Active inserts, a plug and play solution for increasing mechanical properties and reducing porosity in LPDC-ed parts

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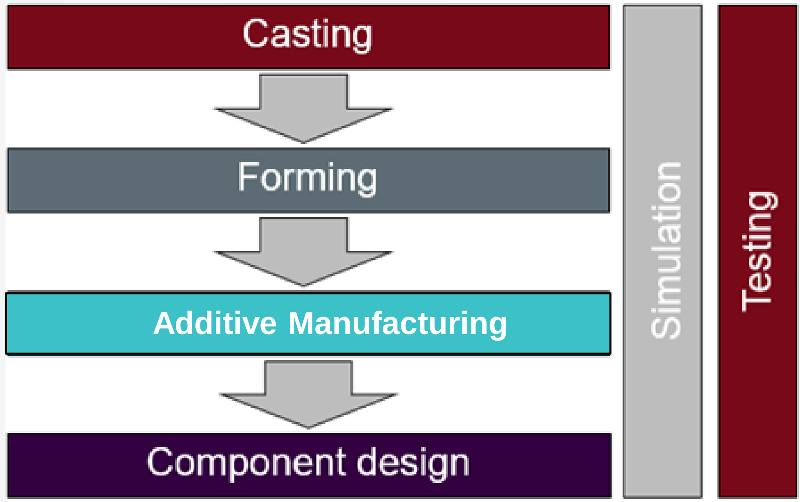
Agenda

- Introduction LKR
- Melt manipulation by the “Active Insert”
- Experimental set-up
  - Mold structure and Process set-up
  - Experimental matrix
- Results
  - Metallographic analysis
  - Mechanical analysis
- Conclusion - Outlook

Introduction LKR

- LKR – Light Metals Technologies GmbH, Austrian Institute of Technology
  - Employees: 60
  - Location: Ranshofen
  - Annual turn-over: ≈ 8 Mio. €
  - 100% subsidiary of AIT (Austrian Insitute of Technology)
    - employees: 1300
  - Part of the largest non-university research institute in Austria

➢ **Research along the process chain for Al and Mg products**



TOOLing2022 Conference & Exhibition

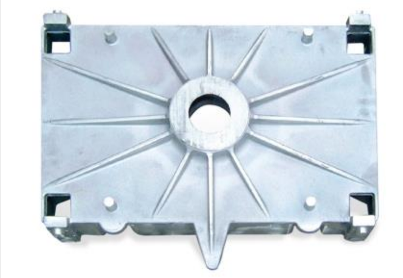
Melt manipulation by the “Active Insert”

NEED OF: Melt manipulation by the "Active Insert"

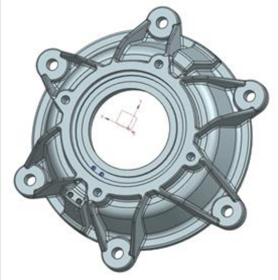
Developments over the last years indicate increasing part requirements for future applications

- Single cast components become cast assemblies
  - Part: Geometries are getting more complex
    - combination of several parts into one assembly
    - thicker part areas due to design reasons
  - Quality: Increasing demand in the areas of…
    - mechanical properties
    - porosity class
    - pressure tightness
    - weldability
    - distortion

Aluminium-Subframe
Kurtz Ersa



Runner
Hermann Sieg GmbH



Powertrain

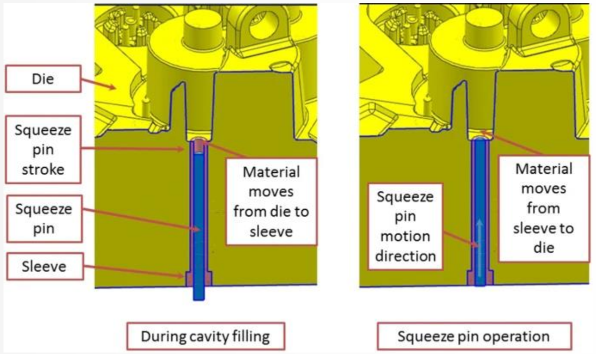
LPDC cylinder crankcase and bed-plate
Rheinmetall

NEED OF: Melt manipulation by the "Active Insert"

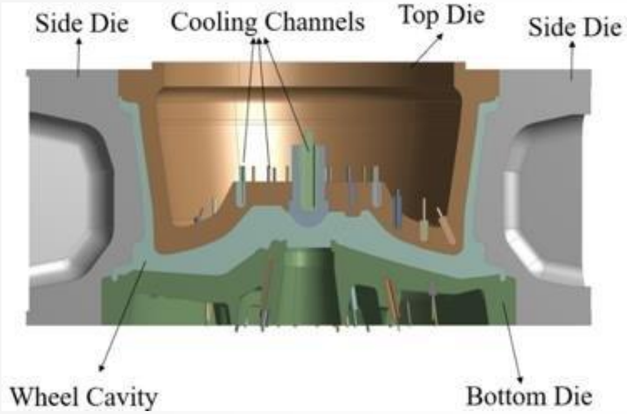
Part access during casting to improve "critical areas"

- Current Methods:
  - Proper process set-up:
    - simulation / design
    - pressure curve optimization
  - Thermal management:
    - thermally conductive inserts
    - close contour:
      - air / water cooling
      - water spot cooling
      - jet-cooler
  - Squeezing

No direct acess to the melt



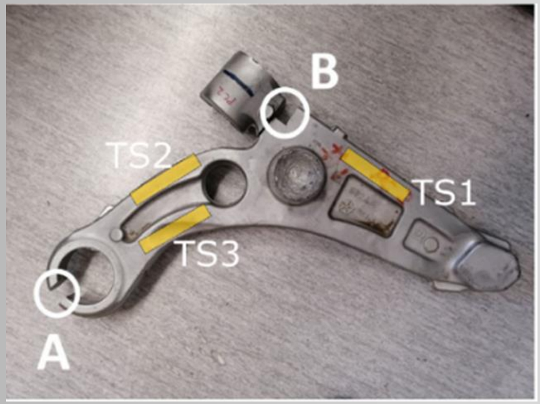
Working of local squeeze pin during cavity filling and during operation
Study on Reduction in Shrinkage Defects, Springer

