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Dimensional metrology with X-ray CT for additively manufactured industrial components: a validation study

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BKR Additive Manufacturing Global Footprint

Dhahran Technology Center
Dhahran, Saudi Arabia

Middle East and India

IET Innovation Center
Bangalore, India

Europe

North America

Enterprise Drilling Services HQ
Celle, Germany

IET Production
Talamona, Italy

IET Innovation center
Florence, Italy

Enterprise HQ
Houston, Texas

700+
part numbers
Qualified

40000+
parts
Produced

Application driven solutions

- Molds, Jigs, Fixtures
- Drilling & Completion Components
- Hole-Opening Products
- Rotating Equipment
- Valves & Pumps Components
- Subsea Equipment
- Heat Exchangers
- Hydraulic Manifolds
- Sensors & Housings

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BKR Additive Manufacturing

Industrial Energy Technology
R&D Lab Firenze, Italy

Industrial Energy Technology
Production Facility Talamona, Italy

40
part numbers
Qualified

10000
parts
Produced

Application driven solutions

- Health & Safety Centers of Excellence
- GE Aviation Certified
- 20 Printers
- Inspection capabilities
- Automated Post process

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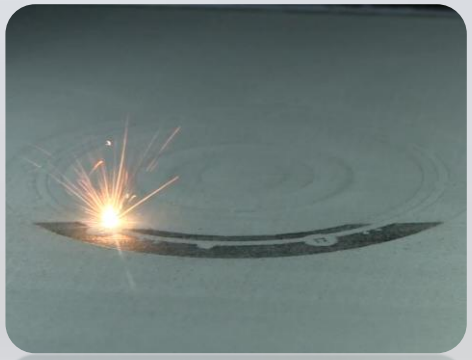
Additive & Inspection Technologies

Powder Bed



Small and Complex

- Combustion parts
- Nozzle Guide Vanes
- Drill Bits
- Valves
- Heat exchangers

Consolidation

Large and Bulk

- NACE compliance
- Impellers
- Pipes

Fused Deposition Modelling (FDM)

Large and Complex

- Prototypes
- Tooling & Fixtures
- Seals
- Corrosive environment

Advanced Inspection for AM Parts

Accurate and Precise

- XCT Tomography
- Coordinate Measurement Machine
- 3D Optical scan
- Focus Variation

Additive Quality Assurance - Challenge

Geometrical and dimensional inspections are crucial to guarantee the quality of AM produced parts.

- Form tolerance
- Wall thickness

Major challenge:

- Real hot gas path nickel-based alloy GT component
- Determination of appropriate inspection technology and validation methods

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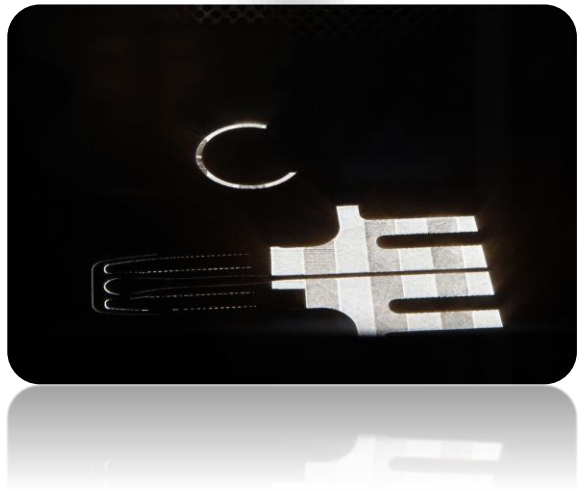
Inspection Data Correlation

