

# TEST CASE DOCUMENTATION AND TESTING RESULTS

ANSYS-QA-LS-DYNA-AWG-ERIF-11-19

TEST CASE ID AWG-ERIF-11

**\*CONSTRAINED Keyword Test Case**

Tested with LS-DYNA® R13.1 Revision 93-g6e31b592d7

Monday 7<sup>th</sup> March, 2022



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| Document Identifier  | ANSYS-QA-LS-DYNA-AWG-ERIF-11-19                      |
| Author(s)            | Prepared by LS-DYNA® Aerospace Working Group         |
| Number of pages      | 24                                                   |
| Date created         | Monday 7 <sup>th</sup> March, 2022                   |
| Distribution         | LS-DYNA® Aerospace Working Group / internal ANSYS QA |

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# **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.

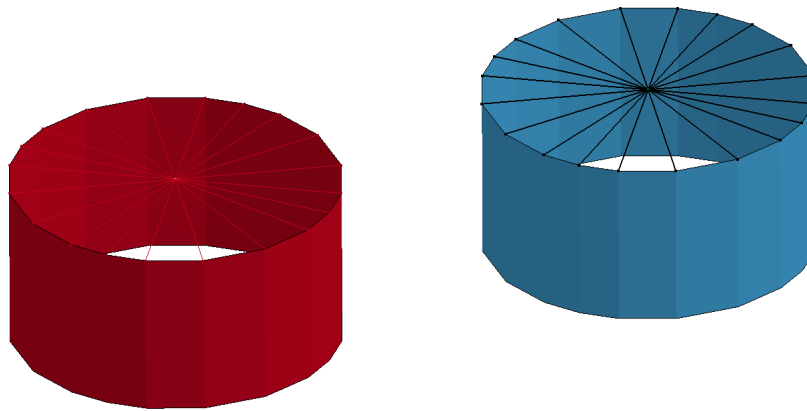


Figure 1: Model sketch: Two cylinders with constraints

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.

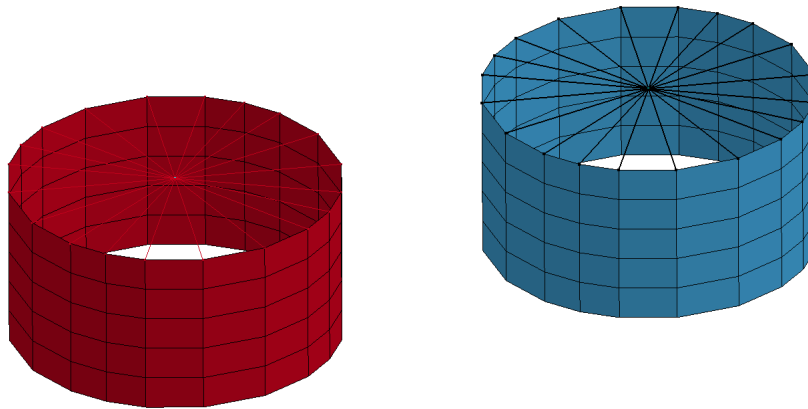


Figure 2: FEA model: Cylinders with constraints

| FEA Model information         |                                                                                                                                             |     |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Sub Test Case ID <sup>1</sup> | 1                                                                                                                                           | 2   |
| Nodes                         | 242                                                                                                                                         | 242 |
| Shell elements                | 200                                                                                                                                         | 200 |
| Shell materials               | 2                                                                                                                                           | 2   |
| Mass elements                 | 2                                                                                                                                           | 2   |
| Nodal rigid bodies            | 1                                                                                                                                           | 1   |
| Units                         | <i>in</i> (length), <i>sec</i> (time), <i>lbf · sec<sup>2</sup>/in</i> (mass), <i>lbf/in<sup>2</sup></i> (stress), <i>lbf · in</i> (energy) |     |

<sup>1</sup> 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 <sup>1</sup> |
|---------------|--------------------|---------------------------------------------------------|--------------------------|------------------------------|
| cougar        | openSUSE Leap 15.2 | Intel <sup>®</sup> Xeon <sup>®</sup> E5- 2697 @ 2.30GHz | Platform MPI 09.01.04.03 | 4                            |

