

# TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AWG-ERIF-10-10

TEST CASE ID AWG-ERIF-10

MAT\_224

Dynamic Punch Test Aluminium 2024

Tested with LS-DYNA® R9 Revision 118235

Friday 14<sup>th</sup> July, 2017

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# Contents

|          |                                                |           |
|----------|------------------------------------------------|-----------|
| <b>1</b> | <b>Introduction</b>                            | <b>1</b>  |
| 1.1      | Purpose of this Document . . . . .             | 1         |
| <b>2</b> | <b>Test Case Information</b>                   | <b>2</b>  |
| <b>3</b> | <b>Test Case Specification</b>                 | <b>3</b>  |
| 3.1      | Test Case Purpose . . . . .                    | 3         |
| 3.2      | Test Case Description . . . . .                | 4         |
| 3.3      | Model Description . . . . .                    | 5         |
| <b>4</b> | <b>Test Specifications</b>                     | <b>7</b>  |
| 4.1      | Test Case Targets . . . . .                    | 7         |
| 4.2      | Pass/Fail Criteria . . . . .                   | 7         |
| <b>5</b> | <b>Test Case Results</b>                       | <b>8</b>  |
| 5.1      | Software and Hardware Specifications . . . . . | 8         |
| 5.2      | Results Summary . . . . .                      | 9         |
| 5.3      | Result Details . . . . .                       | 10        |
| 5.3.1    | Sub Test Case ID 1 - Test Target 1 . . . . .   | 11        |
| 5.3.2    | Sub Test Case ID 2 - Test Target 1 . . . . .   | 12        |
|          | <b>References</b>                              | <b>13</b> |

# **1 Introduction**

## **1.1 Purpose of this Document**

This document specifies the test case AWG-ERIF-10. 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           | MAT_224 Dynamic Punch Test Aluminium 2024 |
| Test Case ID             | AWG-ERIF-10                               |
| Test Case Status         | active                                    |
| Test Case Classification | Example                                   |
| Test Case Source         | NCAC/GWU                                  |
| Tested Keyword           | *MAT_TABULATED_JOHNSON_COOK               |
| 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-10 is the comparison of results from different cpu architectures for punch tests of Aluminium 2024.

The reliability and consistency of LS-DYNA® as a finite element solver for this punch test simulation is evaluated by performing analyses on different cpu architecture platforms.

### 3.2 Test Case Description

This Test Case contains punch tests (see figure 1) performed on a Split Hopkinson Bar (SHB) which are used to examine the failure of Aluminium 2024.

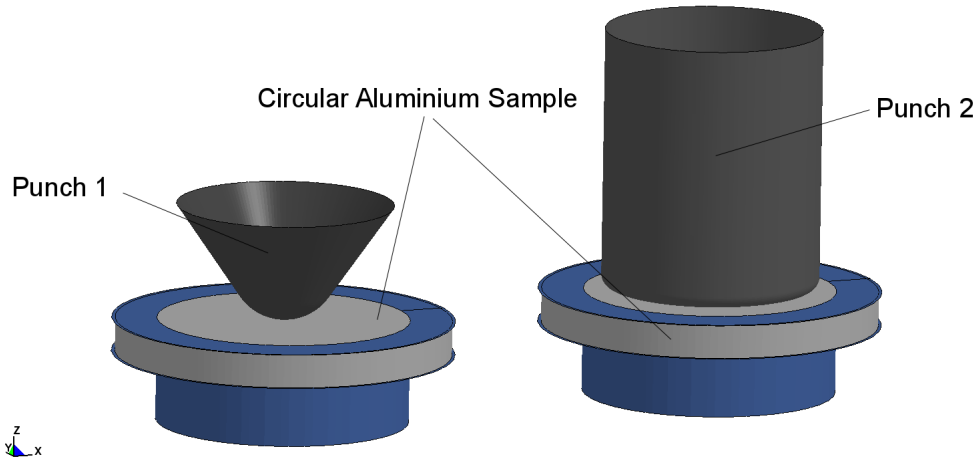


Figure 1: Model sketch: Punch test on circular Aluminium samples with two different punch shapes

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

| Physical Model Information |                                           |
|----------------------------|-------------------------------------------|
| circular sample geometry   | diameter = 14.56 mm, thickness = 1.456 mm |
| sample material            | Aluminium 2024                            |
| punch velocity             | 20 m/sec                                  |

Table 2: Model set-up data

### 3.3 Model Description

The model geometry is discretized with solid elements for the circular Aluminium 2024 sample and shell elements for the punch geometry (see figure 2).

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.

