TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AEROQA-9-3

TEST CASE ID AEROQA-9

MAT 224 - Single Element Tests

Tested with LS-DYNA® R6.1 Revision 74159

Friday 25th May, 2012

LSTC
Livermore Software Technology Corp.

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Confidentiality	**external use**
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Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case AEROQA-9. 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 - Single Element Tests
Test Case ID	AEROQA-9
Test Case Status	active
Test Case Classification	Example
Test Case Source	NCAC / George Washington University
Tested Keyword	*MAT_TABULATED_JOHNSON_COOK, *MAT_PIECEWISE_LINEAR_PLASTICITY, *MAT_JOHNSON_COOK
Member of Test Suite	AEROQA SUITE
Metadata	AEROQA

Table 1: Test Case Summary

3 Test Case Specification

3.1 Test Case Purpose

The purpose of QA Test Case ID AEROQA-9 is the comparison of *MAT_TABULATED_JOHNSON_COOK (*MAT_224) to *MAT_PIECEWISE_LINEAR_PLASTICITY (*MAT_024) and *MAT_JOHNSON_COOK (*MAT_015) , and, in particular, demonstrating the influence of thermal softening and stress triaxiality.
The reliability and consistency of LS-DYNA® as a finite element solver for the single solid element models is evaluated by performing analyses on different cpu architecture platforms and comparing *MAT_224 with reliable implemented material laws in LS-DYNA®.

3.2 Test Case Description

This QA Test Case contains 24 elements (6 rows times 4 columns) see figure 2. Each of the 4 columns specifies a different load case (see table 2 and figure 1), and each of the 6 rows contain elements with different material descriptions and input parameters (see table 3). The specification of element id's with load case, material type, and input properties can be found in table 4.

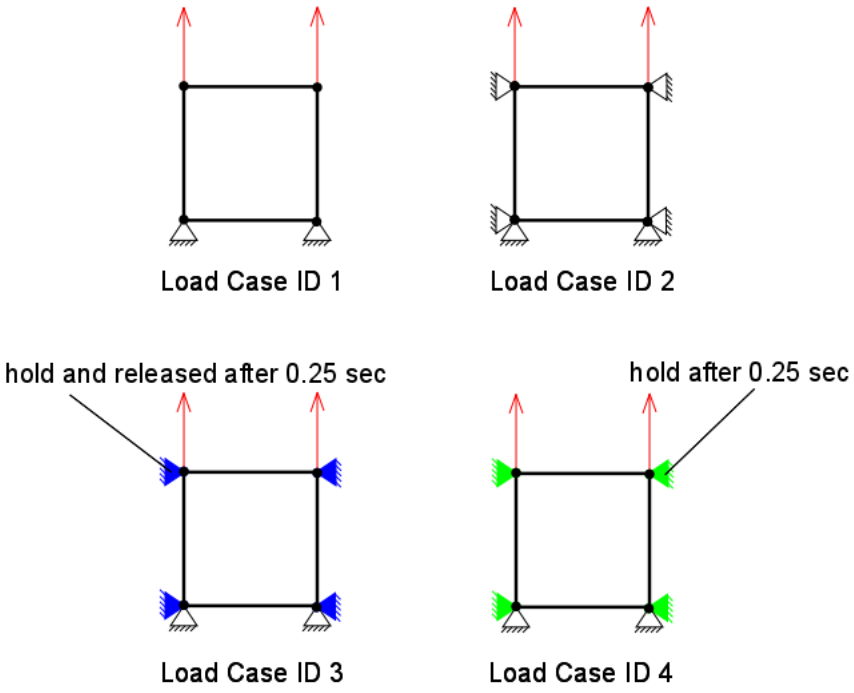

Figure 1: Load Cases

Load Cases ID	Load case specification
1	Uniaxial tension, orthogonal directions free
2	Uniaxial tension, orthogonal directions hold
3	Uniaxial tension, orthogonal directions hold and released after 0.25 seconds
4	Uniaxial tension, orthogonal directions hold after 0.25 seconds

