

# TEST CASE DOCUMENTATION AND TESTING RESULTS

ANSYS-QA-LS-DYNA-AWG-ERIF-3-29

TEST CASE ID AWG-ERIF-3

Rubber Projectile Impacting a Rigid Plate

Tested with LS-DYNA® R14.1 Revision 7-gea5f83301c

Monday 24<sup>th</sup> April, 2023



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# **1 Introduction**

## **1.1 Purpose of this Document**

This document specifies the test case AWG-ERIF-3. 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           | Rubber Projectile Impacting a Rigid Plate |
| Test Case ID             | AWG-ERIF-3                                |
| Test Case Status         | active                                    |
| Test Case Classification | Example                                   |
| Test Case Source         | University of Akron                       |
| Tested Keyword           | *MAT_181 (MAT_SIMPLIFIED_RUBBER)          |
| 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-3 is the comparison of results from different cpu architectures for a bird strike analysis. The cross cpu architecture consistency of LS-DYNA® for this impact simulation is evaluated by performing calculations of two sub test cases with different material parameter curves for the rubber material (see table 4).

### 3.2 Test Case Description

This Test Case contains a bird strike analysis (see figure 1) using a rubber projectile with rate effects impacting a rigid plate. The rubber projectile is used to represent the "bird material" and is modelled using \*MAT\_SIMPLIFIED\_RUBBER (MAT\_181). Two different curves of force vs. change in gauge length at different strain rates are evaluated.

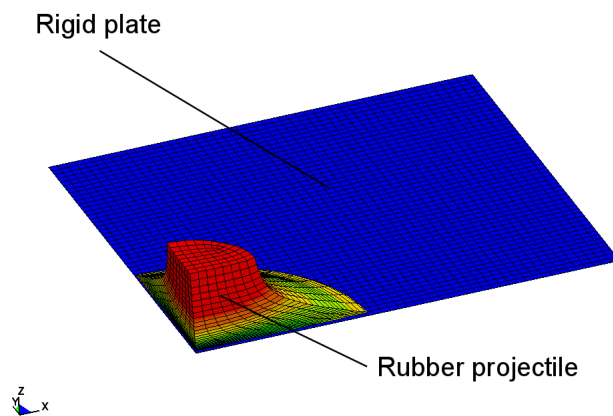


Figure 1: FEA model: Rubber Projectile Impacting a Rigid Plate

The rubber projectile is modelled via a lagrangian approach with solid elements and the rigid plate is modelled with shell elements. A summary of the model set-up can be found in table 2.

| Physical Model Information |                             |
|----------------------------|-----------------------------|
| plate geometry             | 20"x20"                     |
| plate material             | rigid                       |
| projectile geometry        | length = 5" , radius = 1.5" |
| projectile material        | Gelatin                     |
| projectile velocity        | 2800 in/s                   |

Table 2: Model set-up data



### 3.3 Model Description

The model geometry is discretized with solid elements for the projectile and shell elements for the rigid plate. See table 3 for the number of elements and material specifications for the model. Employing symmetry conditions, a quarter model of the actual geometry is used. Symmetry boundary conditions are applied on the symmetry planes and the outer edges of the rigid plate are simply supported. The projectile has an initial z velocity defined on all nodes and is guided along the z axis by boundary conditions applied in the x and y directions on the symmetry plane.

| FEA Model information |                                                                                     |
|-----------------------|-------------------------------------------------------------------------------------|
| Nodes                 | 9793                                                                                |
| Solid elements        | 1500                                                                                |
| Solid materials       | 1                                                                                   |
| Shell elements        | 2500                                                                                |
| Shell materials       | 1                                                                                   |
| Parts                 | 2                                                                                   |
| Plate geometry        | 10"x10"                                                                             |
| Projectile geometry   | length = 5" , radius = 1.5"                                                         |
| Units                 | in (length), s (time), lbf-s <sup>2</sup> /in (mass), psi (stress), lbf-in (energy) |

Table 3: FEA Model Information

Two variations (called sub test cases) of the model are set up with different force versus actual change in gauge length curves for different strain rates (see figure 2 and 3 for details). A summary of these two sub test cases can be found in table 4.

