Assessing Impact Damage in Composite Aircraft Structures using Thermographic NDE

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ABSTRACT

Ensuring safety for the aircraft and spacecraft is utmost, especially in detecting damage or defects before they compromise structural integrity during operation. Thermography emerges as a cost-effective, reliable, and practical method for monitoring structural health as it can provide damage or defect related information within a matter of time. This research aims to explore the efficacy of active flash thermography in assessing impact damage in structural components. The experiments simulated composite plates of quasi-isotropic material properties and analyzed the nodal temperature variation at different delamination locations. Additionally, thermography experiments were conducted on different composite plates, including a demonstrator used in NASA's "Civil Vertical Lift Vehicles" project, to assess impact damage. Furthermore, damage progression in tensile specimens was evaluated under increasing loads, with all areas measured using a pixel counting method. The obtained results were extensively analyzed and compared with Ultrasonic C-scan.

BACKGROUND

- Due to the introduction of Thermographic signal reconstruction (TSR) data processing, thermography has become the most established NDE technique like ultrasonics, X-rays, eddy currents, etc.

- $log_{10}(\Delta T) = a_0 + a_1 log_{10}(t) + a_2 [log_{10}(t)]^2 + \dots + a_n [log_{10}(t)]^n$

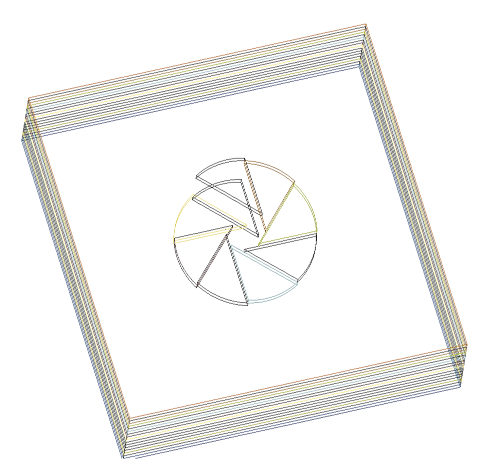
OBJECTIVE

Depth and area measurement of impact damage in composite plates

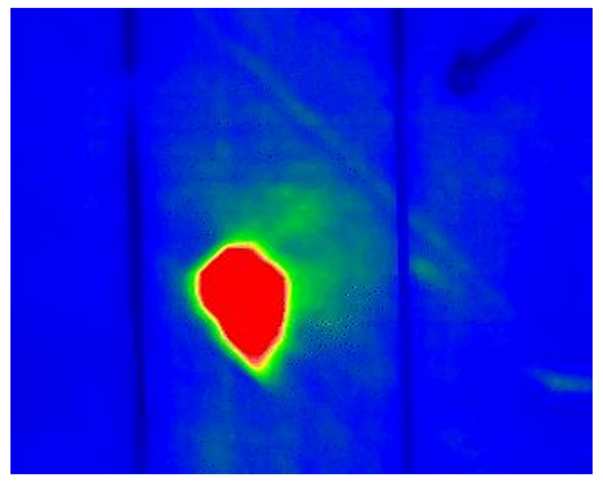
- Processing of numerical and experimental data
- Generation of T-t plots
- Generation of impact damage related images with noise reduction.
- Setting up a calibration profile.
- Comparison of data with Ultrasonic C-scan.

