TEST CASE DOCUMENTATION
AND TESTING RESULTS

TEST CASE ID CESE-BENCH-2.1

Mach 3 Wind Tunnel With a Step

Tested with LS-DYNA® v980 Revision Beta

Friday 1st June, 2012

LSTC
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-BENCH-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	Mach 3 Wind Tunnel With a Step
Test Case ID	CESE-BENCH-2.1
Test Case Status	Under consideration
Test Case Classification	Benchmarking
Metadata	SHOCK WAVES

Table 1: Test Case Summary

3 Test Case Specification

3.1 Test Case Purpose

The purpose of this benchmarking test case is to study the time propagation of shock waves appearing in a supersonic wind tunel with a step.

3.2 Test Case Description

This 2D test problem was introduced more then fifty years ago by [1], but its overall public acknowledgment was taken place after paper by [2]. This problem has proven to be a useful test for a large number of numerical methods, schemes and algorithms during a large number of years. The problem begins with an incoming supersonic flow at Mach 3 in a wind tunnel meeting a step. The wind tunnel is 1 length unit wide and 3 length unit long. The step is 0.2 length units high and is located 0.6 length units from the left-hand end of the tunnel. The problem is considered two dimensional. Once the supersonic flow reaches the step, different shock wave patterns will appear that will be reflected on the wind tunnel's boundaries. The corner of the step is the center of a rarefaction fan and is usually the cause of numerical errors and time delays in the development of the flow. Since the flow at time 4 is still unsteady and steady flow develops by time 12, this benchmarking test case will focus on the flow development up to time 4 and compare the results to those of [2].

3.3 Model Description

Figure (1) offers a view of the uniform mesh used while Table (2) and (3) give some information on the mesh and the parameters used. Special care will be given on the choice of the CESE scheme stabilization parameters as too high values may induce some diffusion of the numerical solution (See CESE theory manual).

Model information	
Element size	0.01
Total number of nodes	51000
Total number of elements	25000

Table 2: Test Case Mesh information

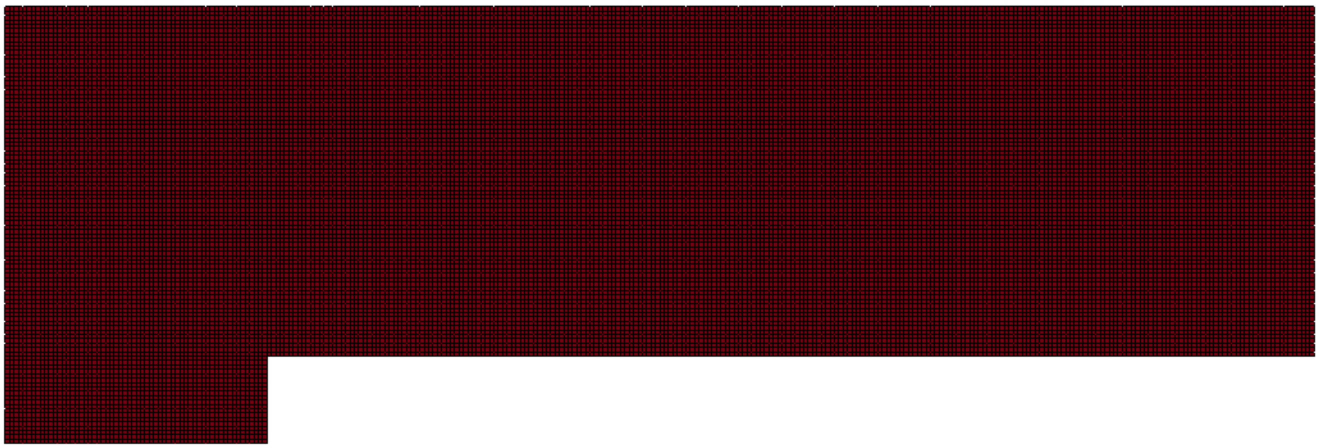

Figure 1: Test Case Mesh

Model physical parameters	
Specific heat at constant volume	0.198413
Specific heat at constant pressure	0.277778
Incoming velocity in the x-direction	3
Incoming velocity in the y-direction	0.0
Incoming Pressure	1
Incoming Density	1.4
CESE scheme stabilization parameters-Method 1	
α	1
β	0.05

Table 3: Test Case Parameters

4 Test Case Results

4.1 Test Case observations

Figures (2) and (3) offer a superposition of the reference results density iso-contours by [2] and the present numerical simulation. The iso-contours of the shock waves are clearly captured and their various impact location and diffusion are in good agreement with the results by [2]. Figure (4) focuses on the t=4s instant and shows the iso-contours of velocity and pressure. Again, the correlation between the results by [2] and the current simulation can be clearly identified.