The material definitions and their parameters can be found in the input decks.

| Sub Test ID | MATERIAL | Parameter Curve | Input Deck Name                     |
|-------------|----------|-----------------|-------------------------------------|
| 1           | MAT_181  | see figure 2    | 5-rate-curve-atan-ten-tan-unload2.k |
| 2           | MAT_181  | see figure 3    | 5-rate-new-curves.k                 |

Table 4: Specification of sub test cases

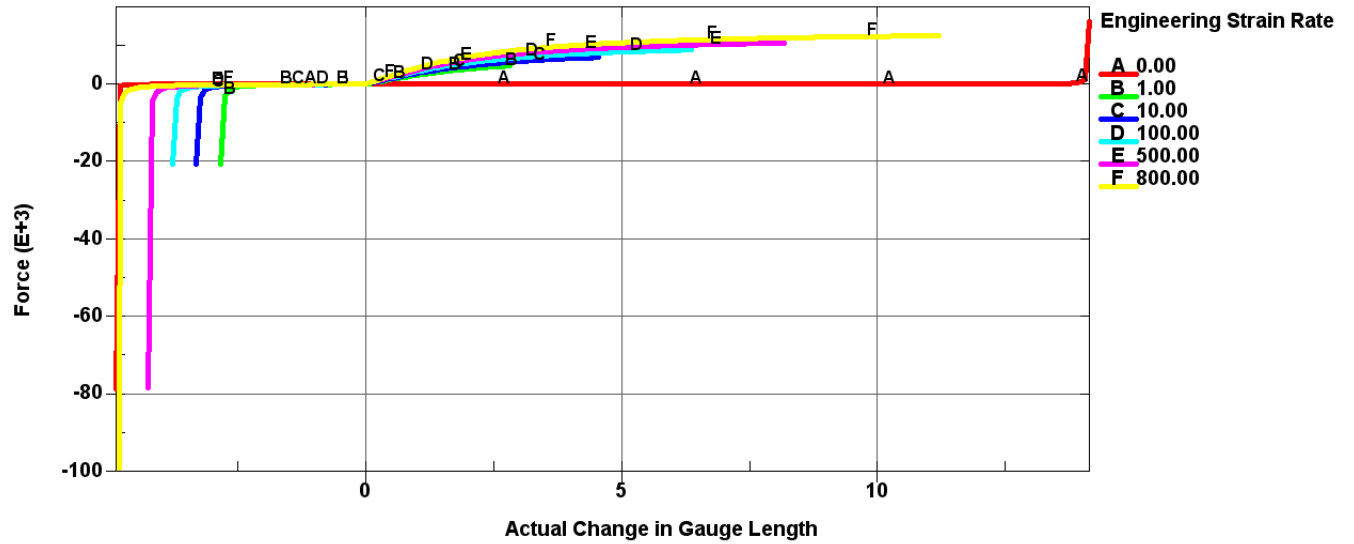


Figure 2: Force versus actual change in gauge length for different engineering strain rates for sub case 1

