TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AWG-ERIF-11-15

TEST CASE ID AWG-ERIF-11

*CONSTRAINED Keyword Test Case

Tested with LS-DYNA® R11.2 Revision 26-gd2ace36

Wednesday 2nd December, 2020

LSTC
Livermore Software Technology Corp.

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Document Information	
Confidentiality	**external use**
Document Identifier	LSTC-QA-LS-DYNA-AWG-ERIF-11-15
Author(s)	Prepared by LS-DYNA® Aerospace Working Group
Number of pages	24
Date created	Wednesday 2nd December, 2020
Distribution	LS-DYNA® Aerospace Working Group / internal LSTC QA

Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case AWG-ERIF-11. 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. The test case specifications also state the target measures for testing and the expected results, as well as their pass and fail criteria.
Testing results are provided in section 5 for the therein mentioned LS-DYNA® version and platforms.

2 Test Case Information

Test Case Summary	
Confidentiality	external use
Test Case Name	*CONSTRAINED Keyword Test Case
Test Case ID	AWG-ERIF-11
Test Case Status	active
Test Case Classification	Example
Test Case Source	NASA
Tested Keyword	*CONSTRAINED_INTERPOLATION, *CONSTRAINED_NODAL_RIGID_BODY
Member of Test Suite	AWG ERIF SUITE
Metadata	AWG ERIF

Table 1: Test Case Summary

3 Test Case Specification

3.1 Test Case Purpose

The purpose of Test Case ID AWG-ERIF-11 is the comparison of results from different cpu architectures for a basic model containing *CONSTRAINED_INTERPOLATION and *CONSTRAINED_NODAL_RIGID_BODY keyword.
The reliability and consistency of LS-DYNA® as a finite element solver for these test cases is evaluated by performing analyses on different cpu architecture platforms.

3.2 Test Case Description

This Test Case contains two approaches to model constraints commonly used in the aerospace industry.
The Test Case contains two separate cylinders (see figure 1), one with a center node connected with a nodal rigid body constraint (node 1000) and the other with an interpolation constraint (node 2000). In the nodal rigid body, no degrees of freedom are released. In the interpolation model, the circumferential nodes are define as independent nodes.
The cylinder radius and length for both cylinders is 10 inches and the base nodes are held fixed.
The thickness of the cylinders is 0.1 inches and the material is a linear elastic aluminum.
The loads are simultaneously applied to both cylinders and they consist of axial forces and bending moments.

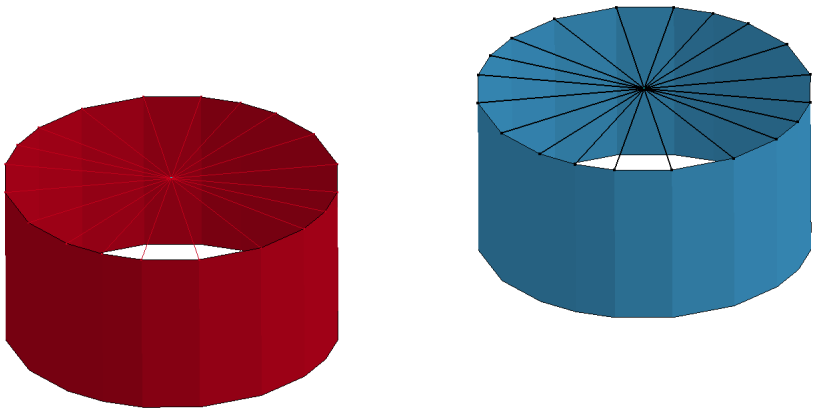

Figure 1: Model sketch: Two cylinders with constraints

Table 2 contains a short summary of the physical model set up.

Physical Model Information	
cylinder radius	10 inches
cylinder length	10 inches
cylinder thickness	0.1 inches
material	linear elastic aluminum

Table 2: Model set-up data

3.3 Model Description

The cylinders are discretized with shell elements (see figure 2).
Forces and moments are applied at the center nodes.
The model specifications can be found in table 3, and table 4 defines the sub test case specification.
The material definitions and their parameters can be found in the input decks.

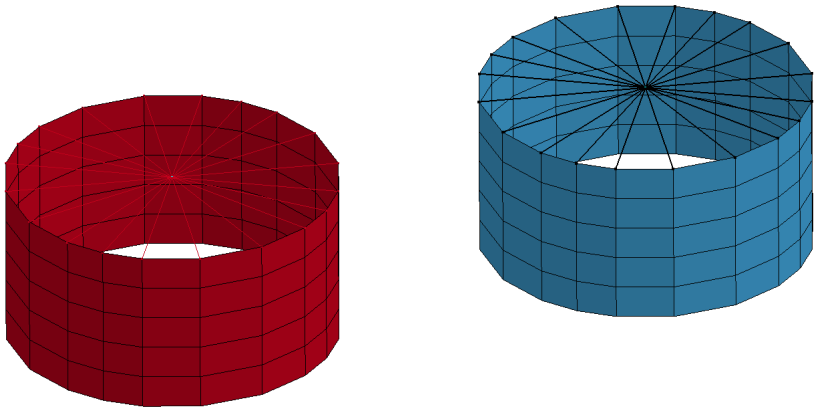

Figure 2: FEA model: Cylinders with constrains

FEA Model information		
Sub Test Case ID [1]	1	2
Nodes	242	242
Shell elements	200	200
Shell materials	2	2
Mass elements	2	2
Nodal rigid bodies	1	1
Units	in (length), sec (time), $lbf \cdot sec^2/in$ (mass), lbf/in^2 (stress), $lbf \cdot in$ (energy)	

[1] Sub Test Case ID refers to the ID's in table 4

Table 3: FEA Model Information

Sub test case ID 1 is a model which is calculated with an explicit time integration method and sub test case ID 2 is the same model setup calculated with an implicit solution method.