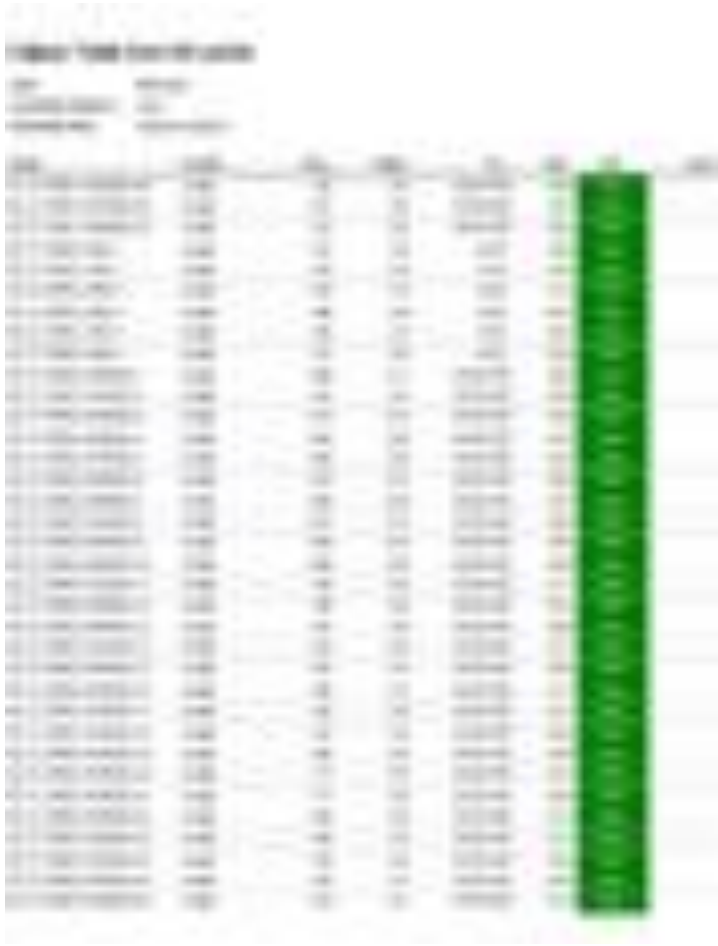
Inspection data correlation is highly regarded for the correct evaluation in a feature-based approach

- Accuracy related to measurement of geometrical features
- Measurement uncertainties
- Component based approach consolidation

Identification of highly significant features:

- X ray CT technique optimization on Phoenix V|tome|x C450 with Metrology 2.0
- Validation of X ray CT measures through comparison with optical scan