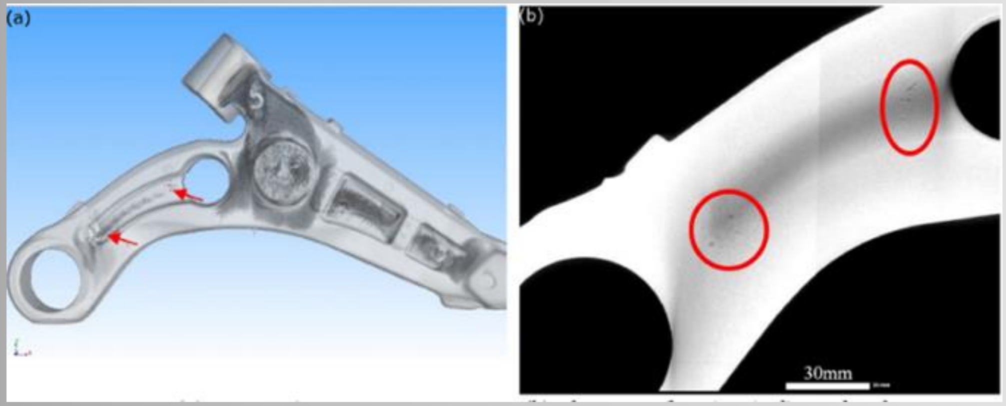


Schematic of LPDC's components
Researchgate.net

NEED OF: Melt manipulation by the "Active Insert"

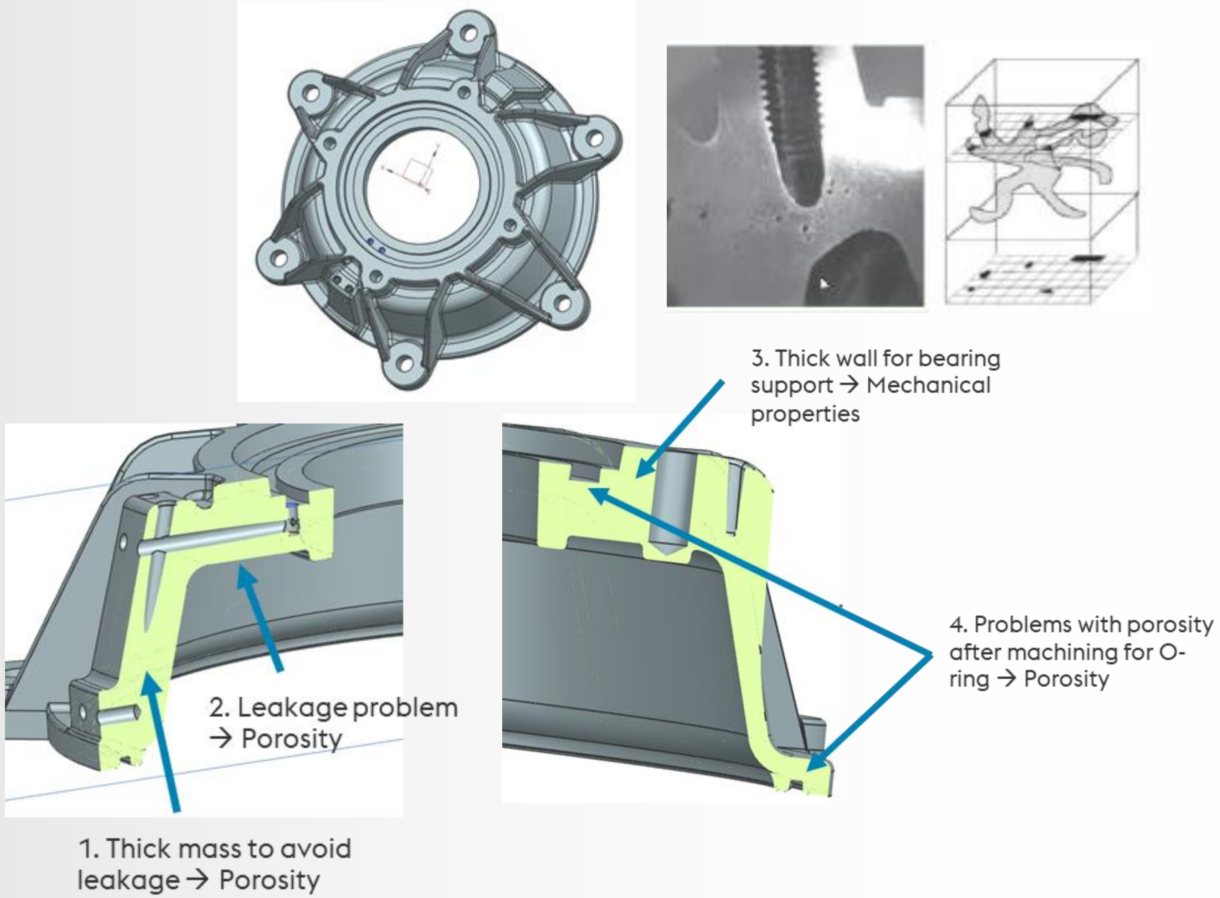
Component examples





Geometry of the cast component (control arm), sampling locations and close up of small dristibuted porosity

ScienceDirect



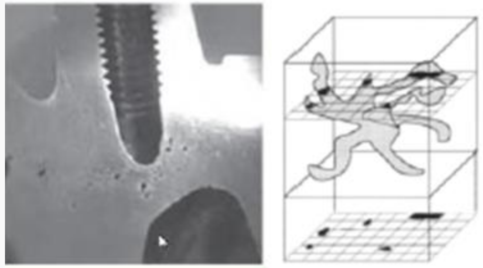
Voestalpine - case study

WHY - Melt manipulation by the “Active Insert”

