Methodology for CFD Design Analysis of National Launch System Nozzle Manifold

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ABSTRACT

The current design environment dictates that high technology CFD (Computational Fluid Dynamics) analysis produce quality results in a timely manner if it is to be integrated into the design process. The design methodology outlined describes the CFD analysis of an NLS (National Launch System) nozzle film cooling manifold. The objective of the analysis was to obtain a qualitative estimate for the flow distribution within the manifold. A complex, 3D, multiple zone, structured grid was generated from a 3D CAD file of the geometry. An Euler solution was computed with a fully implicit compressible flow solver. Post processing consisted of full 3D color graphics and mass averaged performance. The result was a qualitative CFD solution that provided the design team with relevant information concerning the flow distribution in and performance characteristics of the film cooling manifold within an effective time frame. Also, this design methodology was the foundation for a quick turnaround CFD analysis of the next iteration in the manifold design.
METHODOLOGY FOR CFD ANALYSIS
OF A NATIONAL LAUNCH SYSTEM
FILM COOLING NOZZLE MANIFOLD

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NLS MANIFOLD ANALYSIS

- Purpose of the analysis
- Manifold geometry
- Schedule limitations
- Pre-processing
  - Geometry modification
  - Grid generation
- Solution
- Post-processing
  - Color graphics
  - Performance
- Summary
To determine the flow distribution at the exit of the manifold without the effects of a choked orifice. This will identify the flow uniformity as a function of the volute manifold geometry alone.
STME FILM/CONVECTIVE COoled NOZZLE

Turbine Discharge
Nozzle Coolant Manifold

Stiffener Band

Secondary Film Injector (A/A*=7)
Primary Film Injector (A/A*=8)

Brazed

Infiltration Formed / Diffusion Bonded Tubes, Jacket

Convective Coolant Discharge Nozzlet (A/A* = 45)
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SCHEDULE REQUIREMENT

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Contract Mod Proposal
RFO Process
Analytical Design Input

1. Volute Manifold
2. Constant Area Manifold
3. Choked Manifold

Design Decision Milestone

Design & Fab Model
Analytical Pretest Predictions
Flow Testing
Post Test Analysis
Design's Mods & Drafting
RFO/Purchasing
Cast Manifold Ring

FSD SEGMENT
1 SCHEDULE

STME Nozzle Manifold Development
PRELIMINARY
PRE-PROCESSING

- Geometry modification
  - Splitter vane
  - ICEM DDN (CDC)

- Grid generation
  - ICEM DDN, PADDAM, MULCAD (CDC)
  - ~ 130,000 points
  - 19 zones

- Time to complete ~ 7 days
Computational Grid Zones
Computational Grid
Computational Grid Cross Section
SOLUTION

☐ GASP 2.0 (AeroSoft)
   - Fully Implicit
   - Finite volume

☐ 64 MW SGI Machine

☐ Flow solution
   - 3-D inviscid (viscous)
   - 108 CPU hours (∼ 5 days)

☐ Time to complete ∼ 7 days
POST PROCESSING

☐ Color graphics

- FAST (NASA Ames)
- Visualization of flow distribution

☐ Mass averaged performance

- Pratt & Whitney utilities
- Static pressure
- Mach number
- Mass flow rate
NLS MANIFOLD
Normalized Static Pressure

\[ P^{*\text{in}} = 13.11 \]
NLS MANIFOLD

% Mass Flow

Angle (° deg)
SUMMARY

- Working parameters
  - Limited time
  - Complex geometry

- Qualitative results
  - Mass averaged circumferential variations

- Timely response
  - ~ 14 days for first analysis