<sup>1</sup> 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 <sup>1</sup> | Precision <sup>2</sup> | executable                  |
|----------------------|---------|---------|----------------|----------------------------|------------------------|-----------------------------|
| LS-DYNA <sup>®</sup> | 971     | R13.1   | 93-g6e31b592d7 | SMP                        | SP                     | ls971.93-g6e31b592d7.R13.1  |
| LS-DYNA <sup>®</sup> | 971     | R13.1   | 93-g6e31b592d7 | SMP                        | DP                     | ld971.93-g6e31b592d7.R13.1  |
| LS-DYNA <sup>®</sup> | 971     | R13.1   | 93-g6e31b592d7 | MPP                        | SP                     | mpp971.93-g6e31b592d7.R13.1 |
| LS-DYNA <sup>®</sup> | 971     | R13.1   | 93-g6e31b592d7 | MPP                        | DP                     | mpd971.93-g6e31b592d7.R13.1 |

<sup>1</sup> MPP = Massively Parallel Processing, SMP = Symmetric Multiprocessing

<sup>2</sup> SP = single precision, DP = double precision

Table 7: Tested LS-DYNA<sup>®</sup> 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                | <b>PASS</b> |
| 2                | <b>FAIL</b> |

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® R13.1 Revision 93-g6e31b592d7.

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 type, branch and the revision of the executable.

#### **Example for title:**

*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.

### 5.3.1 Sub Test Case ID 1 - Test Target 1

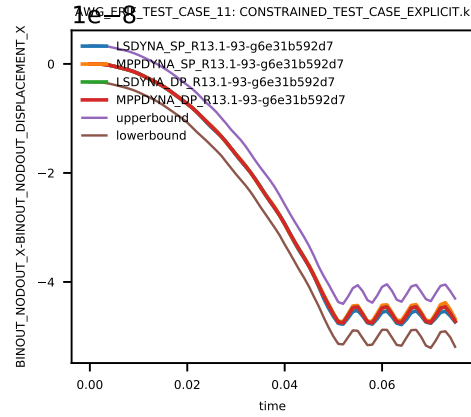


Figure 3: Cross platform results, nodal displacement in x-direction, node 1000, sub test case ID 1

### 5.3.2 Sub Test Case ID 1 - Test Target 2

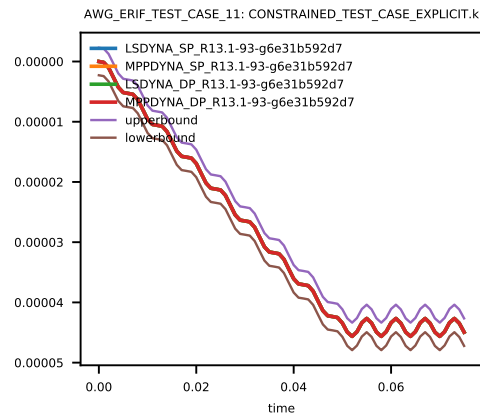


Figure 4: Cross platform results, nodal displacement in y-direction, node 1000, sub test case ID 1



### 5.3.3 Sub Test Case ID 1 - Test Target 3

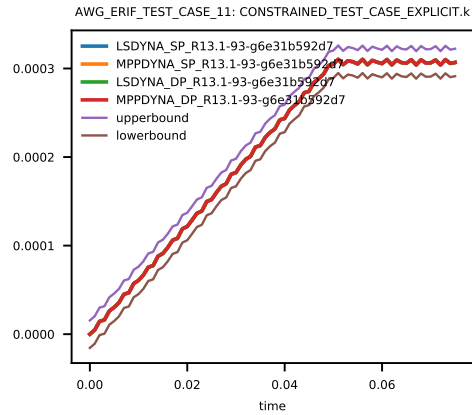


Figure 5: Cross platform results, nodal displacement in z-direction, node 1000, sub test case ID 1

### 5.3.4 Sub Test Case ID 1 - Test Target 4

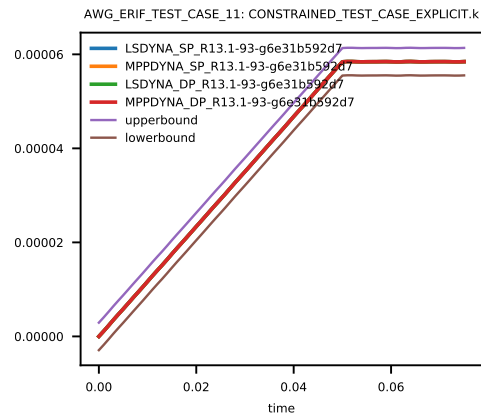


Figure 6: Cross platform results, nodal rotation around x-axis, node 1000, sub test case ID 1

