

Advanced automated High Speed Computed Tomography for production process control



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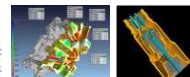


GE imagination at work

X-Ray Technologies



- X-Ray Film
- Computed Radiography (CR)
- Radioscopy
- Digital Radiography (DR)
- Computer-Tomography (CT)
- Analytic/X-ray diffraction



Computer Tomography @ GE

4 global F&E centres (GRC)



Global Research Center Headquarters
Niskayuna, New York



Global Research—Europe
Munich, Germany



John F. Welch Technology Centre
Bangalore, India



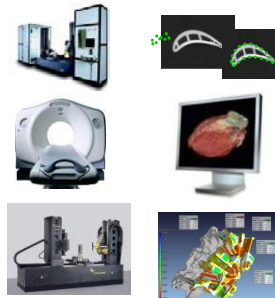
China Technology Center
Shanghai, China

GE product branches with CT expertise & tradition

GE Aviation

GE Healthcare

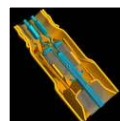
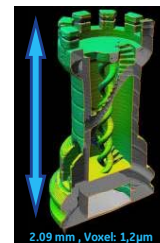
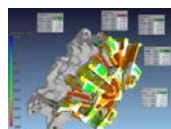
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State of the Art: Industrial CT Products

CT Systems for non destructive **Material Testing, Metrology, Material Science**

- Offline, fan- or cone beam geometry CT
- Part rotates inside the penetrated area
- Very high precisions feasible ($< 1\mu\text{m}$)
- long scan times (5min to several hours)
- Manual part handling
- Mainly interactive Volume data analysis

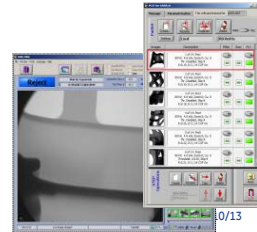
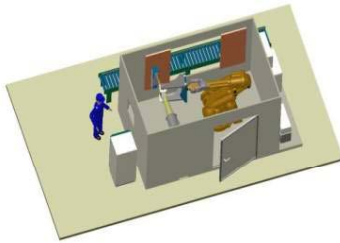


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State of the Art: Inline Inspection Systems

Integrated **full automatic x-ray Inspection** (SABA, ADR)

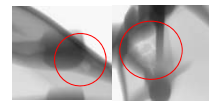
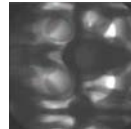
- Inline solution integrated into production, very high throughput
- automatic 2D x-ray inspection (defect detection and classification)
- Robust design, highest availability for 24/7 operation
- Proven technology since 1989, hundredfold in world wide use



Technological Limits

Digital Inline Radiography

- limited depth information, no precise localisation
- Surface roughness/shape influences image quality
- Material consistence (e.g. Lost-Foam) influences image quality
- Complex part fixtures (form-fitting tools, wear out)
- No CAD compare



Computer Tomography (up to now)

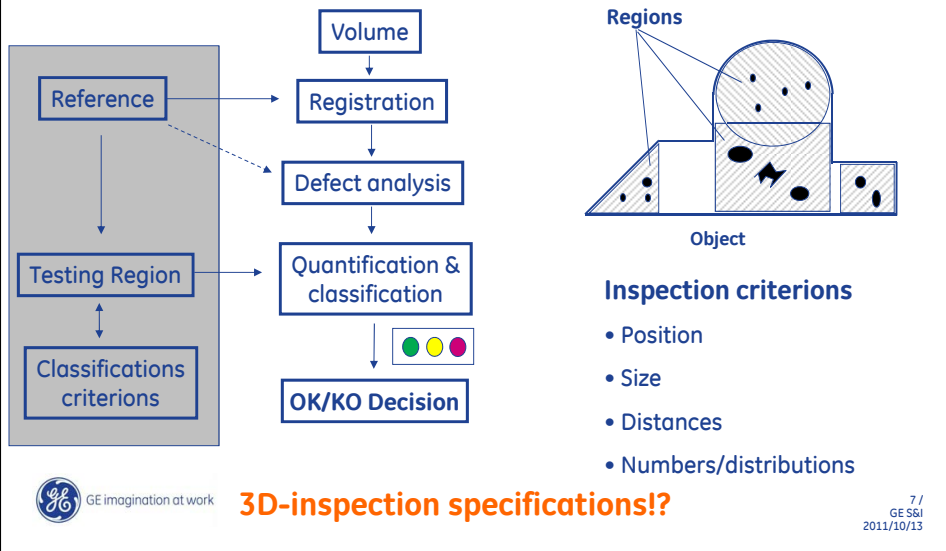
- Relatively long data acquisition times (minutes to hours)
- low throughput, usually manual mounting
- Precise part positioning required
- High amount of data