Sub Test ID	Input Deck Name
1	CONSTRAINED_TEST_CASE_EXPLICIT.k
2	CONSTRAINED_TEST_CASE_IMPLICIT.k

Table 4: Specification of sub test cases

4 Test Specifications

4.1 Test Case Targets

Table 5 displays the test case targets. The test case targets specify values or a series of values taken from the finite element analysis solution of the test case and they are used in a comparison of analysis results on different cpu architectures. They are chosen in a way that they are representative of the numerical model.

Test Case Targets				
Target number	output	component type	component id	retrieved from
1	nodal	x displacement	1000	binout/nodout file
2	nodal	y displacement	1000	binout/nodout file
3	nodal	z displacement	1000	binout/nodout file
4	nodal	x rotation	1000	binout/nodout file
5	nodal	y rotation	1000	binout/nodout file
6	nodal	z rotation	1000	binout/nodout file
7	nodal	x displacement	2000	binout/nodout file
8	nodal	y displacement	2000	binout/nodout file
9	nodal	z displacement	2000	binout/nodout file
10	nodal	x rotation	2000	binout/nodout file
11	nodal	y rotation	2000	binout/nodout file
12	nodal	z rotation	2000	binout/nodout file

Table 5: Test Case targets for Test Case ID AWG-ERIF-11

Test case targets are used to evaluate the cross cpu architecture consistency (see section 4.2). Node 1000 is connected with a nodal rigid body and node 2000 is connected with an interpolation constrained.

4.2 Pass/Fail Criteria

These are the Pass/Fail criteria used for the cross cpu architecture consistency test of the Test Case ID AWG-ERIF-11.

The sub test case passes if the test case target data falls within the corridor bounds. Otherwise the test fails.

The test case corridors are upper and lower bounds for the test case targets. They were defined based on the test target data obtained with LS-DYNA® R9.0 Revision 108899 binaries by the following process:

- For a specific test case target, interpolate the data from different platform and executable (R9.0 Revision 108899) combinations, so that the time domain is the same.
- Calculate the upper and lower bounds by:

$$bound_{up}(i) = max(i) + 0.2 \times [max(i) - min(i)] + 0.05 \times peak$$
$$bound_{low}(i) = min(i) - 0.2 \times [max(i) - min(i)] - 0.05 \times peak$$

  where $max(i)$, $min(i)$ are the maximum and minimum values at the i_{th} time step across all platforms and executable (R9.0 Revision 108899) combinations the test case was calculated with, $peak$ is the maximum absolute y value across the whole time domain, $bound_{up}(i)$ and $bound_{low}(i)$ are the upper and lower bounds for the i_{th} time step.

5 Test Case Results

5.1 Software and Hardware Specifications

In order to ensure cross-platform consistency, the herein mentioned sub test cases are run on platforms specified in table 6 and the results are calculated with software versions defined in table 7.

Platform Name	Operating system	CPU type	MPI-Protocol	Number of cpu's [1]
mars	CentOS 6.5	Intel® Xeon® E5- 2640 @ 2.50GHz	Platform MPI 8.2.0.0	4
dinar3b	SUSE LES 11	AMD® Opteron ® 6276 @ 2300MHz	Platform MPI 8.2.0.0	4

[1] Number of cpu's used for calculation of the test case

Table 6: Used Platforms and CPU Type's

Product	Version	Release	Revision	Parallel type [1]	Precision [2]	executable
LS-DYNA®	971	R11.2	26-gd2ace36	SMP	SP	ls971.26-gd2ace36.R11.2
LS-DYNA®	971	R11.2	26-gd2ace36	SMP	DP	ld971.26-gd2ace36.R11.2
LS-DYNA®	971	R11.2	26-gd2ace36	MPP	SP	mpp971.26-gd2ace36.R11.2
LS-DYNA®	971	R11.2	26-gd2ace36	MPP	DP	mpd971.26-gd2ace36.R11.2

[1] MPP = Massively Parallel Processing, SMP = Symmetric Multiprocessing

[2] SP = single precision, DP = double precision

Table 7: Tested LS-DYNA® version

5.2 Results Summary

Table 8 contains the results of the Test Case ID AWG-ERIF-11 completed with all combinations of software and hardware defined in section 5.1 (1 * 3 * 4 + 1 * 3 * 2 total calculation runs).

Details on the test results can be found in the section 5.3.

The table 8 cross cpu architecture consistency summary is:

- **PASS** - Pass criteria in section 4.2 is attained.
- **FAILED** - Pass criteria in section 4.2 is not attained.
- **ERROR** - sub test case terminates due to error.
- **N/A** - sub test case was not calculated.

Sub Test Case ID	PASS/FAILED
1	**PASS**
2	**PASS**

Table 8: Results summary for Test Case ID AWG-ERIF-11

5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-ERIF-11 for LS-DYNA® R11.2 Revision 26-gd2ace36.

For each sub test case defined in section 3.3 there is a graph displaying the time history of the result target defined in section 4.1 for the platform and software version combinations defined in section 5.1.

The title of the graph states the test case ID and the name of input deck. The legend contains the result file name, output, platform, executable and number of cpu's separated by comma. A minus sign before the number of cpu's refers to the compatibility option for SMP calculations (see [1] for details on this option).

Example for title and legend:

Title:

'AWG_ERIF_TEST_CASE_11: CONSTRAINED_TEST_CASE_EXPLICIT.k' states the test case ID 11 and name of the input deck for sub test case 1.

Legend:

'glstat_internal_energy,ham,ls971.26-gd2ace36.R11.2,4' states that the graph shows the internal energy derived from the 'glstat' output file for an input deck which was calculated on the 'ham' platform with a LS-DYNA® R11.2 Revision 26-gd2ace36 binary (SMP, single precision) on four processors.