### 5.3.5 Sub Test Case ID 1 - Test Target 5

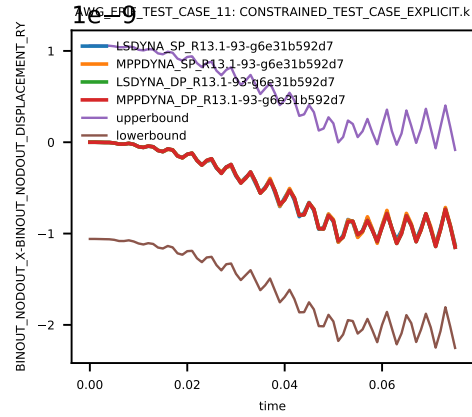


Figure 7: Cross platform results, nodal rotation around y-axis, node 1000, sub test case ID 1

### 5.3.6 Sub Test Case ID 1 - Test Target 6

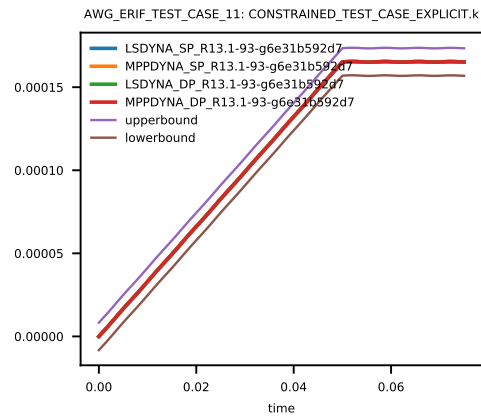


Figure 8: Cross platform results, nodal rotation around z-axis, node 1000, sub test case ID 1

### 5.3.7 Sub Test Case ID 1 - Test Target 7

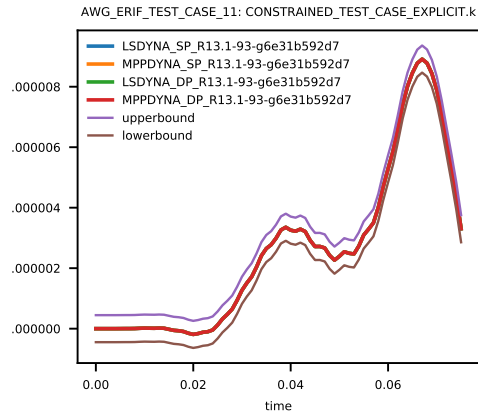


Figure 9: Cross platform results, nodal displacement in x-direction, node 2000, sub test case ID 1

### 5.3.8 Sub Test Case ID 1 - Test Target 8

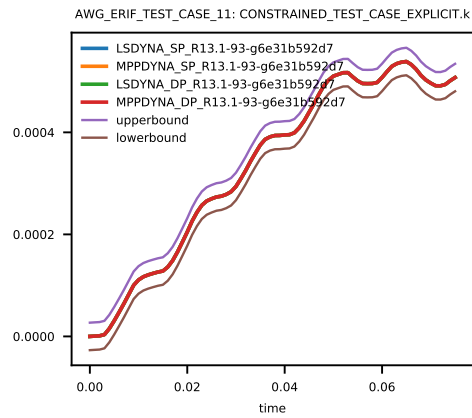


Figure 10: Cross platform results, nodal displacement in y-direction, node 2000, sub test case ID 1

### 5.3.9 Sub Test Case ID 1 - Test Target 9

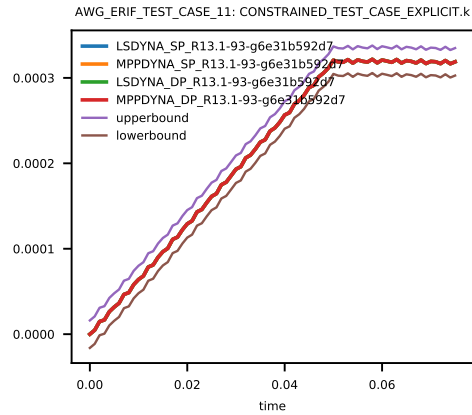


Figure 11: Cross platform results, nodal displacement in z-direction, node 2000, sub test case ID 1