Table 2: Load cases for the single elements test

Material ID	Material specification and parameters
1	Johnson-Cook (MAT_015), vp=1 viscoplastic formulation, m=0, thermal decoupled
2	Piecewise Linear Plasticity (MAT_024), vp =1 viscoplastic formulation
3	Johnson Cook (MAT_015), vp=1 visco plastic formulation, m=1 fully thermal coupling
4	Tabulated Johnson-Cook (MAT_224), beta = 1 Amount of plastic work converted into heat
5	Tabulated Johnson-Cook (MAT_224), beta= 0.6 Amount of plastic work converted into heat
6	Tabulated Johnson-Cook (MAT_224), beta = 1 Amount of plastic work converted into heat, kt = 0

Table 3: Material types for the single elements test

Element ID	Material ID	Load Case ID
1	1	1
2	1	2
3	1	3
4	1	4
5	2	1
6	2	2
7	2	3
8	2	4
9	3	1
10	3	2
11	3	3
12	3	4
13	4	1
14	4	2
15	4	3
16	4	4
17	5	1
18	5	2
19	5	3
20	5	4
21	6	1
22	6	2
23	6	3
24	6	4

Table 4: Material ID and load case ID for the single elements

3.3 Model Description

The model contains 24 solid elements (see figure2). There are 4 columns each with different loading conditions defined on figure 1. Each row contains six solid elements each with different material types and input properties (see table 3).
The model specifications can be found in table 5, and table 6 defines the sub test case specification.

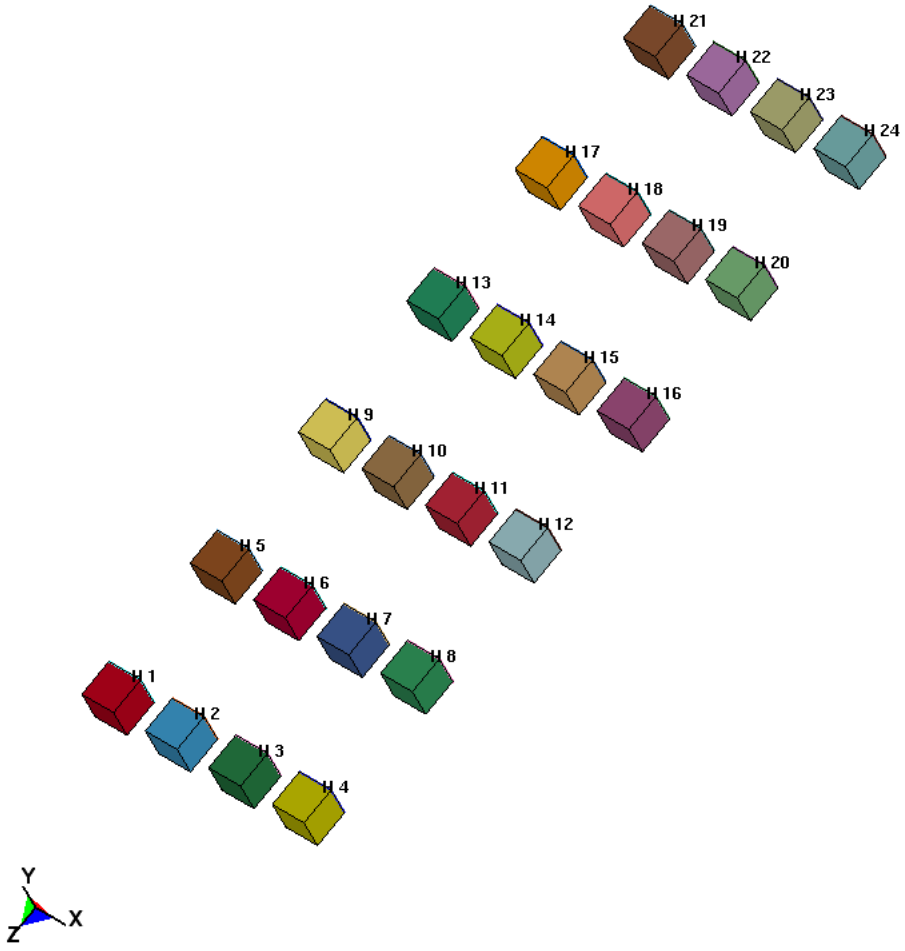

Figure 2: FEA model: 24 elements test, for detailed specifications see table 3

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

FEA Model information	
Nodes	192
Solid elements	24
Solid materials	24
Parts	24
Units	mm (length), sec. (time), tonne (mass), N/mm^2 (stress), Nmm (energy)

Table 5: FEA Model Information

Sub Test Case ID	Input Deck Name
1	MAT_224_single_element.k

Table 6: Specification of sub test cases

4 Test Specifications

4.1 Test Case Targets

Table 7 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 comparisons with each other.