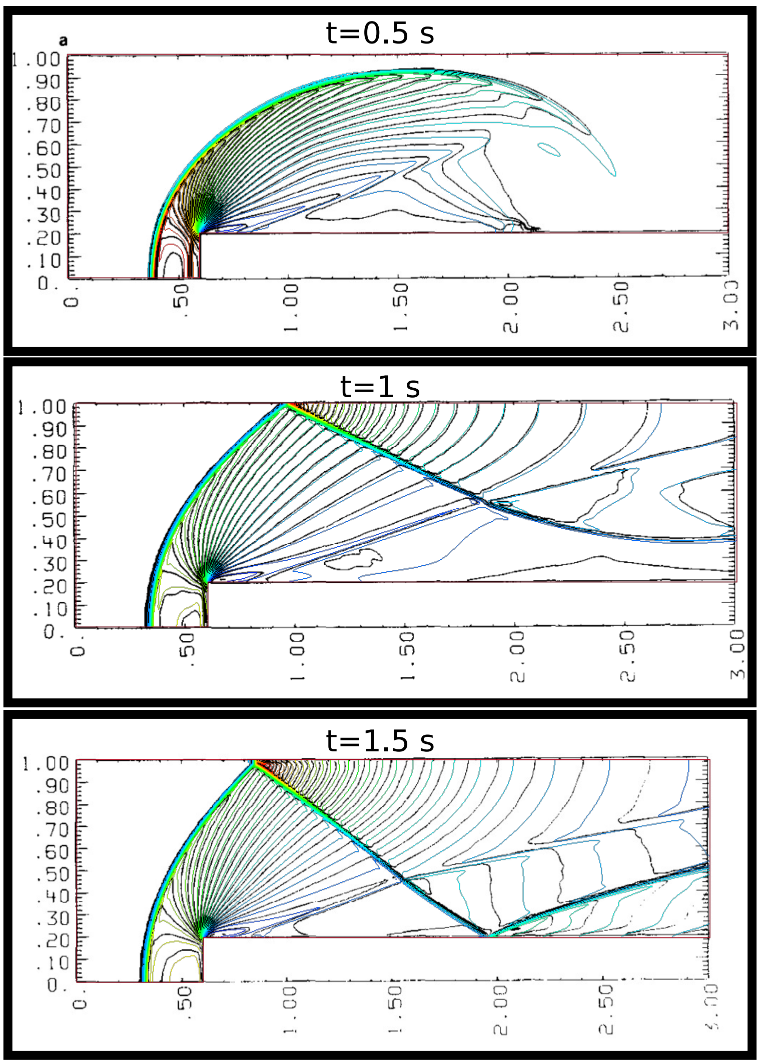

Figure 2: 30 density iso-contours superposition at different instants of the reference results by [2] (black and white) and the current simulation (colors)

