Optimization on CFRP manufacturing processes by using automated thermography

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Outline

• Motivation and context
• Approach – production integrated, automated thermography
• Preparation
• Use case description
• Results
• Summary
• Outlook
Motivation and Context

• High demand on CFRP production capacity, currently and still growing
• Trend towards larger but tailored parts with high level of structural integration
• Requirements
  • increase quality, throughput, layup rate, level of automation, health and safety conditions
  • Decrease production cost, rework, manual labor, processing time
• Choice of process chain towards dry textile layup with subsequent infiltration
  • Modern NCFs and other textile architectures have excellent mechanical properties
  • Modern resin systems are customized to fulfill aerospace requirements
    Reduced process cost
  • No cooling chain
  • Added value on the manufacturer side, but risk and responsibility as well
• Eligibility of production integrated quality assurance
Approach

Process

Cutting → Handling → Preforming → Vacuum bagging → Infiltration → Curing → Demoulding → Trimming

NDT 1

NDT 2

Data acquisition, storage and evaluation

Closed loop for engineering purposes (Design, Analysis, Manufacturing)
Choice of method - optically excited lock-in thermography

Dry textiles at preform stage

- (a) Missing Roving
- (b) Gaps
- (c) Roving-Orientation on curved surface

Cured part at final stage

- 2D- Defects (Delamination)
- 3D- Defects (Porosity, Dry spots)

Fiber orientation
Ply position
Challenges

- Parts to be measured are larger than field of view
- Reduce manual effort
- Reduce cost
- Precise positioning

Need on automation to enable to measure larger part → tiling with a flexible manipulator including accurate positioning of camera during measurement to allow defect localization
Automation concept

• Description of various usage scenarios
• Concept and evaluation phase and selection
• Integration of thermography system in robot control
• Application of industrial bus technology
End-effector prototype

- Flexible set-up
- Ability to carry up to three halogen lamps
- Camera and lamps are adjustable
Hand Eye Calibration
Hand Eye Calibration

- Camera image calibrated to correct optical effects
- Offset values successfully determined $(T\{X, Y, Z\}; R\{A, B, C\})$
Use case description – Rear Pressure Bulkhead
Composite definition

- Non Crimp Fabric - 563g/m² (6/12k rovings)
- Fabric – 200g/m² 2x2 Twill weave
- Resin – 2K Epoxy Larit 135® (RT infiltration and cure)
- Foam core – Polyurethane (PU)
- Layup - symmetric, staggered core cover
- Infiltration process – Vacuum Assisted Process (VAP®)
Design and manufacturing of demonstrator
Measurement at preform stage

- Offline programming including calibration
- Automated measurement for image registration
- Tiling of each view and transformation into part coordinate system

excitation frequency $f=0.5\text{Hz}$
Evaluation on fiber orientation

- Based on phase images
- Measurement of fiber orientation in camera coordinate
- Current work: Transformation into robot coordinates and/or part coordinate system to allow set-actual comparison
Measurement on final part

- Procedure analog to measurement of preform
- Using different set of Thermography parameters
- 11 fields of view for approx. 1m²
- Duration approx. 12 minutes
Evaluation of final part

Artificial defect

Location of markers

Phantom defects

Modulation frequency $f=0.08\text{Hz}$
Evaluation of delaminations on final part

• Based on phase images
• Location, shape and size of artificial delaminations show excellent match
• Inhomogeneities are typical for laminate produced in VAP\textsuperscript{®} technology due to peel ply surface and porosities
• Abundant anomalies arise from part fixtures

Modulation frequency $f=0.08\text{Hz}$
Summary

- Optically excited lock-in thermography proves to cover observation along the CFRP manufacturing process chain at various steps
- Standardized set-up allows transfer to any other robotic work cell, hence NDT of large parts with complex layup and geometry at full scale
- Data exchange with robots and coordinate transformation for automation and localization of defect
- Use case successfully demonstrated the chosen approach of automated thermography
Outlook

- Investigations on correlation between single steps
- Close loop for engineering purposes
- Accuracy of local part coordinate system on part transfer from one to the next process step needs to be improved
Thank you!
Questions?
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