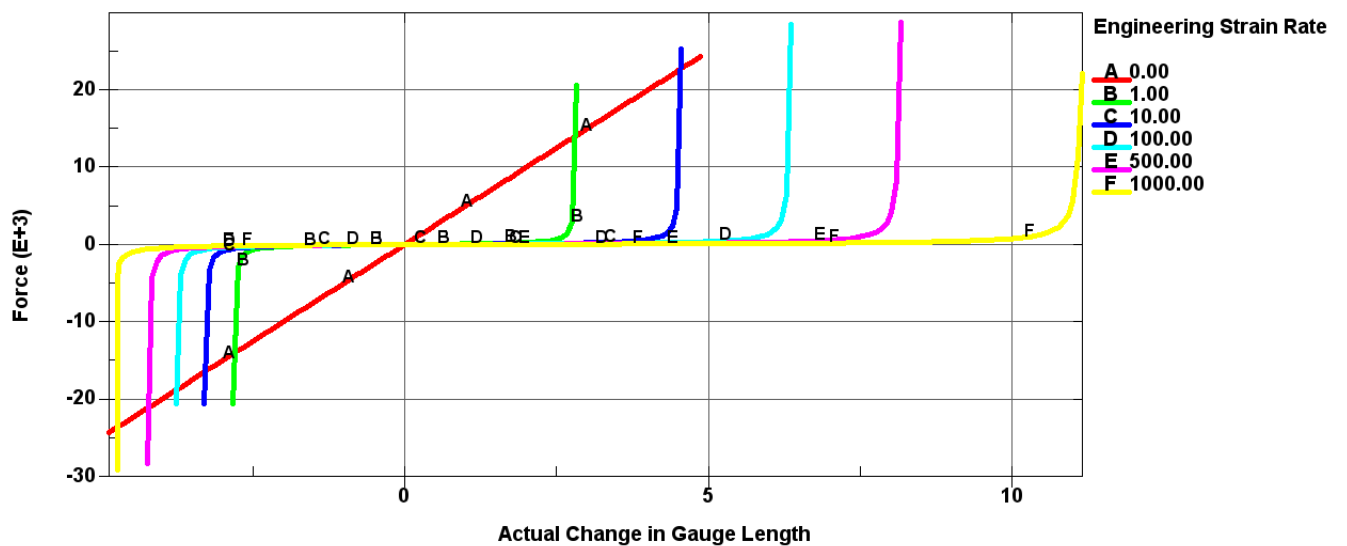


Figure 3: Force versus actual change in gauge length for different engineering strain rates for sub case 2

## 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                 | z-displacement   | node           | 1            | binout/nodout file |
| 2                 | x-displacement   | node           | 9            | binout/nodout file |
| 3                 | z-displacement   | node           | 9            | binout/nodout file |
| 4                 | x-displacement   | node           | 2982         | binout/nodout file |
| 5                 | y-displacement   | node           | 2982         | binout/nodout file |
| 6                 | z-displacement   | node           | 2982         | binout/nodout file |
| 7                 | z-displacement   | node           | 6654         | binout/nodout file |
| 8                 | kinetic energy   | global         | -            | binout/glstat file |
| 9                 | internal energy  | global         | -            | binout/glstat file |
| 10                | hourglass energy | global         | -            | binout/glstat file |

Table 5: Test Case targets for Test Case ID AWG-ERIF-3

The location of the nodes for target number 1 to 7 can be derived from figure 4. The targets are used to evaluate the cross cpu architecture consistency of the model (see section 4.2).

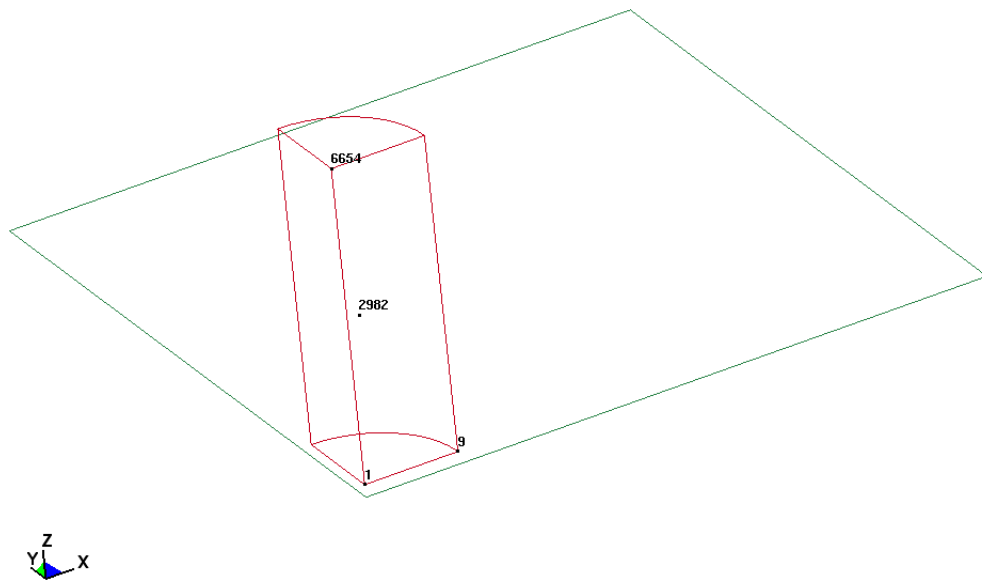


Figure 4: Location of target nodes

## 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-3.

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> | Memory Option |
|----------------|------------------|--------------------------------------|--------------------------------------------------------|------------------------------|---------------|
| cdcc7forming01 | CentOS 7         | Intel® Xeon® Gold 6252 CPU @ 2.10GHz | Platform MPI ISV Edition 08.3.0.2 [10692] Linux x86-64 | 4                            | memory=20M    |

