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Industrial CT

Quality control and process optimization in the casting process with non-destructive examinations (NDE)

CT in the foundry can do much more for you than you may expect

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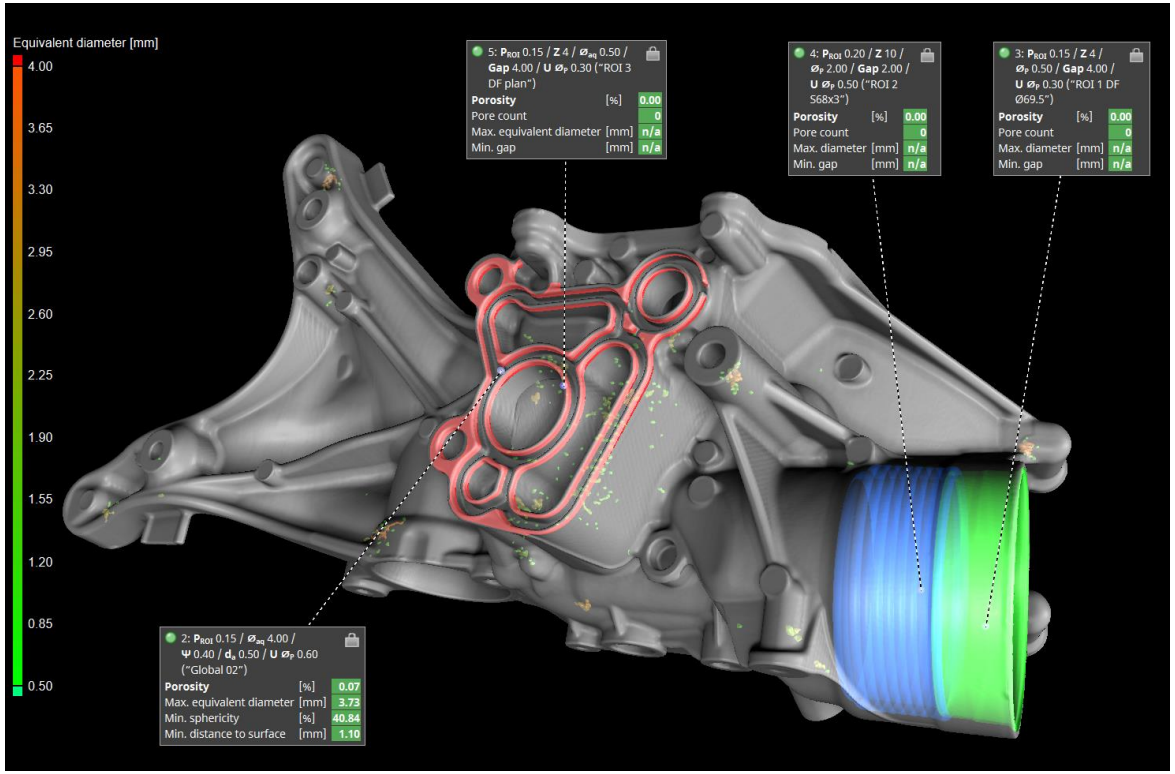
1

Introduction

Imperfections in castings are those **indications** (results of Nondestructive Examination “NDE”) that deviate from the geometric and metallurgical ideal state.

- Castings with imperfections are process-related and **cannot be completely avoided**
- Castings with imperfections are **generally not rejected** before a final analysis and evaluation
- Only the **product specifications** of the casting customer allow a classification as
  "OK" (with imperfections, but within tolerance)
  “NOK” (with one or more casting defects => rejects)



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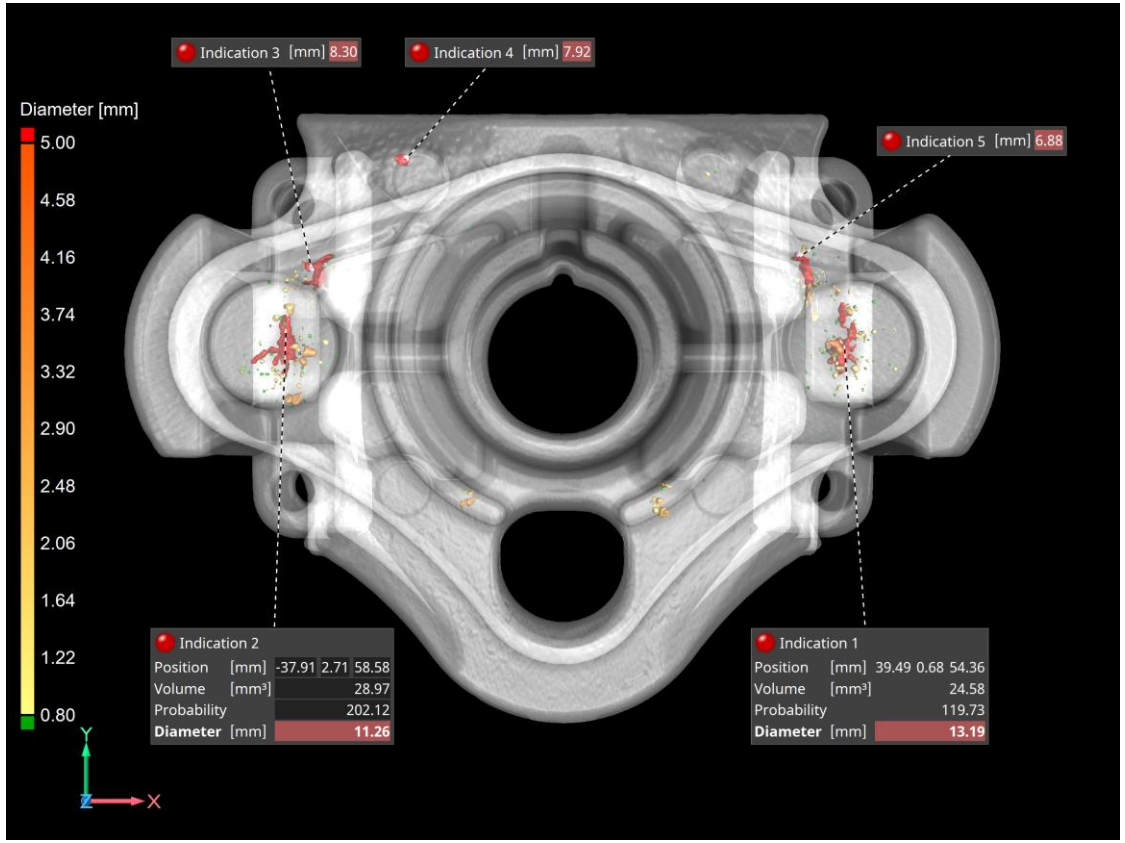
Porosity / Inclusion Analysis (1)