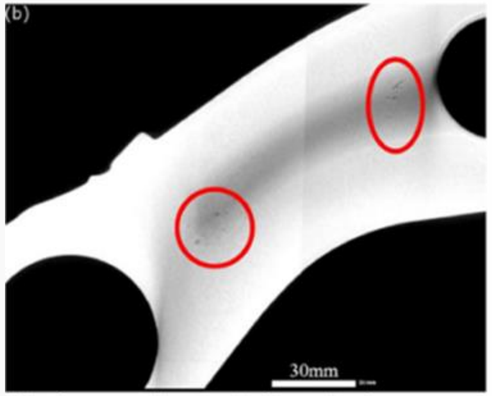
More than 98 % of the part is of good quality. The remaining part (1-2%) leads to the main amount of scrap

There are two main problems:

1. Problem with acute scrap due to localized porosity
   - Leaks in the component/at screw points
     - large local pore
   - At sealing surfaces
     - pore accumulation/networks
2. Areas not reaching target mechanical properties
   - Too low quality -> crack at defect



Porosity near a drilled thread (real part) , Porosity in schematic Illustration in 3D



Active Insert as „new tool“ for problemsolving

Simon Frank
Austrian Institute of Technology - LKR

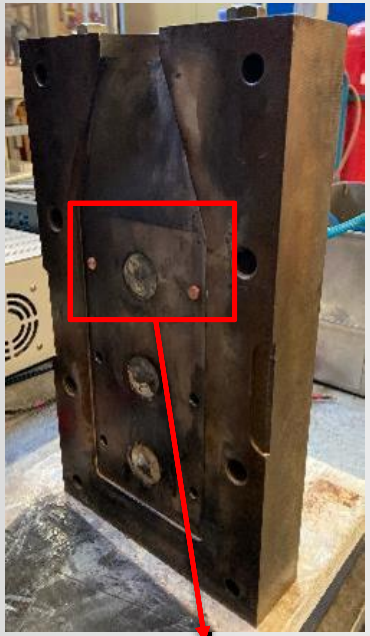
Description of an “Active Insert”

Active Insert

Pins

- Components/Functions
  - Copper Pin
    - introduction of electrical power (current and voltage)
    - electrical cables for power supply

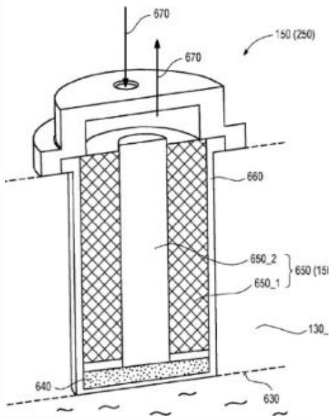
Pin before assembling



Test set up with integrated AI

Actuator

- Components/Functions
  - Coil & Core
    - setting up a magnetic field
  - Housing / Cap
    - main body of the actuator including cooling, cap, coil & core
    - direct contact with melt
  - Cooling
    - preventing components from overheating



Actuator draft

LPDC actuator assambled

Simon Frank
Austrian Institute of Technology - LKR

Description of an "Active Insert"

Pins | **Active Insert** | **Actuator**

- **Pulsed current**
  - Introduced current refines dendrites by:
    - stopping dendrite growing
    - desolating dendrite tips because of high resistance

- **Directional magnetic field**
  - Conductivity of liquids (e.g. melt, plasma, etc.) allows them to be moved
  - Forced movement during solidification leads to concentration and heat equalization
  - Combinatorial interactions have positive influence on the solidification of the melt

EFFECT OF: Melt manipulation by the “Active Insert”

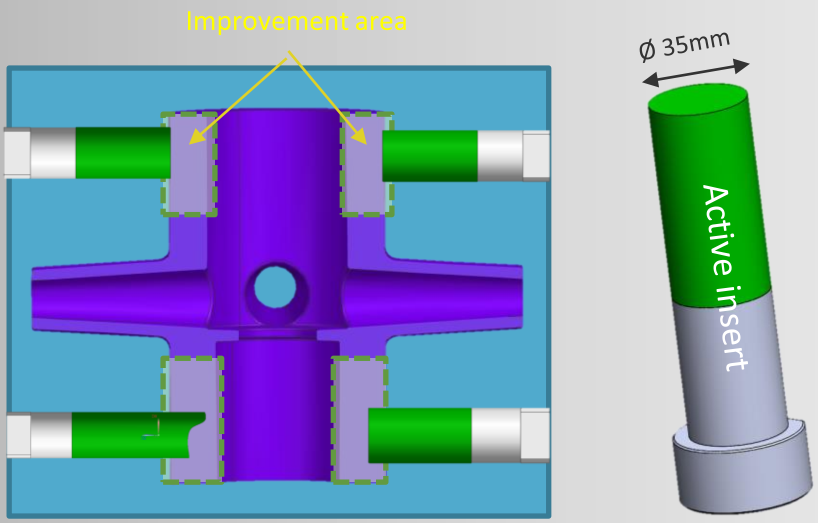
- **Target of the AI:**
  - **Improvement of existing problem areas like**
    - **porosity, inhomogeneity of the matrix, filling defects**
      - Local homogeneous solidification of the entire matrix with homogeneous grain growth and distribution in the part
- <u>Benefits:</u>
  - More homogeneous microstructure
  - Improvement of mechanical properties
  - Better castability
    - Reducing local porosity
    - Less turbulent filling behavior
    - No or less use of grain refiner necessary

HOW TO PLACE: The "Active Insert"

LPDC Active Inserts application example

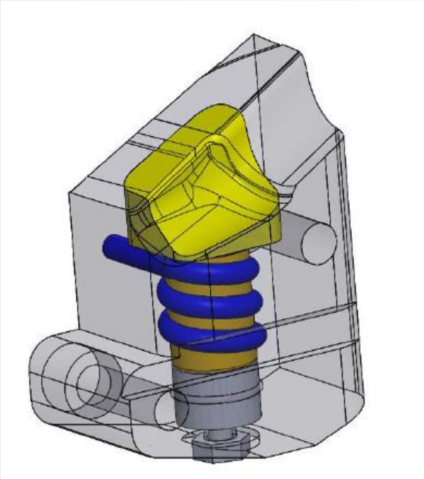
- Allows access to the solidification of the critical part cross-section