5.3.1 Sub Test Case ID 1 - Test Target 1

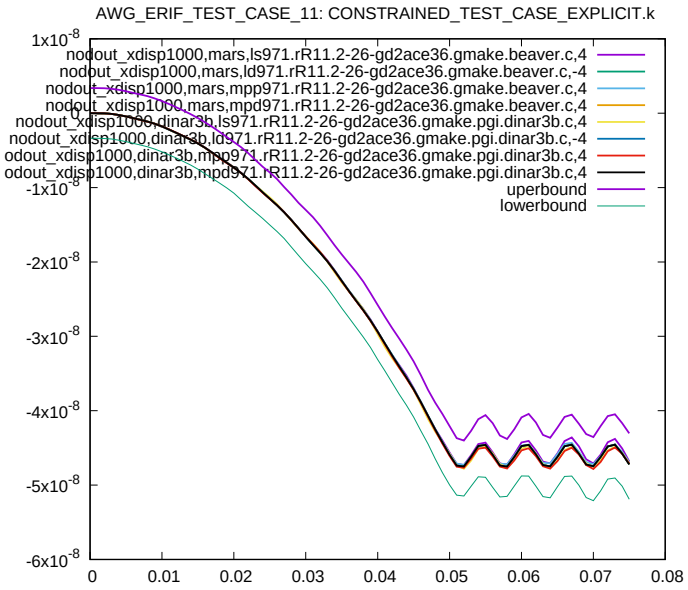

Figure 3: Cross platform results, nodal displacement in x-direction, node 1000, sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

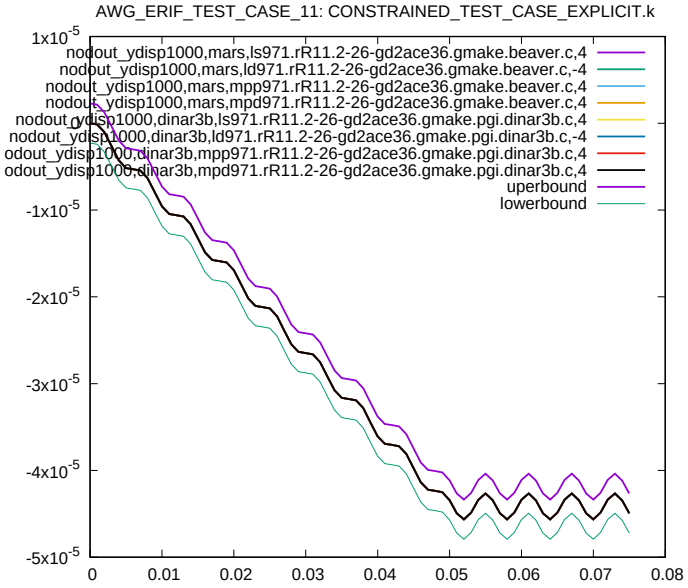

Figure 4: Cross platform results, nodal displacement in y-direction, node 1000, sub test case ID 1

5.3.3 Sub Test Case ID 1 - Test Target 3

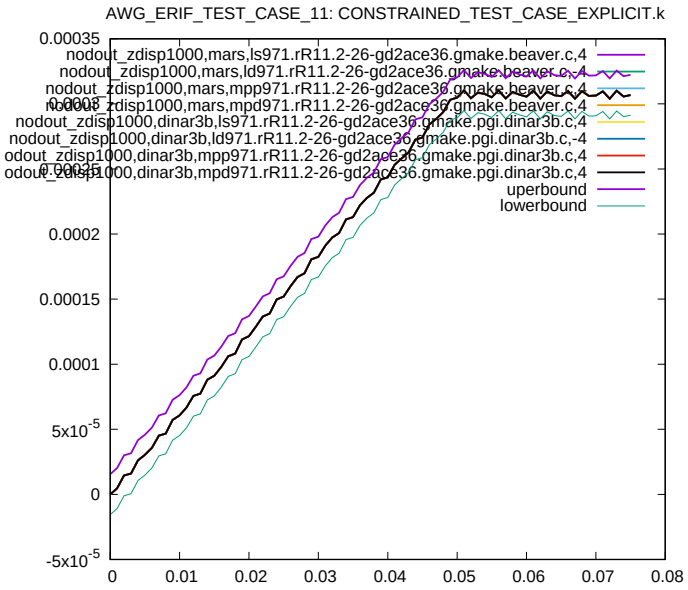

Figure 5: Cross platform results, nodal displacement in z-direction, node 1000, sub test case ID 1

5.3.4 Sub Test Case ID 1 - Test Target 4

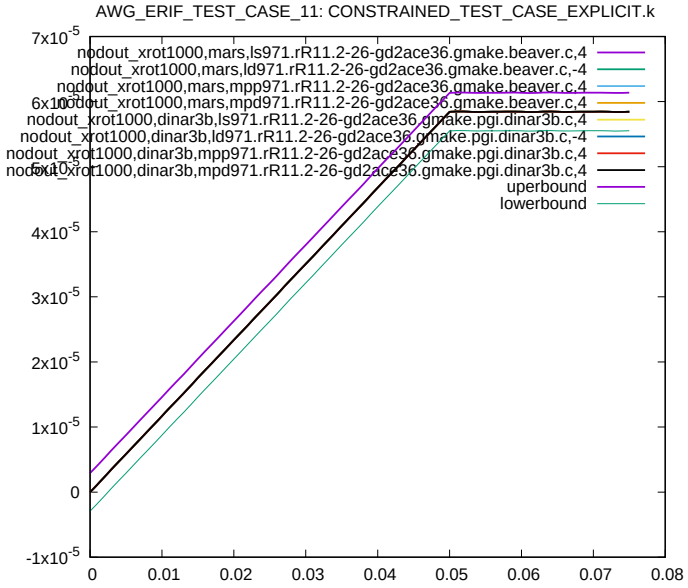

Figure 6: Cross platform results, nodal rotation around x-axis, node 1000, sub test case ID 1