Indicate and analyze typical imperfections in castings
in three dimensions using NDE (Non-Destructive Examination)

- Get detailed information about the indicated imperfections in castings
- Distinguish between gas pores, air entrapments, shrinkage cavities, cracks and inclusions of foreign material
- Determine porosity parameters globally for the entire casting
- or for locally occurring porosities (local porosity concentrations)
- or for individual pores (e.g., the largest five pores = “Big 5”)
- Use filters for small, non-relevant porosities
- Use tolerance settings to classify in OK (green) or NOK (red)



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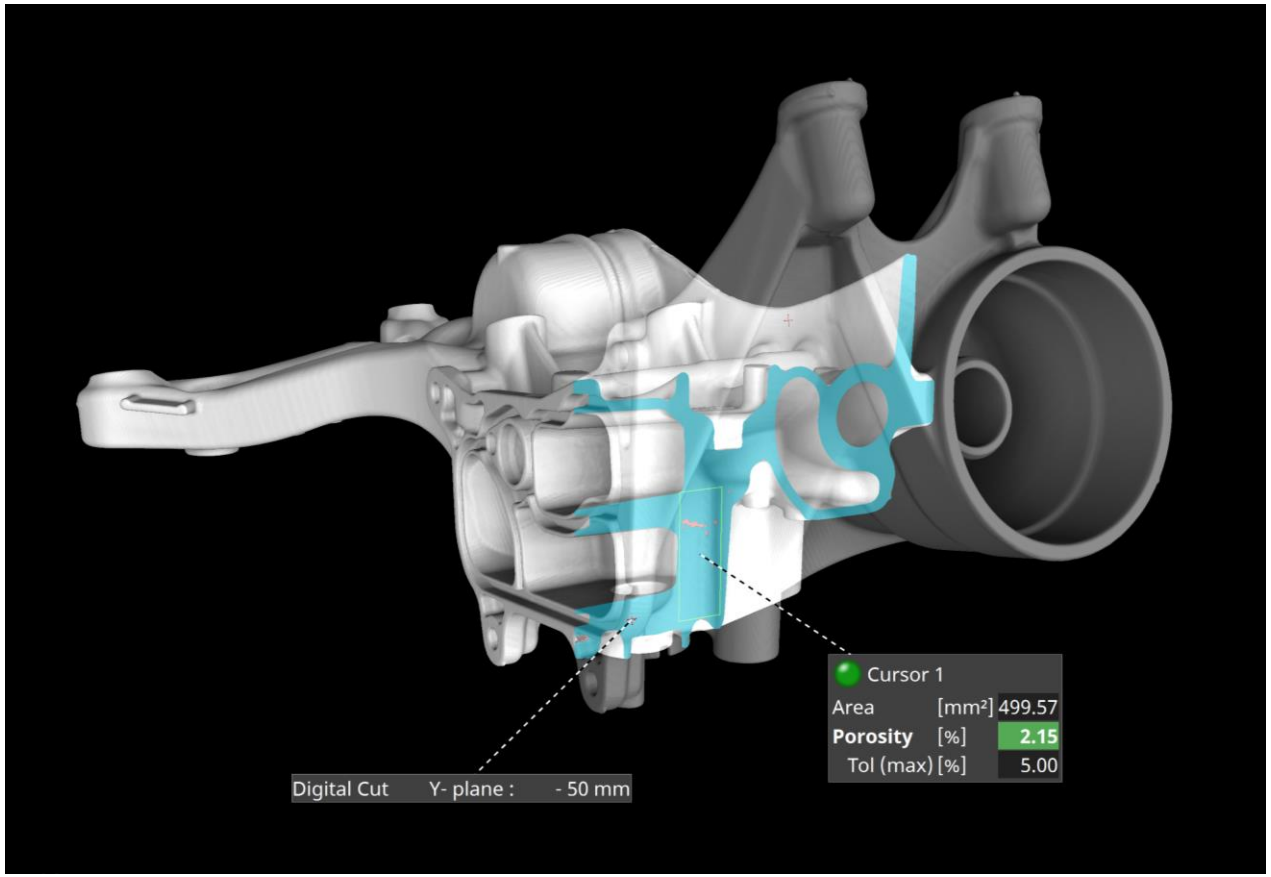
Porosity / Inclusion Analysis (2)