<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® | 971     | R14.1   | 7-gea5f83301c | SMP                        | SP                     | ls971.7-gea5f83301c.R14.1  |
| LS-DYNA® | 971     | R14.1   | 7-gea5f83301c | SMP                        | DP                     | ld971.7-gea5f83301c.R14.1  |
| LS-DYNA® | 971     | R14.1   | 7-gea5f83301c | MPP                        | SP                     | mpp971.7-gea5f83301c.R14.1 |
| LS-DYNA® | 971     | R14.1   | 7-gea5f83301c | MPP                        | DP                     | mpd971.7-gea5f83301c.R14.1 |

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

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

Table 7: Tested LS-DYNA® version

## 5.2 Results Summary

Table 8 contains the results of the Test Case ID AWG-ERIF-3 completed with all combinations of software and hardware defined in section 5.1 (2 \* 4 \* 3 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 ID | PASS/FAILED |
|-------------|-------------|
| 1           | <b>PASS</b> |
| 2           | <b>PASS</b> |

Table 8: Cross cpu architecture results summary for Test Case ID AWG-ERIF-3

### 5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-ERIF-3 for LS-DYNA® R14.1 Revision 7-gea5f83301c.

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\_3: 5-rate-curve-atan-ten-tan-unload2.k' states the test case ID 3 and name of the input deck for sub test case 1.