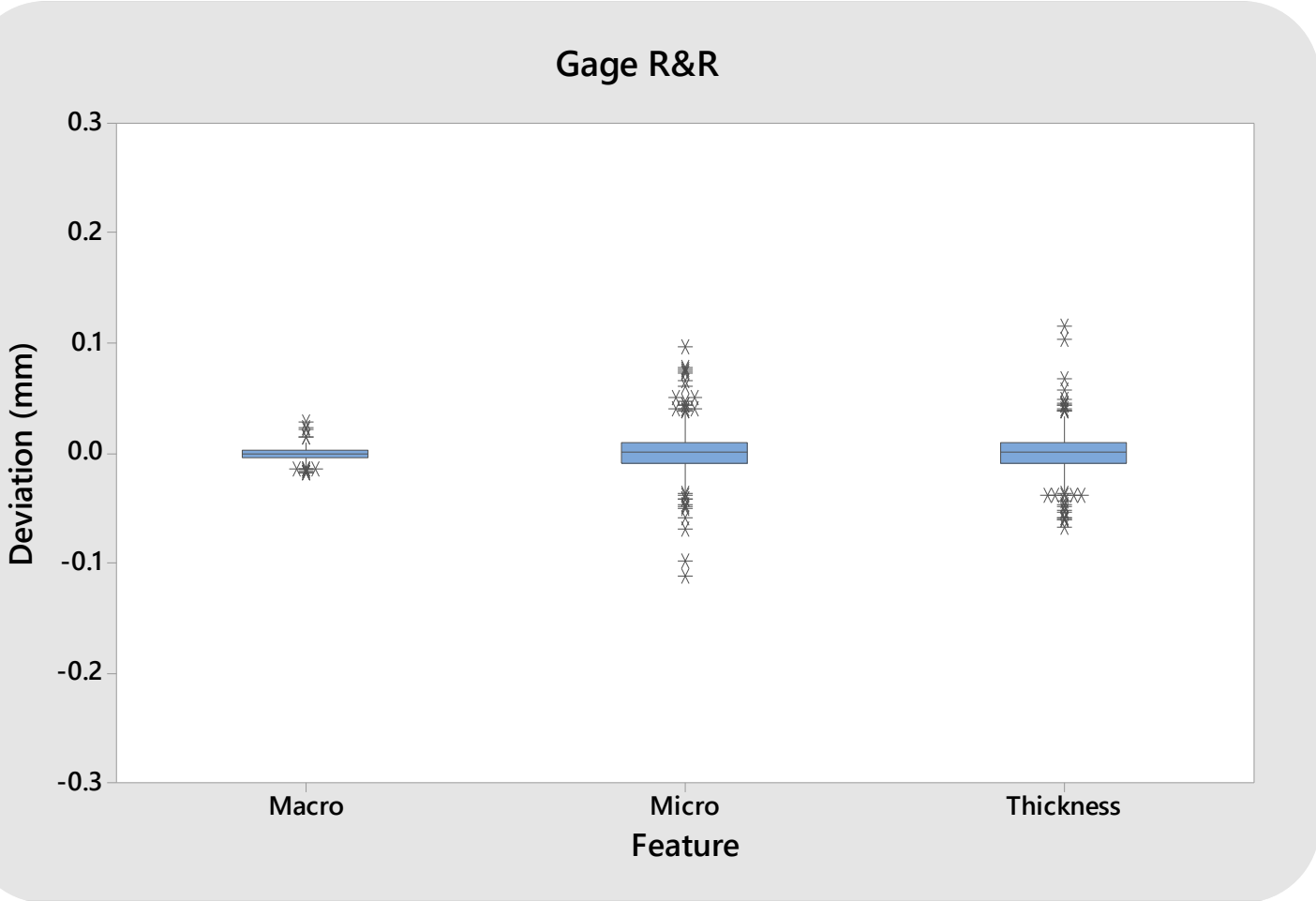




Approximately 400 measurements per part x 10

Performance Evaluation

Gage R&R as a first step to evaluate measurement variability



- Types of measurement variabilities:
  - Operator based
  - Feature based
  - Component based
- Categorical critical feature identification in parts produced by AM:
  - Macro
  - Micro
  - Thickness
- Standard deviations <<0.05 mm are noted with respect to operator and feature based variability

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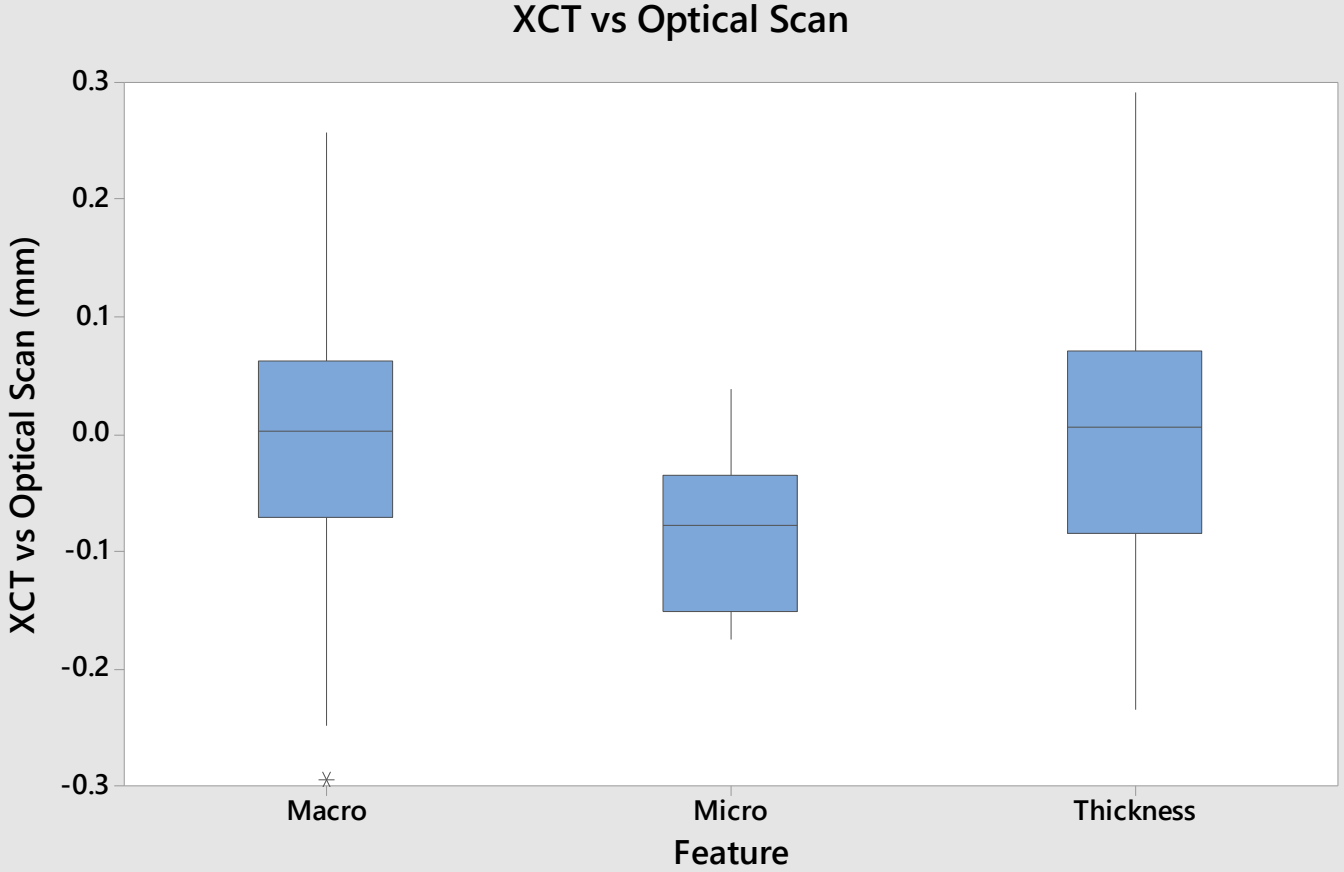
Performance Validation

