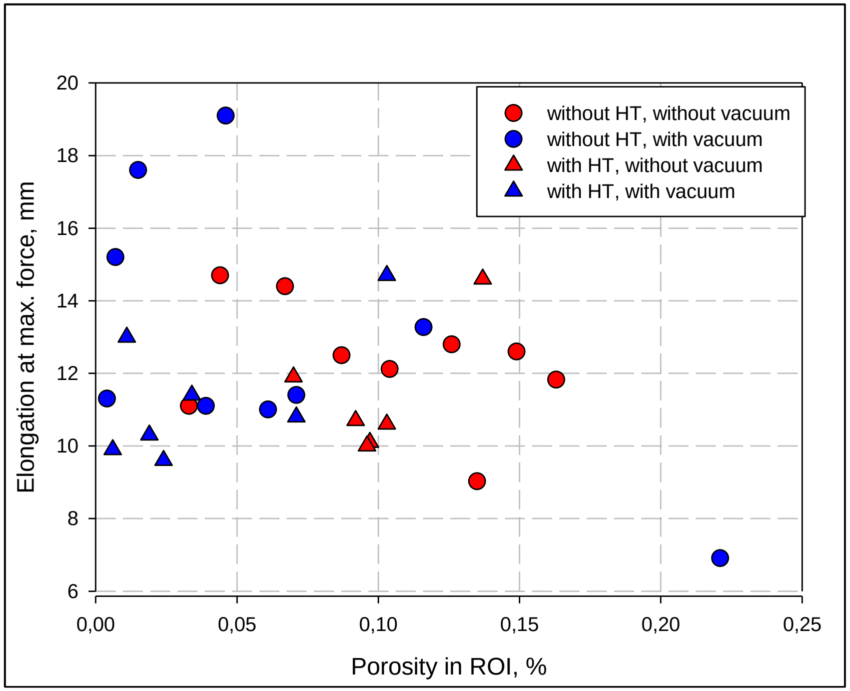
casting simulation – **local hot-spots**

stress simulation – **local stresses**

The area with the highest porosity is also the area with the highest stresses! Local porosity in the ROI was evaluated in computed tomography

Show case: Engine torsion support

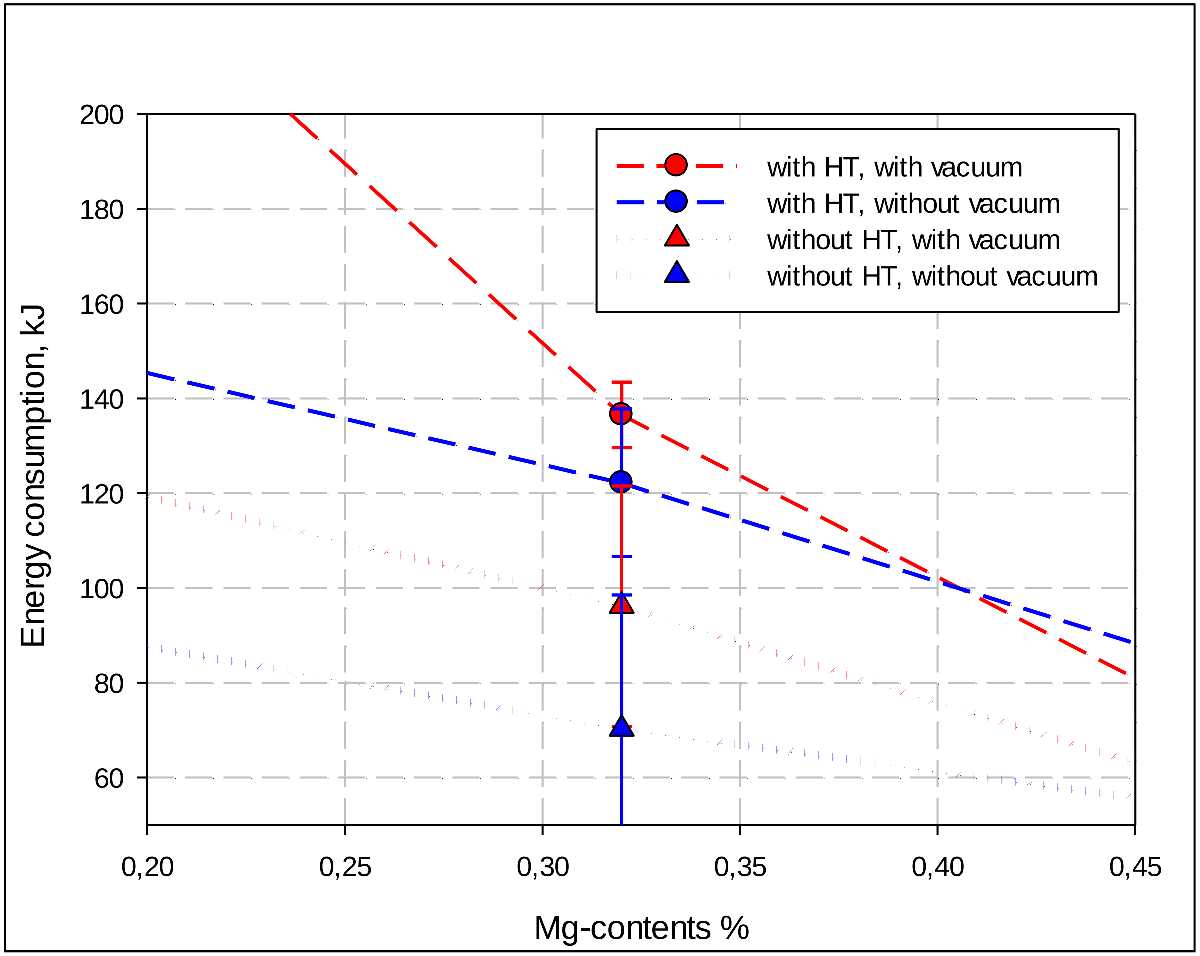




Mg-content: 0,32 %, solution treatment at 470 °C

At a solution treatment temperature of 470 °C elongation is in the same range for parts cast with and without vacuum. **What about the overall casting properties?**

Show case: Engine torsion support



Energy consumption (area under the force-elongation-curve) of **parts produced with optimized process parameters for die evacuation and heat treatment show the best results.** There is much potential for process optimzation!

Contents

Conclusions

- Use of vacuum eliminates the **largest pores**
- Heat treatment with **high solution temperatures leads to massive blistering**
- Blistering is **much lower in vacuum casted parts**
- In this study:
  - porosity **with and without** heat treatment could be clearly reduced
  - the **effect of die evacuation exceeded the effect of skipping solution treatment**
  - lower solution treatment temperatures **lead to lower porosity at the cost of max. force**
  - Vacuum results were **better even with optimized heat treatment parameters**
- Results show **high potential of quality improvement** using optimized vacuum and HT-parameters

Acknowledgements

This work was supported by

Österreichische Forschungsföderungs-Gesellschaft FFG

and by

Fondarex

providing a

High-Vac-Premium

die evacutaion device

Thank you very much!

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