Fatigue Crack and Porosity Measurement in Composite Materials by Thermographic and Ultrasonic Methods

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OUTLINE

• PURPOSE
  Detect thermo-mechanically induced intra-ply fatigue microcracking and manufactured porosity in unlined composite pressure vessels

• DEFECT DESCRIPTIONS
  Porosity
  Microcracking

• THERMOGRAPHY
  Overview of technique
  Strengths and Weaknesses
  Examples of its use for porosity detection

• RESONANT ULTRASONIC SPECTROSCOPY
  Overview of technique
  Strengths and Weaknesses
  Examples of its use for microcracking detection

• CONCLUSIONS
DEFECT DESCRIPTIONS
(Porosity)

Cause/Definition: Voids trapped within a laminate during the curing process due to off-gassing of the resin, air trapped between plies, improper cure schedule, etc.
**DEFECT DESCRIPTIONS**

*(Microcracking)*

**Cause/Definition:** Cracking of the resin used to support the fibers in the laminate due to combined thermal “cryogenic” and mechanical loading.
THERMOGRAPHIC INSPECTION SYSTEM

- Imager: Indigo Merlin Mid
- Detector => Indium Antimonide
- Detector resolution => 256 x 312
- Spectral Response => 3 - 5 μm
- Sensitivity => 0.025 °C NEΔT
- Software: ECHOTHERM® 32 (Thermal Wave Imaging, Inc.)
- Lens => 13 mm
THERMOGRAPHIC ANALYSIS METHOD

- FLASH POWER SUPPLIES
- FLASH POWER CONTROLLER
- SYSTEM CONTROLLER
- VIDEO MONITOR
- CONTROL COMPUTER
- SPECIMEN
- FLASH LAMP
- INFRA-RED CAMERA
THERMOGRAPHIC ANALYSIS METHOD

Thermography Image Sequence

Enhanced Image

Averaged Images

Image subtraction (Image N – Pretrigger)
Clustered Porosity Detected Thermographically

8 inches

Lead foil markers

Porosity

Porosity
THERMOGRAPHIC MATERIAL DEGRADATION TRACKING
THERMOGRAPHY TREND
POROSITY IN GRAPHITE EPOXY

Time (sec.) 2.0 4.0 6.0 8.0 10.0
RESONANCE ULTRASOUND (ACOUSTO-ULTRASONICS)

Pulser
Receiver

Typical Power Spectra
SAMPLE PREPARATION AND TESTING

SAMPLE PREPARATION

MICROCRACK COUNTING

CRYOGENIC TENSILE TESTING IN LIQUID NITROGEN
ANALYSIS (Self Organizing Map Neural Network)

UltraSpec System

Self Organizing Map Neural Network

Energy distributions

Neural Network Data Map

Coordinate
Layer

Resonant
Ultrasound
Spectrum

Kohonen Layer

UltraSpec System

Frequency (kHz)

0.1

0.2

0.3

0.4

0.5

0.6

0.7

0.8

0.9

1

200

400

600

800

1000

1200

1400

1600

1800

0.1

0.2

0.3

0.4

0.5

0.6

0.7

0.8

0.9

1

d-b-before

d-c-after

e-b-before

e-b-after

d-c-before

d-c-after

d-b-after

e-c-before

e-c-after

Energy distributions

Neural Network Data Map
CONCLUSIONS

Thermography has been shown to be capable of detecting clustered porosity and shows promise for quantifying general porosity level.

Resonance ultrasound has been shown capable of detecting the presence of microcracking.

The ability to detect microcracking with resonance ultrasound is dependent upon the number of cracks present.

FUTURE WORK

Validate thermographic porosity level assessment

Quantify microcrack detection