all in

AMAP Kolloquium

ACTech®
a materialise company

Aachen | 11.01.2018 | Thomas Gotte

AMAP Kolloquium

Aachen, January 11th, 2018

Specialities in the prototype castings production: optical measurement and patternless mold manufacturing (sand casting)

Agenda AMAP Kolloquium

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About me

Company overview (short)

Production processes (short):
- Patternless mold manufacturing
- Geometric-optical measurement

Examples (optional)

About me

Born: 09.09.1970 (48 years)
in Freiberg (Saxony)

Residence: Marienberg (Saxony)

Family: Married, 2 children
(m 10 years, f 16 years)

Education: Degree in Business Administration
at Technical University in Chemnitz

Job: Sales Engineer at ACTech
since August 2001

Contact: Phone: +49 3731 169 107
Fax: +49 3731 169 500
Mobile: +49 162 2954 602
E-mail: tgo@actech.de

Agenda AMAP Kolloquium

Aachen | 11.01.2018 | Thomas Gotte

About me

Company overview (short)

Production processes (short):
- Patternless mold manufacturing
- Geometric-optical measurement

Examples (optional)

Company | Overview

Foundation: 1995

Personnel: approx. 375

Production area: 8,500 m² (92,000 sq ft)

Capacity: approx. 10,000 prototypes per year

Turnover 2017: 35 Mio. Euro

QM and EM certifications according to:

ISO 9001:2015 and ISO 14001:2015 (valid until 17.12.2018)

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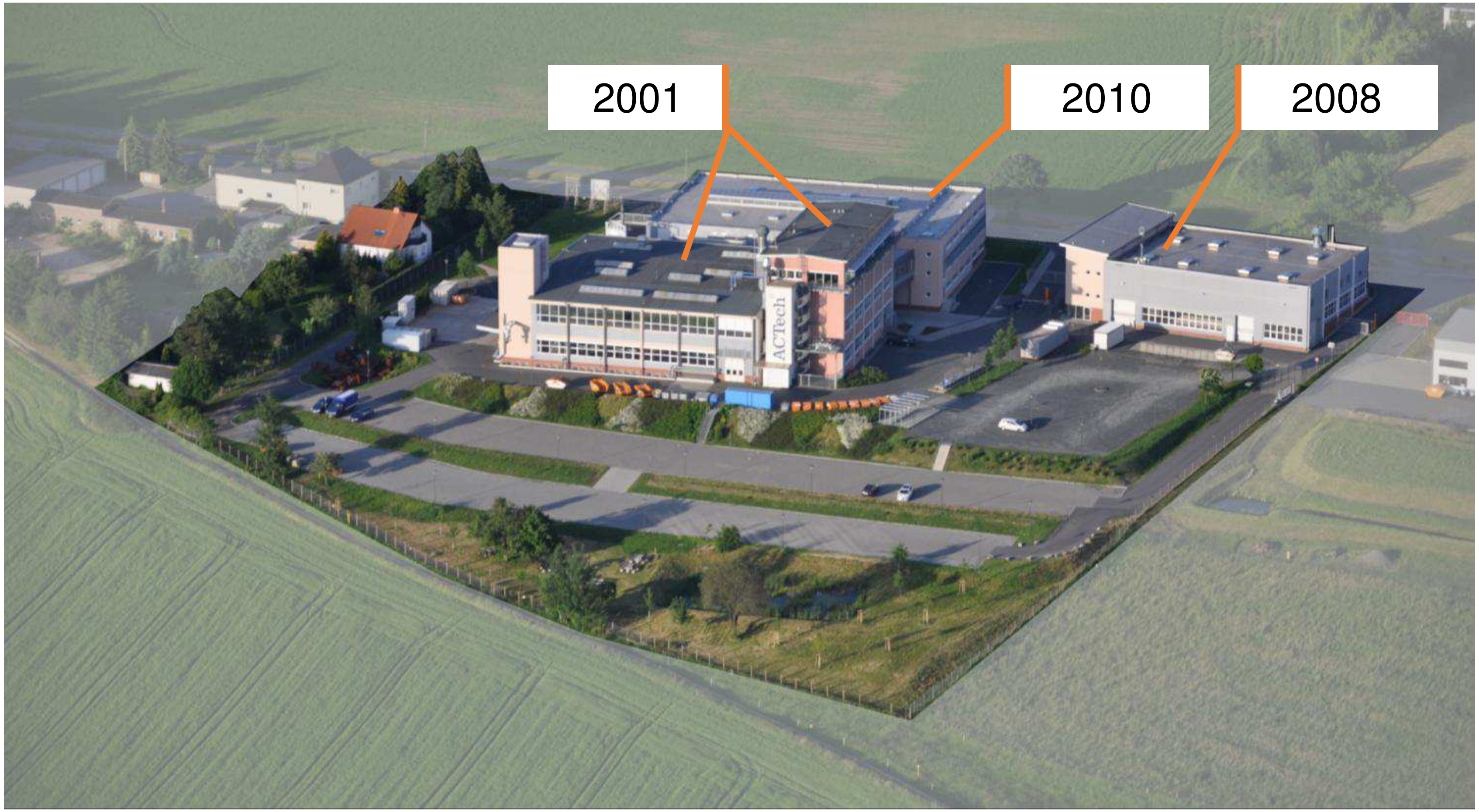

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Company | Plant

Sand casting foundry

- Management, administration
- Mold manufacturing
- Mold assembly
- Foundry shop
- Heat treatment
- Quality control

4,500 m² (48,000 sq ft) shop floor

Company | Plant

CNC shop

- State of the art and extremely flexible

2,000 m² (21,500 sq ft) shop floor

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Company | Plant

Investment casting foundry

- Pattern manufacturing with rapid prototyping
- Mold manufacturing plaster and ceramic

2,000 m² (21,500) sq ft shop floor

ACTech all in
a materialise company

Company | Locations

ACTech GmbH
Freiberg | GERMANY
headquarter | manufacturing
375 employees
all facilities in house

ACTech North America Inc.
Ann Arbor, MI | USA
Sales Office America
9 employees

ACTech GmbH Liaison Office
Bangalore | INDIA
Representation Office Asia
4 employees

Company | Member of the Materialise company

Since October 2017 (from financial investor to strategic investor)

No changes in ACTech’s business model!!!

Materialise with 27 years of experience in 3D metal/plastics printing and belonging software solutions

More information: see press releases on www.materialise.com and www.actech.de

Company | Member of the Materialise company

October 04, 2017

Materialise Acquires ACTech, Full-Service Manufacturer of Complex Metal Parts

Acquisition will enhance Materialise's ability to offer complete manufacturing solutions for unique 3D-printed metal parts.

Leuven, Belgium – October 4, 2017. Materialise (NASDAQ:MTLS), has today announced the acquisition of ACTech, a Germany-based leader in producing limited runs of highly complex cast metal parts. The transaction brings together the metal competencies of Materialise, a leading provider of additive manufacturing solutions and software, with those of ACTech into a comprehensive metal manufacturing offering.

ACTech has over 20 years of deep knowledge and experience in the production, treatment and quality control of complex metal parts. The acquisition of ACTech's expertise and in-house infrastructure will enable Materialise to accelerate the development of its existing metal competence center and take a strong position in the market for the production and delivery of unique, complex 3D-printed metal parts.

> "ACTech knows metal and how to shape it to production standard, and we know Metal 3D Printing. Bringing those two competencies together is vital to the delivery of high added-value metal 3D-printed parts for specialized applications."
>
> —Wilfried Vancraen, founder and CEO of Materialise

Source:

www.materialise.com

Press release from October 4th, 2017

Company | Member of the Materialise company

Since October 2017 (from financial investor to strategic investor)

No changes in ACTech's business model!!!

Materialise with 27 years of experience in 3D metal/plastics printing and belonging software solutions

More information: see press releases on www.materialise.com and www.actech.de

Actual challenge:

Find out synergy effects in both business models

Materialise: Metal printing in Bremen
ACTech: Metal casting in Freiberg

Scope of Business

Manufacturing of prototype castings

- Extremely fast lead time
- Complex parts
- Low quantities
- Close-to-production characteristics
- CNC machining of parts
  ready to be installed

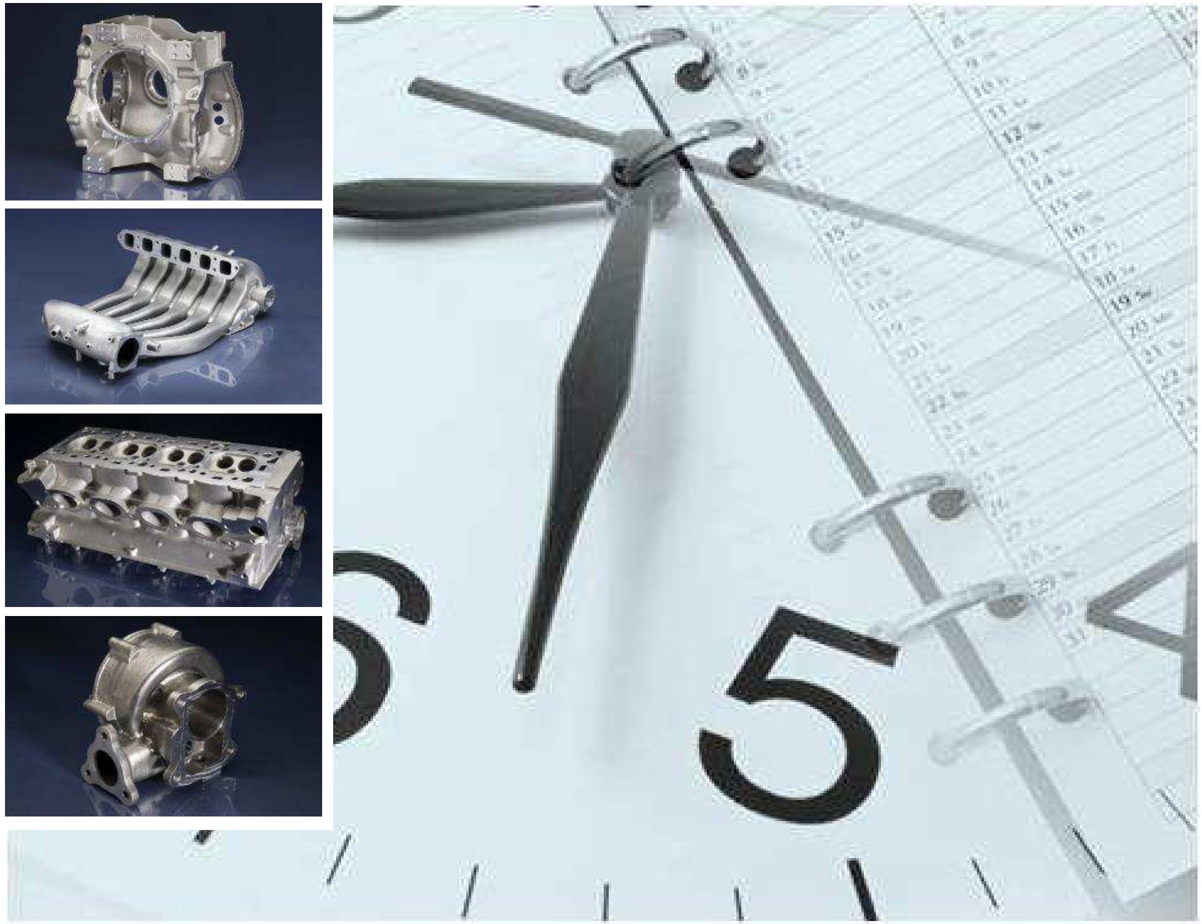
Your advantage

Shortest lead time
- Time optimized planning
- State of the art production technologies

Dependability
- Complete manufacturing processes under one roof

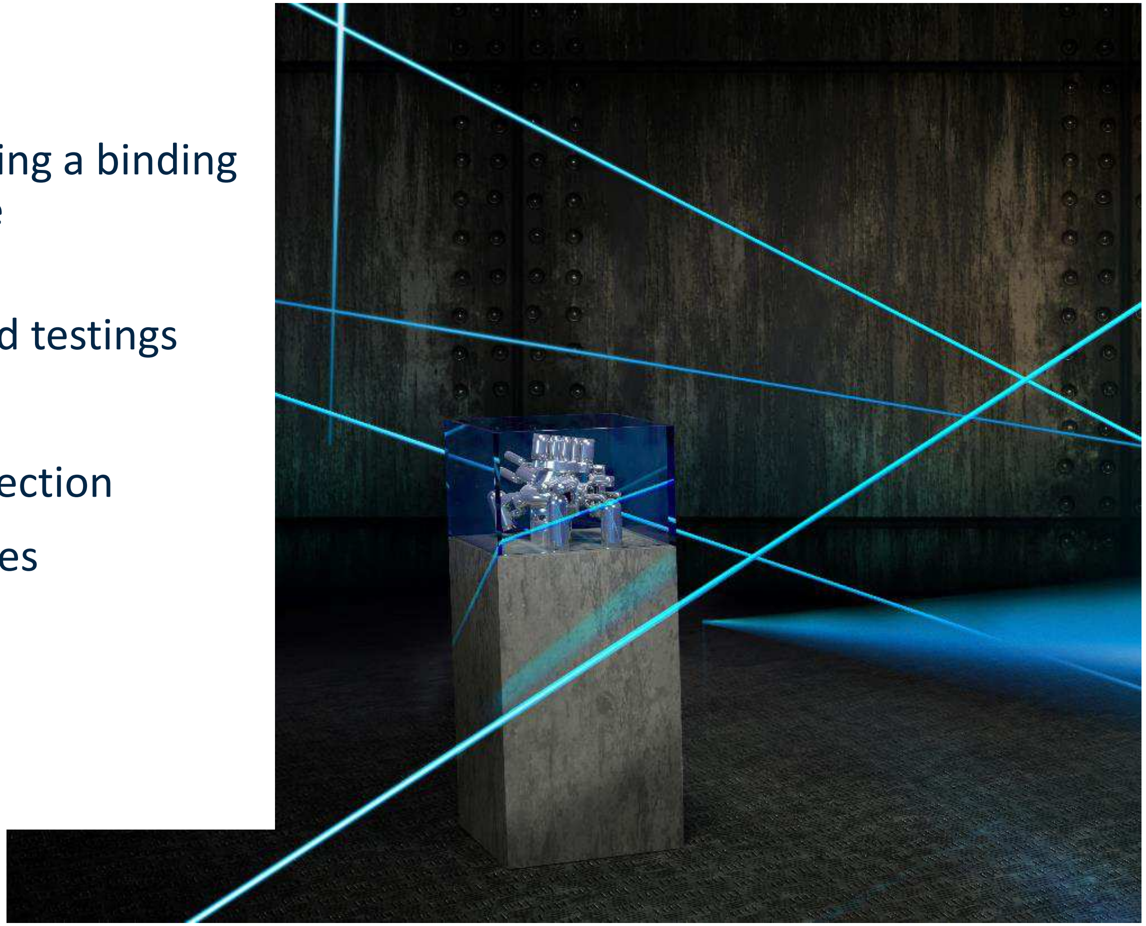
Quality standard
- Experience of approx. 25,000 projects