METHODOLOGY

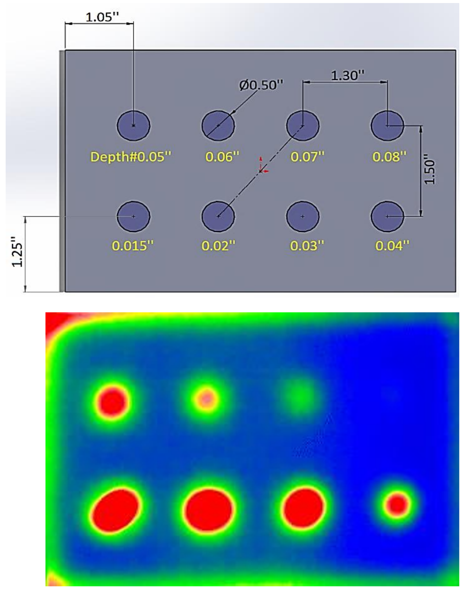
Numerical Analysis



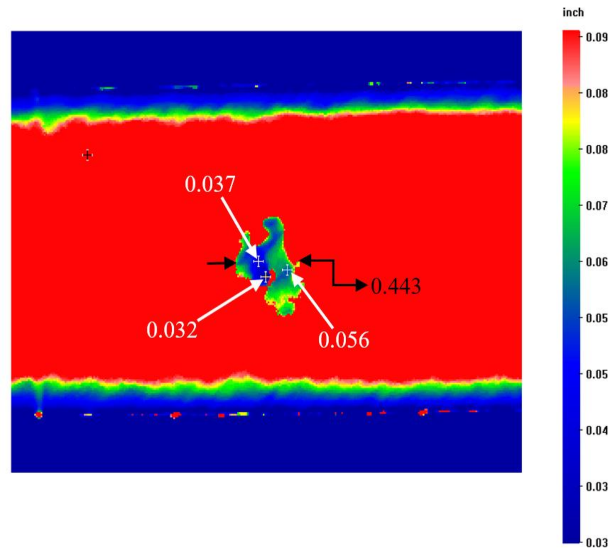
Experimental Analysis



Calibration

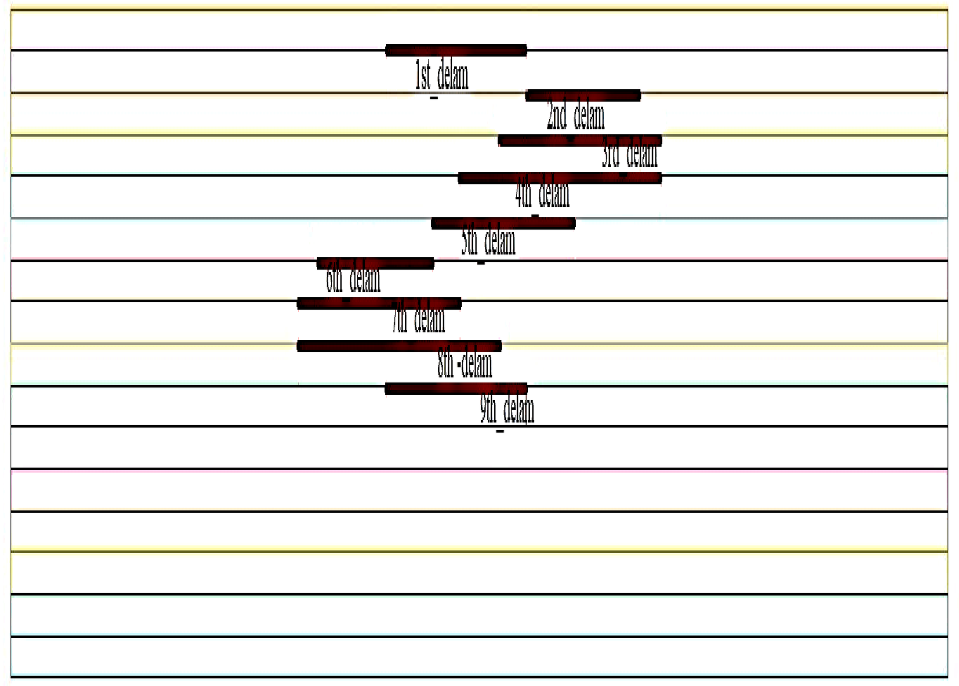


Characterization

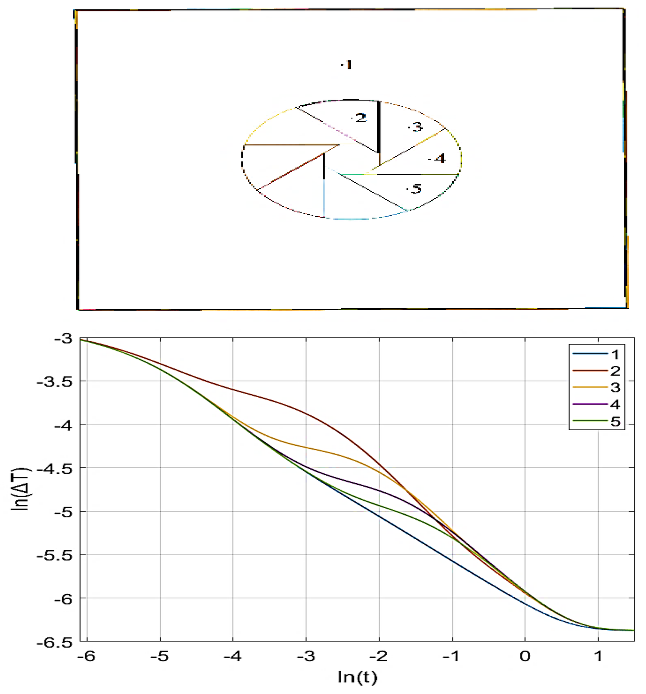


- Material : Quasi-isotropic: 48 ply with lay-up sequence$[45/0/-45/90]_{2s}$ and thickness of 2.286 mm
- Instrument: Thermoscope II equipped with IR camera (FLIR SC 5000) and two xenon lamps for pulse heating