5.3.5 Sub Test Case ID 1 - Test Target 5

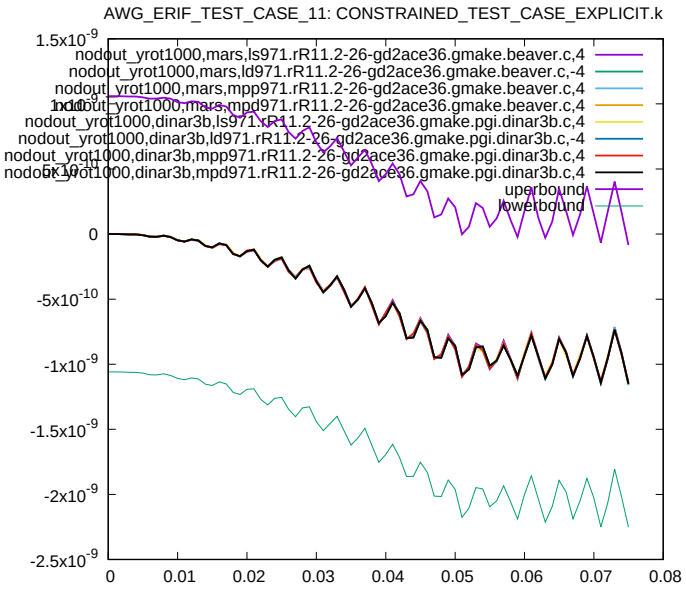

Figure 7: Cross platform results, nodal rotation around y-axis, node 1000, sub test case ID 1

5.3.6 Sub Test Case ID 1 - Test Target 6

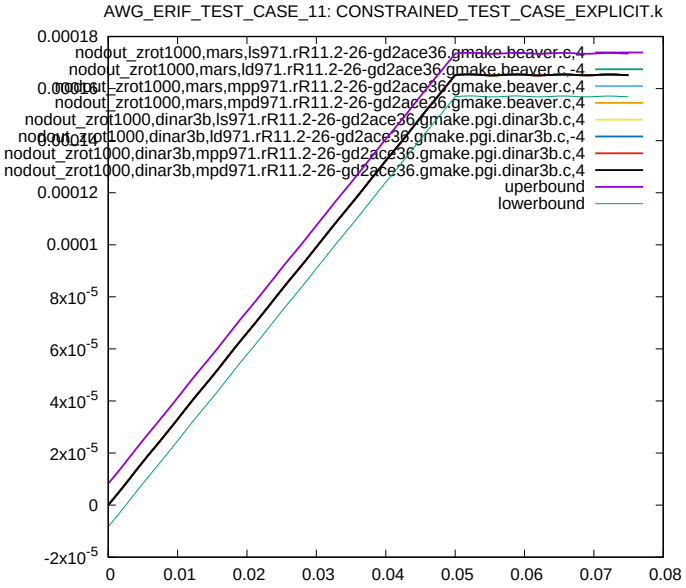

Figure 8: Cross platform results, nodal rotation around z-axis, node 1000, sub test case ID 1

5.3.7 Sub Test Case ID 1 - Test Target 7

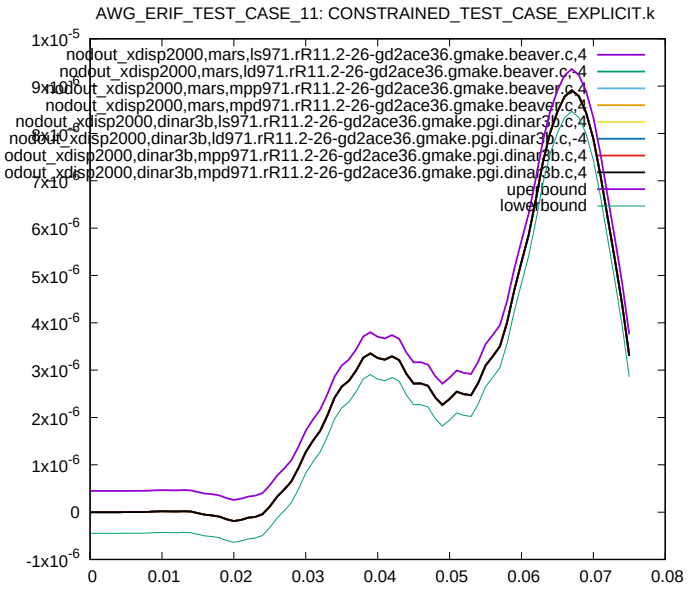

Figure 9: Cross platform results, nodal displacement in x-direction, node 2000, sub test case ID 1

5.3.8 Sub Test Case ID 1 - Test Target 8

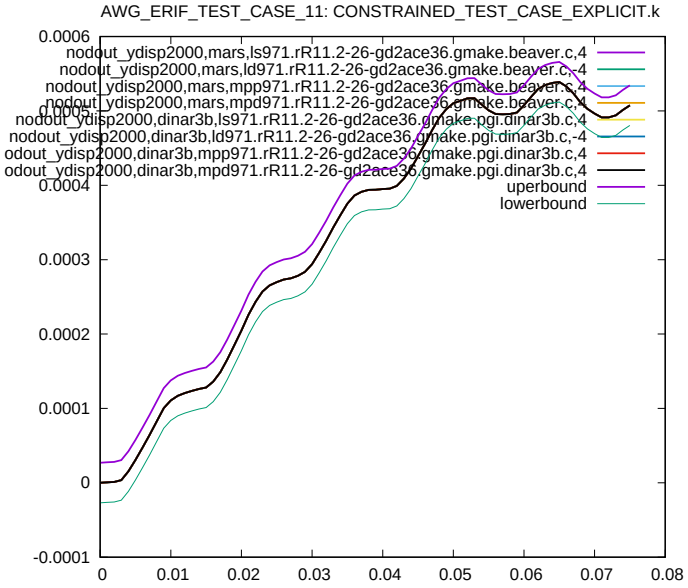

Figure 10: Cross platform results, nodal displacement in y-direction, node 2000, sub test case ID 1