Test Case Targets				
Target number	output	component type	component id	retrieved from
1	sigma zz	elout	1	binout/elout file
2	sigma zz	elout	2	binout/elout file
3	sigma zz	elout	3	binout/elout file
4	sigma zz	elout	4	binout/elout file
5	sigma zz	elout	5	binout/elout file
6	sigma zz	elout	6	binout/elout file
7	sigma zz	elout	7	binout/elout file
8	sigma zz	elout	8	binout/elout file
9	sigma zz	elout	9	binout/elout file
10	sigma zz	elout	10	binout/elout file
11	sigma zz	elout	11	binout/elout file
12	sigma zz	elout	12	binout/elout file
13	sigma zz	elout	13	binout/elout file
14	sigma zz	elout	14	binout/elout file
15	sigma zz	elout	15	binout/elout file
16	sigma zz	elout	16	binout/elout file
17	sigma zz	elout	17	binout/elout file
18	sigma zz	elout	18	binout/elout file
19	sigma zz	elout	19	binout/elout file
20	sigma zz	elout	20	binout/elout file
21	sigma zz	elout	21	binout/elout file
22	sigma zz	elout	22	binout/elout file
23	sigma zz	elout	23	binout/elout file
24	sigma zz	elout	24	binout/elout file

Table 7: Test Case targets for QA Test Case ID AEROQA-9

Test case targets 1 to 24 are used to evaluate the cross cpu architecture consistency.

4.2 Pass/Fail Criteria

These are the Pass/Fail criteria used for the cross cpu architecture consistency of the Test Case ID AEROQA-9.

A test case passes if all of the following criteria are reached:

- For a specific test case target, the maximum distance between an x-y pair of a slope of one cpu architecture/software version combination to at least one x-y pair of all other tested cpu architecture/software version combinations is 15% of the maximum slope value.
- The sigma zz time history of material id's 1, 2 and 6 are equal
- The sigma zz time history of material id's 3 and 4 are equal
- The sigma zz time history of material id's 5 lays in between material id's 6 and 4
- The failure behaviour is equal for material id's 1, 2 and 6
- The failure behaviour is equal for material id's 3 and 4
- The failure behaviour of material id 5 lays in between material id's 6 and 4

Otherwise the the cross cpu architecture consistency fails.

Material id's are defined in table 3.

5 Test Case Results

5.1 Software and Hardware Specifications

In order to ensure cross cpu architecture consistency, the herein mentioned sub test cases are run on platforms specified in table 8 and the results are calculated with software versions defined in table 9.

Platform Name	Operating system	CPU type	MPI-Protocol	Number of cpu's [1]
sandwich	SUSE LES 11.1	Intel® Xeon® E7- 8837 @ 2.67GHz	hpmpi	4
ham	CentOS 5.4	AMD® Opteron ® 8435 @ 800MHz	hpmpi	4
sgi64d	SUSE LES 9.4	Intel® Itanium® 2 @ 1.6GHz	hpmpi	4
origin2	IRIX64 6.5	MIPS R12000 @ 300MHz	MPI 4.4 (MPT 1.9)	4

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

Table 8: Used Platforms and CPU Type's

Product	Version	Release	Revision	Parallel type [1]	Precision [2]	executable
LS-DYNA®	971	R6.1	74159	SMP	SP	ls971.74159.R6.1
LS-DYNA®	971	R6.1	74159	SMP	DP	ld971.74159.R6.1
LS-DYNA®	971	R6.1	74159	MPP	SP	mpp971.74159.R6.1
LS-DYNA®	971	R6.1	74159	MPP	DP	mpd971.74159.R6.1

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

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

Table 9: Tested LS-DYNA® version

5.2 Results Summary

Table 10 contains the results of the QA Test Case ID AEROQA-9 completed with all combinations of software and hardware defined in section 5.1 (1 * 4 * 4 total calculation runs).
Details on the test results can be found in the section 5.3.