### 5.3.10 Sub Test Case ID 1 - Test Target 10

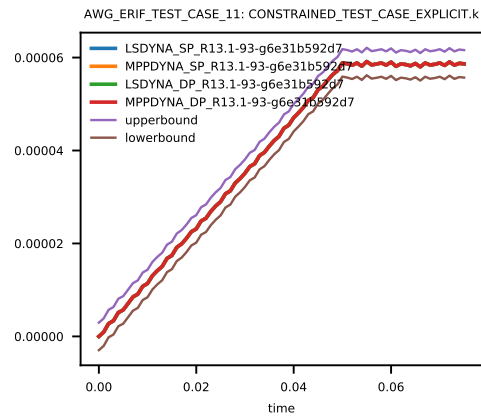


Figure 12: Cross platform results, nodal rotation around x-axis, node 2000, sub test case ID 1

### 5.3.11 Sub Test Case ID 1 - Test Target 11

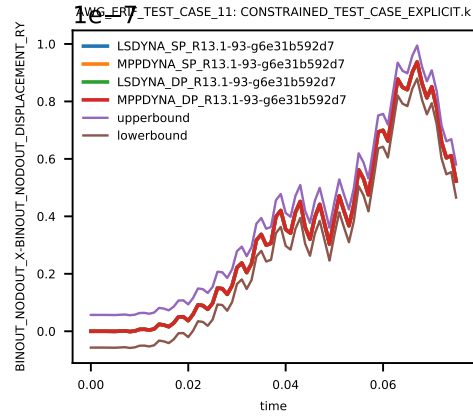


Figure 13: Cross platform results, nodal rotation around y-axis, node 2000, sub test case ID 1

### 5.3.12 Sub Test Case ID 1 - Test Target 12

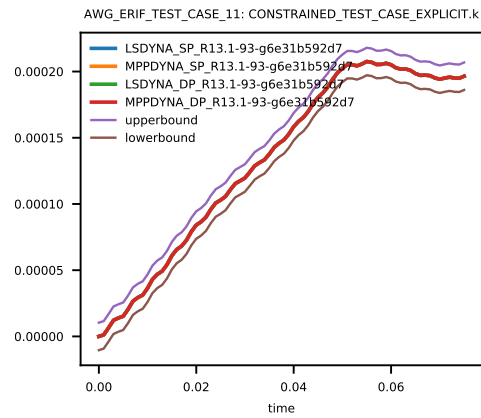


Figure 14: Cross platform results, nodal rotation around z-axis, node 2000, sub test case ID 1

### 5.3.13 Sub Test Case ID 2 - Test Target 1

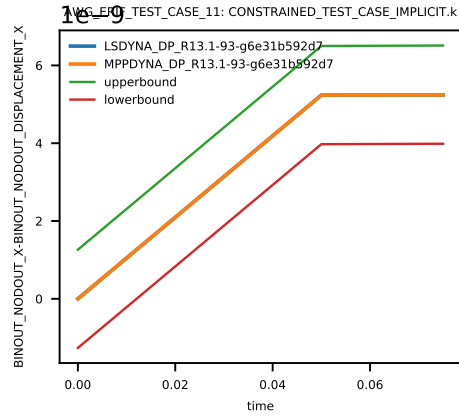


Figure 15: Cross platform results, nodal displacement in x-direction, node 1000, sub test case ID 2

### 5.3.14 Sub Test Case ID 2 - Test Target 2

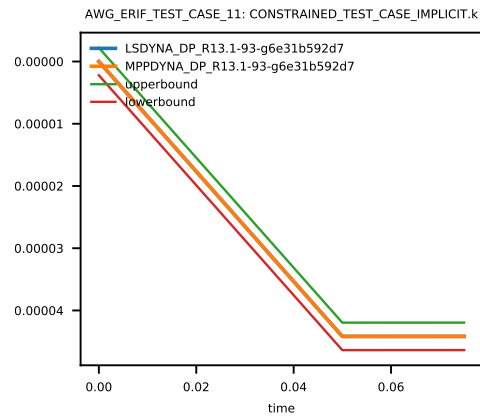


Figure 16: Cross platform results, nodal displacement in y-direction, node 1000, sub test case ID 2