Stator hub of an ironless wheel hub engine

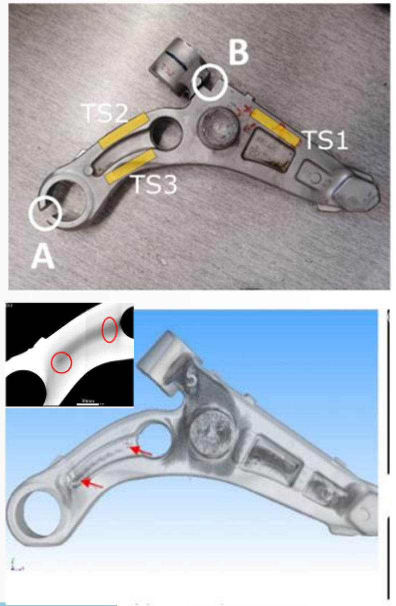


Principle of active use - patent granted and published

Steering knuckle/ wheel carrier



voestalpine



Active insert significantly increases process stability reducing process variations and scrap rates

Simon Frank
Austrian Institute of Technology - LKR

Experimental set-up

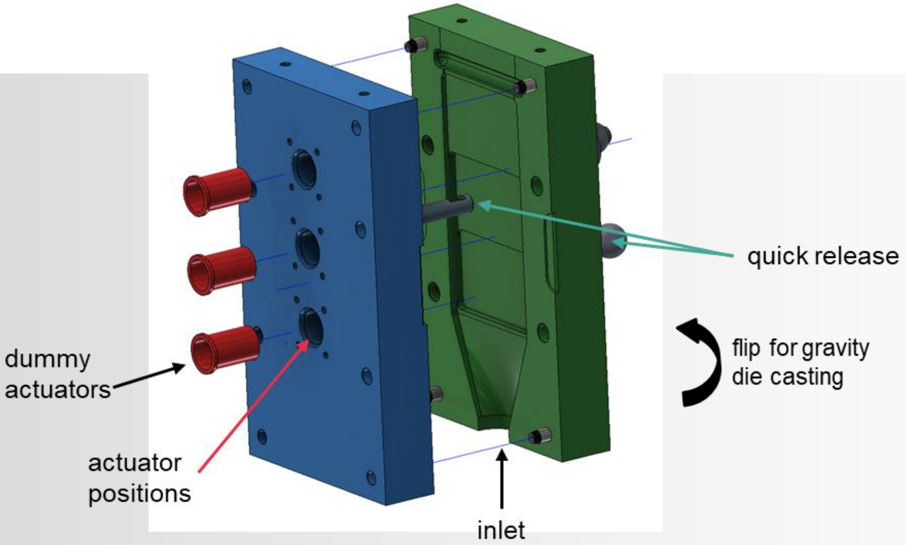
Experimental set-up

- Low-pressure die-casting machine used for experiments
  - AK92 / AL:7-5 – Kurtz GmbH
  - Clamping force: 5t
  - Crucible
    - 200kg Aluminum
    - 120kg Magnesium
  - Heating/cooling
    - Pressurized air /water
    - Heat cooling devices: Robamat
  - Clamping plate: 1050x850mm

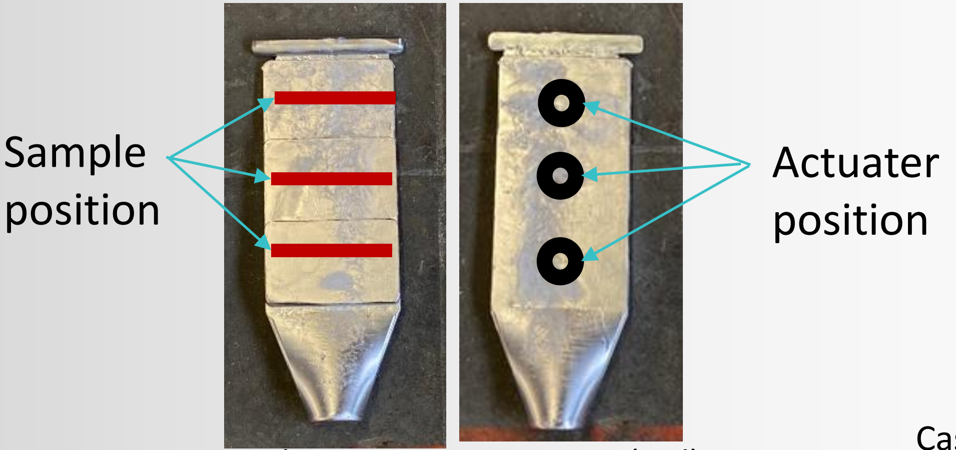
Low-pressure die-casting machine at AIT

Experimental set-up

- Alloy
  - AlSi7Mg0.3
- Casting temperature
  - T_{Melt} 705°C
  - T_{Mould} 250°C
- Casting trials: 3
  - Amount of
    - Casted samples per trial
      - 20 per Parameter
    - Tested samples per trial
      - 20 per Parameter



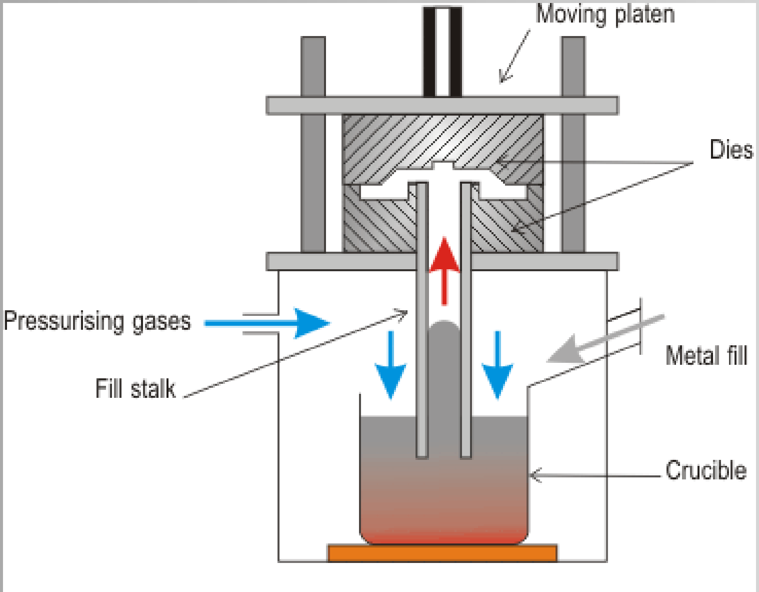
Schematic of LPDC mould as used for casting