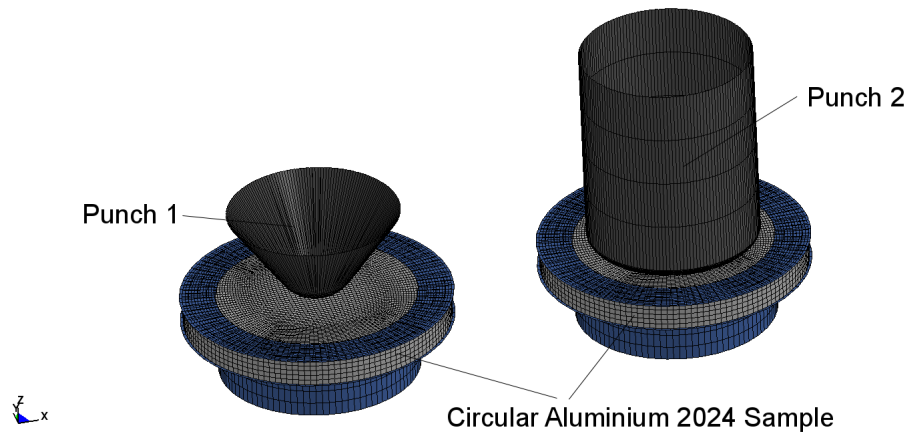


Figure 2: FEA model: Punch test on circular Aluminium samples with two different punch shapes

| FEA Model information         |                                                                               |       |
|-------------------------------|-------------------------------------------------------------------------------|-------|
| Sub Test Case ID <sup>1</sup> | 1                                                                             | 2     |
| Nodes                         | 32882                                                                         | 34544 |
| Solid elements                | 23625                                                                         | 23625 |
| Solid materials               | 1                                                                             | 1     |
| Shell elements                | 3910                                                                          | 5598  |
| Shell materials               | 3                                                                             | 3     |
| Parts                         | 4                                                                             | 4     |
| Units                         | mm (length), s (time), tonne (mass), N/mm <sup>2</sup> (stress), Nmm (energy) |       |

<sup>1</sup> Sub Test Case ID refers to the ID's in table 4

Table 3: FEA Model Information

| Sub Test ID | Punch Type | Input Deck Name |
|-------------|------------|-----------------|
| 1           | Punch 1    | pch1_mod.k      |
| 2           | Punch 2    | pch6_mod.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                 | resultant interface force | z              | 2            | binout/rcforc file |

Table 5: Test Case targets for Test Case ID AWG-ERIF-10

Test case targets are used to evaluate the cross cpu architecture consistency (see section 4.2).

### 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-10.

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<sup>®</sup> 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> |
|---------------|------------------|---------------------------------------------------------|----------------------|------------------------------|
| mars          | CentOS 6.5       | Intel <sup>®</sup> Xeon <sup>®</sup> E5- 2640 @ 2.50GHz | Platform MPI 8.2.0.0 | 4                            |
| dinar3b       | SUSE LES 11      | AMD <sup>®</sup> Opteron <sup>®</sup> 6276 @ 2300MHz    | Platform MPI 8.2.0.0 | 4                            |

<sup>1</sup> Number of cpu's used for calculation of the test case

<sup>2</sup> SGI PROPack 4

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     | R9      | 118235   | SMP                        | SP                     | ls971.118235.R9  |
| LS-DYNA <sup>®</sup> | 971     | R9      | 118235   | SMP                        | DP                     | ld971.118235.R9  |
| LS-DYNA <sup>®</sup> | 971     | R9      | 118235   | MPP                        | SP                     | mpp971.118235.R9 |
| LS-DYNA <sup>®</sup> | 971     | R9      | 118235   | MPP                        | DP                     | mpd971.118235.R9 |

<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-10 completed with all combinations of software and hardware defined in section 5.1 (2 \* 3 \* 4 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>PASS</b> |

Table 8: Results summary for Test Case ID AWG-ERIF-10

### 5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-ERIF-10 for LS-DYNA® R9 Revision 118235.

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\_10: pch1\_mod.k' states the test case ID 10 and name of the input deck for sub test case 1.

##### *Legend:*

'glstat\_internal.energy,ham,ls971.118235.R9,4' 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® R9 Revision 118235 binary (SMP, single precision) on four processors.

