TEST CASE DOCUMENTATION
AND TESTING RESULTS

TEST CASE ID CESE-VER-2.1

Oblique Shock Reflection over a flat plate

Tested with LS-DYNA® v980 Revision Beta

Friday 1st June, 2012

Livermore Software Technology Corp.

Document Information	
Confidentiality	**external use**
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Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case CESE-VER-2.1. It provides general test case information like name and ID as well as information to the confidentiality, status, and classification of the test case.

A detailed description of the test case is given, the purpose of the test case is defined, and the tested features are named. Results and observations are stated and discussed. Testing results are provided in section 4.1 for the therein mentioned LS-DYNA® version and platforms.

2 Test Case Information

Test Case Summary	
Confidentiality	external use
Test Case Name	Oblique Shock Reflection over a flat plate
Test Case ID	CESE-VER-2.1
Test Case Status	Under consideration
Test Case Classification	Verification
Metadata	SHOCK WAVES

Table 1: Test Case Summary

3 Test Case Specification

3.1 Test Case Purpose

This is a 2D steady state problem suggested by [2] and its purpose is to verify the solver's ability to correctly handle and capture strong discontinuities i.e oblique shock waves.

3.2 Test Case Description

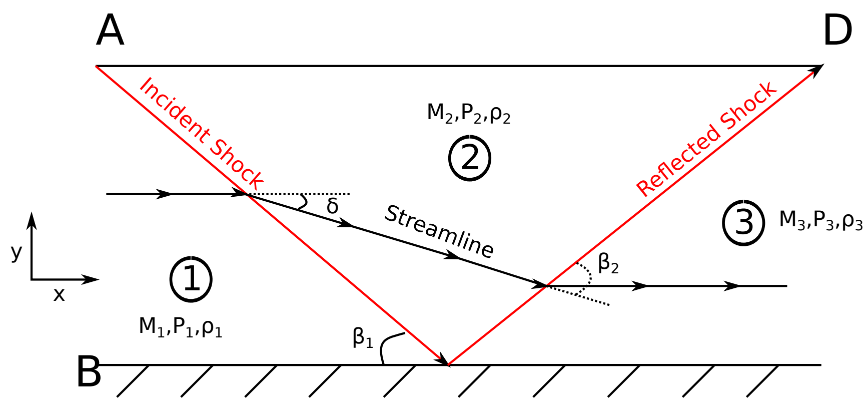

Figure 1: Initial state in the shock tube

Normal shock waves are considered a special case of oblique shock waves that occur in supersonic flows. Figure (1) shows the impact of an incoming oblique shock wave on a solid wall and the behavior of the flow. The reflection of a shock wave is a shock wave thus dividing the fluid domain in three zones with three distinct fluid velocities, pressure, density and temperature. For an oblique shock wave and a calorically perfect gas, it can be shown [1] that between two zones :

$$M_{n_1} = M_1 sin\beta \quad (1)$$

$$\frac{\rho_2}{\rho_1} = \frac{(\gamma+1)M_{n_1}^2}{(\gamma-1)M_{n_1}^2+2} \quad (2)$$

$$\frac{P_2}{P_1} = 1 + \frac{2\gamma}{\gamma+1}(M_{n_1}^2 - 1) \quad (3)$$

$$M_{n_2}^2 = \frac{M_{n_1}^2 + 2/(\gamma-1)}{(2\gamma/(\gamma-1))M_{n_1}^2 - 1} \quad (4)$$

$$tan\delta = 2cot\beta[\frac{M_1^2 sin^2\beta - 1}{M_1^2(\gamma + cos(2\beta)) + 2}] \quad (5)$$

with M_n the normal component of the Mach number and γ the heat capacity ratio.

Therefore, in order to obtain a specific oblique shock angle β, the pressure, density and velocity must be imposed on the AB and AD boundaries.

The test cases's main objective is to determine if the numerical results for zone 1,2 and 3 match the expected analytical results that can be calculated using equation (1),(2),(3),(4) and (5).

3.3 Model Description

The geometry of the model is [4,1] with one layer of elements in the z-direction in order to simulate a 2D-model. Figure (2) shows the mesh used and Table (2) gives some additionnal information on the mesh. The chosen Mach number for zone 1 is 2.9 and the oblique shock wave angle is 29° resulting in the parameters given by Table (3) for AB and AD.

