Advanced and automatic turbine blade inspection, CT resolution optimization and error estimation in reconstructed volumes

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Abstract

The presentation will cover in detail the challenges in fully automatic turbine blade inspection workflows. The presented workflows have been advanced by techniques established and derived from radiography in order to optimize the spatial resolution in X-ray CT and to estimate the errors in the reconstructed volumes. We will demonstrate how such techniques help to speed up the inspection process in tomorrow's inline inspection visions where time really matters.

The blade inspection workflow itself will cover non-destructive testing standards like robust segmentation and sub-resolution precise surface determination which are the prerequisite for actual nominal comparison against CAD and/or reference models and for retrieving precise metrology and GD&T information. Furthermore it will also give attention to rather unpredictable and more challenging inspection tasks like proper and robust detection, segmentation, metrology, and analysis of air vents in turbine blades. We will present how to solve the problem of spatially unstable air vent drill patterns as well as how to properly detect foreign objects, or under- and over-drills for each individual air vent.

The inspection workflow together with the advanced optimization techniques will help to build automatic inline inspection scenarios for the future.
Automatic Turbine Blade Inspection Workflow

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Outline

• Detectability and measurability thoughts
  • Resolution
  • Blurring
  • Positioning
  • Radiographs

• Segmentation
  • Cooling system reconstruction
  • Air vent metrology
  • Defect detection

Data courtesy by diando GmbH
General assumption of resolution

\[ M = \frac{d_{so} + d_{od}}{d_{so}} \]

Geometric blurring

\[ b = (M-1)f \]
Optimising imaging positions

- Radiograph quality is essential for good spatial resolution
- Significantly affects post processing time, repeatability & errors
- Numerical characterisation is essential

Radiograph resolution
Measuring spatial resolution

MTF = \frac{2 \times \text{Amplitude (difference between crest and trough)}}{\text{Overall intensity (sum of crest value and trough value)}}

Optimising scan times
Reduced analysis time

430keV, 197 W, 1500 projections, 120s exposure with LDA

Scan time 3hrs
Pixel size 64.9\textmu m

320keV with Flat panel

Scan time 52min
Pixel size 30\textmu m

Higher resolution
Reduced scan time

Watershed

Area of land that drains into a river system
Watershed

Surface extraction
Voxel precise segmentation

Voxel precise surface

Adjusted surface vs. voxel precise surface
Cooling system reconstruction using ambient occlusion

- Spatially instable air vent patterns
- Creating tolerant search mask
- Thresholding inside mask
- Center line extraction
  - Auto-Skeletonization
Metrology: Meshing extracted air vents from extracted center lines

Metrology: Point extraction from meshed air vents for cylinder fitting
Air vent metrology: Automatically fitted cylinders

Foreign object detection
Overdrill detection

Thank you!

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