Measurement system validation through measurement system comparisons



- Measurement system comparison:
  - X-Ray CT
  - Optical Scan
- Feature based comparison:
  - Macro
  - Micro
  - Thickness
- Standard deviation ~0.09 mm observed between measurement systems irrespective of the features in evaluation

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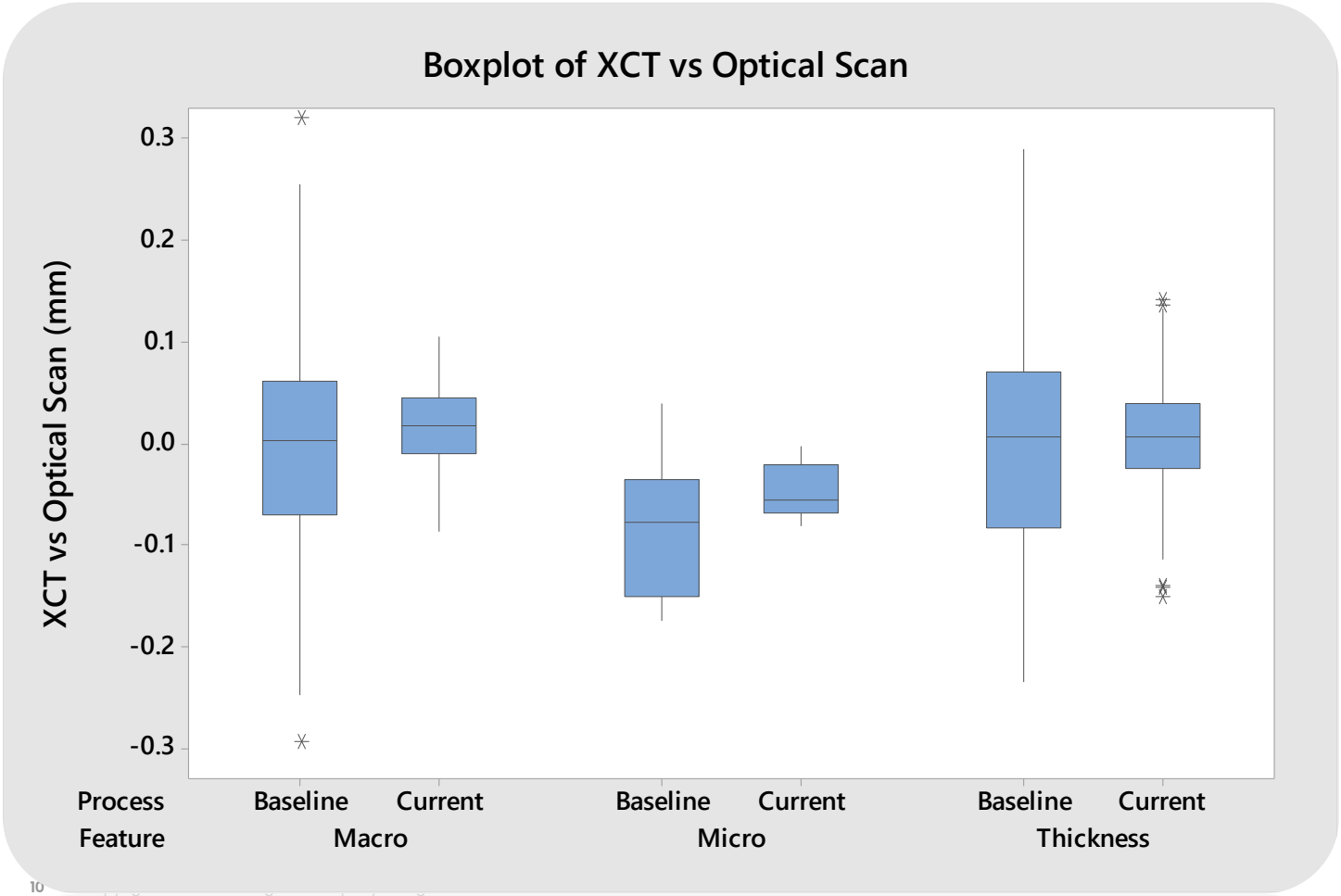
Performance Improvement