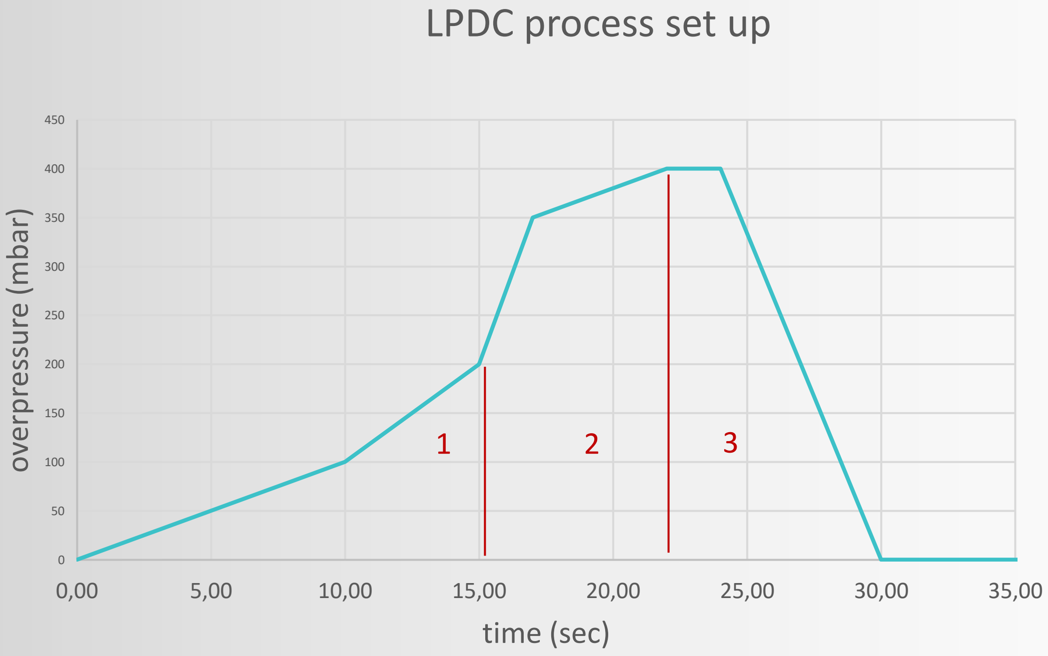
Tensile test specimen areas (red)
DIN 50125-A6x30


Casting set-up with molde in machine at LKR

Experimental set-up – LPDC Process



Schematic of the LPDC process



Schematic LPDC process pressure curve

process parameters as casted (LPDC)	
time [sec]	overpressure [mbar]
0,00	0,00
10,00	100,00
15,00	200,00
17,00	350,00
22,00	400,00
24,00	400,00
30,00	0,00

1	pre-filling of the gating section
2	mould filling component
3	holding pressure to compensate volume shrinkage and release pressure

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Results

Results - Mechanical properties

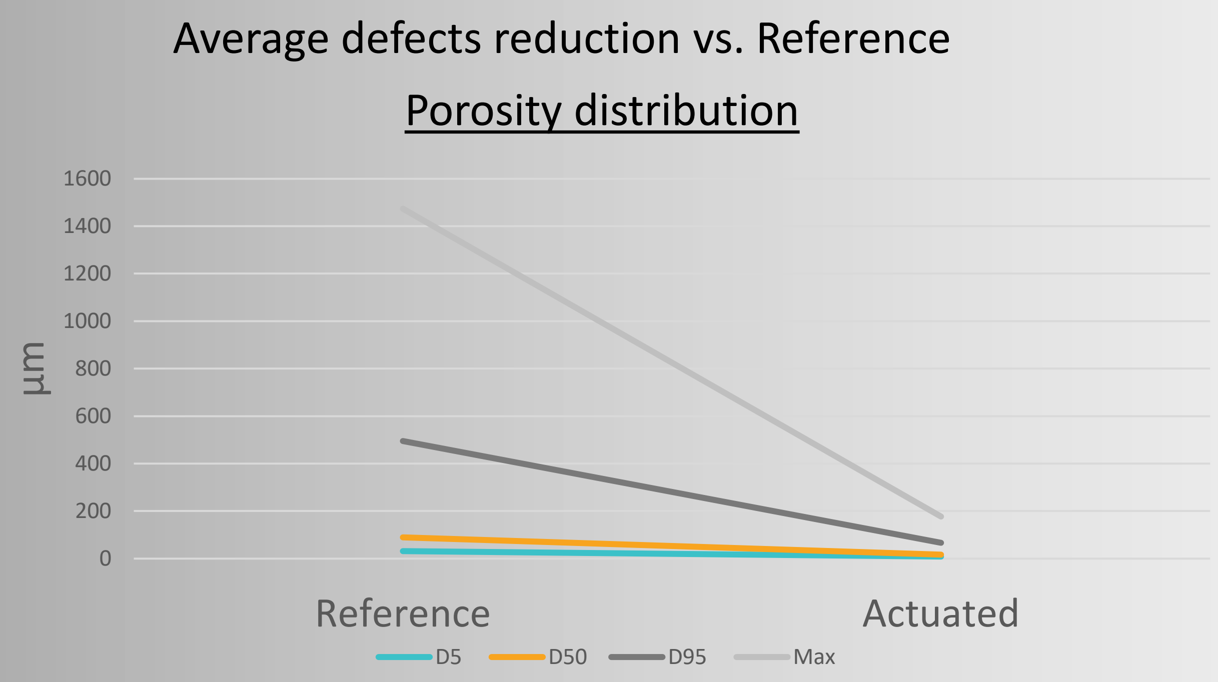
- Alloy AlSi7Mg3,0 (14 mm thickness)
  - Results are consistent through the different casting trials
  - Main benefit is shown in the elongation due to reduced casting defects and homogenous microstructure