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

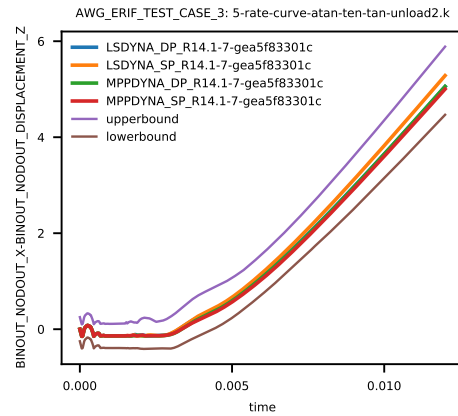


Figure 5: Cross platform results, z-displacement node 1, sub test case ID 1

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

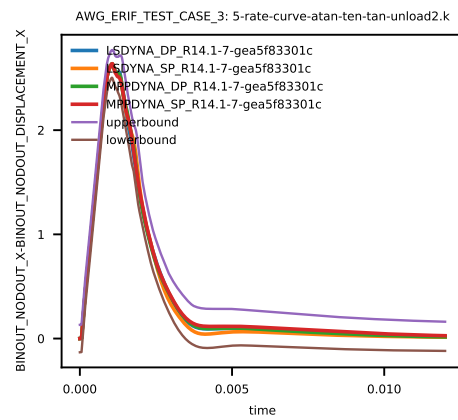


Figure 6: Cross platform results, x-displacement node 9, sub test case ID 1

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

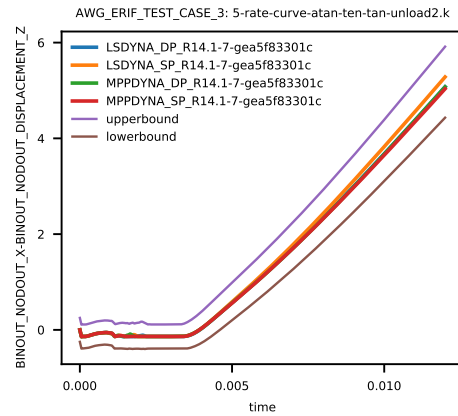


Figure 7: Cross platform results, z-displacement node 9, sub test case ID 1

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

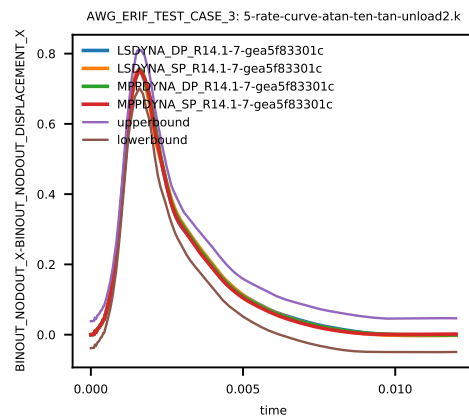


Figure 8: Cross platform results, x-displacement node 2982, sub test case ID 1

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

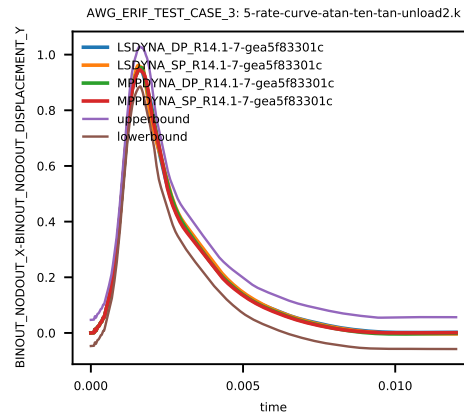


Figure 9: Cross platform results, y-displacement node 2982, sub test case ID 1

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

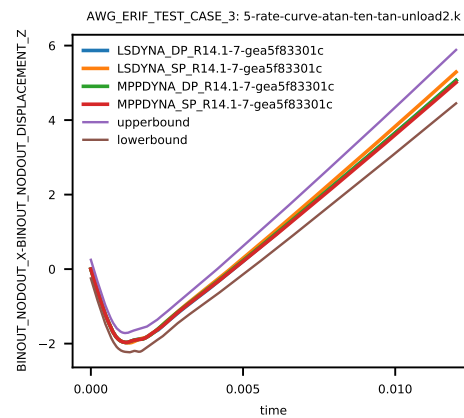


Figure 10: Cross platform results, z-displacement node 2982, sub test case ID 1

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

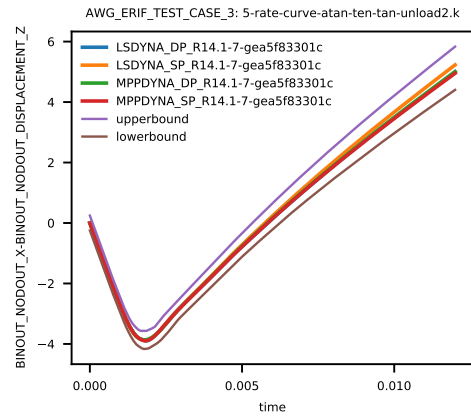