Indicate and analyze imperfections in castings acc. to BDG Reference Sheet P 202

- **“Digital Cut”:** Practice-oriented combined 2D/3D porosity analysis for light metal foundries
- Test for porosities in the casting cross-sections chosen by the foundry itself or specified in customer drawings
- Fast, digital, non-destructive replacement for the time consuming classic metallographic microsection preparation
- Use "Digital Cut" inspection routines (“jobs”) for repeated non-destructive porosity inspections during initial sampling, for requalification inspections or series-related random inspections



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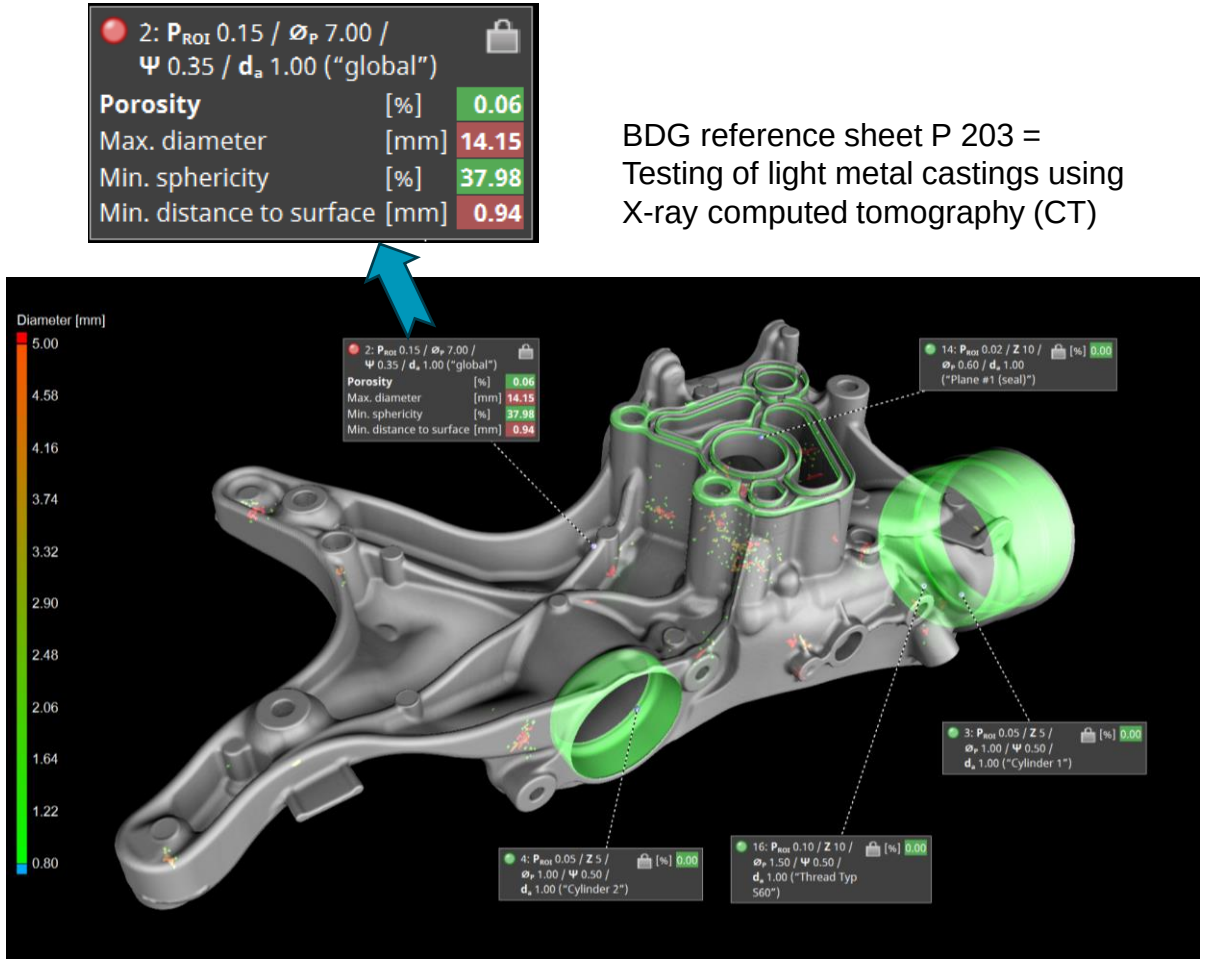
Porosity / Inclusion Analysis (3)

The practice-oriented 3D porosity analysis for light metal foundries acc. to BDG Reference sheet P 203

- Test for porosities in several critical regions with different **P 203 porosity keys** chosen by the foundry or specified in 3D CAD or 2D drawing by customer
- Fully digital, non-destructive replacement for classic metallographic microsection preparation
- Use inspection routines (“jobs”) for repeated porosity inspections during initial sampling, for requalification inspections or series-related random inspections
- Results can be exported to SPC software Q-DAS and statistically evaluated
- Use data as a basis for more precise optimization of the casting processes



BDG reference sheet P 203 = Testing of light metal castings using X-ray computed tomography (CT)