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Non-destructive material testing with CT

Workflow defect detection in in-line inspection (3D-SABA)



Non-destructive material testing with CT

Usage of CAD-models

Detection of part deviations

- Surface extraction necessary
- Actual-Nominal-Comparison (surface deviations)
- Comparison to admissible tolerances
- Compare with CAD-Data of machined part
- Defect unearthing after machining
- Wall thicknesses after machining

CAD Model raw part (green)
CT Surface real part (red)
CAD Model final part (blue)



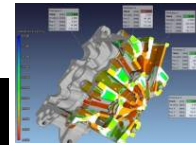
Advantages Inline Computer Tomography

Productivity gain due to 3D inspection techniques

- Scrap reduction thru
 - precise defect localization in 3D
 - determination of part completeness
 - consideration of machining allowance
- Potential replacement of other NDT Technologies, like optical raw casting metrology
- Lower quality costs (e.g. fewer product recalls)
- Reduction of direct labour and cost of operation (Energy, CO₂)



Fast validation in production thru automatic actual-nominal comparison and metrology



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GE Inline-CT System CONCEPT

Inspection volume up to 500mmØ x 1000mm L,
Up to 200kg sample weight

Scan- and inspection times 5-10mm/s
-> 10-60s for typical castings

Spatial resolution $\geq 300\mu\text{m}$
-> min. detectable defect size: $>0.5\text{ mm}$

Penetration length: up to 300mm Al

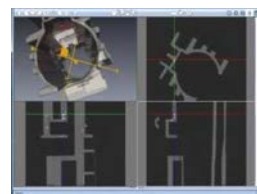
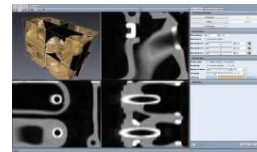
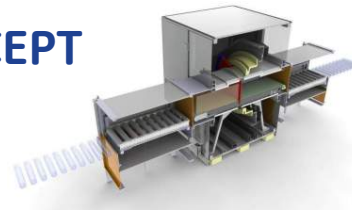
Proprietary automatic defect analysis and -classification

Designed for 24/7 operation in foundries

Belt or Palette conveying systems

Interfaces to adjacent process steps

Core competence and world wide service from GE

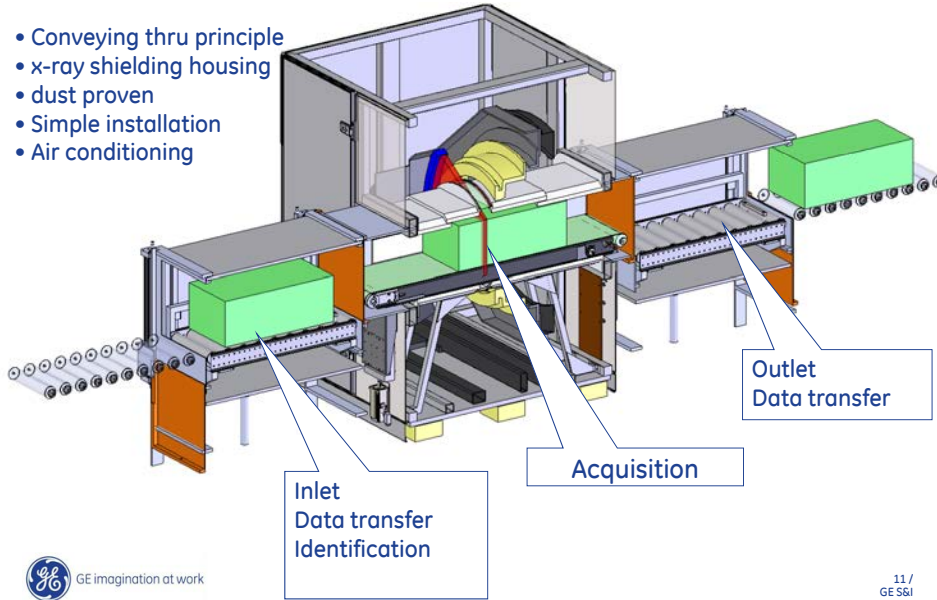


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GE Inline-CT System Solution

