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NUMERICAL STUDY OF THE SSME NOZZLE FLOW FIELDS DURING TRANSIENT OPERATIONS - A COMPARISON OF THE ANIMATED RESULTS WITH TEST

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Abstract

A computational fluid dynamics (CFD) model has been applied to study the transient flow phenomena of the nozzle and exhaust plume of the Space Shuttle Main Engine (SSME), fired at sea level. The CFD model is a time accurate, pressure based, reactive flow solver. A six-species hydrogen/oxygen equilibrium chemistry is used to describe the chemical-thermodynamics. An adaptive upwinding scheme is employed for the spatial discretization, and a predictor, multiple corrector method is used for the temporal solution. Both engine start-up and shut-down processes were simulated. The elapse time is approximately five seconds for both cases. The computed results were animated and compared with the test. The images for the animation were created with PLOT3D and FAST and then animated with ABEKAS. The hysteresis effects, and the issues of free-shock separation, restricted-shock separation and the end-effects were addressed.

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Approach

Computation:

- Time accurate, axisymmetric transport equations
- Extended two-equation turbulence model
- Spatial discretization - adaptive artifical dissipation
- Six species, four equation equilibrium chemistry
- Digital transient model simulated upstream boundary conditions
- Total elapse time is approximately 5 aeconds for both start-up and shut-down transients

Animation:

- PLOT3D and FAST generated images
- ABEKAS generated animatioins

Animations

- Start-up transient animations
  - Pressure
  - Temperature
  - Mach number
- Shut-down transient animaions
  - Pressure
  - Temperature
  - Mach number
- Hot-fire test photography: from visible to IR
  - Start-up transient
  - Shut-down transient
- A comparison of computed thrust coefficients with those of measurement
  - Start-up transient
  - Shut-down transient

Summary

- The CFD animations compared well with the hot-fire test photography
- The restricted-shock separation and end-effect separation have been captured by the CFD calculation
- The computed thrust coefficient histories compared reasonably well with those of the hot-fire test data