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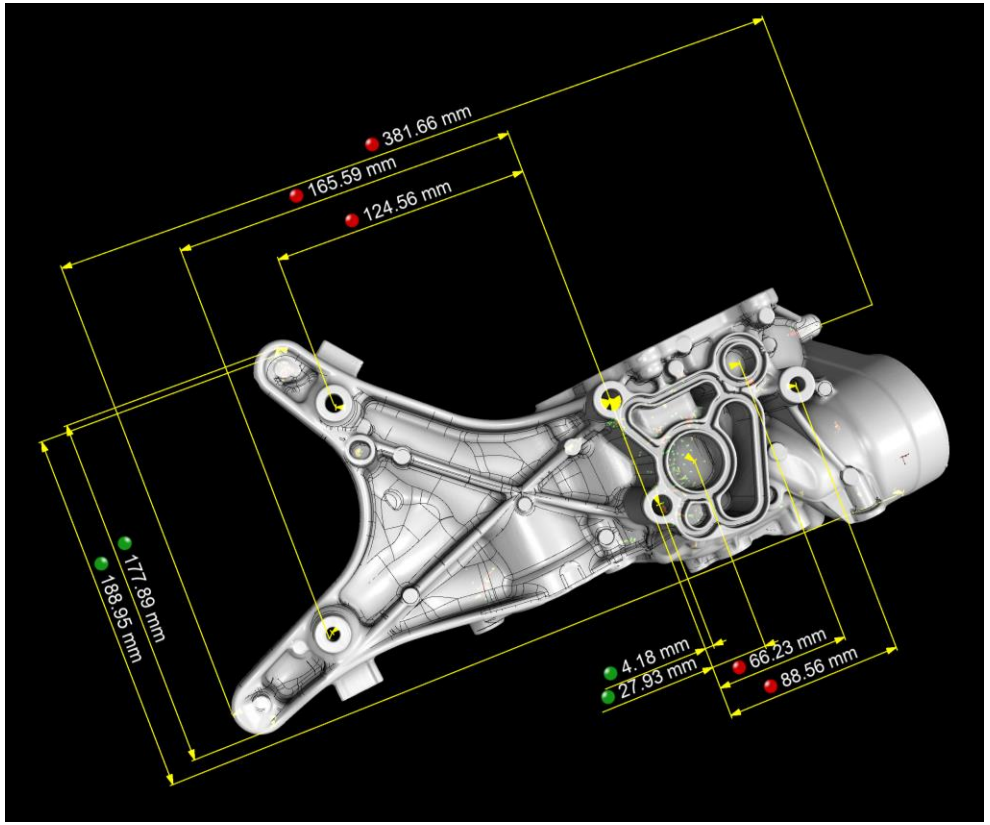
Dimensional Metrology

3D metrology for casting applications: Checking of dozens of geometric dimensions in a matter of seconds

- Use industrial CT as conventional coordinate measuring machine for series-accompanying distance measurements including tolerance evaluation, comparable to a conventional setting gauge
- Check out casting dimensions for inner and outer contours, distances and dimensions for pre-cast and/or punched holes and openings
- Save a lot of time for first dimensional evaluation during initial sampling and later when monitoring the series casting process
- Use inspection routines (“jobs”) for repeated dimensional checks for any number of CT scans during the product's lifetime
- Results can be exported to SPC software Q-DAS and statistically evaluated



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Automated industrial CT Inspection

If the customer requirements in terms of safety and/or functionality are very high: **Quality assurance with 100% Inline-CT inspection** using innovative machine learning functionalities based on artificial intelligence

- Industry applications: CT cycle time below two minutes
- Fast CT analyzes even with limited image quality
- The scope of any re-inspections can be significantly restricted or even reduced to spot checks
- Digitize and export CT inspection data for SPC and optimize the casting process based on selected porosity parameters
- The improved efficiency in quality assurance leads to significant cost reductions in the ongoing operation of a foundry
- Experiences from the industry: Inline-CT systems amortize in a short time

Automated CT Inspection with VGinLINE & VG Machine Learning

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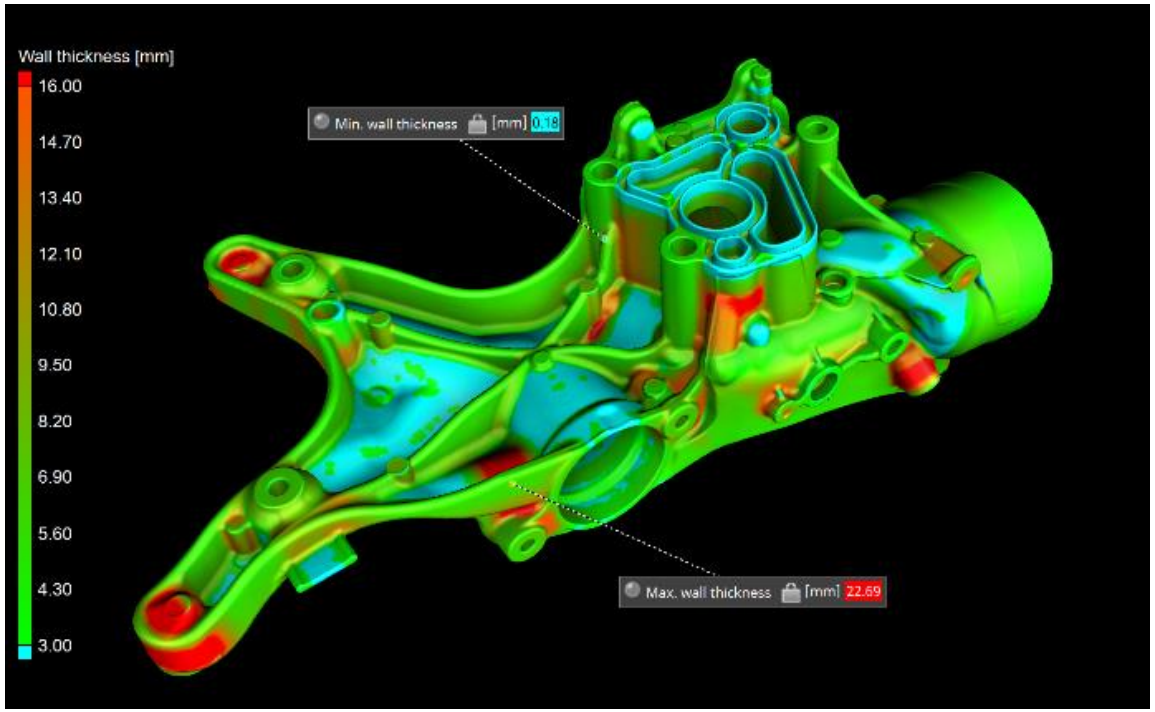
Wall Thickness Analysis

