3D FLOW ANALYSIS OF THE ALTERNATE SSME HPOT TAD

C.A.Kubinski
Government Engines & Space Propulsion Division
West Palm Beach, Florida

ABSTRACT

This paper describes the results of numerical flow analyses performed in support of design development of the Space Shuttle Main Engine Alternate High Pressure Oxidizer Turbine Turn-around duct (TAD). The flow domain has been modeled using a 3D, Navier–Stokes, general purpose flow solver. The goal of this effort is to achieve an alternate TAD exit flow distribution which closely matches that of the baseline configuration. 3D Navier Stokes CFD analyses were employed to evaluate numerous candidate geometry modifications to the TAD flowpath in order to achieve this goal. The design iterations are summarized, as well as a description of the computational model, numerical results and the conclusions based on these calculations.
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Cheryl A. Kubinski
Pratt & Whitney (GESP)
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SSME ATD HPOT TAD REDESIGN

Outline

I. Problem Overview

II. Background – Differences Between Rocketdyne Baseline and ATD HPOT TAD
   • Geometrical
   • Aerodynamic

III. Approach
   • Minimize Differences using CFD tools to predict flowfield differences

IV. Status
   • Modified ATD TAD Configuration Defined Which Emulates Rocketdyne Baseline
Engine Turning Vane Cracking Investigation

- Engine turning cracking occurs at inside vane leading edge, pressure and suction side.

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*Problem Overview*

- Engine turning vane cracking occurs with P&W HPOTP
- Fractography analysis indicates cracking is due to HCF.
- Fault tree failure analysis indicates flow environment induced loads result in HCF incidents.
- Flow environment induced loads may result from:
  - Interface velocity distribution
  - Unsteadiness/turbulence
  - Turbine thermal profiles
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Description of STAR—CD

- General Purpose, 3D Navier Stokes Flow Solver
- Body—Fitted, Unstructured Mesh allows for modelling of Complex Geometries
- Rapid Turn—Around
- TAD Calibration Cases
  - Arizona State University Test Case (D.Metzger)
  - NASA—Ames Test Case (D.Monson)
Code Verification

Measured / CFD Predicted Static Pressure With Trip Strips
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Code Verification

Measured vs Predicted Nusselt Number For Model Without Trip Strips
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A TD

Predicted TAD Flow Pattern Differences

Rocketdyne Baseline

REFLEX Axisymmetric Analysis (MSFC)
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Differences in Velocity Distributions at Interface Plane

REFLEQX Axisymmetric Analysis (MSFC)
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Differences in Velocity Distributions at Interface Plane

3D Analysis
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Splitter and Inner Turn Contours Modified to Reduce Velocity Near Inner Vane
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CFD Models Differ in Prediction of Flow Separation For Modified TAD

Axisymmetric Model

3D Model

Separation Point

Separation Point
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Axisymmetric Analysis Indicates Velocity Near Inner Vane Still At Goal Level
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3D Analysis of ATD Redesign TAD Indicates Velocity Near Inner Vane At Goal Level

![Graph showing velocity comparison between ATD Baseline Configuration and ATD Redesign Configuration for Inner and Outer Vane Leading Edges.](image)
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Summary

- Major Differences Between the Rocketdyne and ATD TAD's Have Been Identified and Addressed
  - Interface Velocity Distribution
  - TAD Mass Flow Split
  - Fluctuating Pressures Along GOX Hex Vanes
  - Engine-Side Cavities

- Modified ATD TAD Recommended for Incorporation Into the ATD HPOT – Supported By:
  - Axisymmetric CFD Results
  - 3D CFD Results