Planning security
- LIVE project status available online 24/7



No risk strategy

- Response to enquiries within 24 hours including a binding quote and the shortest possible delivery time
- In-house project management, mold design, mold production, foundry, CNC machining and testings
- Data security audited by our customers
- Certified in-house quality assurance and inspection
- Punctual delivery of ready-to-install prototypes

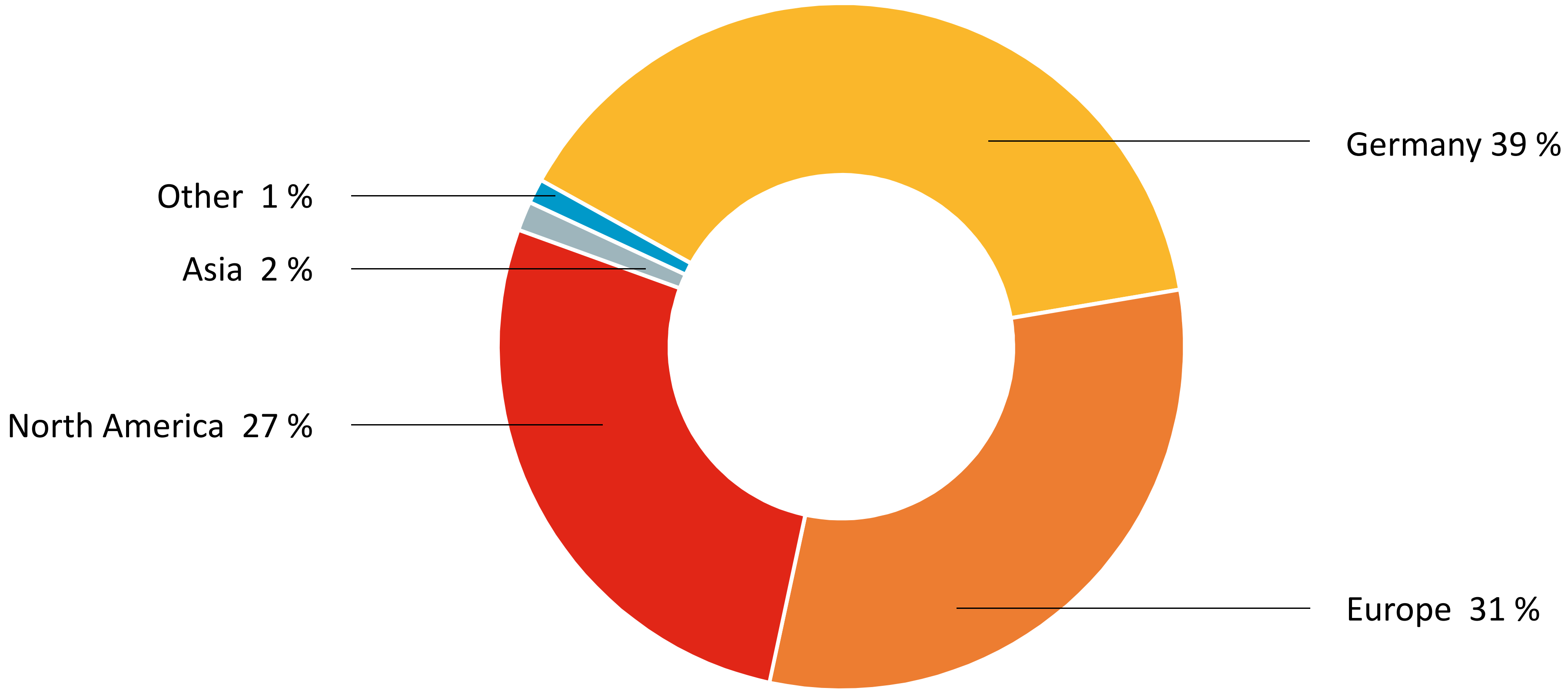


Facts and Figures

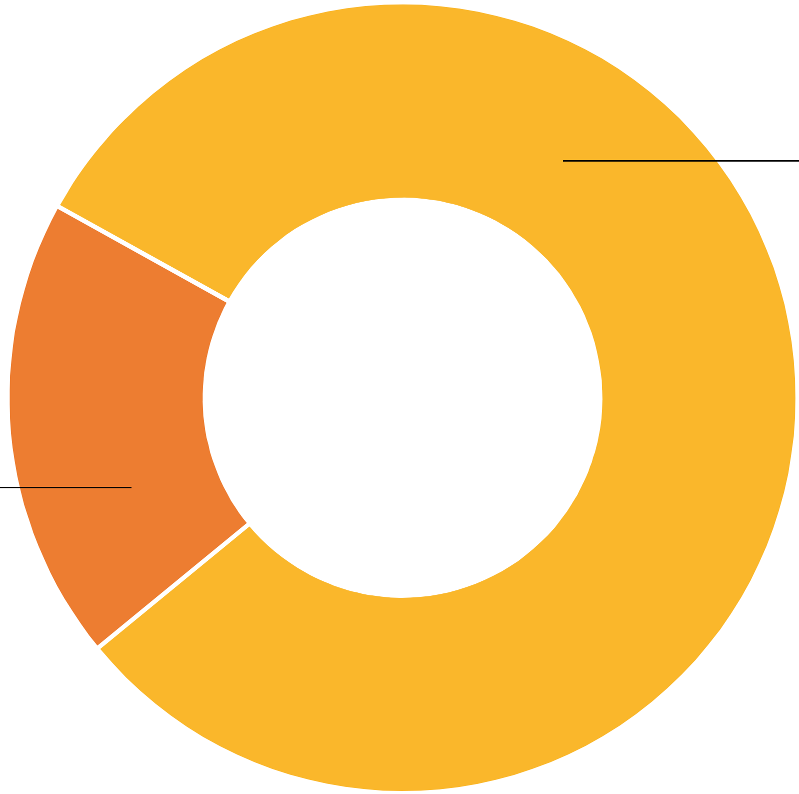
More than 25,000 different casting designs.
More than 190,000 castings total.
More than 1,200 customers in 36 countries.
Annual capacity: more than 10,000 prototype castings.

ACTech® all in
a materialise company

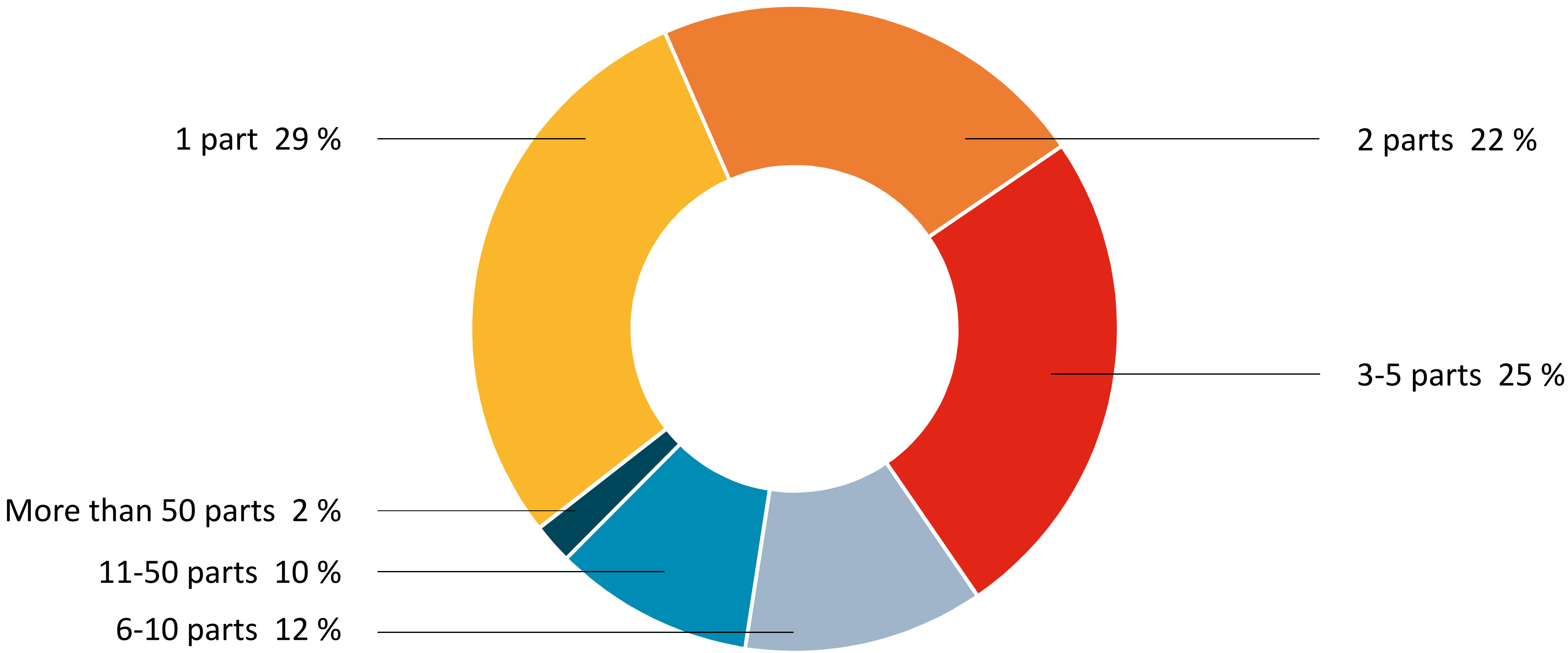
Structure of sales volume | location of our customers



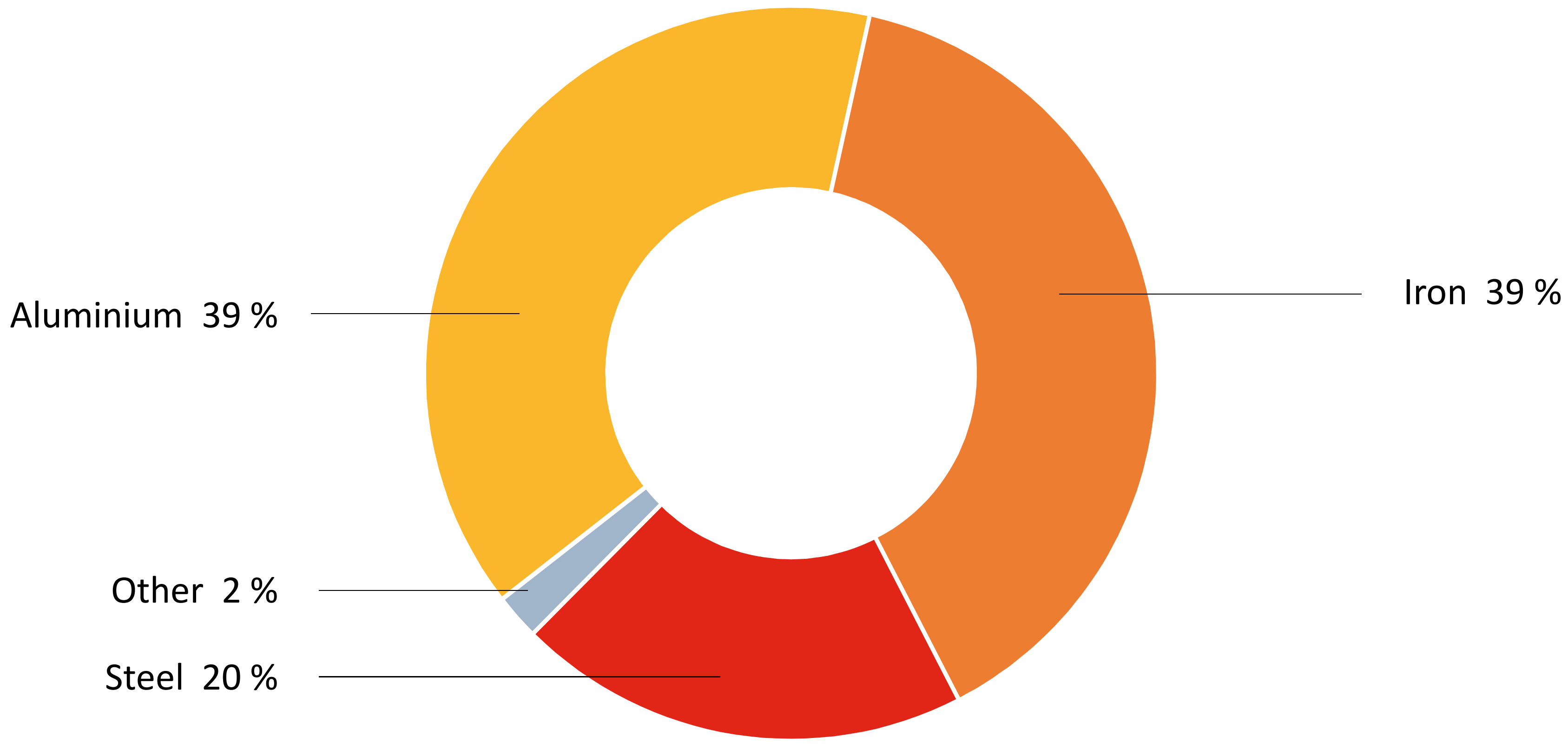
Structure of sales volume | business area of our customers