Wall thickness analysis with color-coded representation for complex geometries

- Check wall thickness deviations directly on CT scans, automatically and quickly, without time-consuming CMM work and/or destroying castings with saw cuts
- Set tolerances for minimum, maximum or average wall thickness and display the results in 2D/3D views
- Quickly identify massive, quality-affecting material accumulations
- Can be used on voxel data (CT scan), point clouds, surface meshes or directly on CAD data
- Use inspection routines (“jobs”) for repeated checks for any number of CT scans during the product's lifetime



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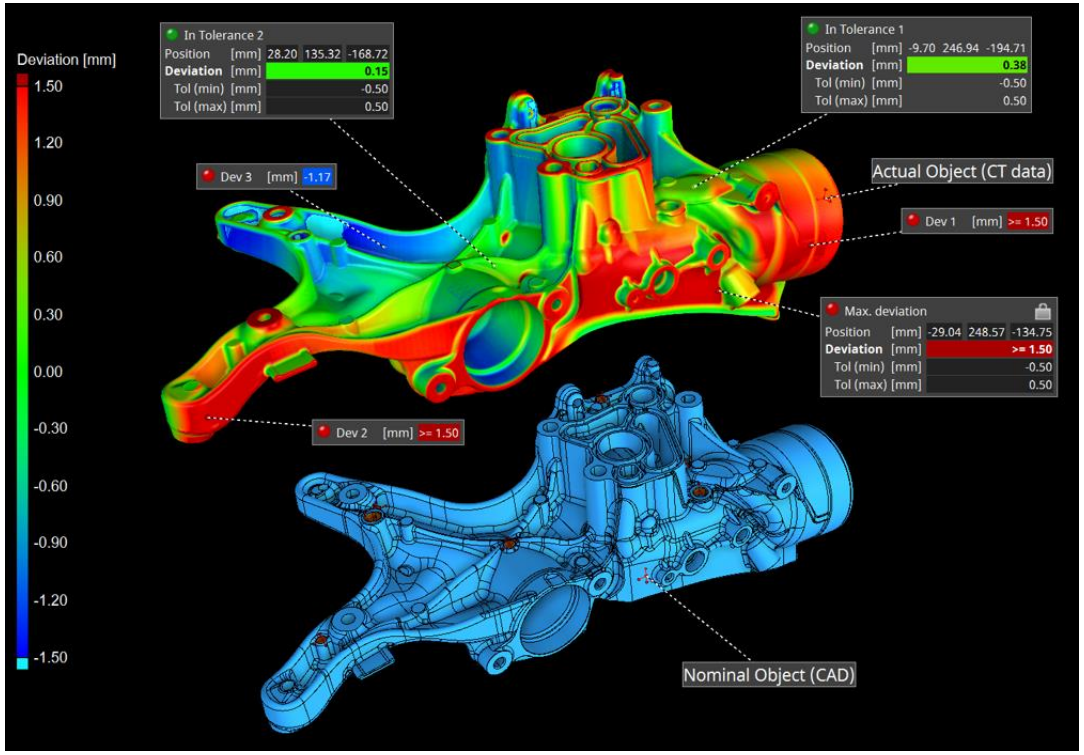
Nominal / Actual Comparison

The color-coded Nominal/Actual Comparison offers an easily understandable representation of contour deviations of your scanned casting compared to a reference data set

Check and measure contour deviations:

- Shrinkage and component deformation/distortion after demolding, due to locally different part cooling and/or mold cooling conditions
- Damaged mold contours (e.g., demolition of exposed shaping contours or mold inserts)
- Mold misalignment or mold halves that do not close correctly
- Mold wear (erosions, heat checks, other damages)
- Deformations during demolding, caused by wear and tear on mold contours or by material build-up on mold contours (release agent build-up, material adhesions, undercuts)