- Conveying thru principle
- x-ray shielding housing
- dust proven
- Simple installation
- Air conditioning



Comparison to conventional CT Technology

High Resolution CT:

- (1) Cylinder head scan with voids, several hours
- (2) 450kVp, cone beam CT with digit. Flat panel in Multiline Mode (8 Rows)
- (3) Orig. 150 μ m voxel size (12GB) here 4x Binning

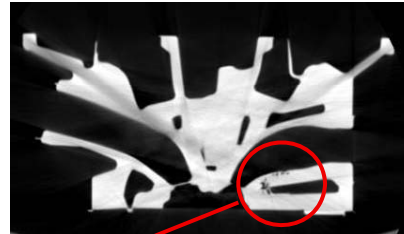
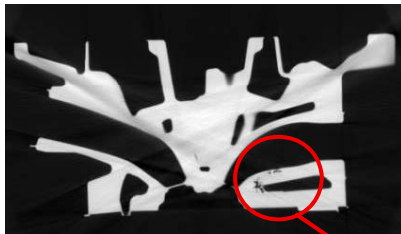


Prototype Scan:

- (1) "Standard" inline Scans: helical, < 100 seconds
- (2) 140kVp, 25mA
- (3) 0,6mm voxel size

V|tome|x image data binned to 600 μ m

Prototype with 600 μ m voxel size



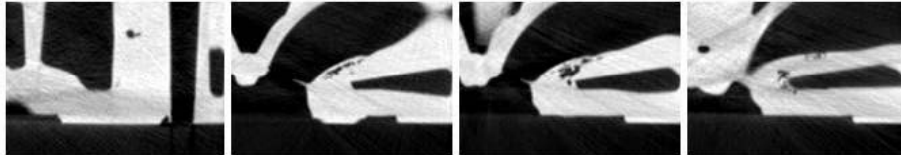
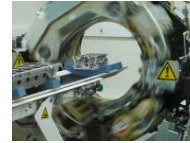
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comparison of spatial resolution

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Comparison

Inline CT slices



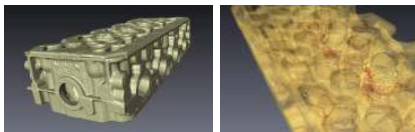
V|tome|x I450 slices
(4x Binning)



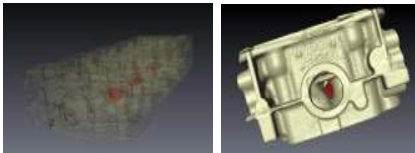
CT Results, AI Parts

Cylinder head:

Scan time : 60 seconds

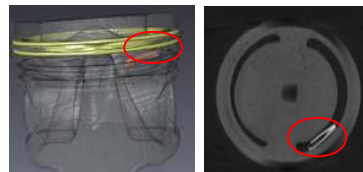


Sand core remains and porosities



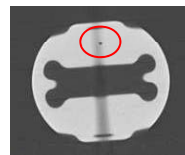
Piston with Fe Ring:

Scan times: 15 seconds



Red: core remains
Yellow: piston ring

Cooling channel
Material inclusion of higher density

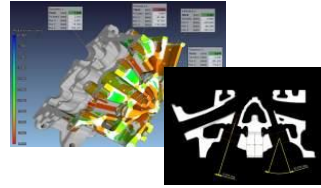
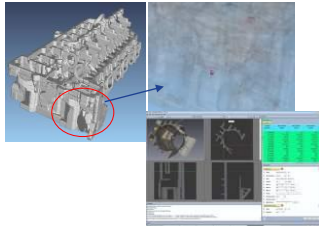
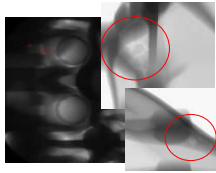


Porosities inside
the piston



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Roadmap

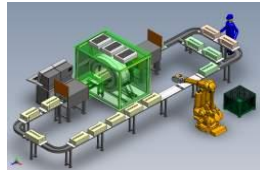
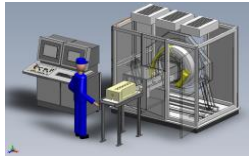


2D NDT

Fast 3D NDT

Inline CT 3D-ADR NDT

Inline-Metrology



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