The table 10 cross cpu architecture consistency and validation 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**

Table 10: Validation results summary for QA Test Case ID AEROQA-9

5.3 Result Details

The following subsections contain detailed results for the QA Test Case ID AEROQA-9 for LS-DYNA® R6.1 Revision 74159.

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 name of the input deck, the result file name, and the output separated by underscores. The legend contains the result file name, output, platform, and executable. The last number of the legend specifies the number of cpu's used to calculate the example. A leading minus sign refers to the compatibility option for SMP calculations (see [1] for details on this option).

Example for title and legend:

Title:
'MAT_224_single_element.k: elout_solid_szz_1_1_1' states that the input deck for sub test case 1 was used to calculate these results. The component displayed is the zz stress of element number 1 derived from the 'elout' output file.

Legend:
'elout_solid_szz_1_1_1_sandwich_ls971.74159.R6.1_4' states that the graph shows the zz stress of element id 1 derived from the 'elout' output file for an input deck which was calculated on the 'sandwich' platform with a LS-DYNA® R6.1 Revision 74159 binary (SMP, single precision) on four processors.

5.3.1 Sub Test Case ID 1 - Test Target 1

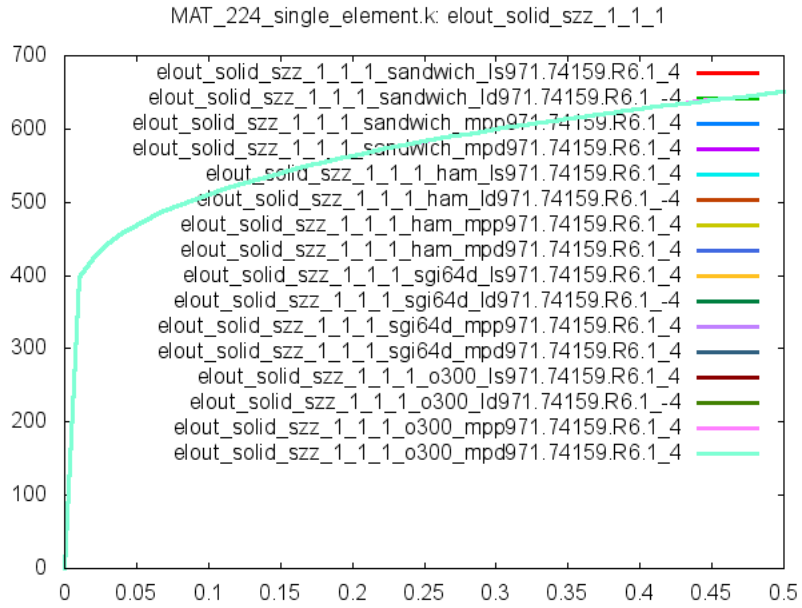

Figure 3: Cross platform results, zz stress element id 1, sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