### 5.3.15 Sub Test Case ID 2 - Test Target 3

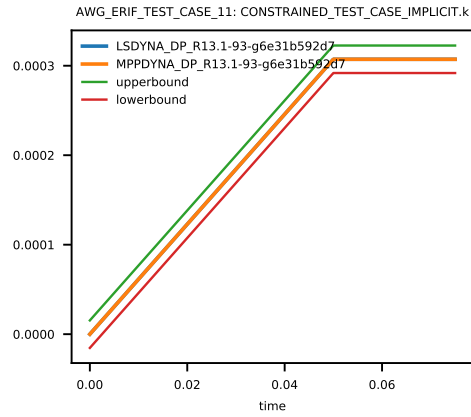


Figure 17: Cross platform results, nodal displacement in z-direction, node 1000, sub test case ID 2

### 5.3.16 Sub Test Case ID 2 - Test Target 4

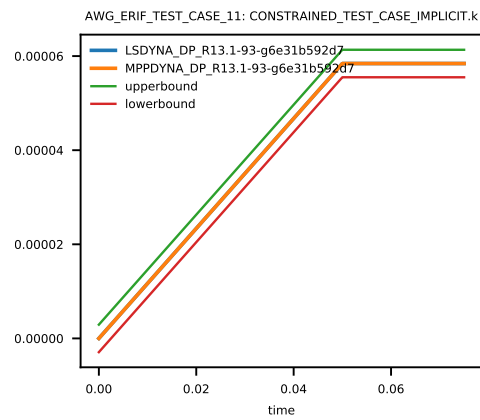


Figure 18: Cross platform results, nodal rotation around x-axis, node 1000, sub test case ID 2

### 5.3.17 Sub Test Case ID 2 - Test Target 5

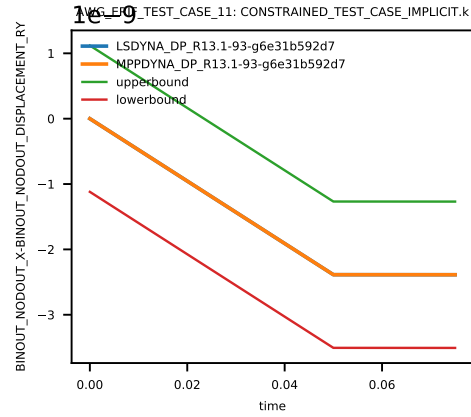


Figure 19: Cross platform results, nodal rotation around y-axis, node 1000, sub test case ID 2

### 5.3.18 Sub Test Case ID 2 - Test Target 6

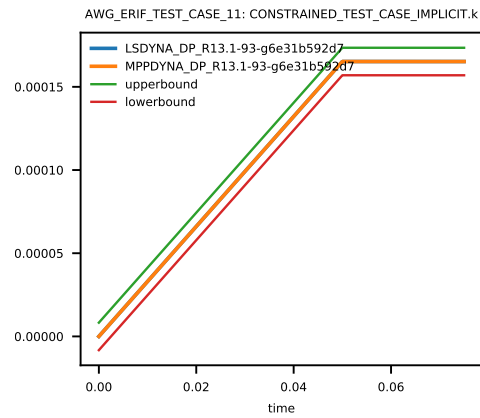


Figure 20: Cross platform results, nodal rotation around z-axis, node 1000, sub test case ID 2



### 5.3.19 Sub Test Case ID 2 - Test Target 7

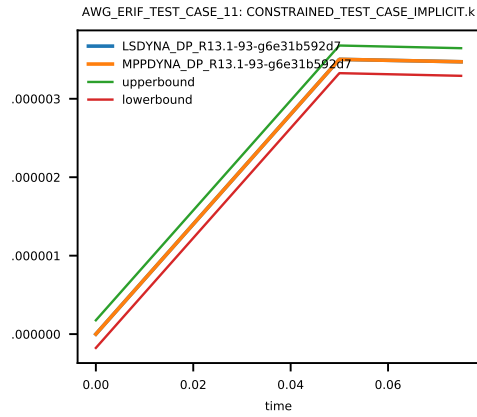


Figure 21: Cross platform results, nodal displacement in x-direction, node 2000, sub test case ID 2