5.3.9 Sub Test Case ID 1 - Test Target 9

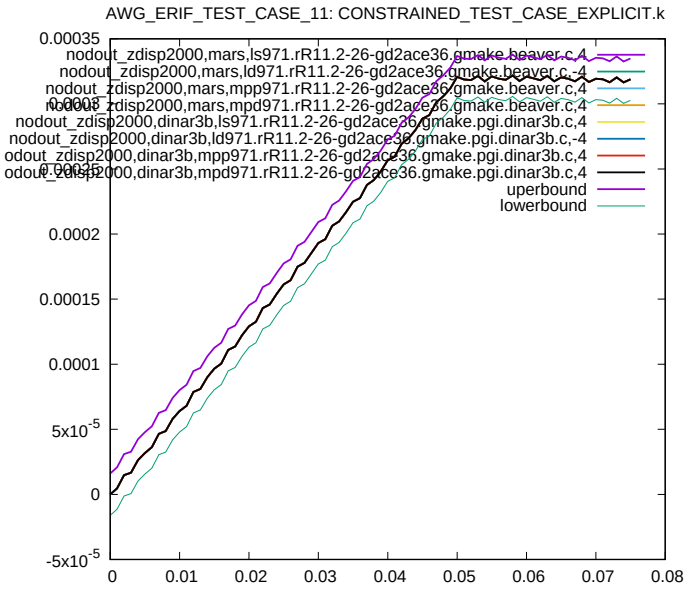

Figure 11: Cross platform results, nodal displacement in z-direction, node 2000, sub test case ID 1

5.3.10 Sub Test Case ID 1 - Test Target 10

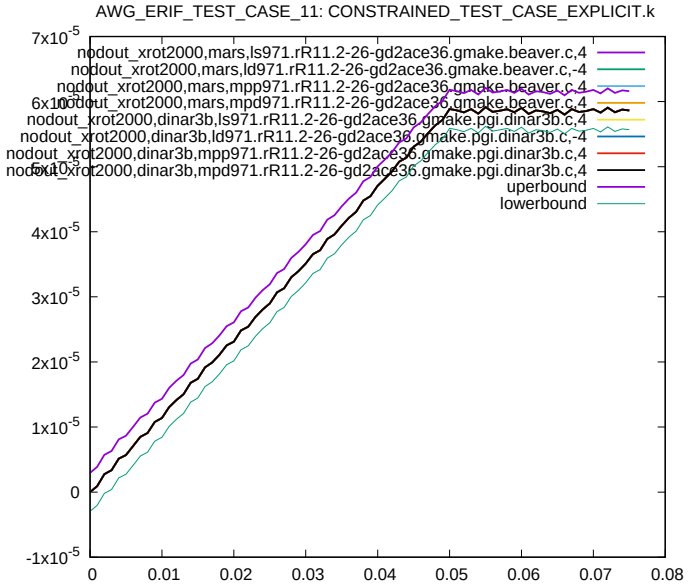

Figure 12: Cross platform results, nodal rotation around x-axis, node 2000, sub test case ID 1

5.3.11 Sub Test Case ID 1 - Test Target 11

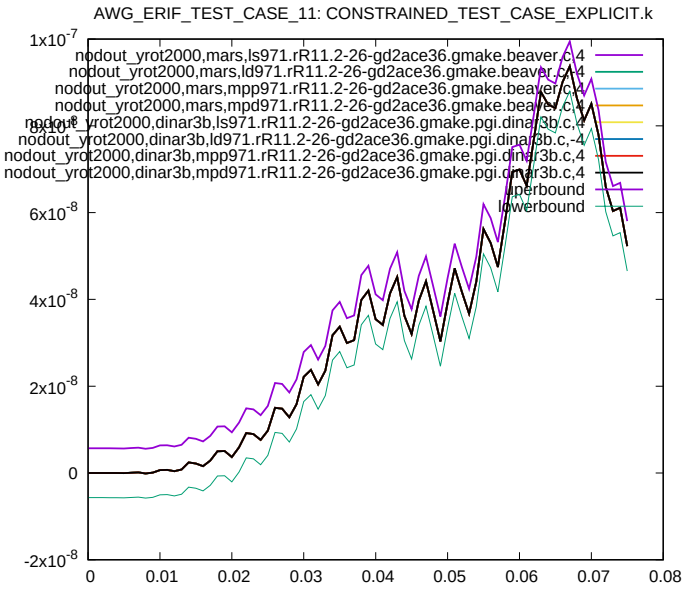

Figure 13: Cross platform results, nodal rotation around y-axis, node 2000, sub test case ID 1

5.3.12 Sub Test Case ID 1 - Test Target 12

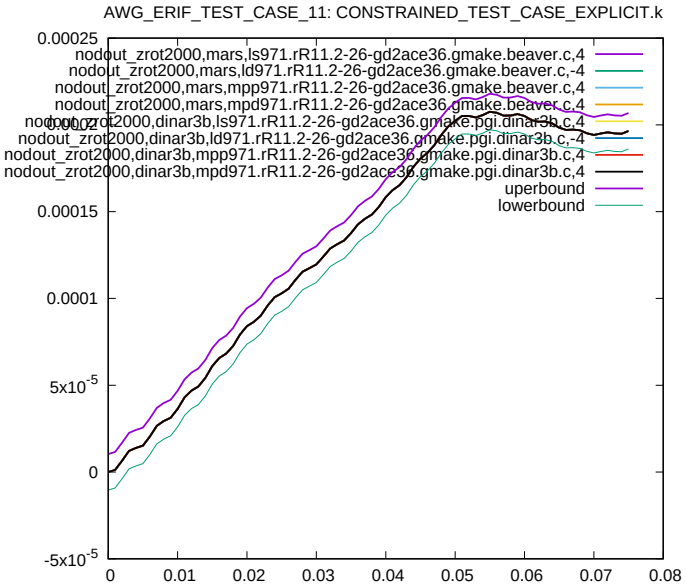

Figure 14: Cross platform results, nodal rotation around z-axis, node 2000, sub test case ID 1