Structure of projects | number of castings per order



Structure of projects | material of castings



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About me

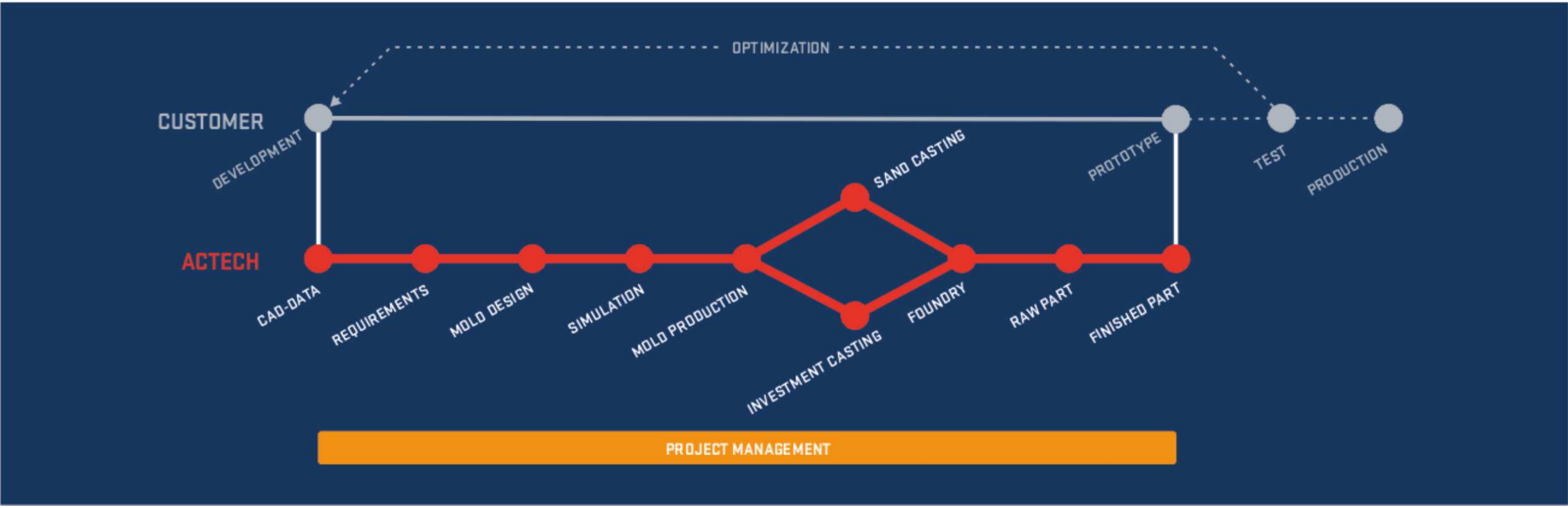
Company overview (short)

Production processes (short)

- Patternless mold manufacturing
- Geometric-optical measurement

Examples (optional)

High speed workflow



Requirements

To choose the right casting technology we need the following information:

- Quantity of parts
- Material specifications
- Necessary tests
- CNC machining requirements
- Desired delivery schedule

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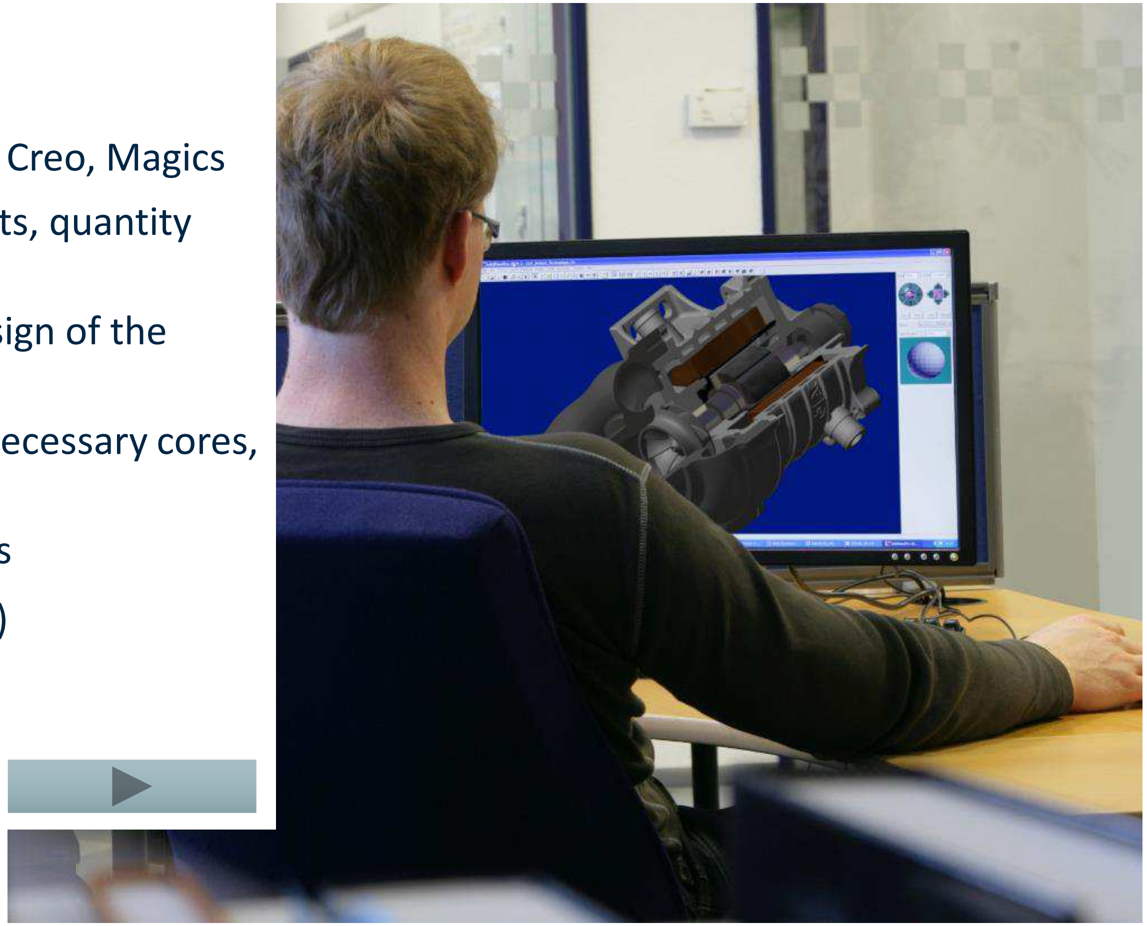
Mold design | Simulation

- CATIA, ProE, Siemens NX, GeoMagic, 3Devolution, Creo, Magics
- Mold design depending on customers requirements, quantity and used rapid prototyping technologies
- Raw part design, adding machining allowance, design of the prepared feeding and gating system
- Define the split lines for mold segmentation and necessary cores, cores fitted with core prints for mold assembly
- Mold segments and cores are fitted with interlocks
- Mold filling and solidification simulation (PROCast)
- Prediction of possible casting defects
- Optimization of casting technology



Mold manufacturing

SAND CASTING

- Laser sintering
- Direct Mold Milling®
- 3D furan-resin printing
- 3D phenolic-resin printing

INVESTMENT CASTING

- Ceramic Shell Process
- Plaster Mold Process

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- Geometric-optical measurement

Examples (optional)

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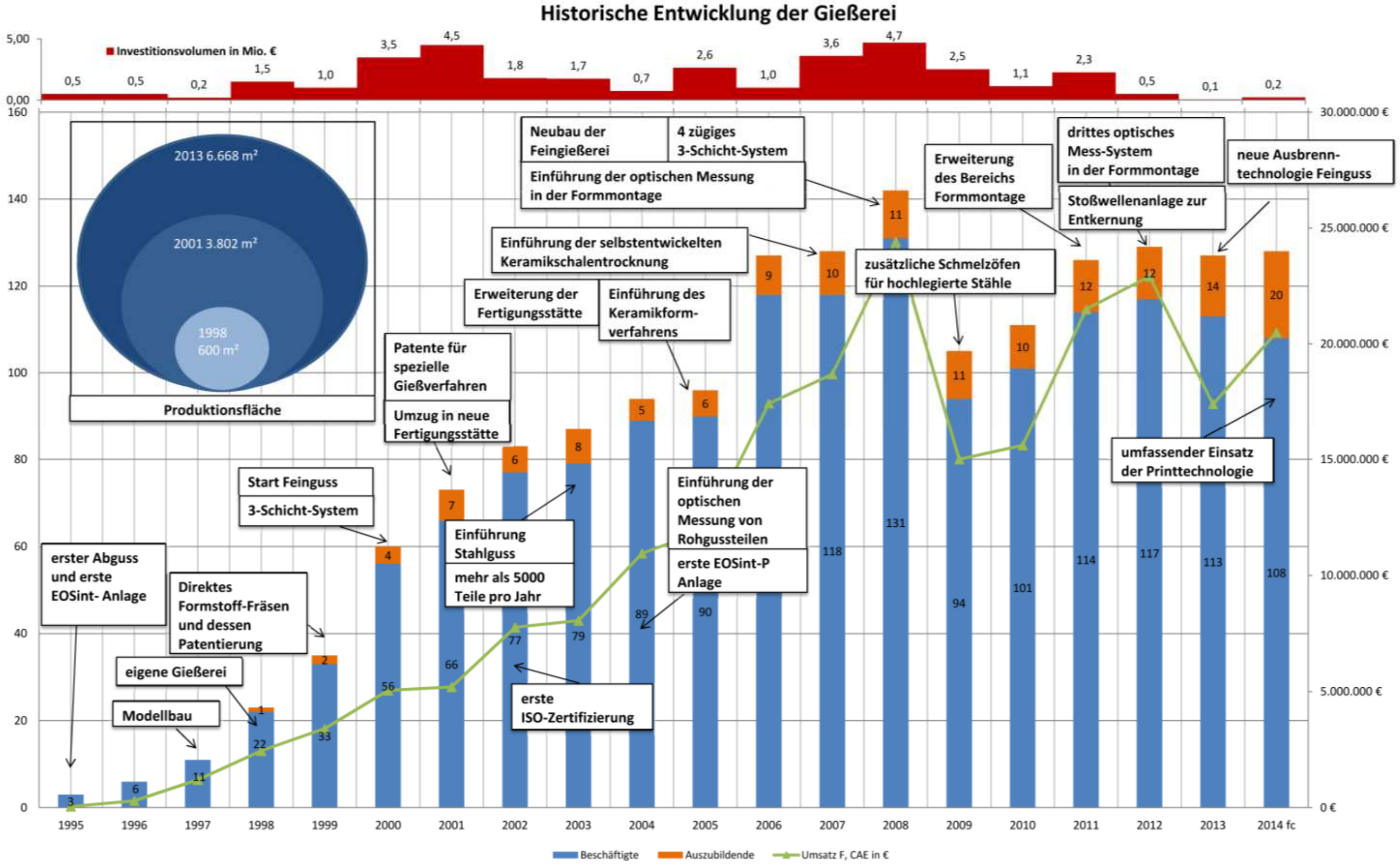

RP in use

1995

Start of laser sintering - 1st machine

Mold manufacturing | Sand Casting

Laser sintering of sand cores and molds [1 of 2]

- 1st important process for tool-free casting production
- Layerwise process of cores and mold segments
- Complex filigree core packages with least tolerances in one piece
- Undercuts easy to produce
- No draft angles and fillets are necessary
- Layer approx. 0.2 mm
- Build volume: 720 x 360 x 360 mm
- Running doble laser systems