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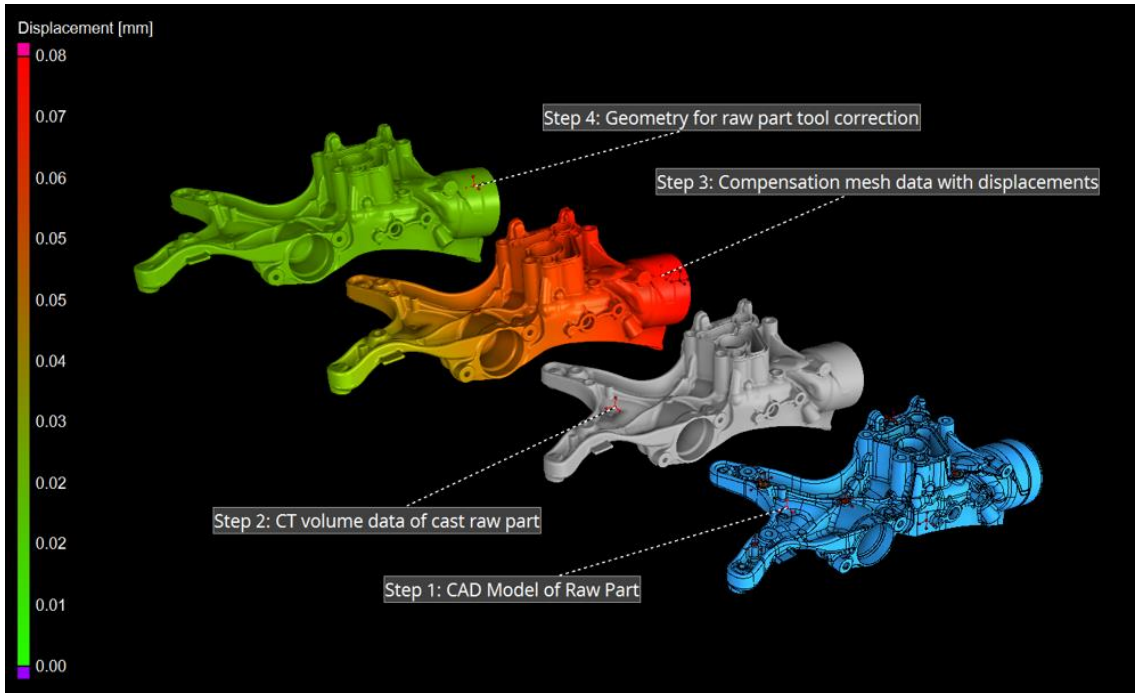
Manufacturing Geometry Correction

Correct the contour deviations caused by shrinkage, component distortion or manufacturing errors in the casting mold

- Identify the required changes to the mold after initial sampling
- Translate the new surface information into a CAD/CAM geometry that compensates for the deviations
- The new CAD/CAM geometry is then used by the mold maker for mold correction/mold optimization

Benefits:

- Reduction of iterations for corrections on newly projected casting molds
- Both CMM measuring capacities and casting and machining capacities that are freed up can be used more productively



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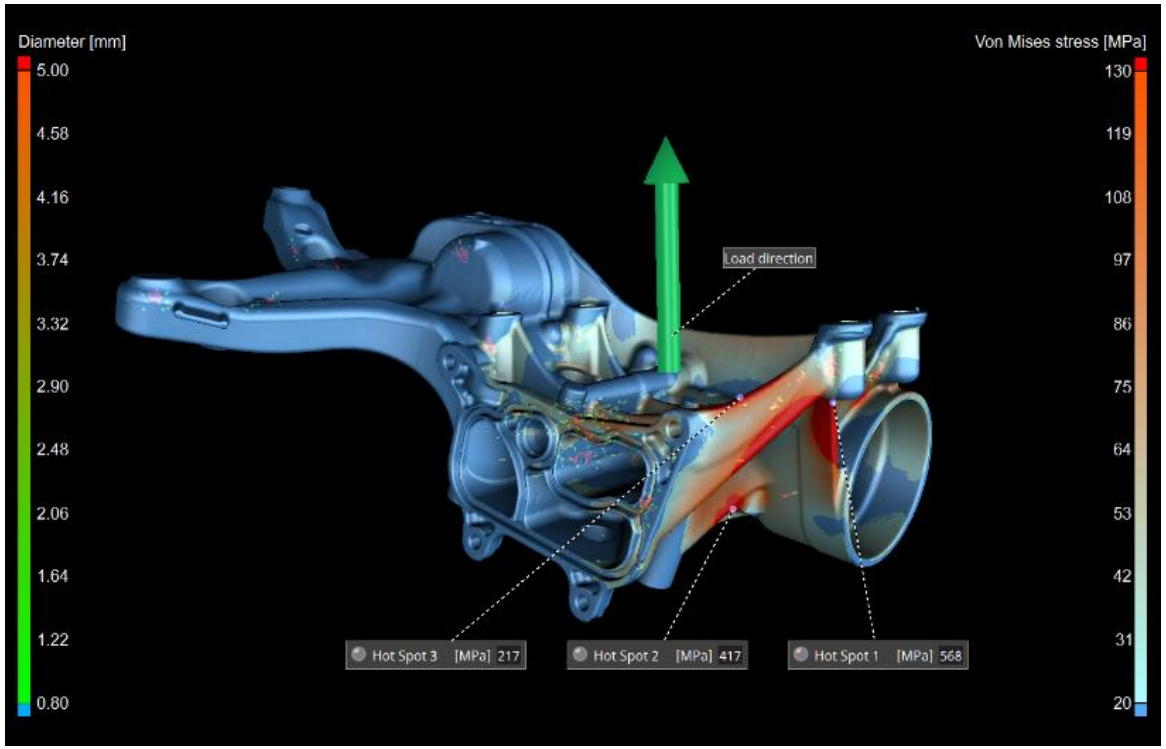
Micromechanics Simulation

However, production-related imperfections that cannot be completely avoided, such as porosity, and do not necessarily lead to casting rejects!