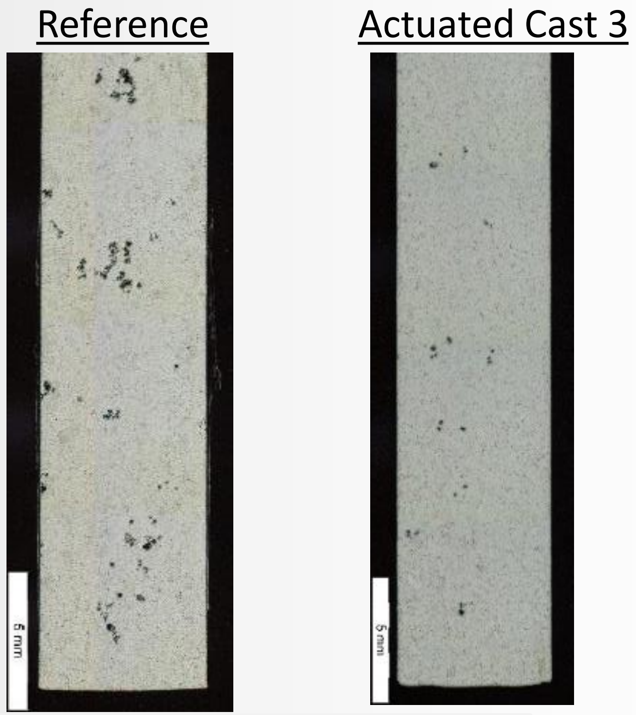
	Reference 0W/0%		Cast 1 10-500W/0%		Cast 2 0W/30-80%		Cast 3 10-500W/30-80%	
	Value	Deviation	Value	Deviation	Value	Deviation	Value	Deviation
YS	89 MPa	3,0	91,8 MPa (+3%)	1,0	91,4 MPa (+3%)	3,8	94,4 MPa (+6%)	2,7
UTS	160 MPa	6,0	176 MPa (+10%)	3,7	174 MPa (+9%)	3,1	178,3 MPa (+11,5%)	4,7
E	2,48 %	0,5	3,8 % (+53%)	0,5	3,55 % (+43%)	0,5	3,3 % (+33%)	0,5

The increase in mechanical properties is in the same level down to 6mm in thickness and should be in the same range for other Al and Mg alloys (not proved so far)

Results - SHRINKAGE POROSITY AND CASTING DEFECTS

- Average defect reduction vs. Reference: up to **-75%**

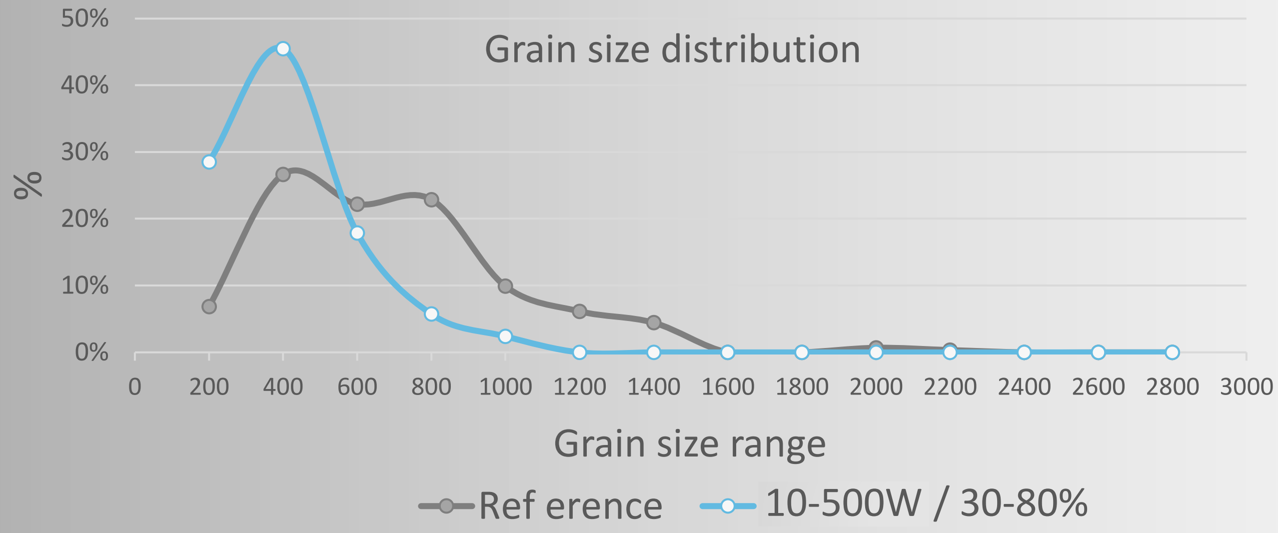


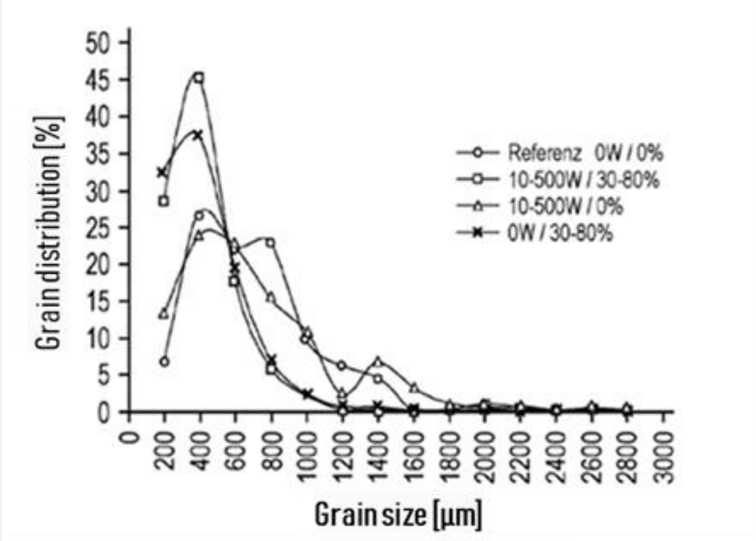


Big decrease in dendritic porosity accomplished due to the reduced grain size (-30%) and more rounded grains → Improved part filling