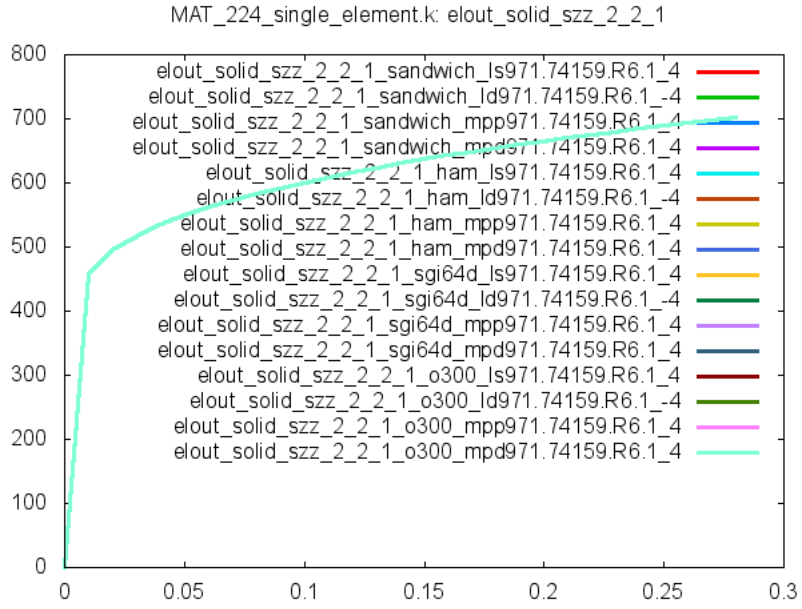

Figure 4: Cross platform results, zz stress element id 2, sub test case ID 1

5.3.3 Sub Test Case ID 1 - Test Target 3

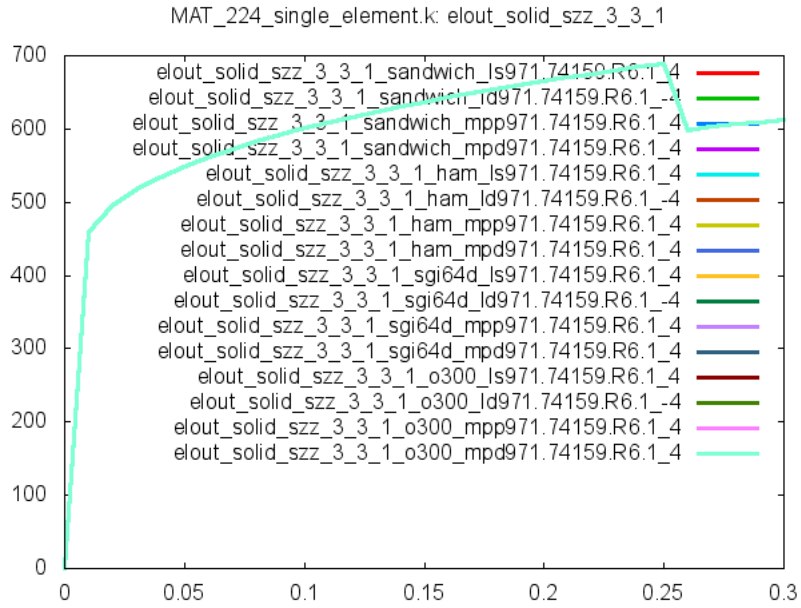

Figure 5: Cross platform results, zz stress element id 3, sub test case ID 1

5.3.4 Sub Test Case ID 1 - Test Target 4

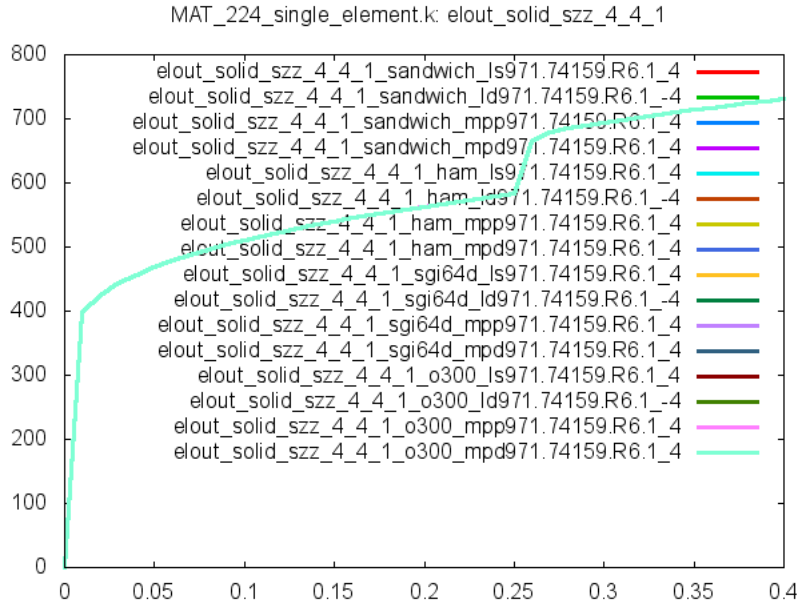

Figure 6: Cross platform results, zz stress element id 4, sub test case ID 1