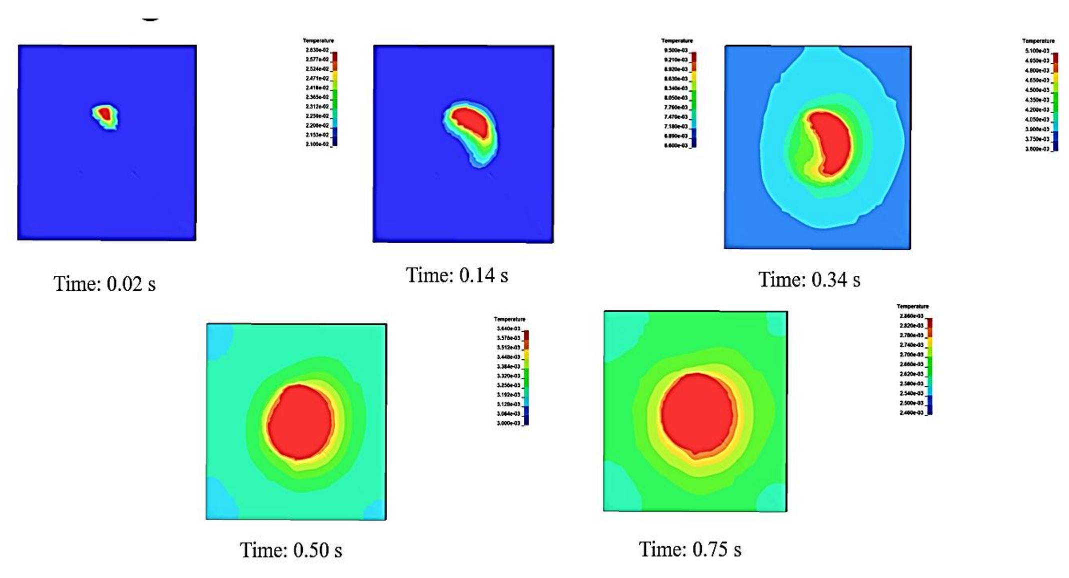
RESULTS



Clockwise spiral distribution of delaminations along the thickness direction

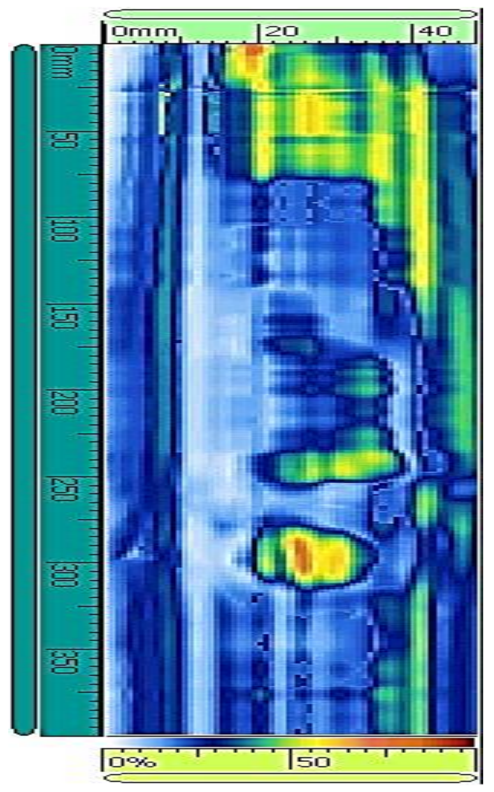


Nodal temperature variation at different delamination locations.