5.3.13 Sub Test Case ID 2 - Test Target 1

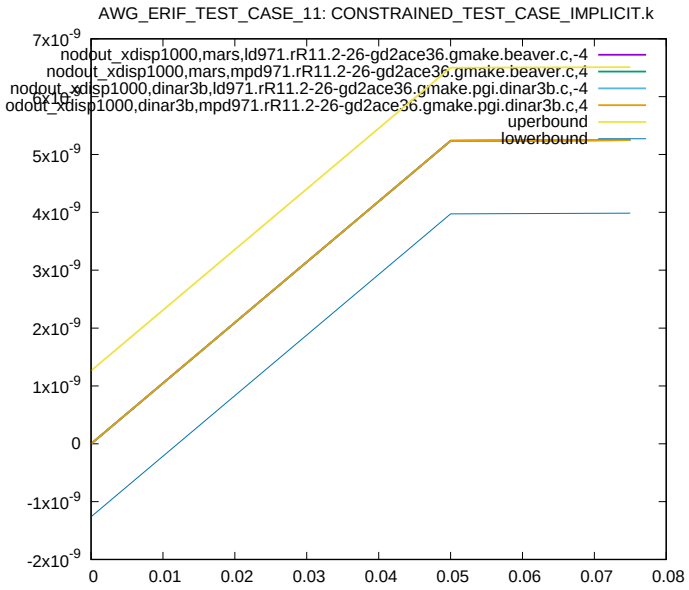

Figure 15: Cross platform results, nodal displacement in x-direction, node 1000, sub test case ID 2

5.3.14 Sub Test Case ID 2 - Test Target 2

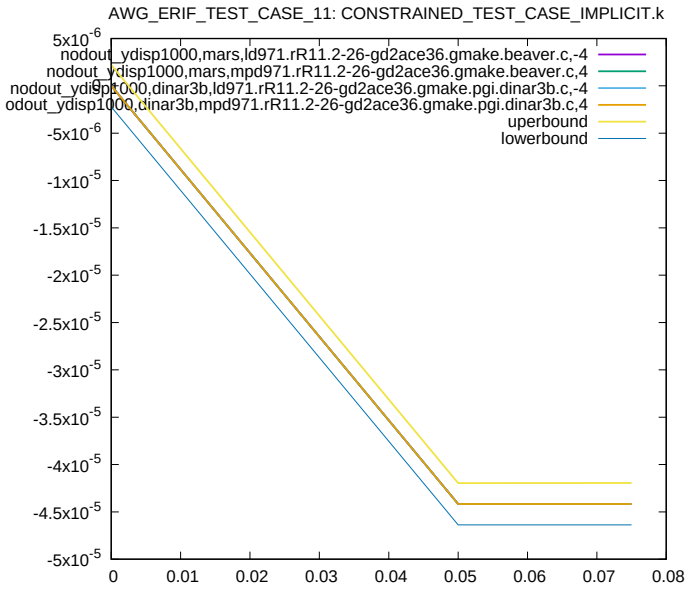

Figure 16: Cross platform results, nodal displacement in y-direction, node 1000, sub test case ID 2

5.3.15 Sub Test Case ID 2 - Test Target 3

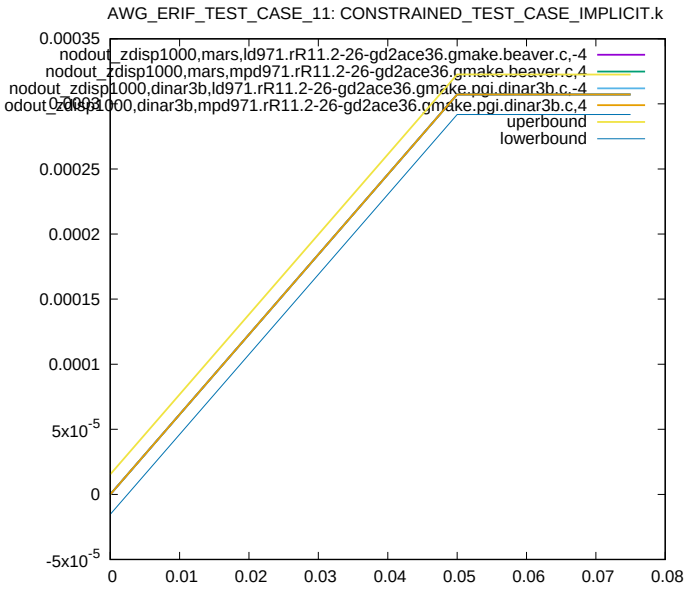

Figure 17: Cross platform results, nodal displacement in z-direction, node 1000, sub test case ID 2

5.3.16 Sub Test Case ID 2 - Test Target 4

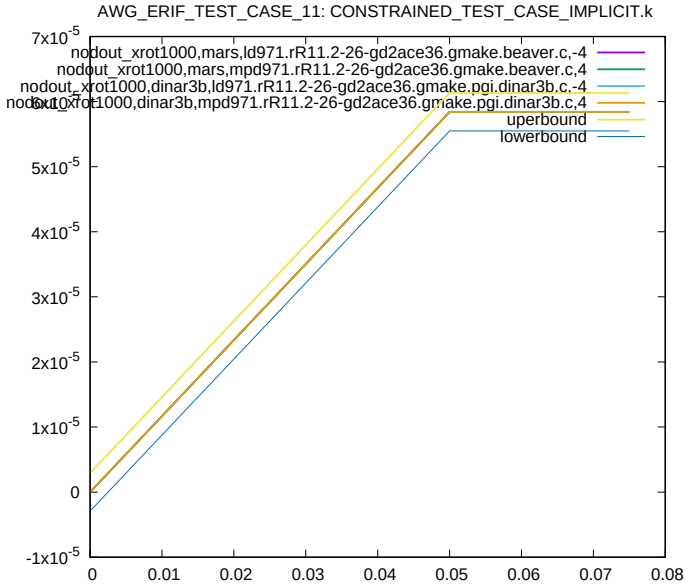

Figure 18: Cross platform results, nodal rotation around x-axis, node 1000, sub test case ID 2

