Progress in Fielding a Zero-Focus Shadowgraph System for Ablation Measurement During Arc Jet Testing

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Aerospace Testing Alliance
Thermal and Fluids Analysis Workshop 2004

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See also ADM201871, Proceedings for the Tri-Sponsored Symposium on the Advancements in Heatshield Technology Held in Redstone Arsenal, Alabama on 14-16 September, 2004., The original document contains color images.
Outline

• Materials Testing in Arc Heated Tunnels
• Facility Description
• Issues - Motivation for New Technique
• Shadowgraph Technique
• Shadowgraph Images
• Image Reduction Method
• Conclusions
Objective

- Replace Manual Film-Based Recession Measurement System with CCD Camera System that is Less Labor Intensive and Eliminates Film.
Schematic of HEAT H1 Facility
DOD Arc Heater Flight Simulation Envelope

- Hypersonic Interceptor Ascent (Typ.)
- Lifting Body Reentry (Shuttle)
- SCRamJet Ascent
- Maneuvering Reentry
- AEDC H2
- AEDC H1 & H3
- ICBM (Typ.)
Typical Tests Performed

- Missile Nosetip
- Scramjet Leading Edge
- Missile Nosetip
- Reentry Vehicle Heat Shield
- Reentry Nosetip
- Cooled Seeker Window
- Missile Forebody
- Scramjet Leading Edge
Film Reading

Technique

• Test article filmed during a run using split ND Filter
• Film developed, lengths determined manually
• Results typically available overnight

Issues

• Exposure, filtering, variances in test article brightness
• Little feedback soon after test, difficult to make adjustments
• Environmental issues
CCD/Image Analysis

Technique

• Record digital images using a CCD Camera
• Use image analysis software to determine profiles and ablation rates immediately after test

Advantages

• Immediate feedback
• Less labor intensive
• No chemicals
Difficulties in Using Images/Self-Luminosity

- Test article stagnation region extremely bright, washing out edges
- Split ND filter, natural brightness variations cause many edges
- Still have filtering issues due to variations in test article brightness
Standard Film Image of a Nosetip Test in H1
Proposed Solution:
Zero Focus Shadowgraph

• Laser backlighting creates silhouette of test article

• Laser line filtered to eliminate self luminance

• Resultant image has high contrast test article edges

• Ideal for computer automated edge detection and tracking
Zero-focus Shadowgraph Configuration

- Laser
- Nozzle
- Beam expander
- Filter pack
- Imaging lens
- Test article
- Flow field
- Camera
Receiver Assembly
Arc-Specific Issues  
- Solutions

- Blocking of extreme test article incandescence
  - wavelength selection & “robust” filter design

- Flow density gradients create severe vignetting
  - Large aperture system & reduced vignetting design

- Radiant heat induced drift of filters
  - Front end IR blockers

- “Facility Smoke and Fire Tolerance”
  - Facility hardened system design
Filter Temperature Shift
Zero-focus Shadowgraph of Nose-tip Test
Image Processing on Zero Focus Shadowgraph

- Processing steps:
  - Setup the Image characteristics
    - Threshold levels
    - Area of interest
    - Process loop extremes
    - Image Inversion
  - Locate target pattern and determine leading edge
  - Calculate edge distance for each row and create shape
Image Processing on Zero Focus Shadowgraph

• Processing Complications
  – File Conversion
    • File had to be converted from the original AVI to a binary array in order to use standard programming techniques. Software based on LabVIEW™ from National Instruments™ (IMAQ image processing add-on toolkit)
    • LabVIEW™ conversion utilities were used to convert bitmap to data array
  – Non-Uniformity of Background
    • Optical artifacts in addition to bow-shock imagery caused problems setting a well defined target .vs. background threshold level.
    • An image inversion was performed prior to application of a Multi level threshold in order to convert original image to single bit image
  – Target Shape Definition
    • LabVIEW™ IMAQ toolkit provides a very useful pattern recognition tool.
    • Pattern recognition “highly” dependent on quality of imagery
    • Optimized optics on imager are needed in order to provide more defined target .vs. background contrast.
Image Processing on Zero Focus Shadowgraph

- Sample movie showing image processing of typical test article.
Conclusions

• Images of significant contrast were produced, suitable for image analysis
• Preliminary image analysis has been applied
• Capability to determine test article shape via automated analysis has been demonstrated
• Technique has the potential to reduce turn-around time to support decisions during test matrix execution