### 5.3.20 Sub Test Case ID 2 - Test Target 8

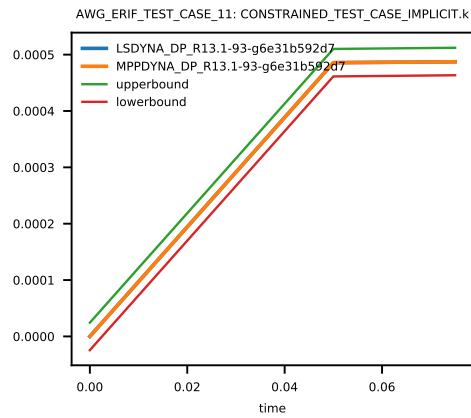


Figure 22: Cross platform results, nodal displacement in y-direction, node 2000, sub test case ID 2

### 5.3.21 Sub Test Case ID 2 - Test Target 9

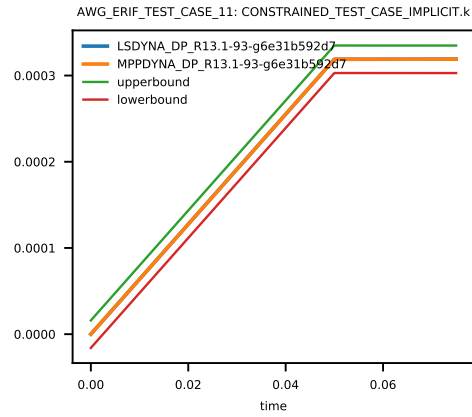


Figure 23: Cross platform results, nodal displacement in z-direction, node 2000, sub test case ID 2

### 5.3.22 Sub Test Case ID 2 - Test Target 10

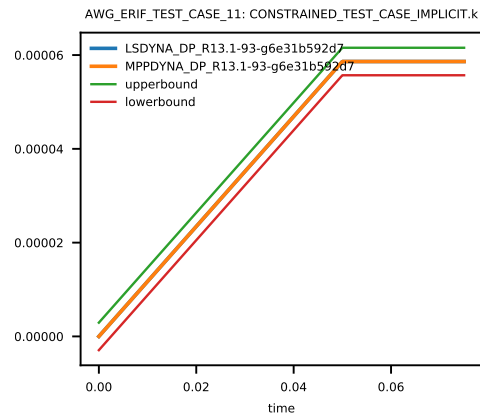


Figure 24: Cross platform results, nodal rotation around x-axis, node 2000, sub test case ID 2

### 5.3.23 Sub Test Case ID 2 - Test Target 11

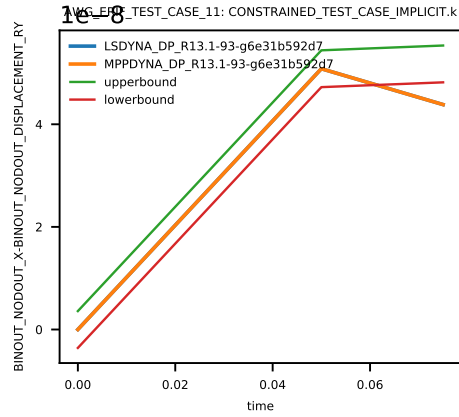


Figure 25: Cross platform results, nodal rotation around y-axis, node 2000, sub test case ID 2

### 5.3.24 Sub Test Case ID 2 - Test Target 12

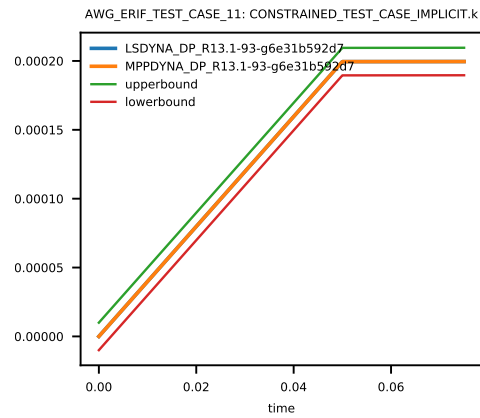


Figure 26: Cross platform results, nodal rotation around z-axis, node 2000, sub test case ID 2

## References