ADVANCES IN THE USE OF THERMOGRAPHY TO INSPECT COMPOSITE TANKS FOR LIQUID FUEL PROPULSION SYSTEMS

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ADVANCES IN THE USE OF THERMOGRAPHY TO INSPECT COMPOSITE TANKS FOR LIQUID FUEL PROPULSION SYSTEMS

- Background
- Thermographic Inspection System
- Thermographic Analysis Method
  - RP-1 Graphite/Epoxy Tank
  - Scan and Defect Map
  - Method of Inspection
    - Defect: Inclusions, Ply Wrinkle, Delaminations
- Graphite Composite Cryogenic Feedline
  - Method
  - Image Map
    - Defects: Inclusions (Shallow/Deep), Resin rich area
- Material Degradation NDE
- Summary
• DETECT DEFECTS
  – After manufacture.
  – Prior and after use.

• WHAT IS A DEFECT?
  – Determined by Experience: manufacturing, testing, analysis, and use.

• USUAL SUSPECTS
  • Foreign Objects-tape, bagging film, release cloth, human debris, etc. IBSG
  • Delamination. IBSG
  • Microcracking UB
  • Porosity UB
  • wrinkles

• Note: IBSG = Island of Bad, Surrounded by Good. UB = Uniformly Bad.
NONDESTRUCTIVE EVALUATION OF COMPOSITES

- Usual Nondestructive Tools for Composites
  1. Visual
  2. Ultrasound
     Moderate Frequency (0.5-20 MHz)
     Spectroscopy (Ultraspec, 0.5-2 MHz)
     Acoustic Microscope (5-500 MHz)
  3. Radiography
  4. Coin Tap
  5. Thermography
  6. Acoustic Emission
  7. Computer Tomography-(X-ray)
  8. Shearography
  9. Eddy Current
Why use thermography?

- Area Method—covers area relatively quickly.
- Inspect normal and unusual shapes.
- No contamination of the surface.
  - May require removable coating if surface is shiny.
  - May be noncontact.
- Directly size anomalies using video caliper.
THERMOGRAPHIC INSPECTION SYSTEM

- Imager: Indigo Merlin Mid
- Detector => Indium Antimonide
- Detector resolution => 256 x 256
- Spectral Response => 3 - 5 μm
- Sensitivity => 0.025 °C NEΔT
- Lens => 25 mm

- Software: ECHOTHERM® 32
  (Thermal Wave Imaging, Inc.)
THERMOGRAPHIC ANALYSIS METHOD

SPECIMEN

FLASH LAMP

INFRA-RED CAMERA

B/W MONITOR

FLASH POWER CONTROLLER

SYSTEM CONTROLLER

FLASH POWER SUPPLIES
THERMOGRAPHIC ANALYSIS METHOD

Thermography Image Sequence

Averaged Images

Enhanced Image

Image subtraction (Image N – Pretrigger)
RP1 Tank
Inspection of Inner belly Band

Access port

Flash system utilized on tank exterior
b. Photomicrograph (Fluorescent Penetrant)

Wrinkle at zone A5

da. Thermogram
Photomicrograph (Fluorescent Penetrant)

Delaminations at region S5
Time-Temperature Comparison for Inclusion and Delaminations

- Inclusion
- Delamination (S5)
- Delamination (A5)

Temperature (°C)

Time (Seconds)

65 60 55 50 45 40 35 30 25

0 0.5 1 1.5 2 2.5 3
Cryogenic Feedline Thermography

A. Acreage (Flash)

B. Fillet (Lamp)

C. Build-up (Lamp)

D. Build-up (Flash)
Thermographic indication of inclusion

View 1

Photomicrographs of Teflon tape inclusions
Time-Temperature Comparison for Inclusions at Different Depths

![Graph showing time-temperature comparison for different depths](image-url)
TO TRACK MATERIAL DEGRADATION

Image Processing Computer

IR Camera

Video Display

Specimen

Electronic Optical Gate

Fiber Optic

Laser

Thermal Diffusivity Measurement for Material Condition Measurement
POROSITY IN GRAPHITE EPOXY

Temperature Increase (°C)

Time (sec.)

0  2.0  4.0  6.0  8.0  10.0

TREND: INCREASING POROSITY

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a1 --- a2 --- a3
b1 --- b2 --- b3
c1 --- c2 --- c3
d1 --- d2 --- d3
e1 --- e2 --- e3
SUMMARY

- Thermography is a useful tool for field evaluation of large complex composite structures.

- Identification and characterization of manufacturing and service related defects/damage by thermographic methods pose two entirely different challenges to nondestructive testing personnel.

- Much research has been placed on developing alternative ways for performing thermographic inspections to locate and size abnormalities, but it is the interpretation of such findings that ultimately determine the usefulness of such testing.

- The microstructure of several commonly found defects in composite structures (graphite/epoxy RP-1 fuel tank and a graphite composite cryogenic fuel feedline) have been related to their thermographic image counterpart.

- The results show the challenges a thermographer faces when trying to evaluate defects; i.e. determining the type, size and location of irregularities in a material.

- Methods to track the overall degradation of material needs development. Tanks may wear out relatively uniformly due to exposure to low temperatures and stress.