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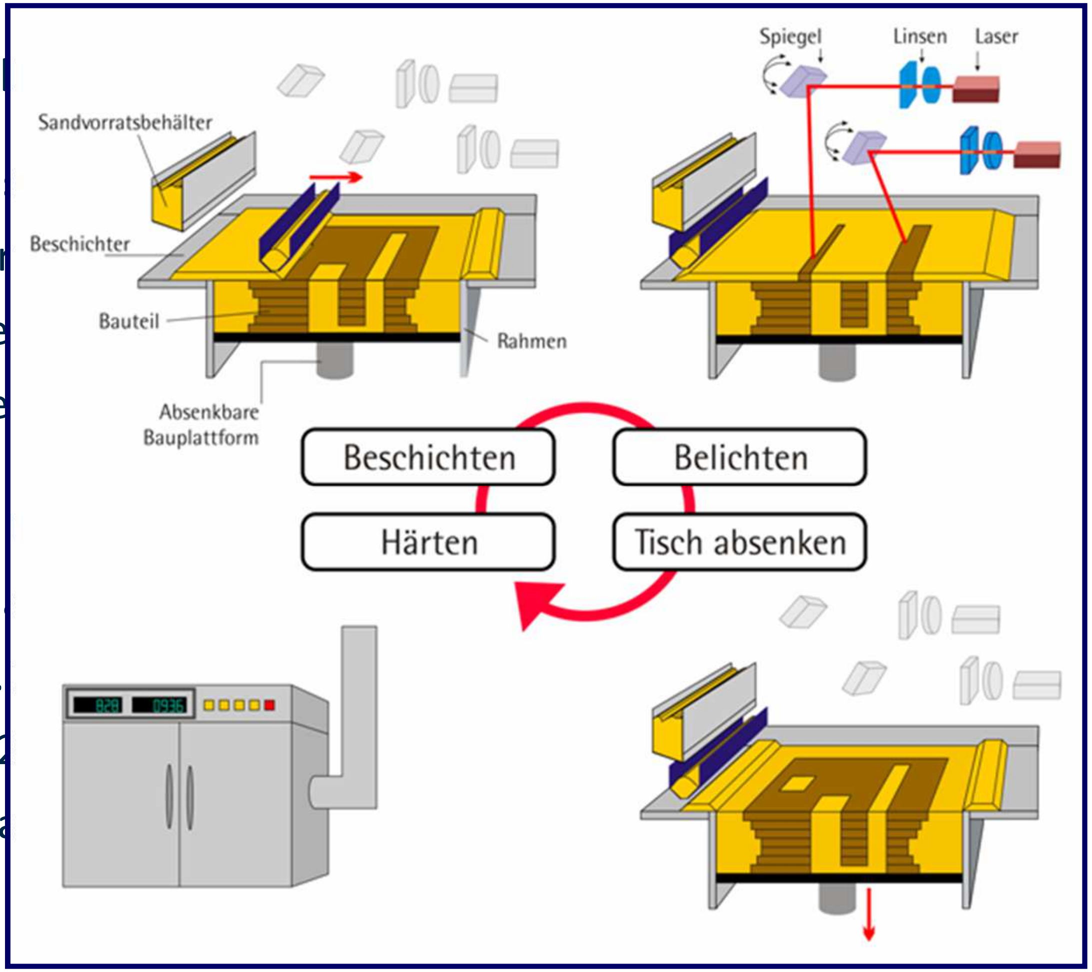
Mold ma

Laser sintering of

- 1st important pr
- Layerwise proce
- Complex filigree one piece
- Undercuts easy
- No draft angles
- Layer approx. 0.
- Build volume: 72
- Running doble la



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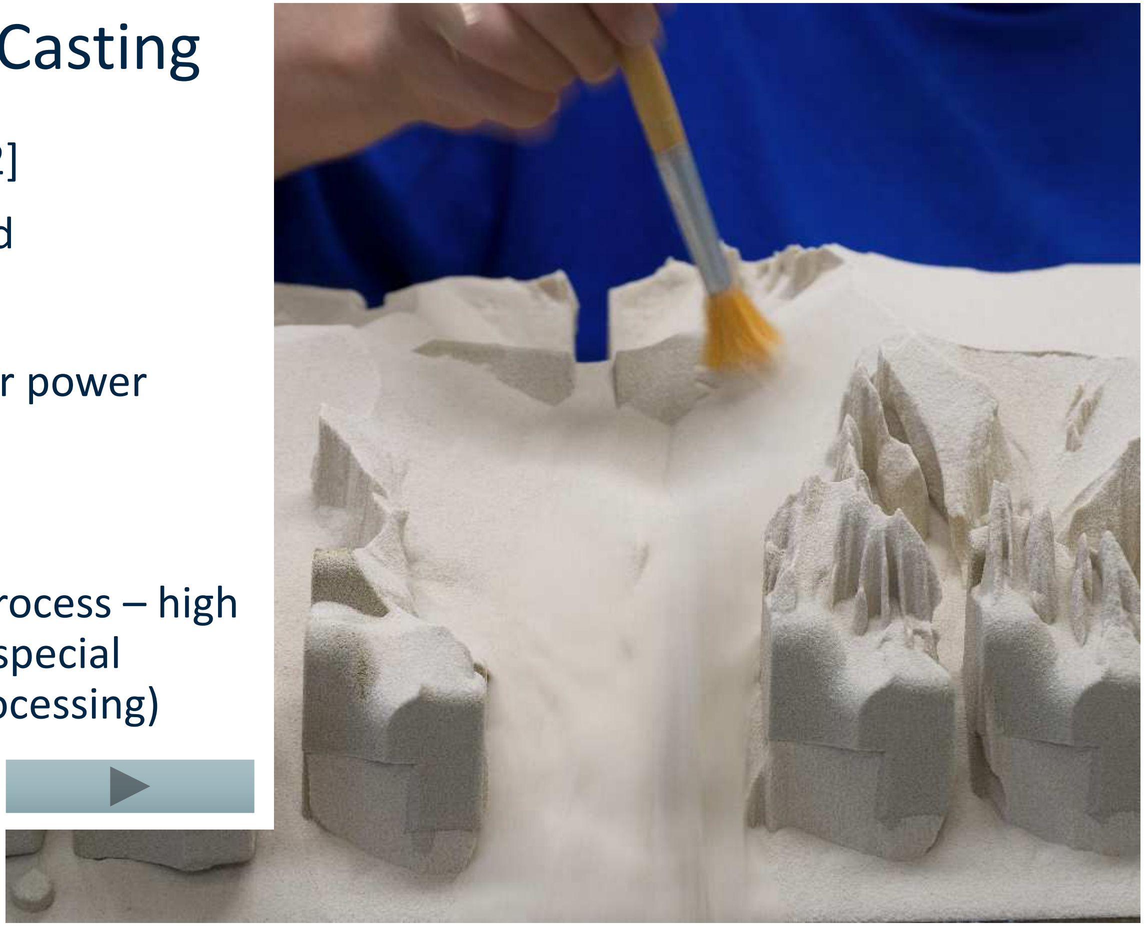
Mold manufacturing | Sand Casting

Laser sintering of sand cores and molds [2 of 2]

- All standard sand casting alloys can be poured
- Core-in-core solutions are possible
- Low productivity because of point-based laser power
- Manual finish and post-processing necessary
- High binder content (approx. 5.5 %)
- 20 % of final strength during laser sintering process – high strength jump after post-hardening process (special knowhow in support technology and post-processing)
- High strengths with more than 1,000 N/cm²



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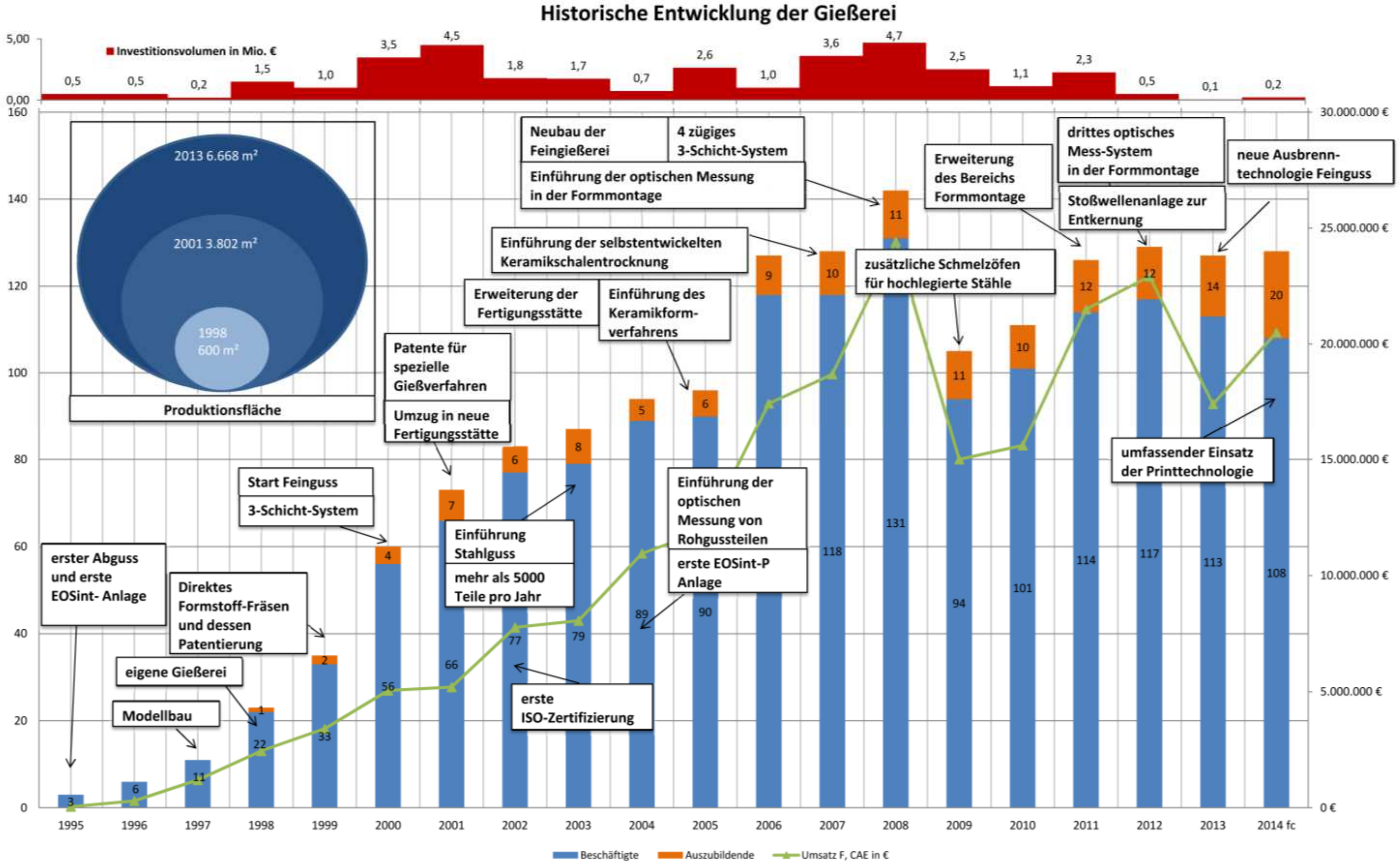


RP in use

1995

Start of laser sintering - 1st machine

1999

Start of Direct Mold Milling® - 1st machine

Mold manufacturing | Sand Casting

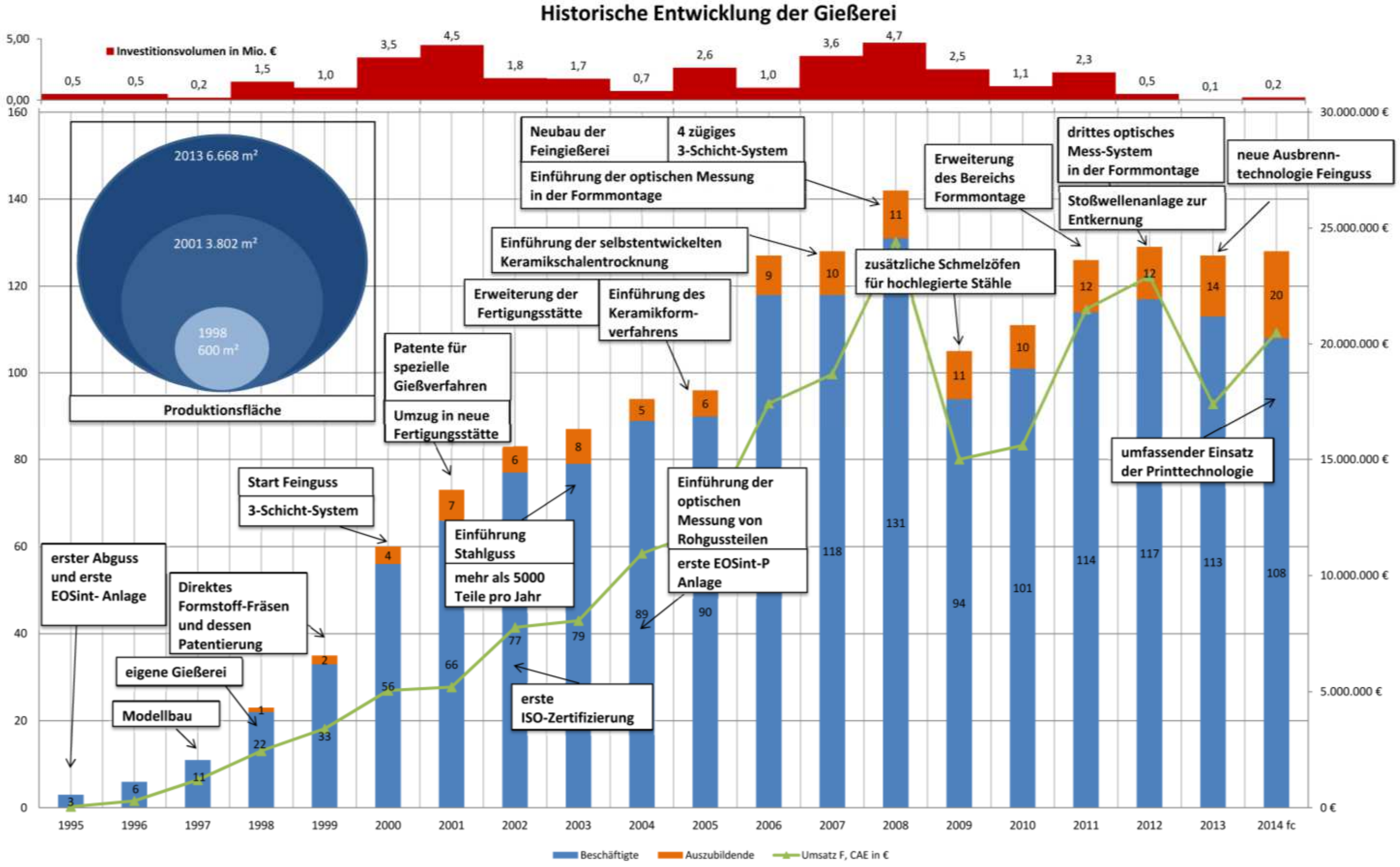
DIRECT MOLD MILLING® [1 of 2]

- Mold segments up to 2,400 x 1,400 x 800 mm
- Larger molds are possible by segementation
- No draft angles and fillets are necessary
- All standard sand casting alloys can be poured
- Production of undercuts is limited but no problem in combination with cores and mold segments produced with other RP technologies
- Processibility of all usual molding material systems
- Very large molds are available within a few hours

Mold manufacturing | Sand Casting

DIRECT MOLD MILLING® [2 of 2]

- Highest variance in the molding material systems
- No directionality (anisotropy) of the characteristics in the molding material
- No expensive finish of adherent sand deposits
- Surface quality primary depends on grain size of the mold base material - this will not be cut but teared out of bond
- Simple application of usual foundry handling systems (molding boxes, reinforcements etc.)