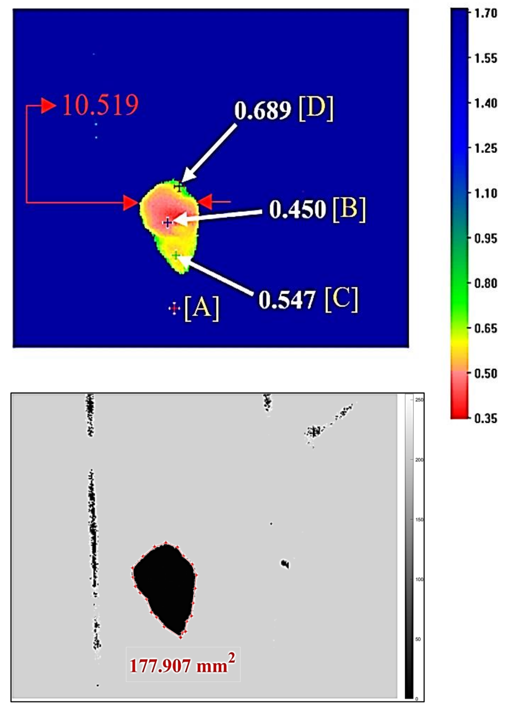


Thermographic profiles of delamination's at different times

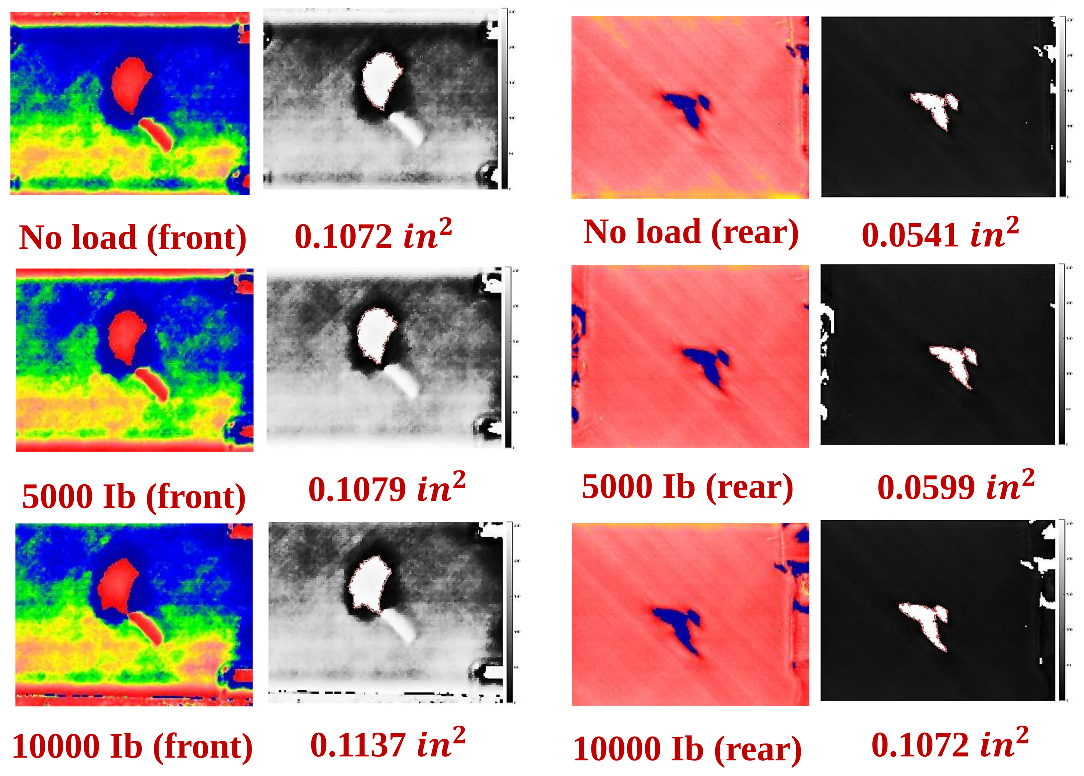
UAM Demonstrator used for "Civil Vertical Lift Vehicles" project



Ultrasonic C-scan of impact damage on demonstrator



Thermographic evaluation of impact damage on demonstrator



Damage growth in tensile specimen as load is applied

CALCULATIONS

- Using Break time $t^* = 4.511$ sec (thickness L=0.002184 m)
- $\alpha_z = 3.37e - 7\ m^2/sec$
- t* = 0.1915 sec (deviation of temperature curve related to 'B' from sound zone temperature curve 'A')
- Depth Calculation
  L= $\sqrt{(t^* \pi\ \alpha_z)}$
- Depth of location 'B' = 0.450 m

CONCLUSIONS

- T-t plots are useful for setting the threshold value.
- Calibration profile (established with the R^2 value of 0.976) determined the depth values close to the those measured by temperature variation curve.
- Damage assessment using thermography is effective and timesaving in comparison with Ultrasonic C-scan.

Future Work

- Determination of smaller defect or damage beneath larger damage using heat conductive material.

References

[1] Letchuman Sripragash, Mannur Sundaresan, "*Non-uniformity correction and sound zone detection in pulse thermographic nondestructive evaluation*", NDT & E International, Volume 87, 2017, Pages 60-67, ISSN 0963-8695, https://doi.org/10.1016/j.ndteint.2017.01.006.

[2] L. Sripragash, M. Sundaresan (2015). *A Quantitative Thermographic Nondestructive Technique (TNDT) for Damage Assessment.* (ProQuest Number: 3718806) [Doctoral dissertation, NC A&T State University]. ProQuest LLC.

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