- Check the influence of imperfections on the strength properties with only little effort
- Executed directly on CT scans, no time-consuming volume meshing required
- Simulated stresses (tensile, compressive or torsional) can be directly related to the underlying material structure including imperfections indicated by the CT scan
- No simulation knowledge required



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Reverse Engineering

Creation of CAD data models based on 3D CT scans

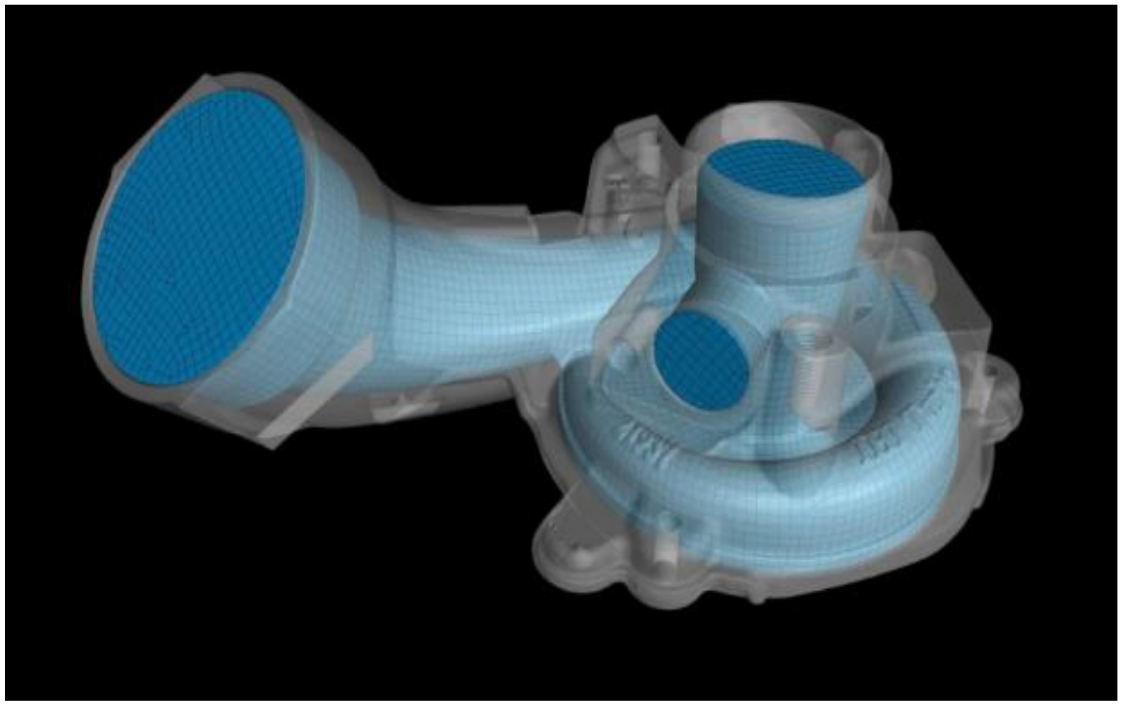
- No 3D CAD data exist from older product?
- Or actual casting or tooling is different than the 3D CAD master model?
- Or handcrafted design models must be available digitally?

Create a Digital Twin:

- Convert CT scans into CAD models
- Including all inner geometries like media carrying channels
- Export the new CAD models to your CAD system

Example:

- Digitally separate complex areas of a component, such as media-carrying channels in a pump housing, and use them in CAD models to design and produce a 3D printed sand core



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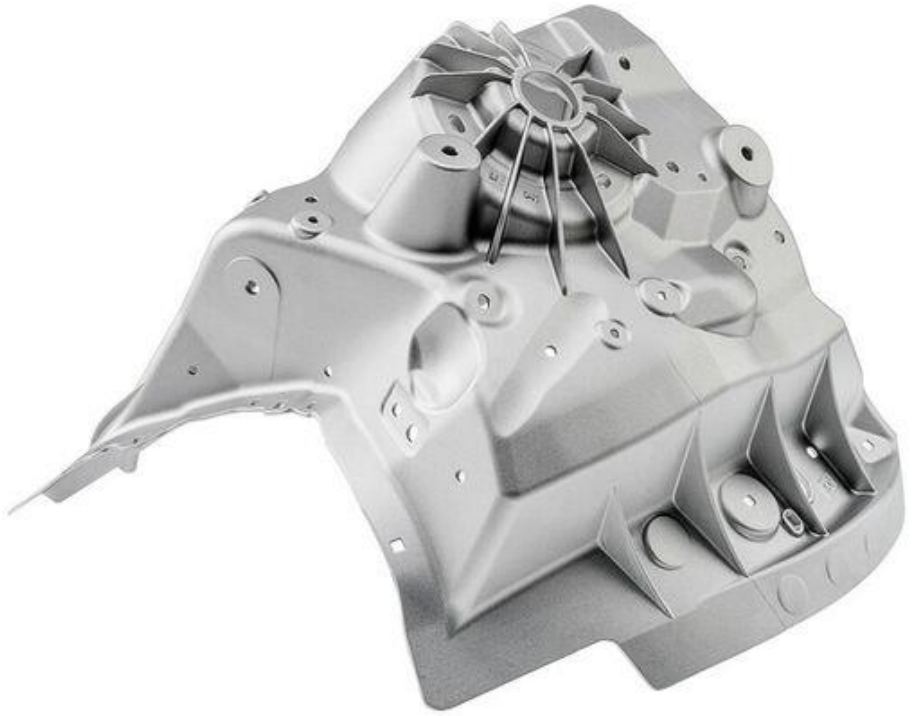
Cost reduction potential using Atline-CT (1)