RP in use

1995
Start of laser sintering - 1st machine

1999
Start of Direct Mold Milling® - 1st machine

2016
Start of 3D sand printing - 1st machine

Mold manufacturing | Sand Casting

3D PRINTING

- Highest flexibility similar to the laser sintering process but much larger build volumes
- Layer approx. 0.25 to 0.30 mm usually
- Higher productivity because of line-based printheads and wider printheads (ready for small series)
- 80 % of final strength during printing process – simple post-processing
- For fragile cores and mold segments furan-resin based system is not sufficient – phenolic-resin process necessary
- Available molding material systems for printing increase (furan-resin based, phenolic-resin based, inorganics in combination with different mold base materials)

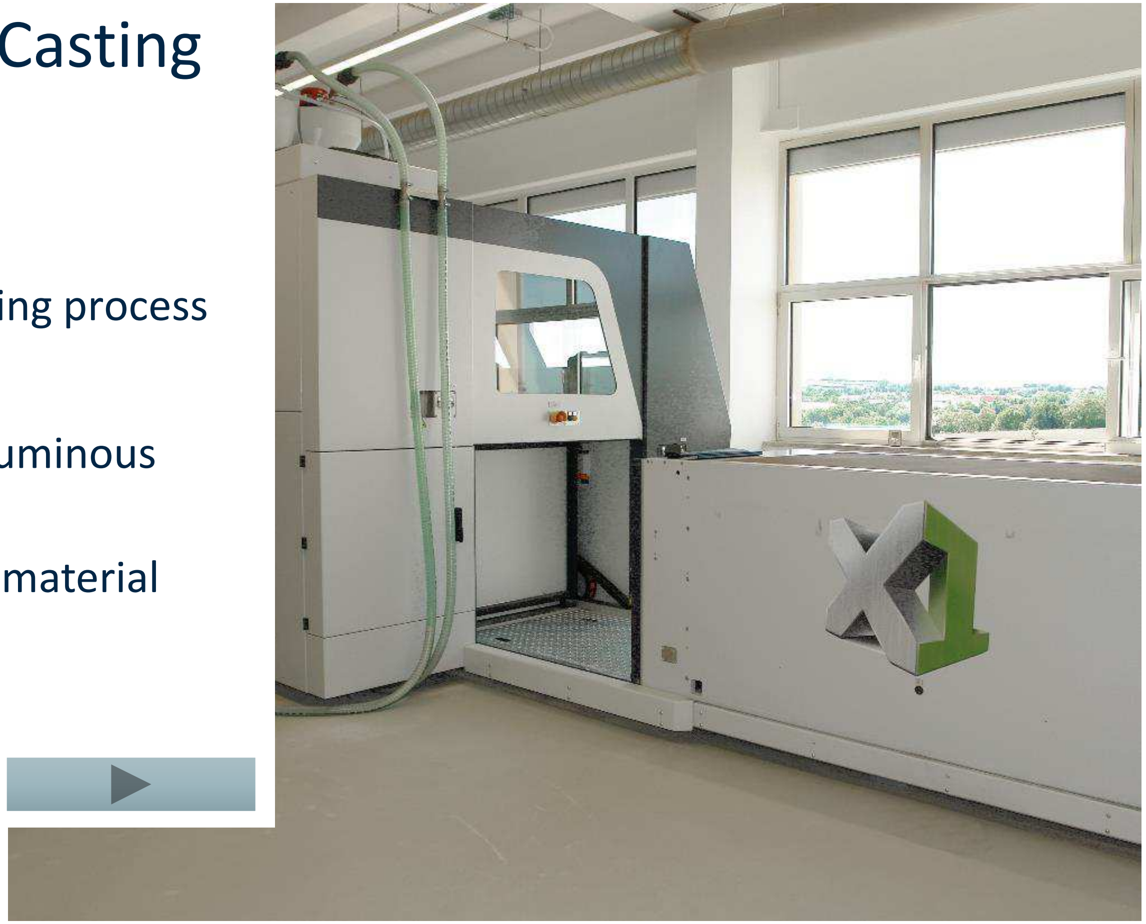
Source: ExOne

Source: Voxeljet

Mold manufacturing | Sand Casting

3D FURAN-RESIN PRINTING

- Build volume: 1,800 x 1,000 x 700 mm
- 2-job-box-system for continuous manufacturing process
- Undercuts easy to produce
- Application: complex mold segments and voluminous cores for aluminum, iron and steel castings
- Use of inexpensive quartz sand as mold base material



Mold manufacturing | Sand Casting

3D PHENOLIC-RESIN PRINTING (CHP)

- New development by company ExOne in 2015 – ACTech is first user
- In the past: post-processing with microwaves necessary – today: no more post-processing (Cold Hardening Process)
- Build volume: 800 x 500 x 400 mm
- Undercuts easy to produce
- Application: complex cores with higher strenght, core-in-core solutions for aluminum, iron and steel castings
- Today: material costs for synthetic mullite mold base material approx. 25 times higher than quartz sand

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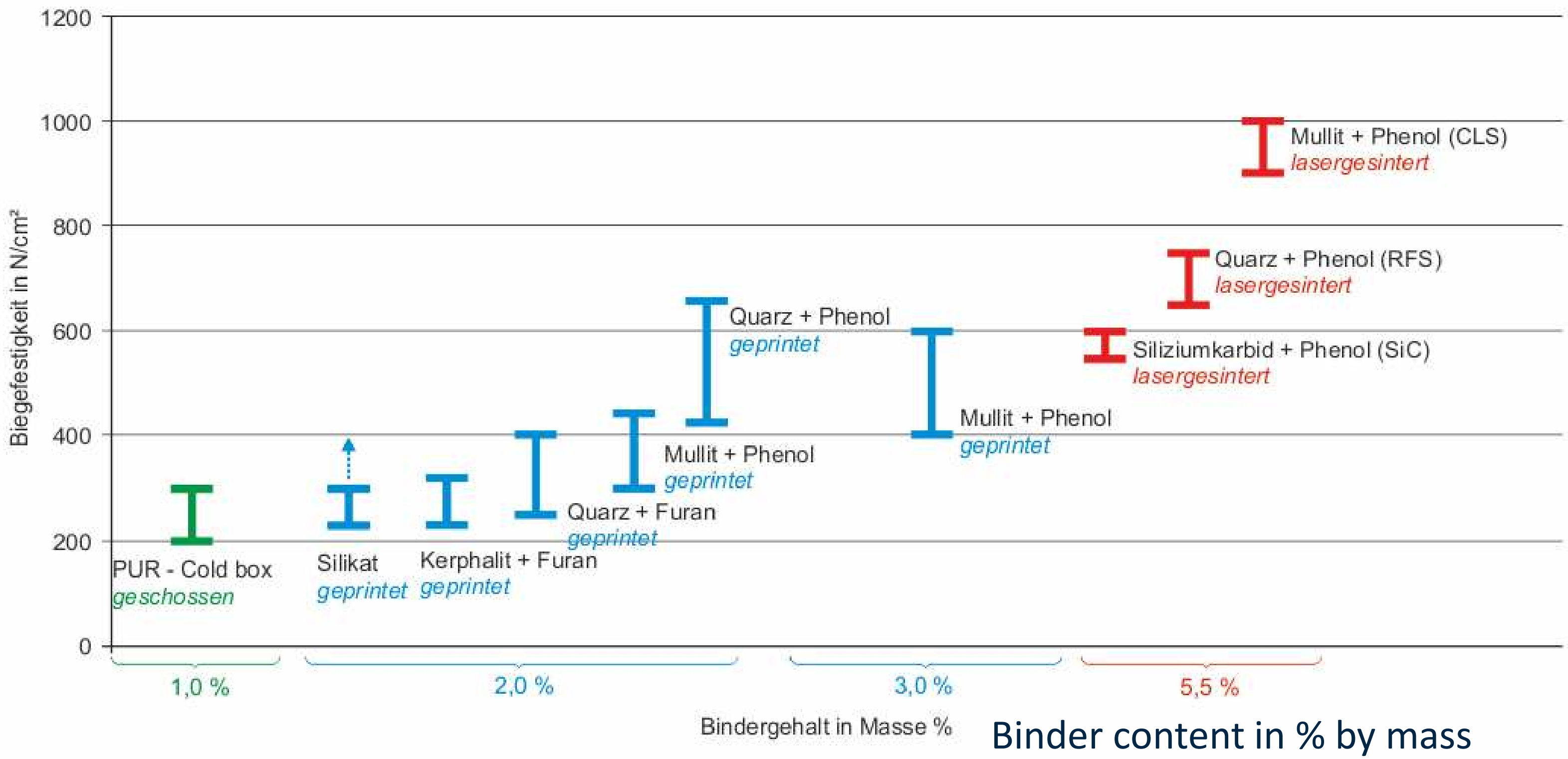
Mold manufacturing | Sand Casting

Excursus strengths

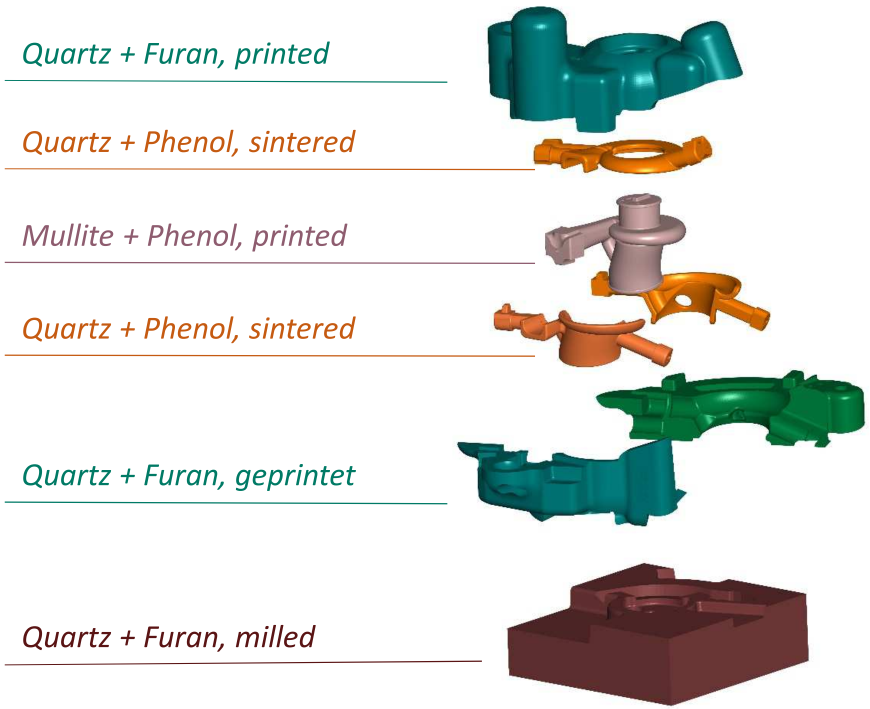
Flexural strengths in N/cm²



Binder content in % by mass

Mold manufacturing | Sand Casting

Mold assembly for a water-cooled aluminum exhaust turbine housing – an example



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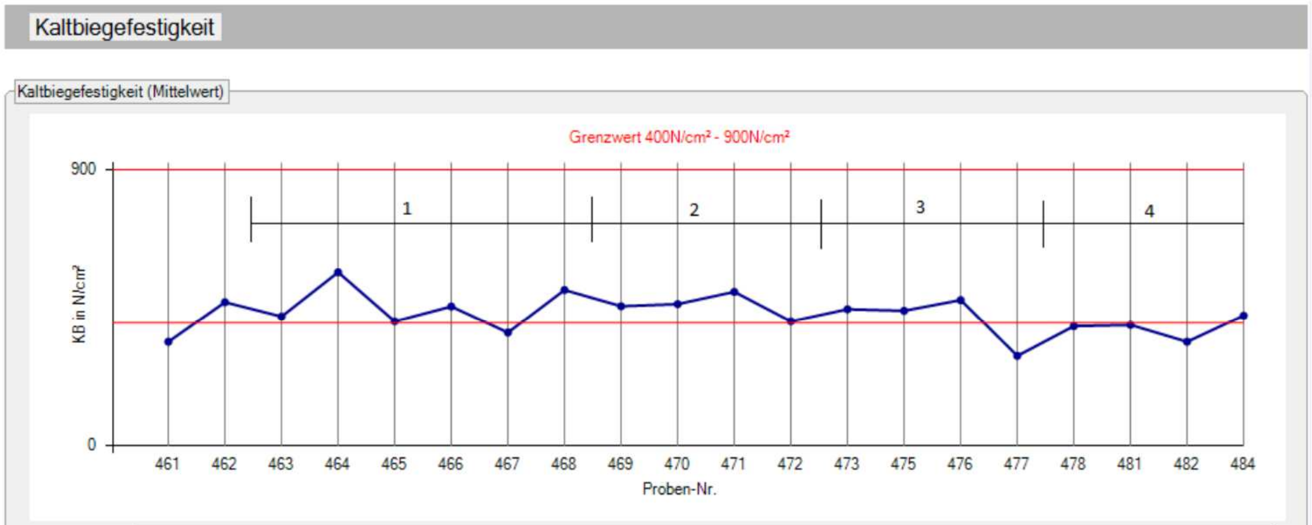
Mold manufacturing | Sand Casting

ACHTUNG: neue Folie 09.01.2018
Muss noch übersetzt werden!!!