5.3.17 Sub Test Case ID 2 - Test Target 5

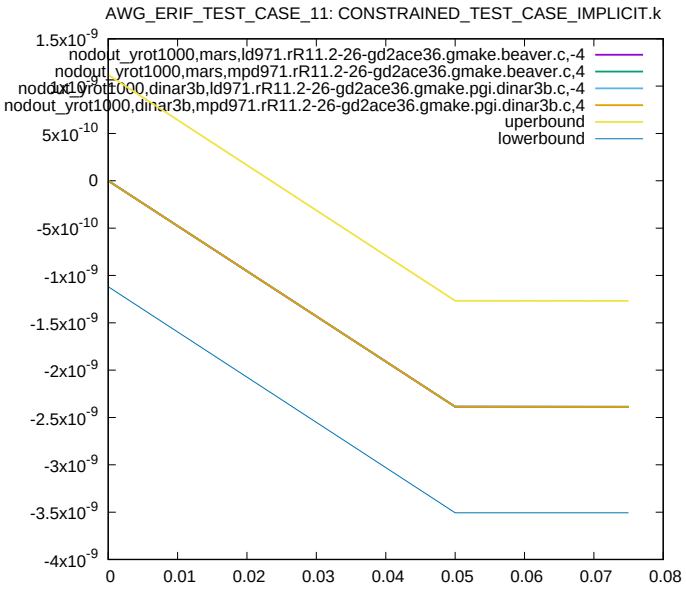

Figure 19: Cross platform results, nodal rotation around y-axis, node 1000, sub test case ID 2

5.3.18 Sub Test Case ID 2 - Test Target 6

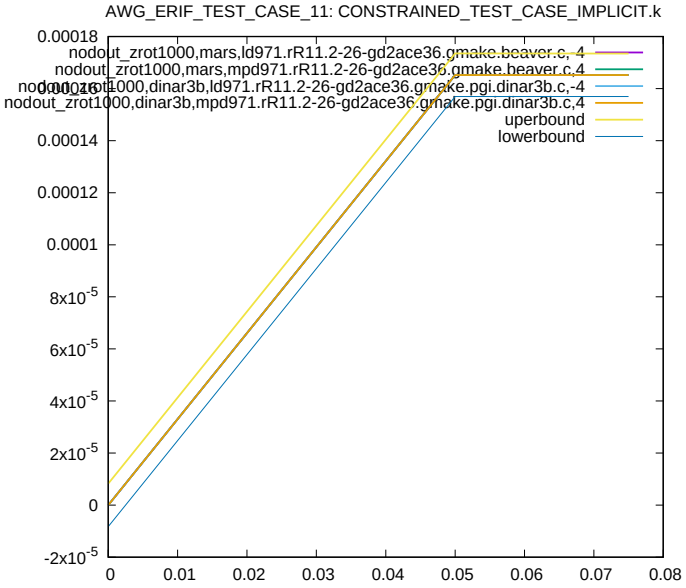

Figure 20: Cross platform results, nodal rotation around z-axis, node 1000, sub test case ID 2

5.3.19 Sub Test Case ID 2 - Test Target 7

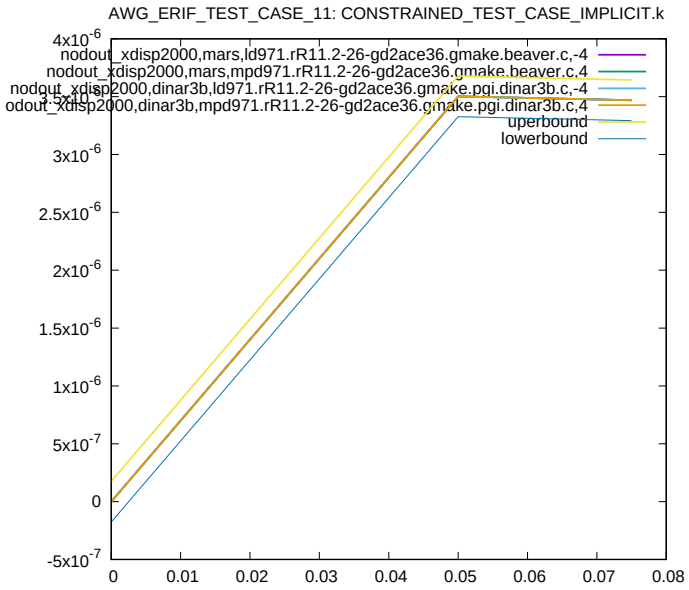

Figure 21: Cross platform results, nodal displacement in x-direction, node 2000, sub test case ID 2

5.3.20 Sub Test Case ID 2 - Test Target 8

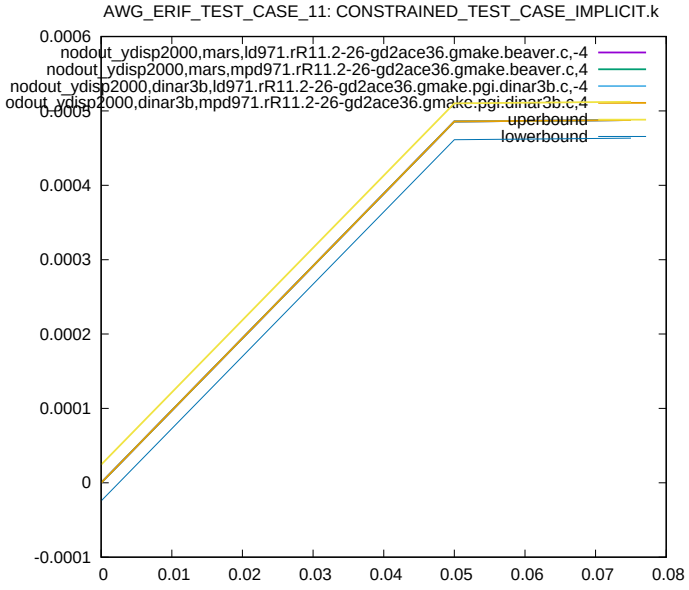

Figure 22: Cross platform results, nodal displacement in y-direction, node 2000, sub test case ID 2

