NSAERO APPLICATION NOTE
Oblique shock on a 15 degree Wedge at Mach 2.5

Introduction

This verification case involves the computation of the supersonic flow field past a wedge with a half angle of 15 degrees. This application note demonstrates the capability of NSAERO to model the flow field with structured, unstructured and hybrid meshes. NSAERO is a multi-block computational fluid dynamics software package available from Analytical Methods, Inc.

Problem Description

The free-stream Mach number is 2.5, as the flow meets the leading edge of the wedge, an oblique shock is formed as the flow turns to become tangent with the wedge surface.

Problem Setup

The computational domain is bounded along the bottom by the symmetry plane of the wedge and the wedge surface. The inflow is located at about x=-0.15 m. The outflow is placed at x=0.3m and the far-field boundary is placed at y=0.3m to place it well above the oblique shock. First, three grids are generated for an inviscid computation. The grid (a) (Figure 1) is a structured block with a grid density of 87x51, the grid (b) (Figure 2) is obtained from the grid (a) by triangulation (4437 nodes and 8600 elements). The grid (c) (Figure 3) is generated by having in mind the approximate solution and less elements are generated where unnecessary by keeping the same density on the wedge boundary. Second, for laminar flow, refinement closed to the wall is required with a wall spacing of 0.1 mm. The grid (d) (Figure 4) is a structured block with 87x51.Finally, the grid (e) (Figure 5) is formed by splitting the grid (d) into two domains (87x31 & 87x21), the first domain closed to wedge wall is kept and the second domain is regenerated with an unstructured elements (triangles).

Results

The runs are summarized in Table 1. The calculated static pressure ratio P2/P1 is compared with the analytical solution (2.4675) from Anderson [1] . NSAERO accurately predicts the pressure ratio but also the angle of the oblique shock for all grids. It shows the capability of NSAERO to deal with structured, unstructured and hybrid blocks without affecting the accuracy of the solution. Unstructured blocks give some flexibility to the users compared to structured blocks. It avoids the excessive grid refinement from structured blocks. The well-known advantage of structured block closed to the wall is adapted in case the flow is considered viscous by generated hybrid meshes. The pressure ratio along the wedge wall is depicted in Figures 6 & 7 for meshes a,b,c and for meshes d,e, respectively.

Mesh	Time steps	Run time(s)	Conv	Mem. (kB)	P2/P1	Error %
a	500	18	11	1831	2.4679	0.024
b	500	51	6	6578	2.4681	0.017
c	500	22	6	2359	2.4665	0.048
d	2000	115	5	1831	NA	NA
e	2000	110	5	2488	NA	NA

Table 1 Summary of run times and convergence on PC P4 2GHz (Linux)

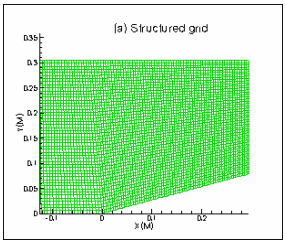

Figure 1 Mesh (a)

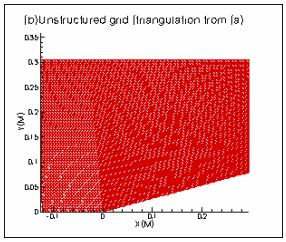

Figure 2 Mesh (b)

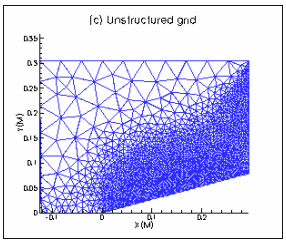

Figure 3 Mesh (c)

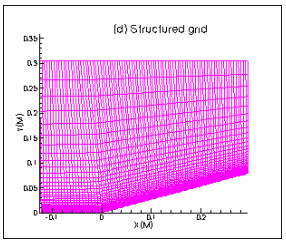

Figure 4 Mesh (d)

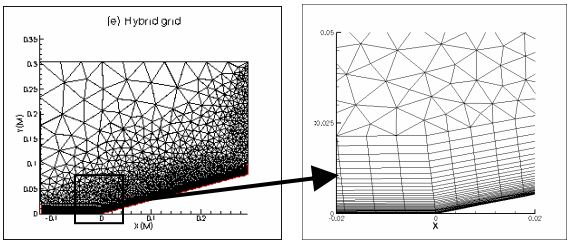

Figure 5 Mesh (e) and zoom-up of (e)

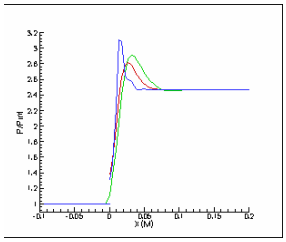

Figure 6 Pressure ratio

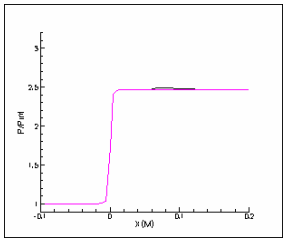

Figure 7 Pressure ratio

[1] Anderson, J.D., Modern Compressible Flow, McGraw Hill, New York, 1982.