5.3.5 Sub Test Case ID 1 - Test Target 5

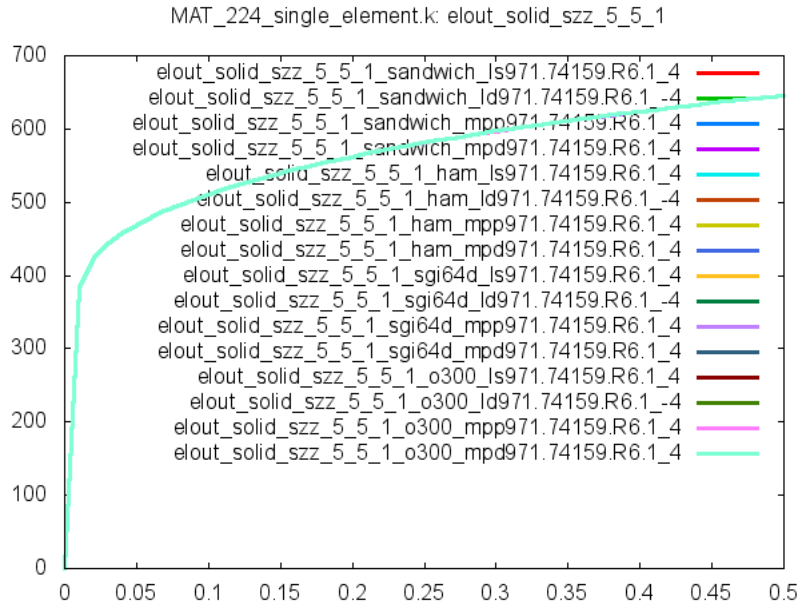

Figure 7: Cross platform results, zz stress element id 5, sub test case ID 1

5.3.6 Sub Test Case ID 1 - Test Target 6

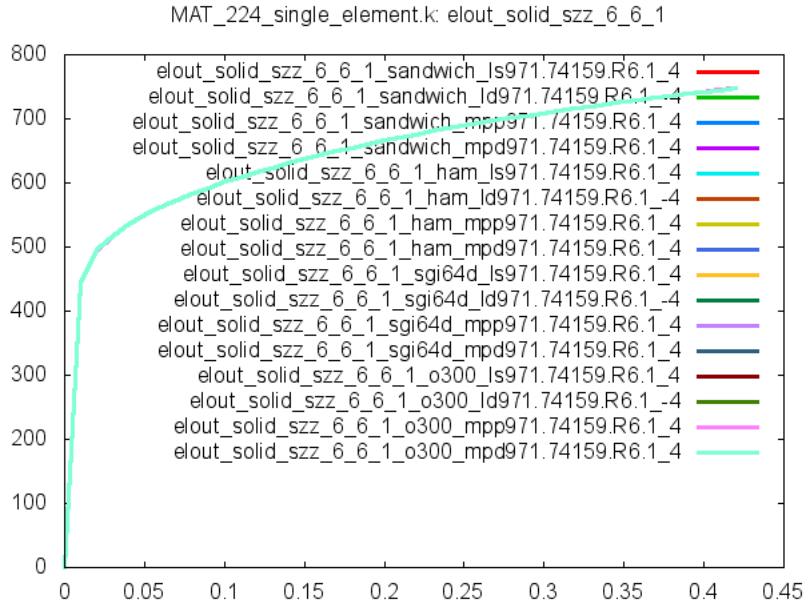

Figure 8: Cross platform results, zz stress element id 6, sub test case ID 1

5.3.7 Sub Test Case ID 1 - Test Target 7

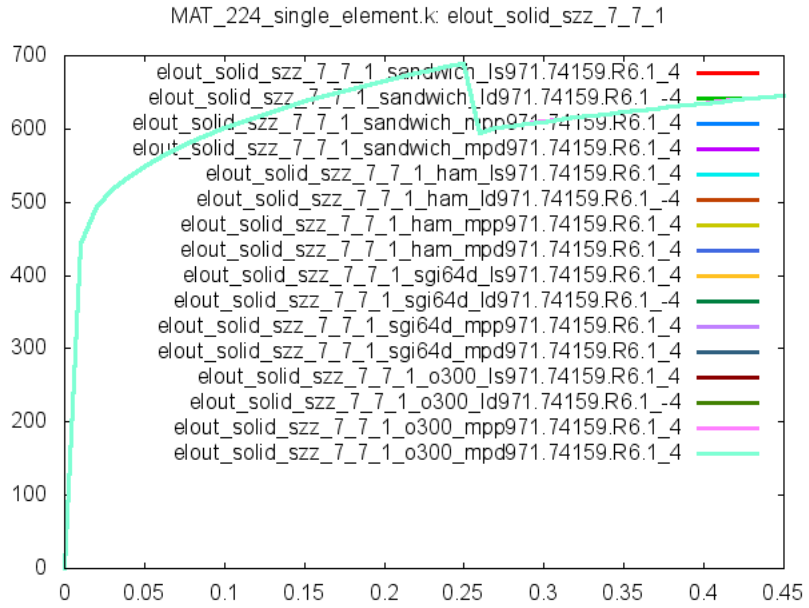

