NSAERO APPLICATION NOTE
Validation of the Space Shuttle Orbiter Flow during Atmospheric Reentry

Introduction

This application note validates NSAERO to model the 3D flow field around complex reentry vehicles with finite-rate chemistry. NSAERO is a multi block computational fluid dynamics software package available from Analytical Methods, Inc.

Problem Description

The flight condition is a Mach number of 24 and 40 deg angle of attack at high altitude (74 km).

Problem Setup

The computational domain is constituted of a single block with 75x61x161 points in the stream-wise, normal, and azimuthal directions, respectively (Figure 1). The model for dissociating air consists of 5 species and 17 reactions[1]. It includes thermal non-equilibrium with all molecular vibrational energies and electronic excitation energies considered to be in equilibrium with each other. The thermal non-equilibrium is treated more simply than with the park model - a simple Landau Teller expression is used for the vibrational/electronic/electron energy source term. The wall is isothermal with a temperature of 1400 K. No catalysis and radiation are imposed at the wall due to the lack of input data. The case demonstrates also the capability of NSAERO in using the mesh adaptation for 3D configuratiom.

Results

Figure 1 shows the 3D grid with the O2 density contours. Figure 2 shows the Mach number contours. The flight data[2] for the windward and leeward centerline pressures compared favorably with NSAERO results, as shown in Figure.3. The pressure distribution at 60% wing span (Figure 4) and at 10% fuselage station (Figure 5) demonstrate the good agreement with NSAERO calculations. The deviation seen in Figure 4 is attributed to the non-modeling of the bleed-through from the gap (18cm) between the inboard and outboard elevon.

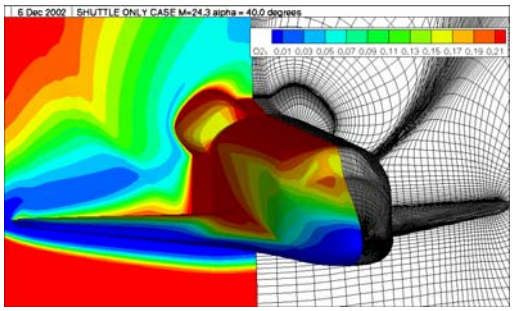

Figure 1 O2 density contours and grid

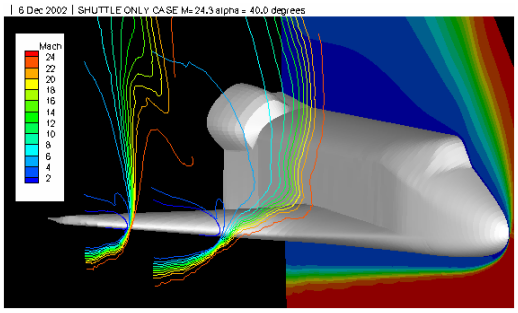

Figure 2 Mach Number contours at Y/B=0, Y/B=0.6 and Y/B = 0.85

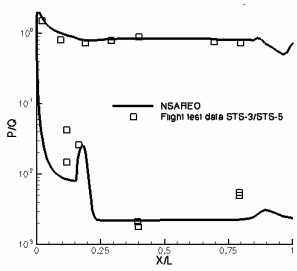

Figure 3 Pressure distribution along the fuselage centerline

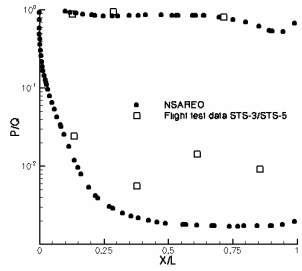

Figure 4 Pressure along the wing chord at Y/B=0.6

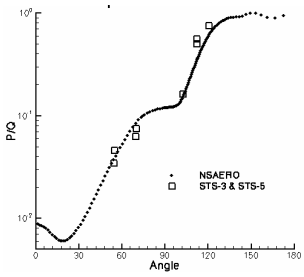

Figure 5 Pressure around the fuselage at X/L=0.1 (0 deg = windward – 180 deg = leeward)

[1] Park, C., *Assessment of Two-Temperature Kinetic Model for Ionizing Air*, AIAA Journal of Thermophysics and Heat Transfer, Vol. 3, No. 3, pp 233-244, July 1989.
[2] W.L. Kleb & K.J. Weilmuenster, *Characteristics of the shuttle Orbiter Leeside Flow During a Reentry Condition, 1992.*