Example: Suspension Strut Dome LH & RH version

- HPDC with 2-cavity mold / DCM 3500t
- Annual quantity: 60000 sets (LH & RH)
- Casting weight (raw part): 4.5 kg/each
- Shot weight: 13.5 kg
- Alloy: AlSi10MnMg
- Two-stage heat treatment T7
- Straightening process
- Machining process
- Washing, pickling, preserving process
- Random control casting quality raw part: 1 pcs per cavity/shift 2D X-ray
- Random control casting geometry raw part: 1 pcs per cavity/shift CMM
- Random control machining final part: 1 pcs per version LH & RH CMM

Casting cost:	EUR	20.78	(share of alloy: EUR 12.60)
Machining cost:	EUR	13.05	
Final part:	**EUR**	**33.83**	



Suspension strut dome example
(Source: Buhler AG)

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Cost reduction potential using Atline-CT (2)

Example: Suspension Strut Dome LH & RH version

Annual scrap cost (w/o alloy cost)

Casting cost per part:	EUR	**10.90**	/	OEE 62.5%	/	Scrap rate 12 %	=>	Scrap amount: 14,400 pcs
Annual deficit 1:	**EUR**	**- 156,960.00**						
Casting & Machining cost:	EUR	**10.90+18.00**	/	OEE 82.5%	/	Scrap rate 16 %	=>	Scrap amount: 19,200 pcs
Annual deficit 2:	**EUR**	**- 554,880.00**						
Summary deficit 1 + 2:	**EUR**	**- 711,840.00**						

Note:
This example is a fictional one. Real numbers can vary up or down depending on the conditions in a foundry.
Basically, the example shows that too high scrap rates can quickly lead to creditworthiness problems within a foundry!

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Cost reduction potential using Atline-CT (3)

Objectives:

Reduce scrap rate to 3% maximum within 12 month and reduce production cost to calculated values.

Indicate and evaluate and classify porosities in Suspension Strut Domes much more precisely and optimize all processes which have its influences on high scrap rates.

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Cost reduction potential using Atline-CT (4)

Part of solution:

- Porosity Inspection
  - quantification and classification of porosities
  - for casting process and venting optimizations
- Nominal/Actual Comparison & Manufacturing Geometry Correction
  - Casting geometry optimizations
  - Prevention of component distortion
- Dimensional Metrology
  - Measurement of the pre-cast and punched holes

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Cost reduction potential using Atline-CT (5)

Example: Suspension Strut Dome LH & RH version

Invest in Atline-CT inspection equipment:	**EUR**	**750,000.00**	
Plus, reserves for maintenance, repairs, trainings:	EUR	75,000.00	(= 10% of CT investment, annually)
Summary of CT Invest:	**EUR**	**825,000.00**	

Note: Share of labor cost is calculated in production cost “CT inspection”

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Cost reduction potential using Atline-CT (6)

Example: Suspension Strut Dome LH & RH version

Reduction of cast rejects by 9 percentage points

Casting cost per part:	**EUR**	**8.89**	/ OEE 75%	/ Scrap rate 3%	(minus 10,800 pcs)
Annual cost benefit 1:	**EUR**	**96,012.00**			

Reduction of rejects after machining by 12 percentage points

Cost per part:	**EUR**	**8.89+14.85**	/ OEE 87,5%	/ Scrap rate 4%	(minus 14.400 pcs)
Annual cost benefit 2:	**EUR**	**341,856.00**			

Note:
In this example, the new CT-Atline system is only utilized to 10%!
This means that around 90% of the capacity of the CT system is available for other, comparable projects!

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Cost reduction potential using Atline-CT (7)

Example: Suspension Strut Dome LH & RH version

Benefit by cost reductions in 2nd year of production

Annual cost benefit 1:	EUR	96,012.00
Annual cost benefit 2:	EUR	341,856.00
Summary cost reductions:	**EUR**	**437,868.00**
CT-Atline equipment invest:	**EUR**	**825,000.00**

Product price before optimizations:
EUR 41.50 (minus EUR 7.67)

Product price after first optimizations:
EUR 36.34 (minus EUR 2.51)

Calculated product price:
(Contract with customer)
EUR 33.83

Amortization of CT investment less than 2 years! (approx. 23 month)

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Resume

Industrial Computed Tomography (iCT) in the foundry can do much more for you than you may expect

- Atline-CT systems for production ramp-up and series-accompanying sample tests
- Inline-CT systems for 100% quality assurance if requirements in terms of safety and/or functionality are very high

Wide range of testing options for cast parts based on an industrial CT, e.g.,

- Porosity / Inclusion Analysis: Inspection for quantification and classification of imperfections
- Measurement and comparison of contour deviations and/or wall thicknesses on castings
- Measurement of dozens of geometric dimensions in a matter of seconds
- Reverse Engineering: create new CAD data models based on 3D CT data
- And much more

Suspension Strut Dome example show, that an investment in CT-Atline equipment can amortize in short times

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Glück auf!

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