Figure 11: Cross platform results, z-displacement node 6654, sub test case ID 1

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

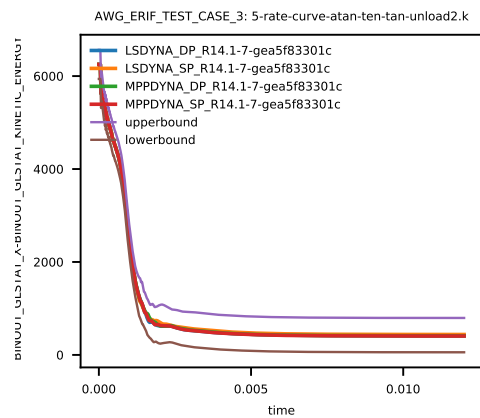


Figure 12: Cross platform results, global kinetic energy, sub test case ID 1

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

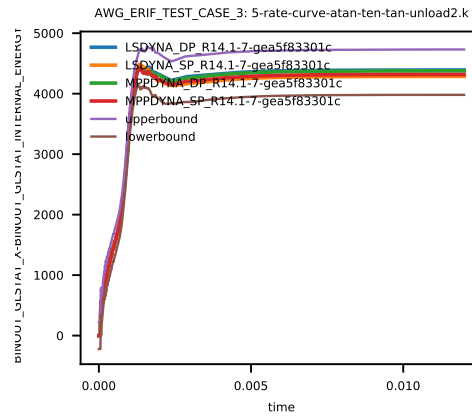


Figure 13: Cross platform results, global internal energy, sub test case ID 1

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

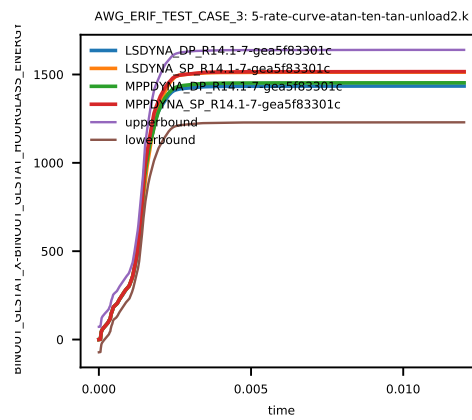


Figure 14: Cross platform results, global hourglass energy, sub test case ID 1

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

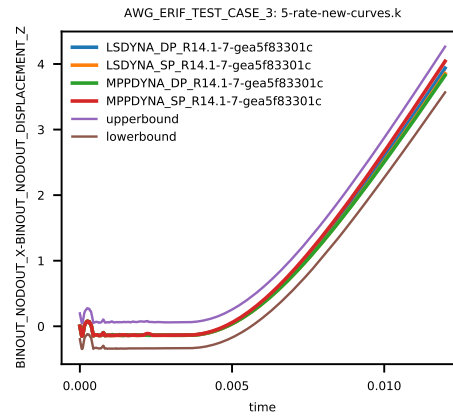


Figure 15: Cross platform results, z-displacement node 1, sub test case ID 2

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

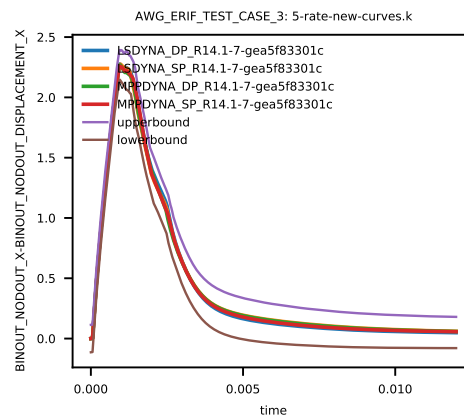


Figure 16: Cross platform results, x-displacement node 9, sub test case ID 2

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

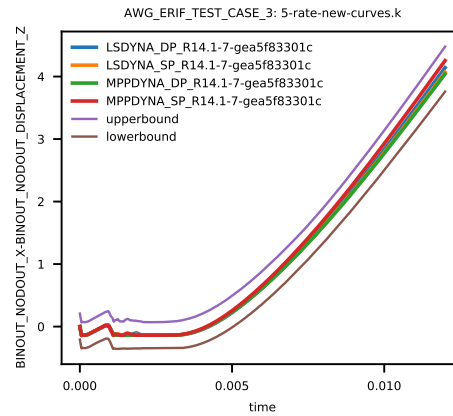


Figure 17: Cross platform results, z-displacement node 9, sub test case ID 2

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