5.3.21 Sub Test Case ID 2 - Test Target 9

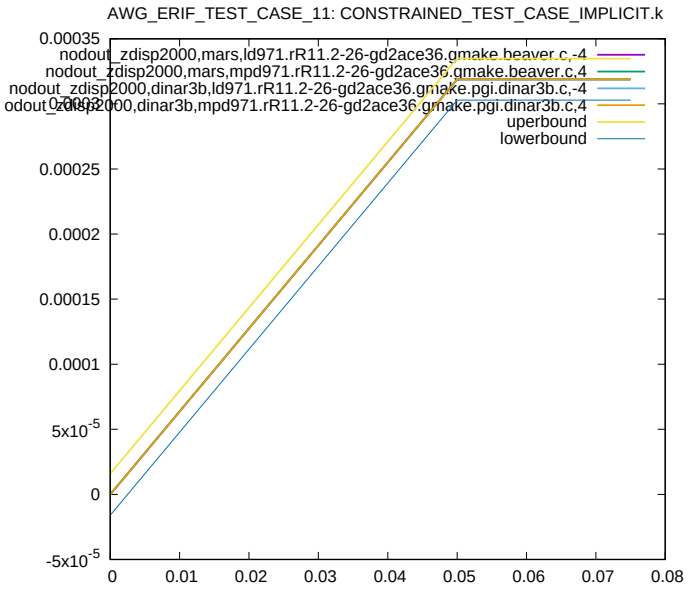

Figure 23: Cross platform results, nodal displacement in z-direction, node 2000, sub test case ID 2

5.3.22 Sub Test Case ID 2 - Test Target 10

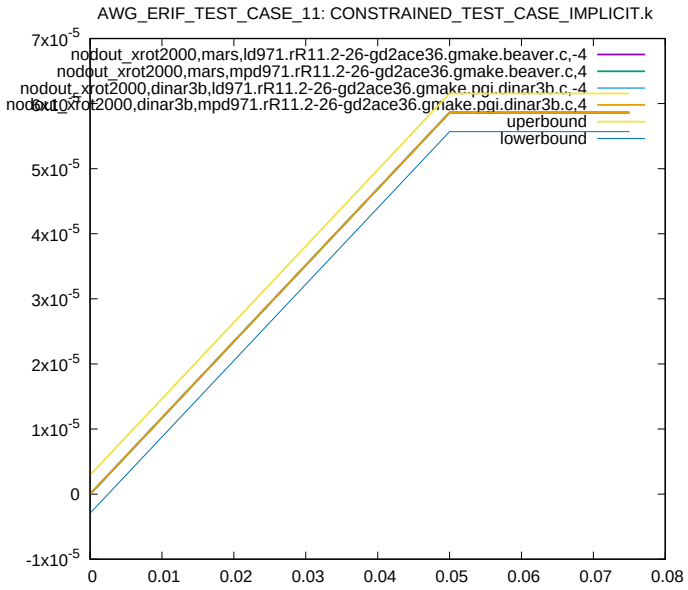

Figure 24: Cross platform results, nodal rotation around x-axis, node 2000, sub test case ID 2

5.3.23 Sub Test Case ID 2 - Test Target 11

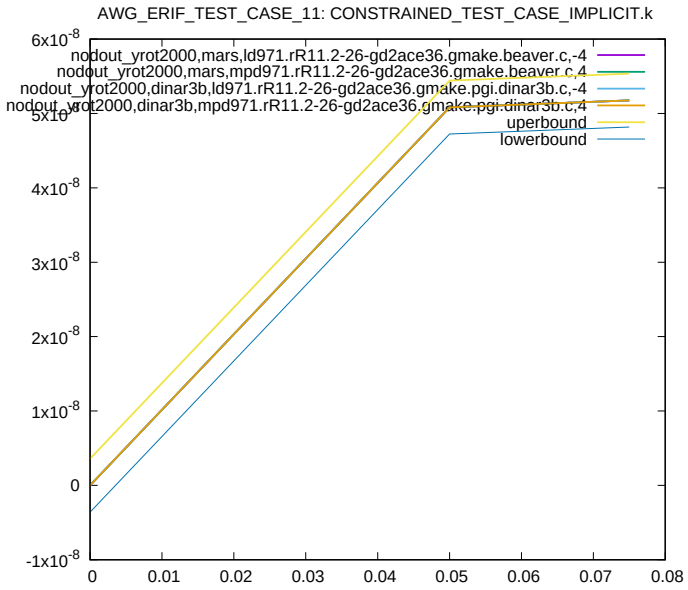

Figure 25: Cross platform results, nodal rotation around y-axis, node 2000, sub test case ID 2

5.3.24 Sub Test Case ID 2 - Test Target 12

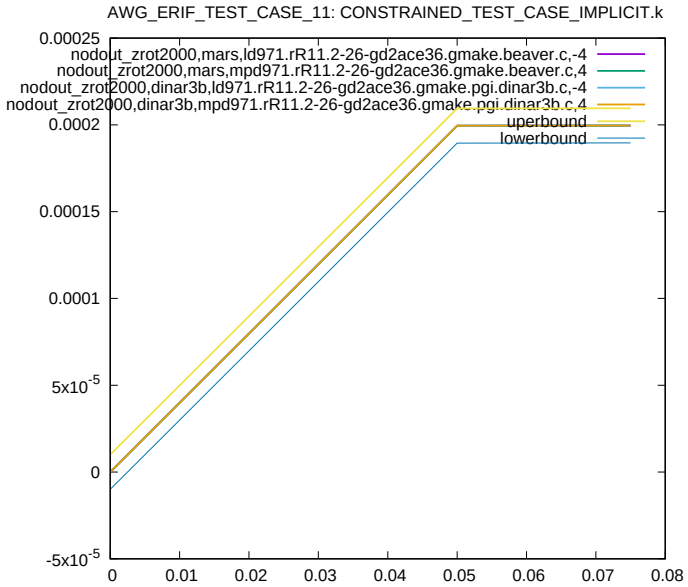

Figure 26: Cross platform results, nodal rotation around z-axis, node 2000, sub test case ID 2

References

[1] LSTC, *LS-DYNA KEYWORD USER MANUAL*, 7374 Las Positas Road, Livermore, CA, 94551, USA, version 971 ed., May 2007.