NSAERO APPLICATION NOTE

Two-stream Axisymmetric Nozzle

Introduction

The fluid dynamics of jet propulsion systems is generally very complex with both compressibility and viscosity playing crucial roles. Consider the turbofan exhaust nozzle/after-body, the fan stream is under-expanded and a system of expansion fans and shock waves exist between the after-body and the mixing layer trailing the fan cowl. This application note demonstrates the capability of NSAERO to model axisymmetric turbo nozzle flows. NSAERO is a multi-block computational fluid dynamics software package available from Analytical Methods, Inc. The current application is axisymmetric flow with no-swirl, but NSAERO can model axisymmetric flows with swirl as well as fully three-dimensional flows.

Problem Description

The flow field was calculated about a model-scale axisymmetric turbofan exhaust nozzle/after-body. The primary exhaust plume was simulated in the experimental test by a solid sting. Since the exhaust nozzle was situated in an experimental test cell, the external flow was nearly quiescent and resulted only from entrainment into the fan jet mixing layer. The calculation was done for a nozzle pressure ratio of 2.6.

Problem Setup

The computational domain was broken into three zones as shown in Figure 1. Three grids densities were run to determine the grid convergence of the solution. The zonal dimensions for the three grids are shown in Table 1.

Experimental measured total pressure profiles were imposed on the subsonic inflow boundary of the fan stream. The total temperature of the air was approximately 288.33 K and assumed uniform along both the internal fan stream inflow boundary and the external inflow boundary. The ambient static pressure was 14.68 psia.

Results

The runs are summarized in Table 2. The fine mesh Mach number contours are shown in Figure 2 and the calculated after-body static pressure distribution is compared with measured pressure data in Figure 3. NSAERO accurately predicts the location of the expansion and compression waves.

Mesh	Zone1	Zone 2	Zone 3	Total
Coarse	22x21	22x29	39x49	3011
Medium	22x31	22x39	59x69	6511
Fine	41x50	41x58	88x109	14020

Table 1 Zonal grid densities

Mesh	Time steps	Run time (min)	Conver-gence	Memory (kB)
Coarse	2000	2	4	1530
Medium	2000	4	4	2690
Fine	4000	22	3	6479

Table 2 Summary of run times and convergence on PC P4 2GHz (Linux)

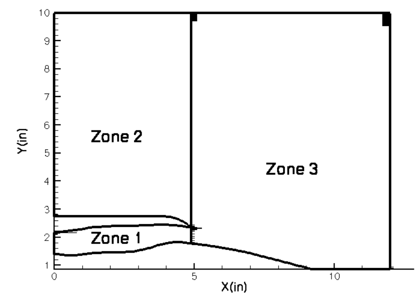

Figure 1 Zonal configuration for the two-stream turbofan nozzle calculation

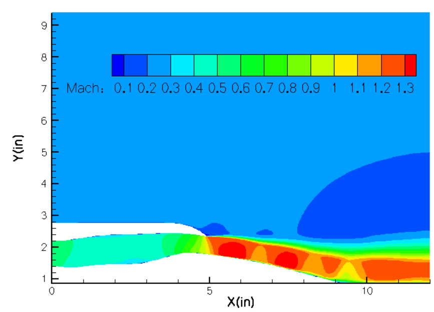

Figure 2 Calculated Mach number contour

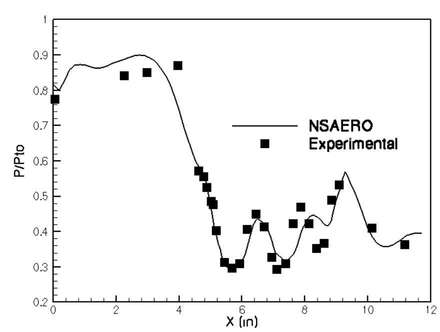

Figure 3 Comparison of calculated wall pressures with Experiment from[1]

[1] M.K. Peery & S.T. Imlay " An efficient Implicit Method for Solving Viscous MultiStream Nozzle/Afterbody Flow Fields, AIAA 86-1380 June 1986.