Quality assurance | Checking molding material

- Bindergehalte wird über Glühverlust charakterisiert
- Grünfestigkeit am Biegeriegel bzw. Scheibenbiegefestigkeit „gebauter“ Prüfkörper unter Berücksichtigung der Baulage pro Baujob
- Granulometrische Kennwerte, Überkorn muss vermieden werden → Schichtfehler



Proben-Nr.	461	462	463	464	465	466	467	468	469	470	471	472	473	475	476	477	478	481	482	484
KB in N/cm²	338	468	421	566	405	454	368	508	455	462	502	405	445	440	475	292	389	393	338	424

Grenzwert: 400N/cm² - 900N/cm²

Mold manufacturing | Sand Casting

Patternless mold manufacturing – Summary [1 of 3]

The selection of patternless core manufacturing technology is based on casting technology criteria and the quality requirements of the casting:

• Geometry	Dimensions, complexity Mass-volume ratio Core intensity
• Alloy	Aluminum Steel, iron
• Casting properties	Mechanical properties Wall thicknesses Lightweight designs

Mold manufacturing | Sand Casting

Patternless mold manufacturing – Summary [2 of 3]

Within the rapid prototyping core manufacturing technologies the following factors can be influenced conditionally:

• Strength	Molding material system Position inside building volume
• Gas permeability/volume/shock	Binder content Mold base material Gas discharge
• Surface	Mold base material Position inside building volume Finishing/coating activities

Mold manufacturing | Sand Casting

Patternless mold manufacturing – Summary [3 of 3]

- For the production of individual prototype castings is one additive-generative molding process not enough. Just the combination of the different RP processes allows the diversity
- For industrialization, various technical and organizational tools are necessary, which take into account the process specifics of additive-generative manufacturing in order to achieve a stable, process-reliable production.
- Mono production allows the qualification of a single additive-generative process for mass production.

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Company overview (short)

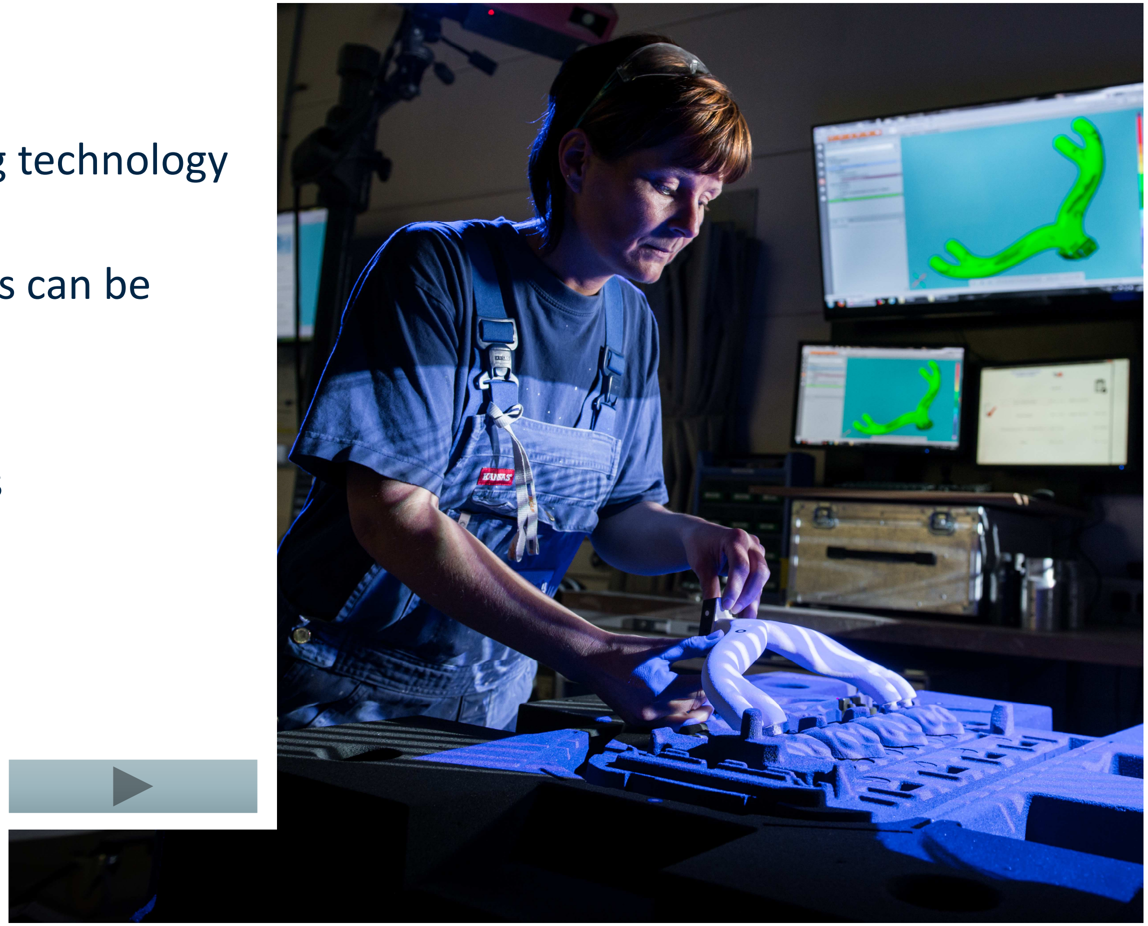
Production processes (short)

- Patternless mold manufacturing
- Geometric-optical measurement

Examples (optional)

Mold Assembly

- Exact mold assembly with modern measuring technology for lowest tolerances
- Mold segments from the various technologies can be combined
- Coating of mold segments and cores
- Completion with foundry-specific accessories (filter, chill iron, thermal feeder)



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Foundry

- Aluminum, grey iron, ductile iron, compacted graphite iron, alloyed and high alloyed steel, alloys following customers specification
- Directional solidification for better mechanical properties
- Vacuum supported pouring technology for thin wall thicknesses
- 850 kg melting capacity for aluminum
- 500 kg melting capacity for iron and steel alloys
- Core removal with shock wave technology

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- Patternless mold manufacturing
- **Geometric-optical measurement**

Examples (optional)

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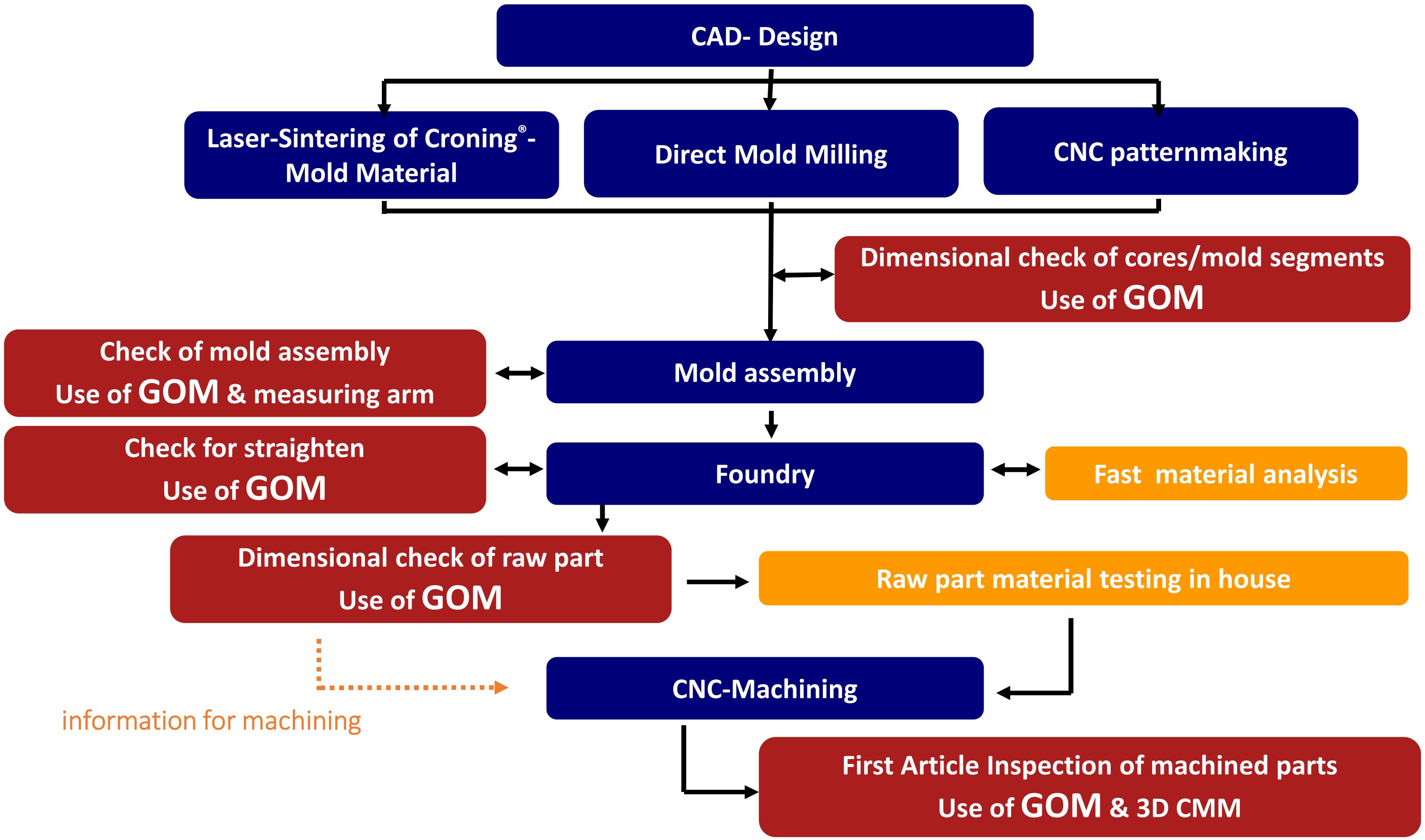
Raw part treatment and testing

- Geometric-optical measurement vs CAD data set
- Various heat treatment processes
- Tightness testing, crack detection, Fluoroscopy
- X-ray inspection (160 kV device, radioscopy)
- Visual inspection and endoscopy up to 2 mm diameter
- Ultrasonic thickness gauge
- Surface treatment requested by customer



Geometric
Optical
Measurement

5 application areas along production chain

Optical measurement systems used for:

Dimensional check of cores/mold segments
Use of GOM

Measuring of cores and mold segments as inspection in process

Check of mold assembly
Use of GOM & measuring arm

Check for straighten processes
Use of GOM

Measuring assemblies for double-checking the actual assembly with nominal CAD assembly as well as detection of assembly distortions

Dimensional check of raw part
Use of GOM

Measuring of the raw castings used as:

- Check of distortion and shrinkage allowance for internal quality inspection
- Raw casting inspection, including customer report
- Detection of optimal machining alignment

First Article Inspection of machined parts
Use of GOM & 3D CMM

Inspection of the machined parts only in lower accuracy compared to tactile CMM

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Dimensional check of cores/mold segments
Use of GOM

Check of mold assembly
Use of GOM & measuring arm

Check for straighten processes
Use of GOM

Dimensional check of raw part
Use of GOM

First Article Inspection of machined parts
Use of GOM & 3D CMM

GOM in use

Hardware: 8 ATOS systems, 1 TRITOP system & 3 offline stations
Software: ATOS Professional & GOM Inspect Professional

- **ATOS Triple Scan Generation II** (5 million pixels)

measuring volumes	distance meassuring points
1,000 x 750 x 750 mm	0.413 mm
560 x 420 x 420 mm	0.226 mm

