The Adaptive Deployable Entry and Placement Technology (ADEPT)

- A mechanically deployable decelerator is being considered as an entry, descent and landing (EDL) system to enable Human Mars class missions.
- Ground rules for the Mars studies required aerocapture, orbit, and then entry.
- Utilizes a 3-D woven carbon cloth fabric as both heatshield and primary structure.
- Design guidelines required 6 layers remaining after all entry events.

The Problem

- The peak heating predicted for the ADEPT carbon cloth is <15 W/cm² and resulting temperatures were predicted to be ~1490K.
- Predictions for carbon mass loss were performed using equilibrium thermochemistry, which is only accurate for T>2000K.
- Carbon oxidation is kinetically controlled at T<2000K, and mass loss drops off considerably from equilibrium values.
- Equilibrium predictions resulted in a 15-layer carbon cloth design, with the cloth representing >90% of the TPS mass.
- Design of the cloth thickness and mass would be significantly reduced if kinetics were considered, but development of the kinetic constants for Carbon in CO₂ would be costly and difficult to implement in the trade studies.

The Solution (This project in red)

- Develop an engineering model to describe the recession rate of the carbon as a function of the partial pressure of monatomic oxygen, which could easily be implemented in the trade study computational stream.
- The AIF uses Nitrogen, Oxygen and Argon rather than Air and Argon (like the IHF) for testing.
- Develop a stagnation test article design that can be used in the AIF with varying levels of Oxygen.
- Develop a relationship for the recession as a function of the oxygen concentration.

2: Design Approach

The Approach

- Repurpose an existing nearly square fabric-tensioning design from earlier ADEPT testing (Bilaterally Loaded Abatement Model (BLAM)) that was used in a wedge holder to evaluate the response of the cloth in shear while under load.
- Simplify the design by removing the load cell and therefore negating the need for a water cooled part.
- Place an insulating collar around the tensioning section and a new back plate.
- Build a prototype (in process).

Original ADEPT BLAM design

Simplified, modified

3: Analysis

Analysis Approach

- CFD analysis of a typical AIF test condition on model with a target of ~70 W/cm² ±2x predicted entry environments.
- Very conservative 3-D Finite Element model developed for the new carbon cloth design.
  - 20,000 hex elements, 12814 nodes.
  - 100 W/cm² and 50 W/cm² constant heatflux applied to top surface for 5 minutes, followed by 10 minute cooldown.
  - Only top and bottom surface re-radiating to the environment, all other surfaces adiabatic.
  - Transverse-isotropy properties included for thermal modeling.
  - Carbon cloth has much higher conductivity in-plane than through the thickness.
- Future analysis work would include the LA200 collar and the graphite frame beneath the cloth.

The Results

- Analysis shows that the collar material will survive heating due to the carbon cloth in proximity (T_{coll} ≈ T_{coll - LA200}), as will all other materials in contact.
- This design should work well in the AIF in flows with heatfluxes at or below 100 W/cm² with no loss of material integrity.

4: Summary

A new stagnation test article has been designed for developing an engineering model representing the mass loss of carbon cloth as a function of the partial pressure of monatomic oxygen for more reasonable predictions of carbon cloth thickness requirements in low heat loading environments.

5: Acknowledgements

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