Results – Grain size distribution

- Grain size in the case of **activated samples** follows a narrow gauss curve around 370 µm with a small deviation from the value
- Grain size in the case of the **reference sample** is not homogeneous with peaks at ~370µm but also 800µm and 1400µm

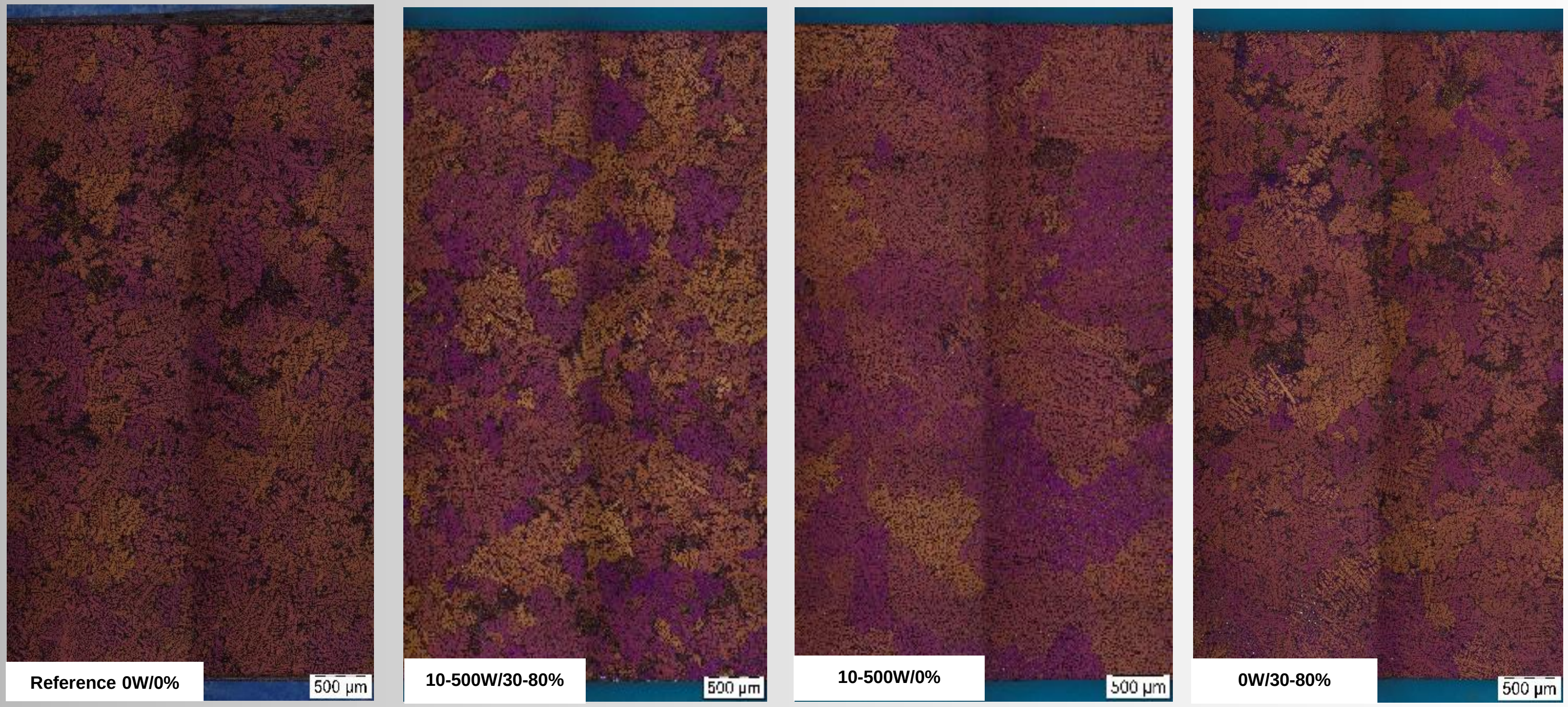




The more homogeneous grain size distribution leads to further process stability and consistent mechanical properties