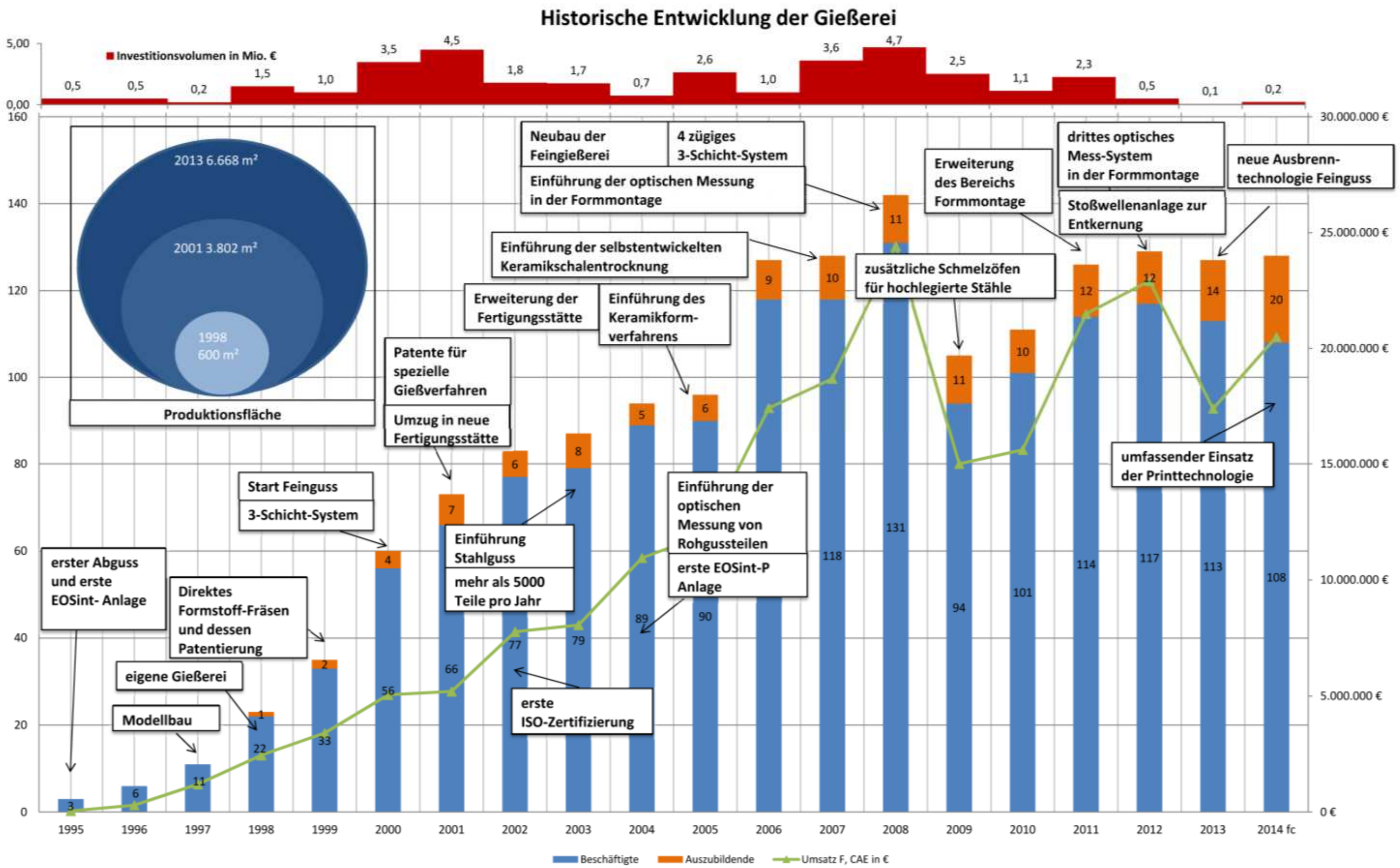
- **ATOS Triple Scan Generation III** (8 million pixels)

measuring volumes	distance meassuring points
1,000 x 750 x 750 mm	0.329 mm
750 x 530 x 520 mm	0.213 mm
560 x 420 x 420 mm	0.176 mm

Source: www.gom.com

- **ATOS TRITOP**
for big parts > 1,500 mm

- **Offline stations** for evaluations of the scans



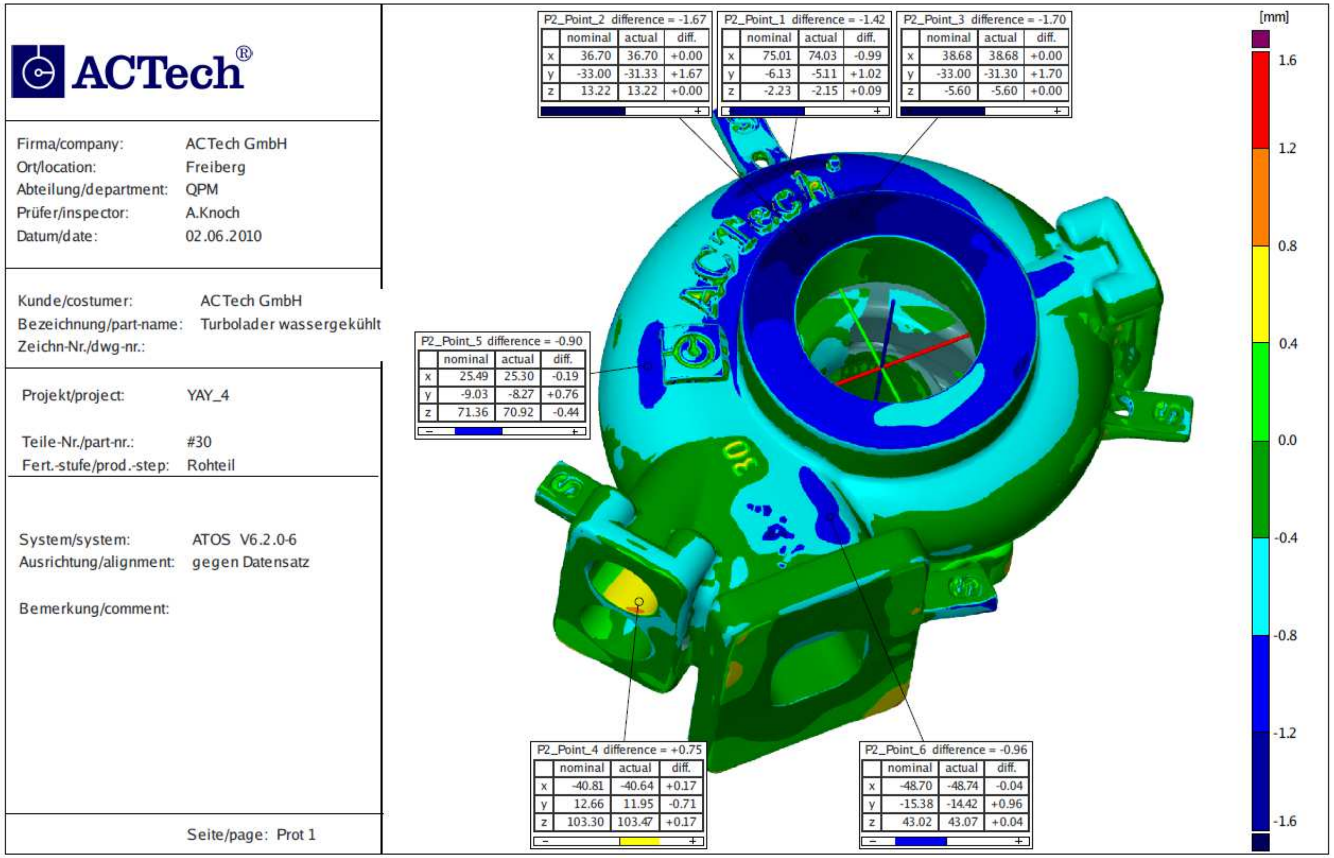
GOM in use

2004
Start of dimensional checks of raw parts

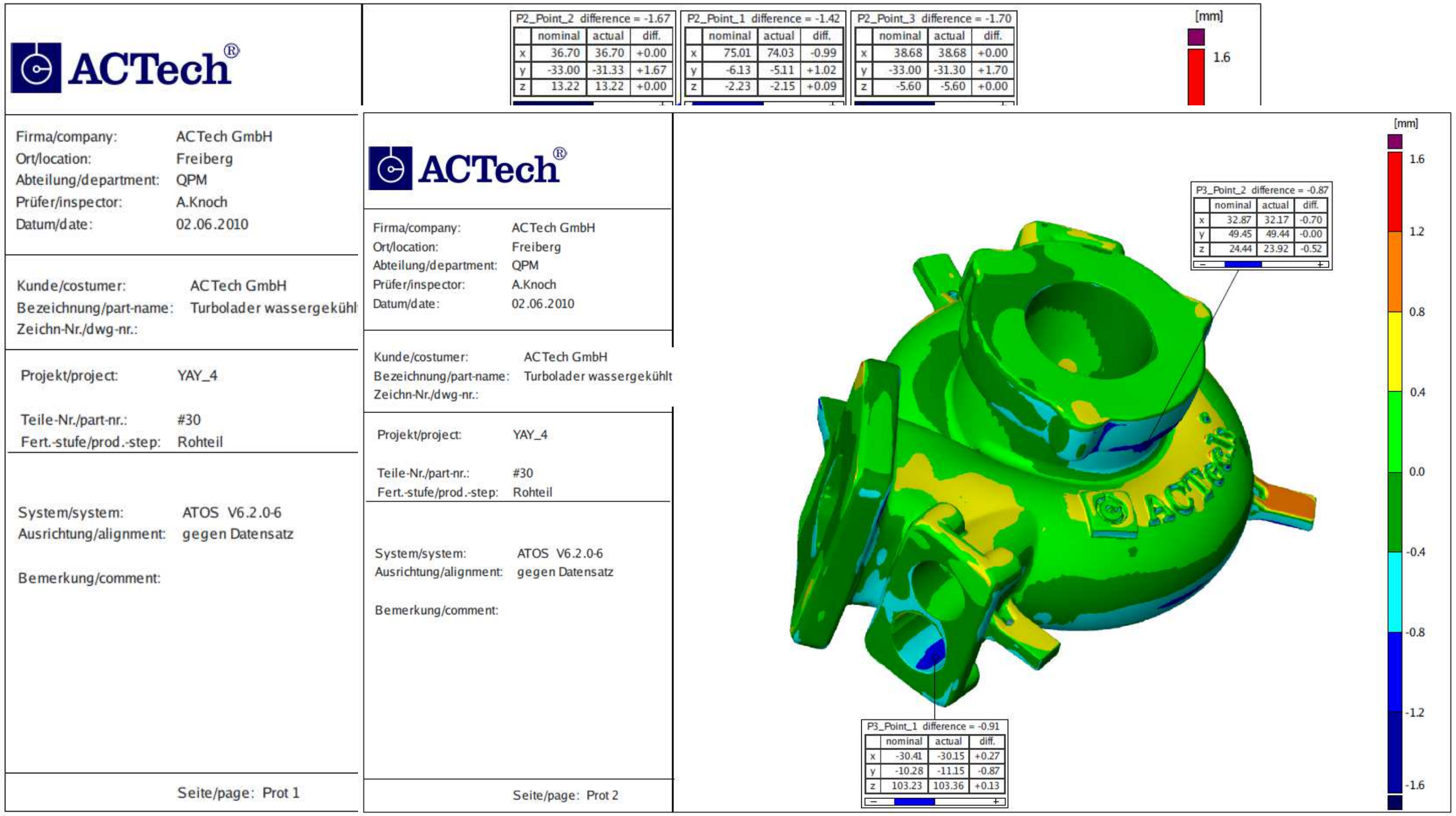
2012
3rd GOM system in the mold assembly installed

2017
now 9 optical systems running in 5 departments

GOM – example for a protocol for a raw casting



GOM – example for a protocol for a raw casting



ACTech®

Firma/company:	ACTech GmbH
Ort/location:	Freiberg
Abteilung/department:	QPM
Prüfer/inspector:	A.Knoch
Datum/date:	02.06.2010
Kunde/costumer:	ACTech GmbH
Bezeichnung/part-name:	Turbolader wassergekühlt
Zeichn-Nr./dwg-nr.:	
Projekt/project:	YAY_4
Teile-Nr./part-nr.:	#30
Fert.-stufe/prod.-step:	Rohteil
System/system:	ATOS V6.2.0-6
Ausrichtung/alignment:	gegen Datensatz
Bemerkung/comment:	

Seite/page: Prot 1

P2_Point_2 difference = -1.67

	nominal	actual	diff.
x	36.70	36.70	+0.00
y	-33.00	-31.33	+1.67
z	13.22	13.22	+0.00

P2_Point_1 difference = -1.42

	nominal	actual	diff.
x	75.01	74.03	-0.99
y	-6.13	-5.11	+1.02
z	-2.23	-2.15	+0.09

P2_Point_3 difference = -1.70

	nominal	actual	diff.
x	38.68	38.68	+0.00
y	-33.00	-31.30	+1.70
z	-5.60	-5.60	+0.00

Seite/page: Prot 2

P3_Point_2 difference = -0.87

	nominal	actual	diff.
x	32.87	32.17	-0.70
y	49.45	49.44	-0.00
z	24.44	23.92	-0.52

P3_Point_1 difference = -0.91

	nominal	actual	diff.
x	-30.41	-30.15	+0.27
y	-10.28	-11.15	-0.87
z	103.23	103.36	+0.13