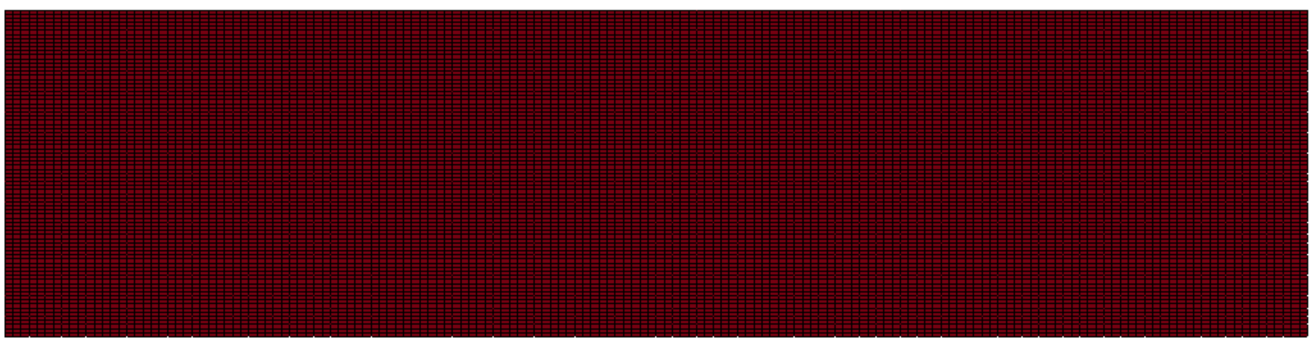

Figure 2: Test Case Geometry and Mesh

Model information	
Nodes	26082
Solid elements	12800
Parts	1

Table 2: Test Case Mesh information

Model physical parameters		
	AB	AD
Velocity in the x-direction	2.9	2.6193
Velocity in the y-direction	0	-0.50632
Pressure	1/1.4	1.5282
Density	1	1.7

Table 3: Test Case Parameters

4 Test Case Results

4.1 Test Case observations

Figure (3) shows the velocity fringes and highlights the decomposition of the domain in three zones with an incident and reflected shock wave. Figure (4) shows the pressure contours and show the shock wave diffusion. In order to have a smaller diffusion, a finer mesh can be employed. Finally, Figure (5) shows the excellent agreement between numerical results and analytical solutions.