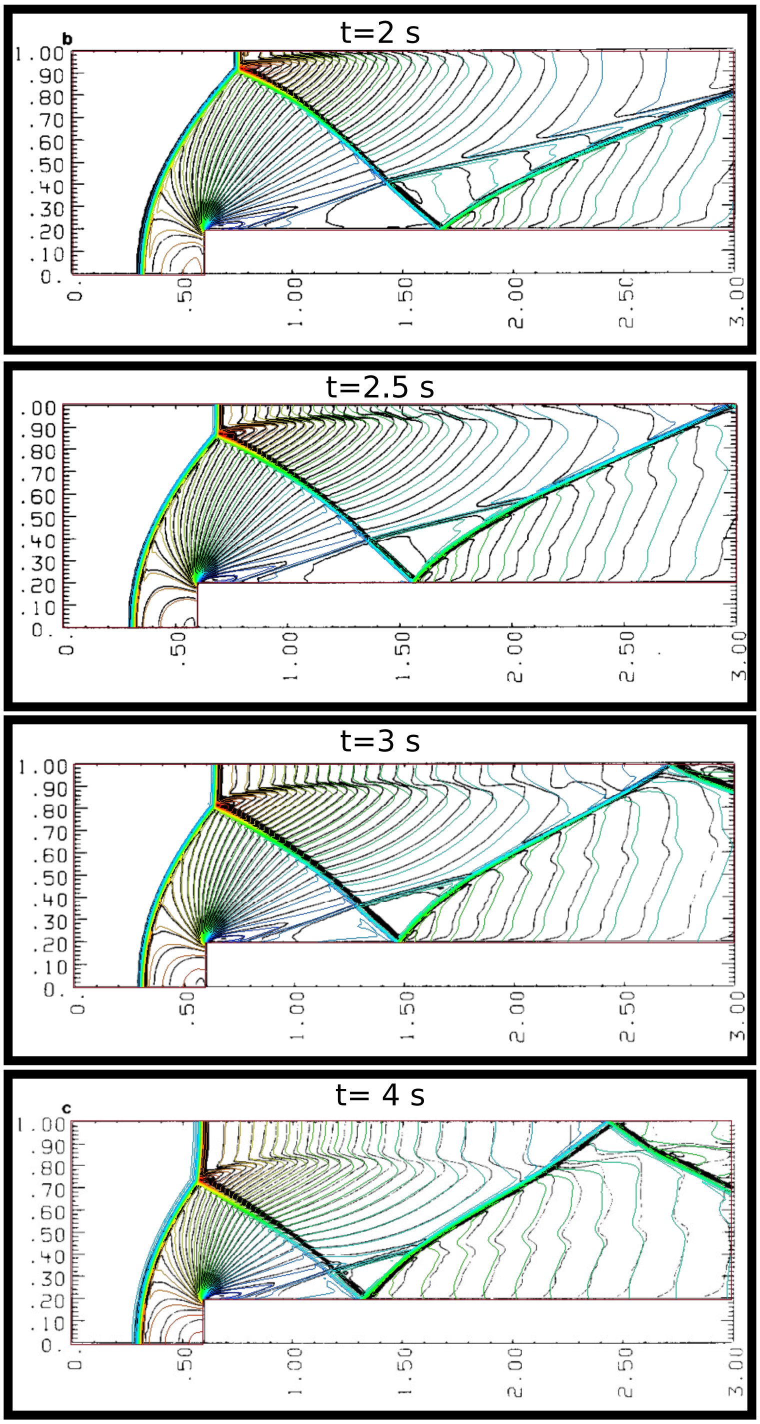

Figure 3: 30 density iso-contours superposition at different instants of the reference results by [2] (black and white) and the current simulation (colors)

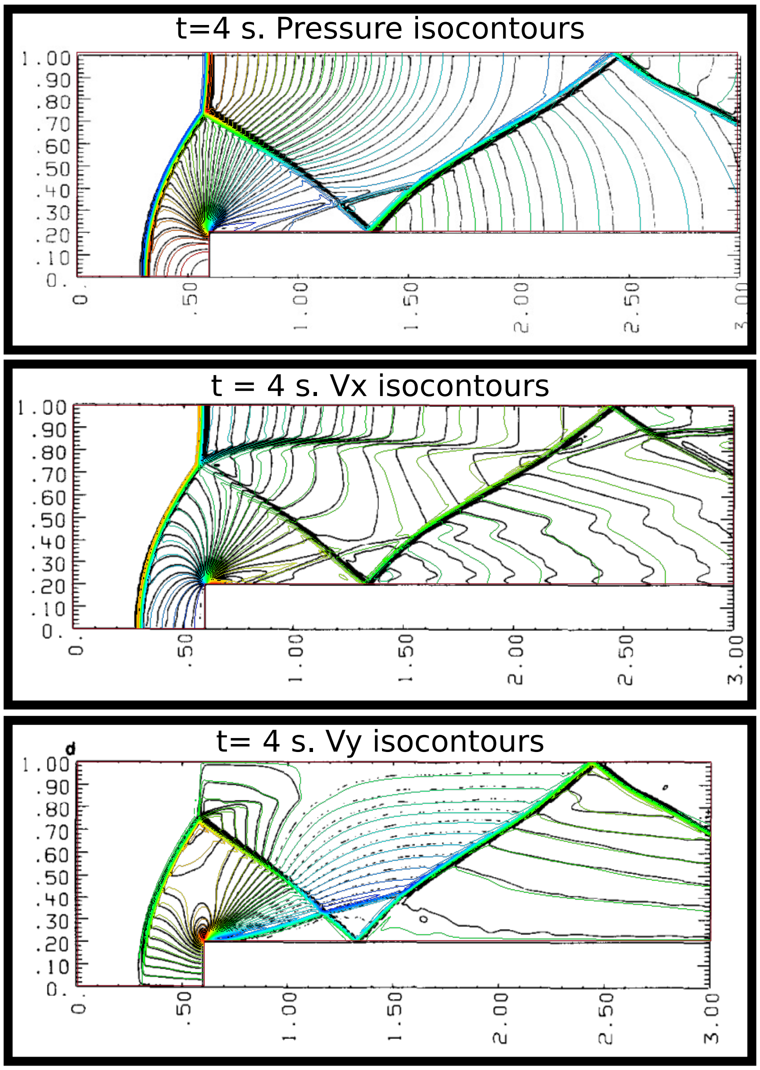

Figure 4: 30 velocity and pressure iso-contours superposition at different instant of the reference results by [2] (black and white) and the current simulation (colors)

References

[1] A. Emery, *An evaluation of several differencing methods for inviscid fluid flow problems*, Journal of Computational Physics, 2 (1968), pp. 306–331.

[2] P. Woodward and P. Colella, *The numerical simulation of two-dimensional fluid flow with strong shocks*, Journal of Computational Physics, 54 (1984), pp. 115–173.