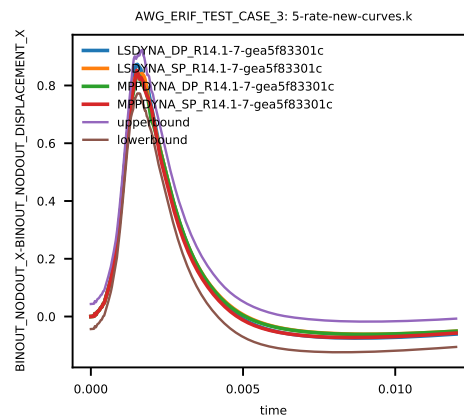


Figure 18: Cross platform results, x-displacement node 2982, sub test case ID 2

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

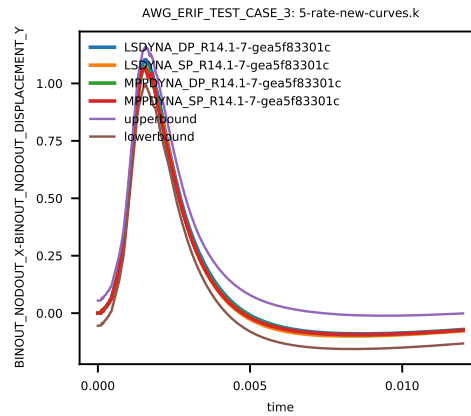


Figure 19: Cross platform results, y-displacement node 2982, sub test case ID 2

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

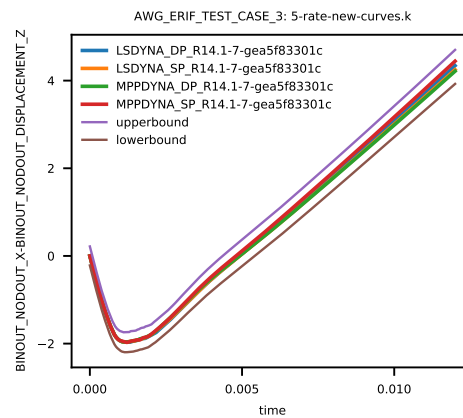


Figure 20: Cross platform results, z-displacement node 2982, sub test case ID 2



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

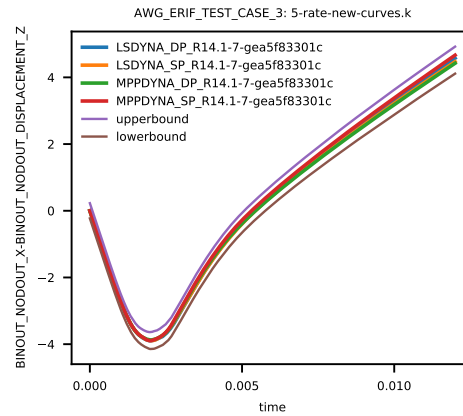


Figure 21: Cross platform results, z-displacement node 6654, sub test case ID 2

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

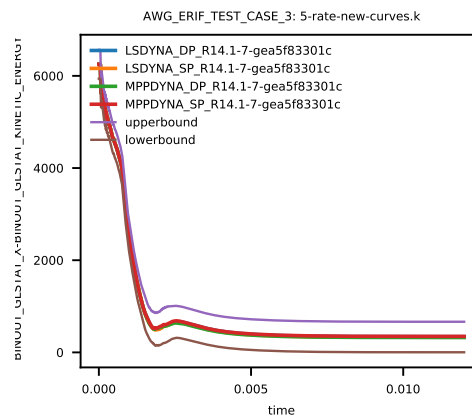


Figure 22: Cross platform results, global kinetic energy, sub test case ID 2

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

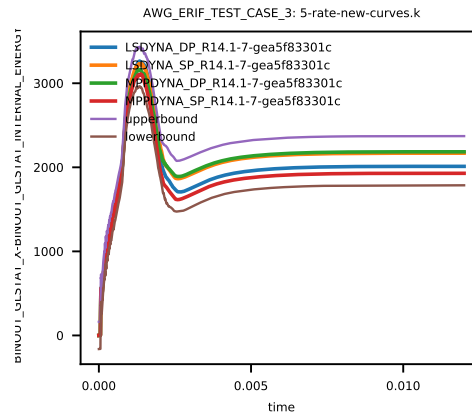


Figure 23: Cross platform results, global internal energy, sub test case ID 2

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

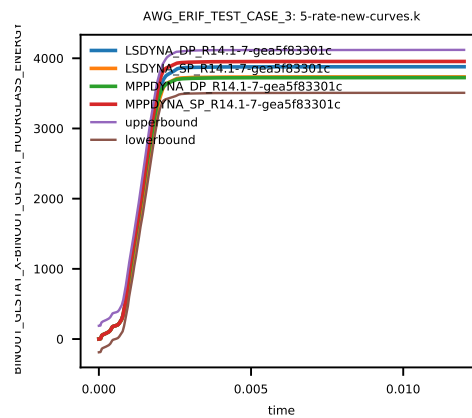


Figure 24: Cross platform results, global hourglass energy, sub test case ID 2

## References