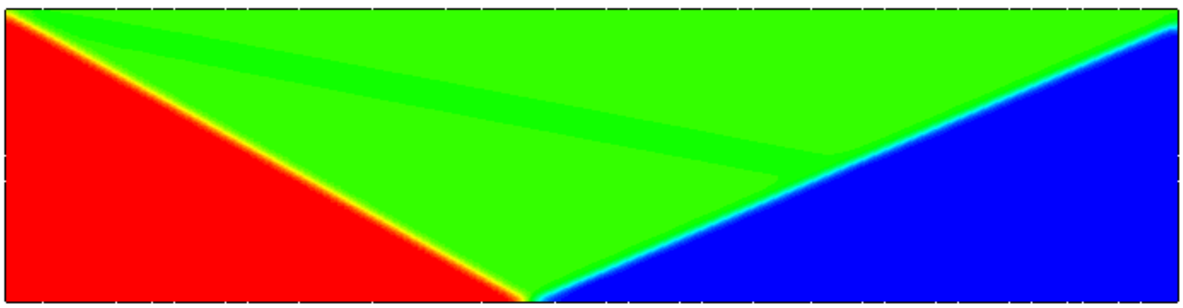

Figure 3: Test Case Velocity profile

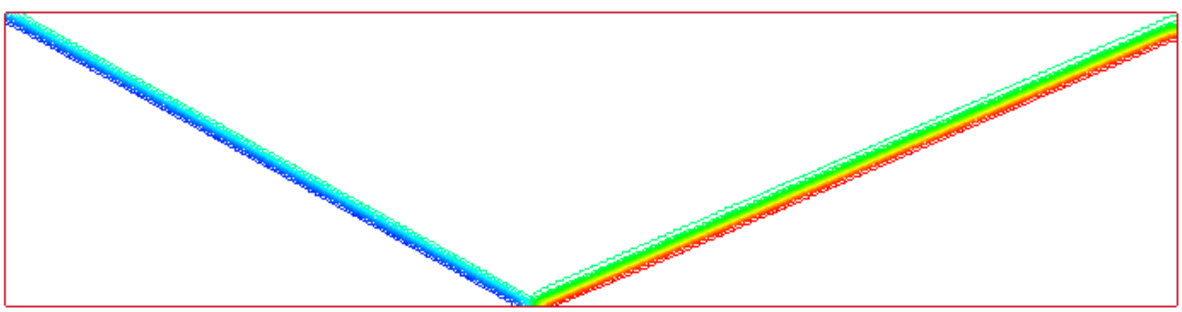

Figure 4: Test Case Pressure Isosurfaces

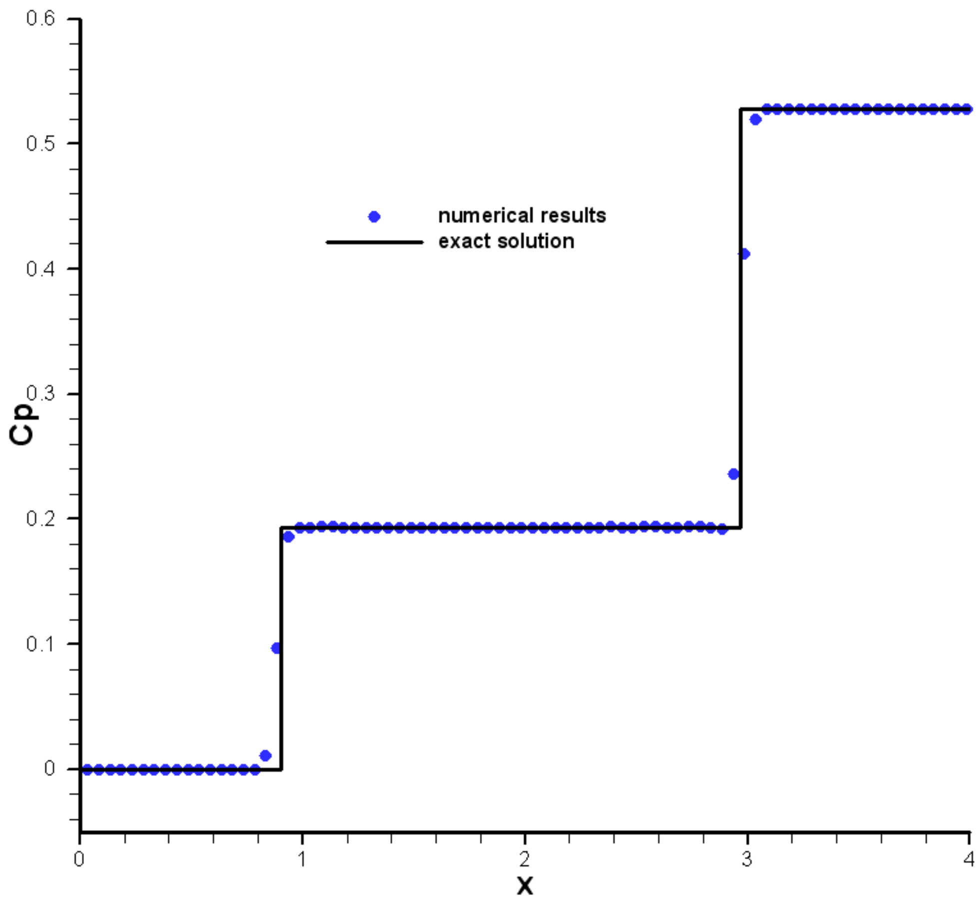

Figure 5: Pressure coefficient for zones 1,2 and 3

References

[1] J. D. ANDERSON, *Modern Compressible Flow with historical perspective*, Mc Graw Hill, 2003.

[2] R. W. H.C. YEE AND A. HARTEN, *Implicit total variation diminishing (tvd) schemes for steady-state calculations*, AIAA Paper, (1982).