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

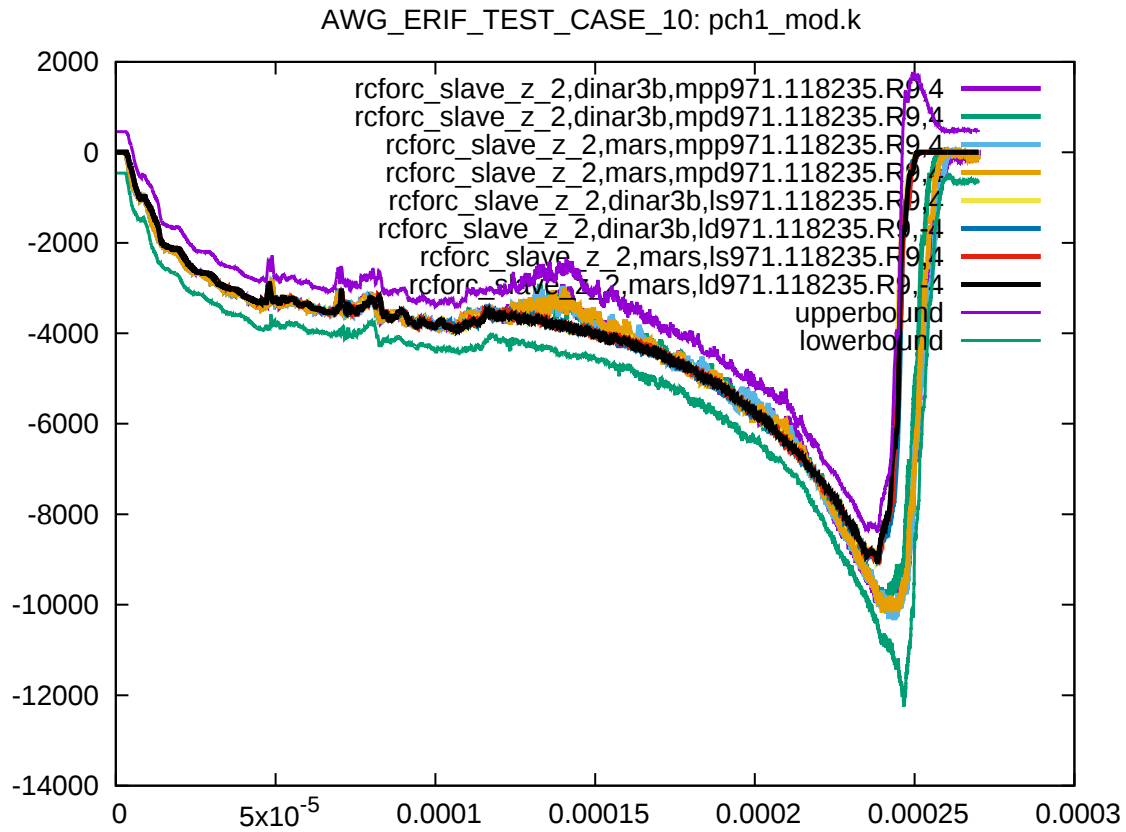


Figure 3: Cross platform results, resultant force in z-direction, sub test case ID 1

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

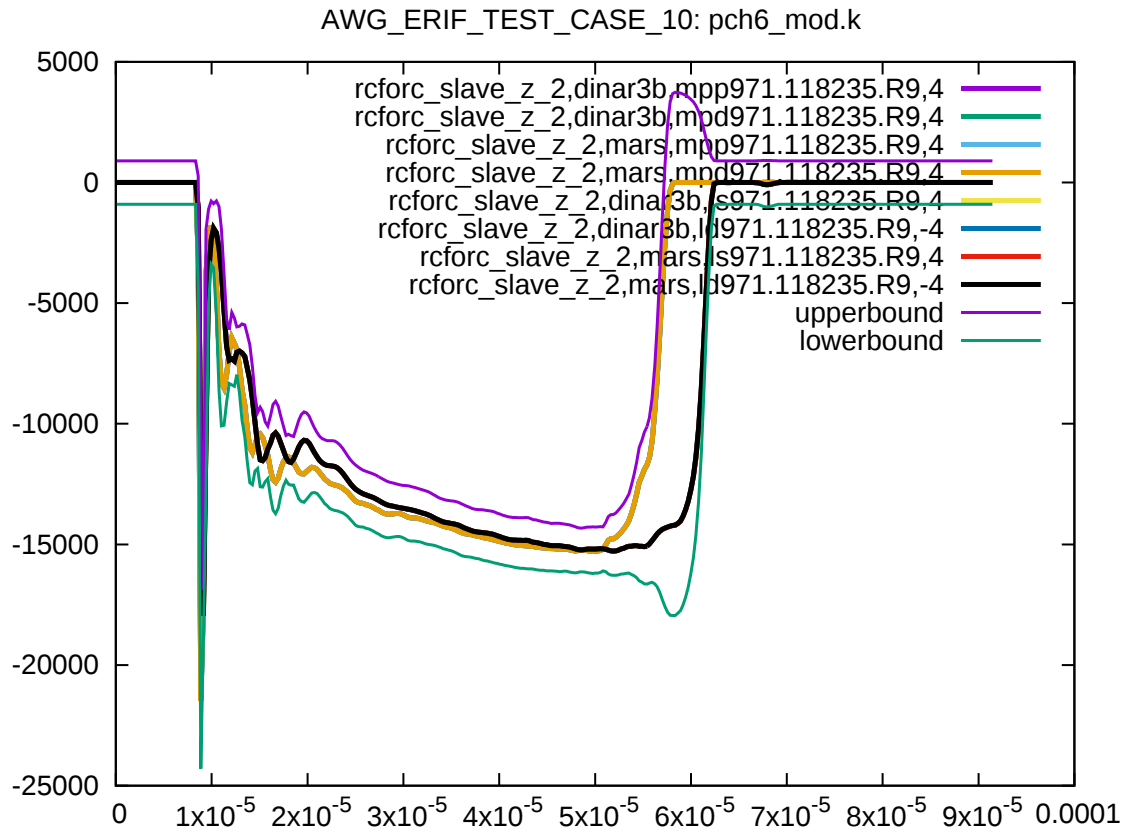


Figure 4: Cross platform results, resultant force in z-direction, sub test case ID 2

## References

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