Measurement system validation through measurement system comparisons



Measurement system comparison:

- X-Ray CT
- Optical Scan

Improvements:

- Component positioning & alignment
- Automation of CT data elaboration
- Robust feature identification

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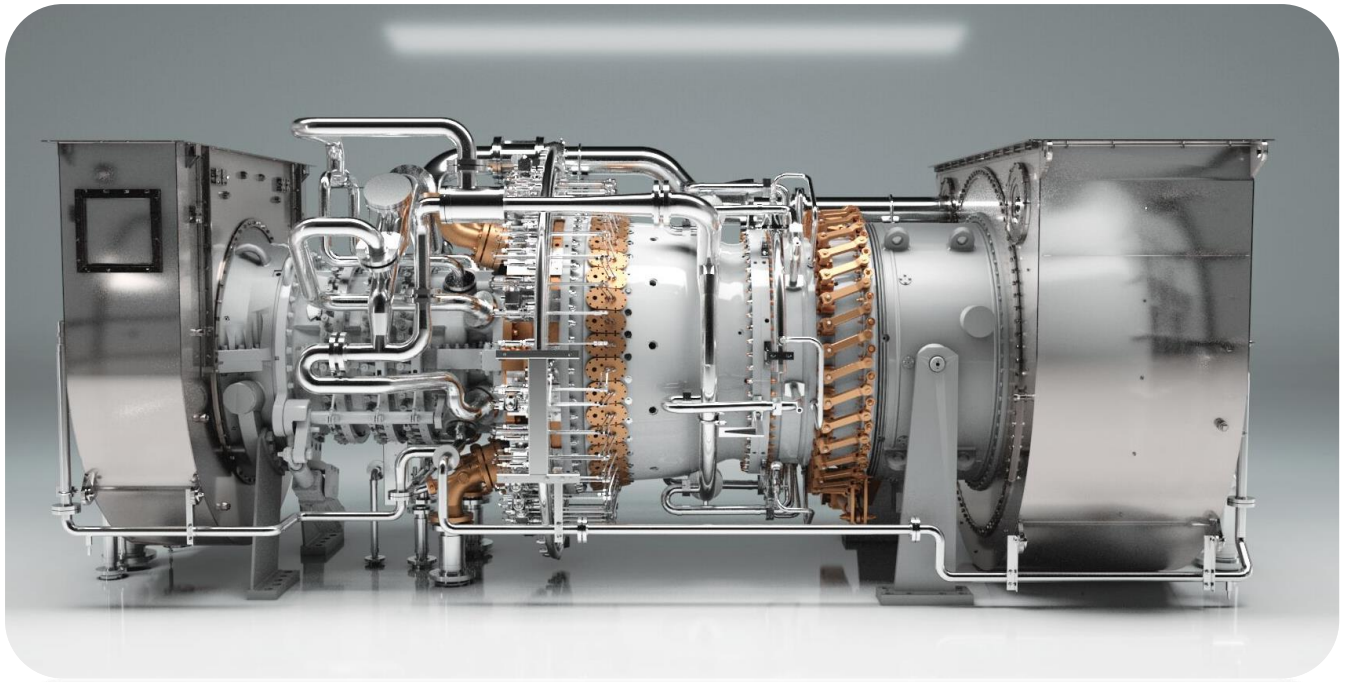

Conclusions

- Identified of appropriate measurement technology for specific AM produced parts
- Measurement system performance validated with rigorous comparison to guarantee the quality of inspection

What's next....

- Extend measurement system performance evaluation with application of Metrology upgrade

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