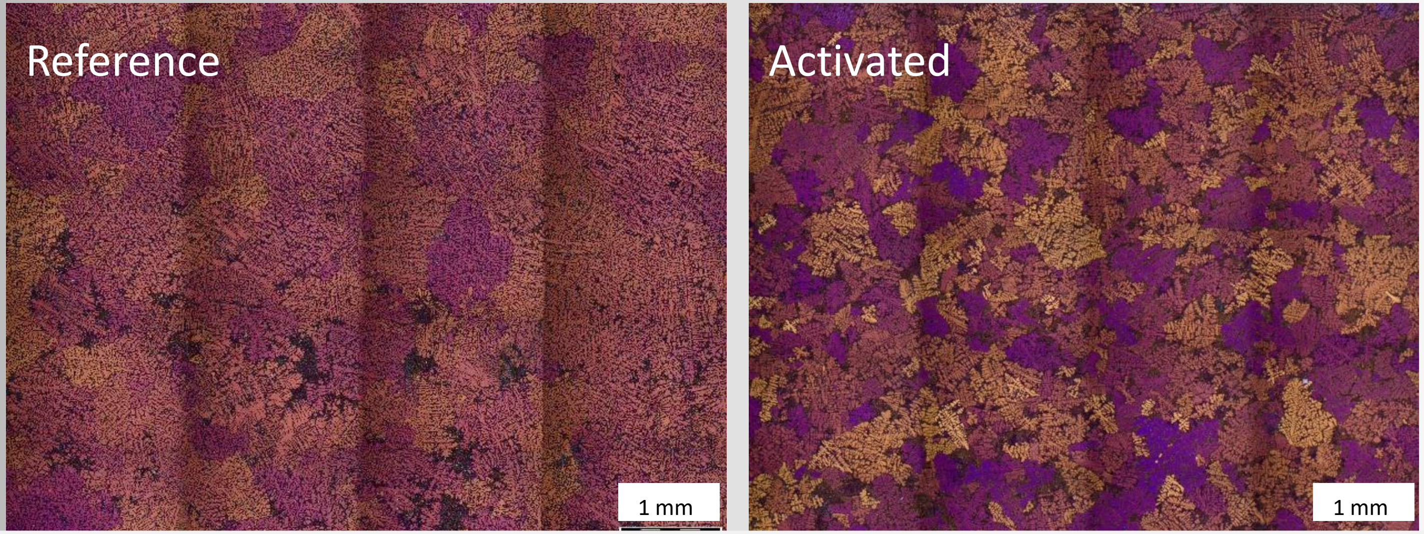
Results – Grain size

- Metallographic results: Etched metallographic pictures of different casting trials with varied parameter sets



Results – Grain size

- Smaller grain size is achieved (-30%)
- Smaller and better distributed defects in the matrix → Driver for the better mechanical properties
- Higher homogeneity between different samples compared to reference achieved

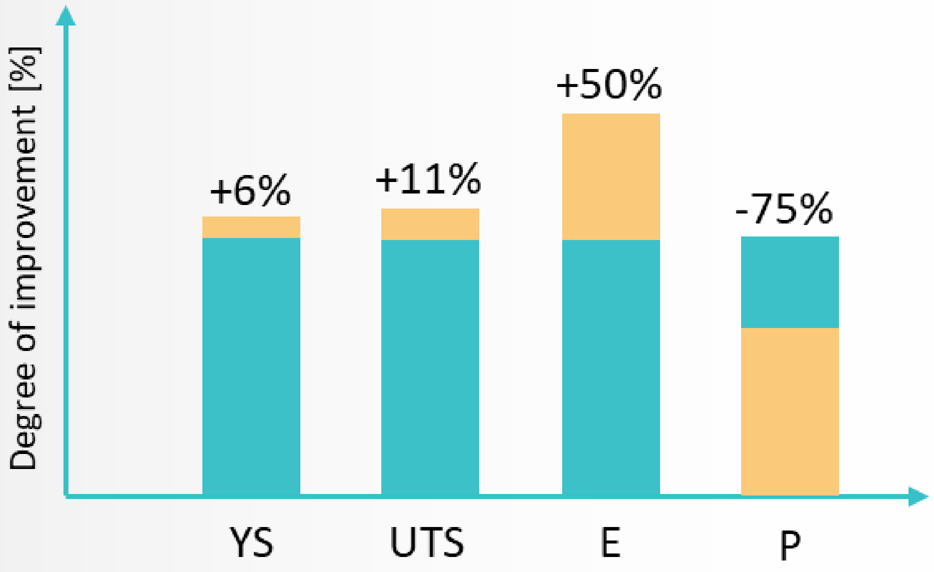


More homogeneous microstructure and fewer casting defects are achieved between samples when using active insert compared to reference -> Higher process stability leads to reduced scrap rate

Conclusion - Outlook

Conclusion

- Positive influence on the solidifying melt through targeted use of the “Active Insert” proved
  - Increase in mechanical properties
  - Improved microstructure (homogeneity)
  - Grain size reduced by 30%
  - Dendritic porosity reduced by 75% due to grainsize reduction and their rounder geometry

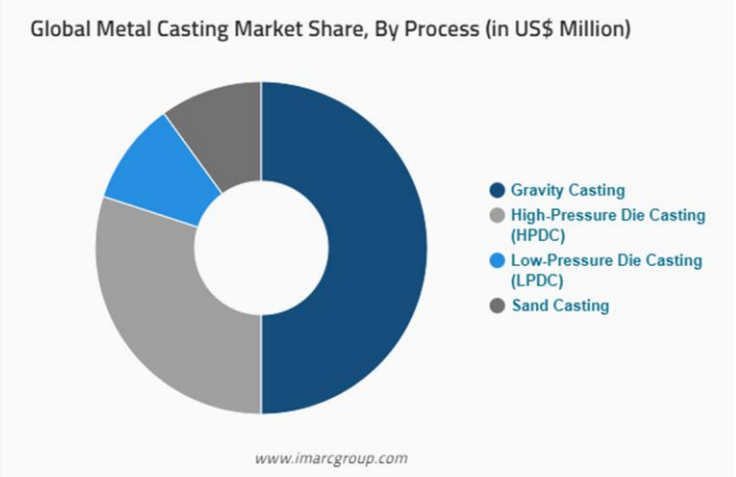


Active Insert: Pins and Actuator

The combination of the actuator and pins showed the best results

Outlook

- High market potential
  - Technical improvement of the system offers wider application areas
    - several other casting process applications possible (e.g. Gravity Casting)
- Next steps and further development together with voestalpine
  - Increase knowledge about system (ATM: TRL5 -> TRL6)
    - validate results in industrial application
    - validate process stability and service life
    - test several alloys to widen the scope of the application area
    - further parameter investigations and design optimizations
  - Develop a "Blackbox" to aim at an all-in-one solution
    - pre-series mould at customer sight



From labor environment to industry level

Acknowledgment

The authors would like to **thank voestalpine High Performance Metals GmbH for financing** the project, the successful cooperation and the technical support.

voestalpine

ONE STEP AHEAD.

Active inserts, a plug and play solution for increasing mechanical properties and reducing porosity in LPDC-ed parts

THANK YOU!

voestalpine Additive Manufacturing Center GmbH

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