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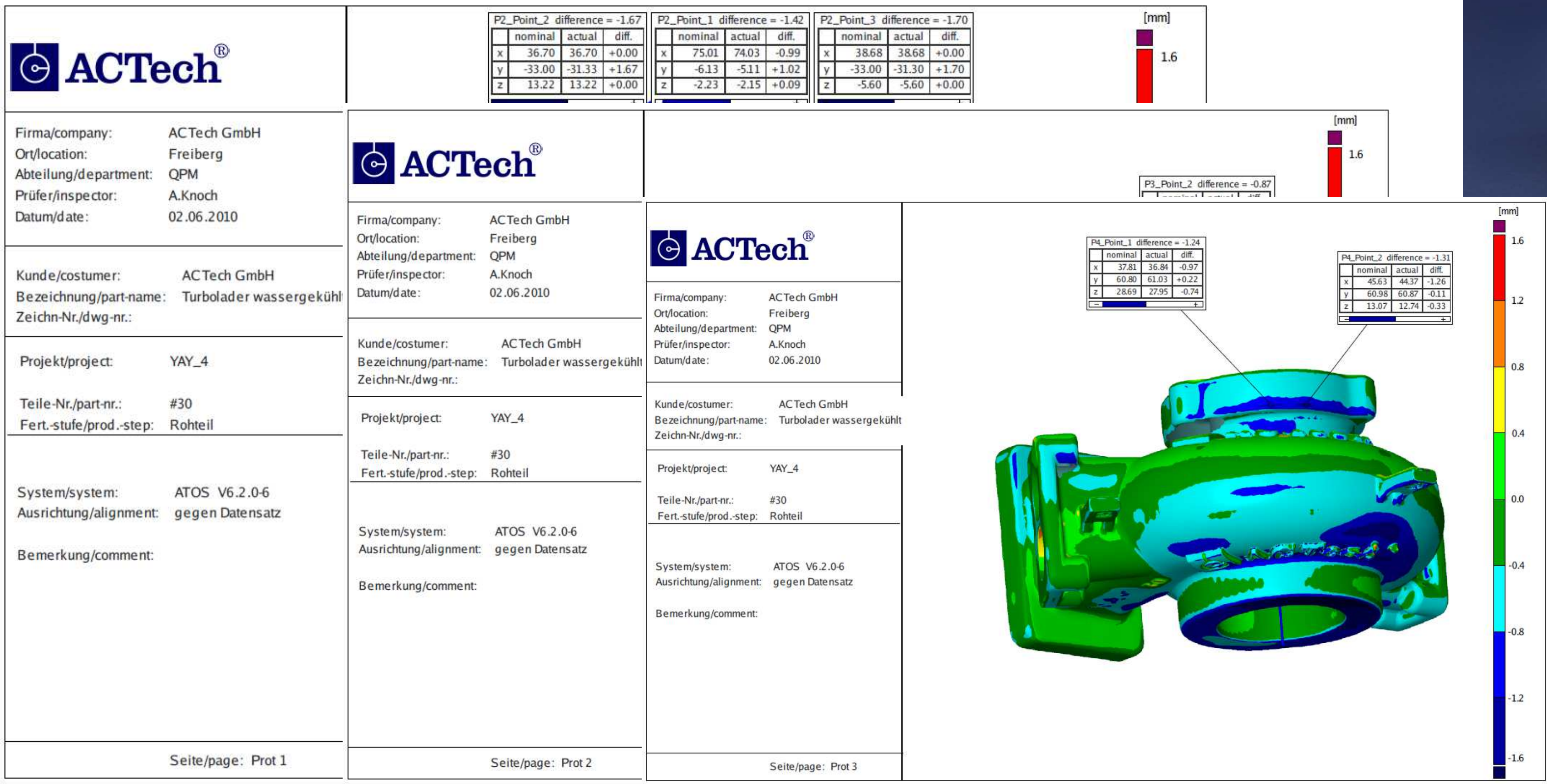
GOM – example for a protocol for a raw casting



ACTech®

Firma/company: ACTech GmbH
Ort/location: Freiberg
Abteilung/department: QPM
Prüfer/inspector: A.Knoch
Datum/date: 02.06.2010

Kunde/costumer: ACTech GmbH
Bezeichnung/part-name: Turbolader wassergekühlt
Zeichn-Nr./dwg-nr.:

Projekt/project: YAY_4

Teile-Nr./part-nr.: #30
Fert.-stufe/prod.-step: Rohteil

System/system: ATOS V6.2.0-6
Ausrichtung/alignment: gegen Datensatz

Bemerkung/comment:

Seite/page: Prot 1

P2_Point_2 difference = -1.67

	nominal	actual	diff.
x	36.70	36.70	+0.00
y	-33.00	-31.33	+1.67
z	13.22	13.22	+0.00

P2_Point_1 difference = -1.42

	nominal	actual	diff.
x	75.01	74.03	-0.99
y	-6.13	-5.11	+1.02
z	-2.23	-2.15	+0.09

P2_Point_3 difference = -1.70

	nominal	actual	diff.
x	38.68	38.68	+0.00
y	-33.00	-31.30	+1.70
z	-5.60	-5.60	+0.00

Seite/page: Prot 2

P3_Point_2 difference = -0.87

Seite/page: Prot 3

P4_Point_1 difference = -1.24

	nominal	actual	diff.
x	37.81	36.84	-0.97
y	60.80	61.03	+0.22
z	28.69	27.95	-0.74

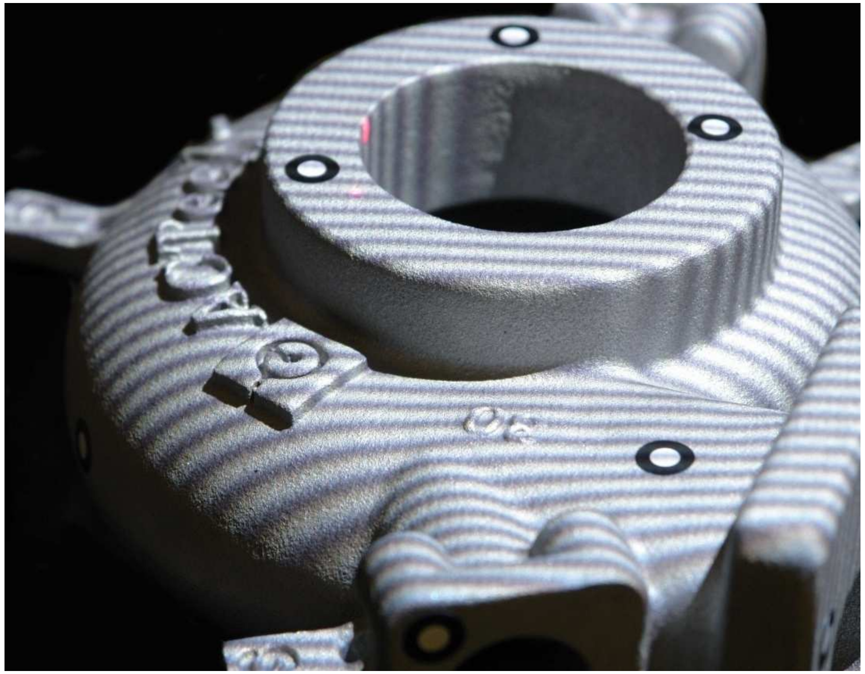
P4_Point_2 difference = -1.31

	nominal	actual	diff.
x	45.63	44.37	-1.26
y	60.98	60.87	-0.11
z	13.07	12.74	-0.33

Optical measuring systems in the rapid prototyping casting process

Using optical measuring systems for measuring and analysis throughout the steps of the Rapid Prototyping process of castings has some quantifiable advantages:

- Time and cost reduction
- Ensure short lead times
- Reduced scrap
- Improved process stability
- Increased dimensional accuracy
- Reduced machine set-up time



Agenda AMAP Kolloquium

Aachen | 11.01.2018 | Thomas Gotte

About me

Company overview (short)

Production processes (short)

- Patternless mold manufacturing
- Geometric-optical measurement

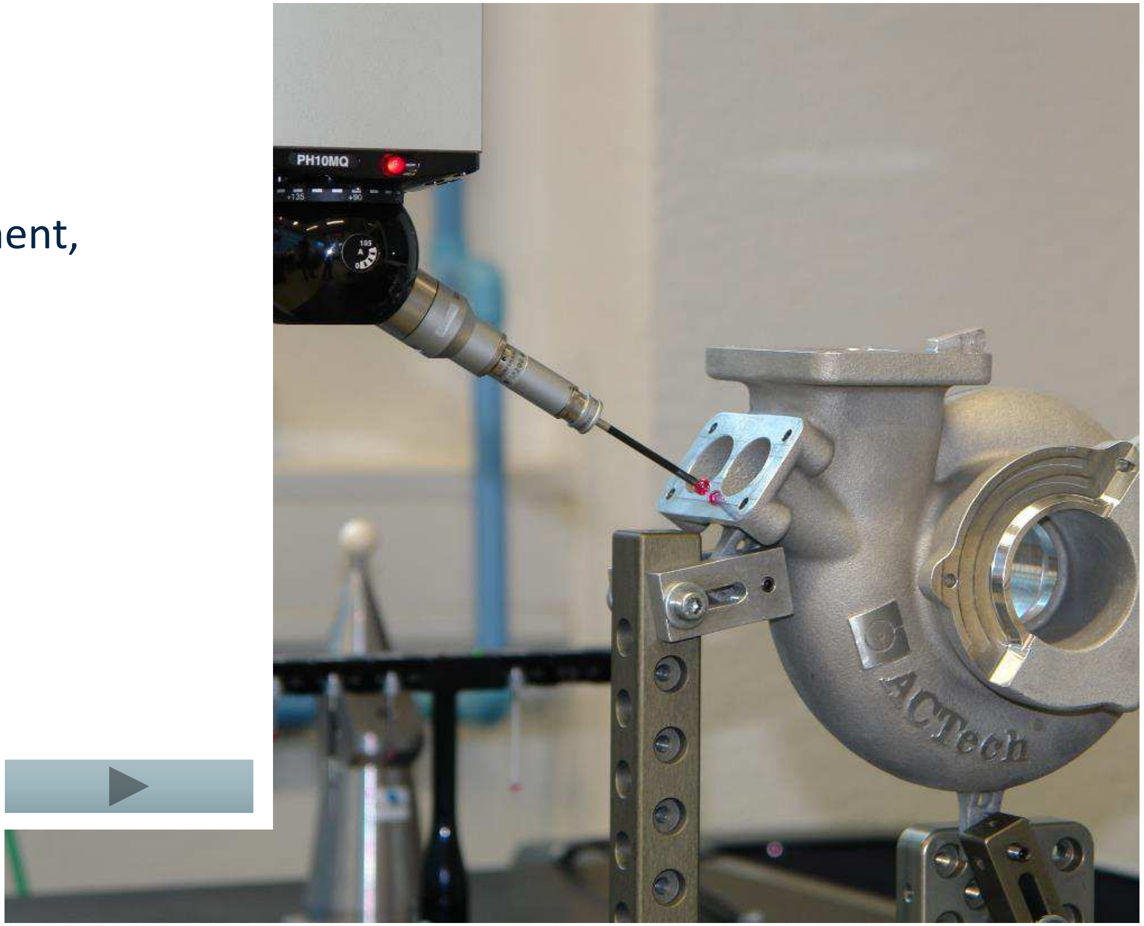
Examples (optional)

CNC Machining

- CAM programming with Tebis and TopSolid
- VERICUT machining simulation
- Alignment with live optical measurement (GOM) raw part data vs 3D CAD data
- Complete external machining setup
  - Tool presetter with online data transfer
  - Shuttle table systems
- CNC machining
  - 5 axis simultaneous technology
  - mill/turn and turn/mill technology
  - up to 1,500 mm table size available

Finished part inspection

- In-process measurement technology
- Quality testing with 3D coordinate measurement, contour and roughness measurement
- Tightness testing and assembly
- Final quality check and report



Project Management

- **Lead Project Manager**
  - responsible for all internal and external communication
  - coordinate work of the foundry project managers and the machining project manager
  - provide technical customer service for key accounts and special projects
- **Foundry Project Manager**
  - specialized in casting techniques, applications and materials
  - responsible for raw part production details
- **Machining Project Manager**
  - specialized in product groups, independent of markets or technology
  - responsible for manufacturing details of machining
- **LIVE project tracking for customers**
  - updated 4 times a day

Agenda AMAP Kolloquium

Aachen | 11.01.2018 | Thomas Gotte

About me

Company overview (short)

Production processes (in details):

- Patternless mold manufacturing
- Geomtric-optical measurement

Examples (optional)

Cylinder head with integrated exhaust collector

- Material: EN AC-AlSi7Mg0.3
- Dimensions: 510 x 360 x 340 mm
- Delivery: 6 weeks including assembly machining
- Quantity: 2

Cylinder block

- Material: EN-GJL-250
- Dimensions: 355 x 341 x 269 mm
- Delivery: first component after 7 weeks including assembly machining and honing
- Quantity: 5

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Integral turbine housing

- Material: EN-GJSA-X NiSiCr 35 5 2
- Dimensions: 110 x 103 x 65 mm
- Delivery: 3.5 weeks including machining
- Quantity: 2

Compressor housing

- Material: EN AC-AlSi8Cu3
- Dimensions: 154 x 132 x 73 mm
- Delivery: 3 weeks including machining
- Quantity: 2

Rear axle transmission

- Material: EN AC-AlSi7Mg0.3 T6
- Dimensions: 332 x 318 x 237 mm
- Delivery: 4 weeks including machining
- Quantity: 3

Intake module

- Material: EN AC-AlSi8Cu3
- Dimensions: 384 x 372 x 150 mm
- Delivery: 4.5 weeks including machining
- Quantity: 2

Coolant distribution

- Material: EN AC-AlSi7Mg0.3 T6
- Dimensions: 504 x 397 x 132 mm
- Delivery: first batch after 5 weeks including machining
- Quantity: 70

Inlet case (turbines)

- Material: EN AC-AlSi7Mg0.6
- Dimensions: 520 x 520 x 350 mm
- Delivery: 5 weeks including machining
- Quantity: 1

Turbine inlet housing

- Material: EN-GJS-400
- Dimensions: 1,200 x 1,200 x 550 mm
- Delivery: 6 weeks
  including machining
- Quantity: 1

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Compressor wheel

- Material: EN AC-AlSi8Cu3
- Dimensions: 475 x 475 x 250 mm
- Delivery: 3.5 weeks
- Quantity: 1

Main gear housing (helicopter)

- Material: EN AC-AlSi7Mg0.6 T6
- Dimensions: 1,347 x 1,065 x 544 mm
- Delivery: 7.5 weeks including machining
- Quantity: 1

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Turbine housing

- Material: GX 40 CrNiSi 25 20
- Dimensions: 110 x 103 x 65 mm
- Delivery: 3.5 weeks
  including machining
- Quantity: 3

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Turbine housing

- Material: GX 40 CrNiSi 25 20
- Dimensions: 146 x 146 x 103 mm
- Delivery: 3.5 weeks including machining
- Quantity: 1

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Contact

Thank you for your attention!

Thomas Gotte

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