Figure 9: Cross platform results, zz stress element id 7, sub test case ID 1

5.3.8 Sub Test Case ID 1 - Test Target 8

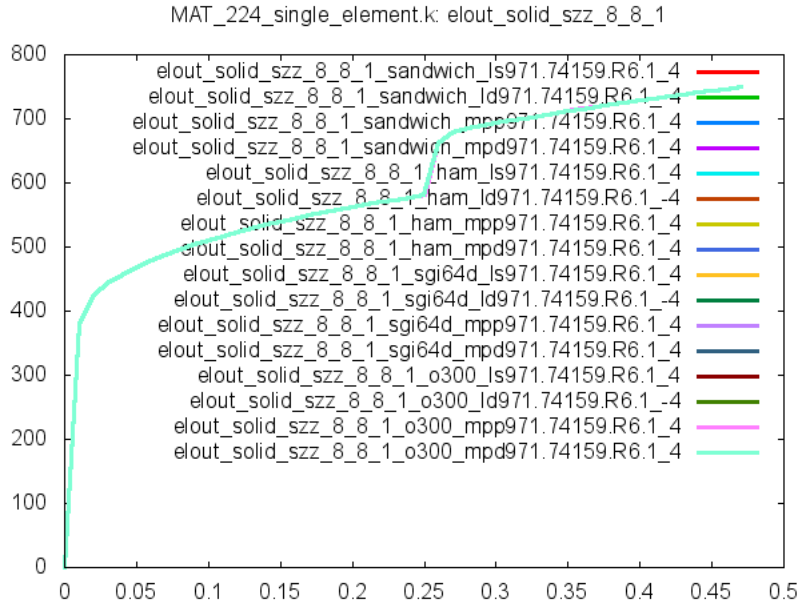

Figure 10: Cross platform results, zz stress element id 8, sub test case ID 1

5.3.9 Sub Test Case ID 1 - Test Target 9

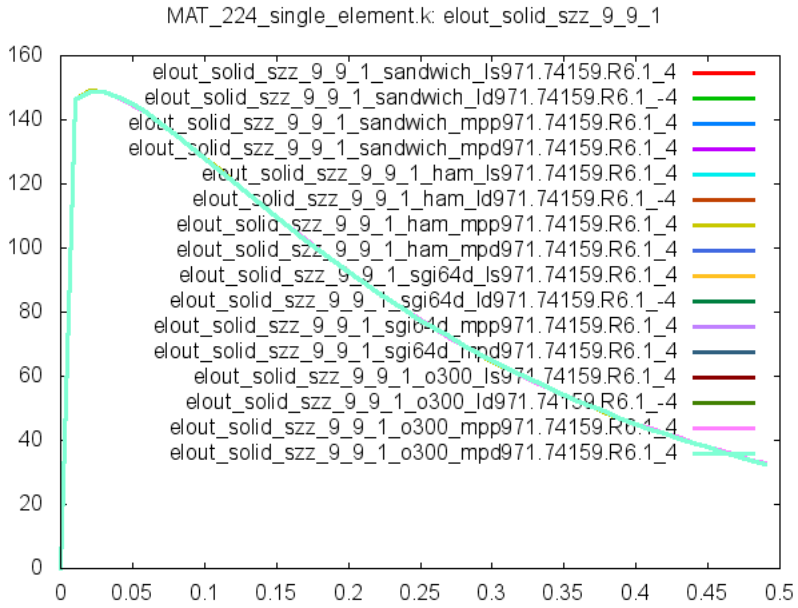

Figure 11: Cross platform results, zz stress element id 9, sub test case ID 1

5.3.10 Sub Test Case ID 1 - Test Target 10

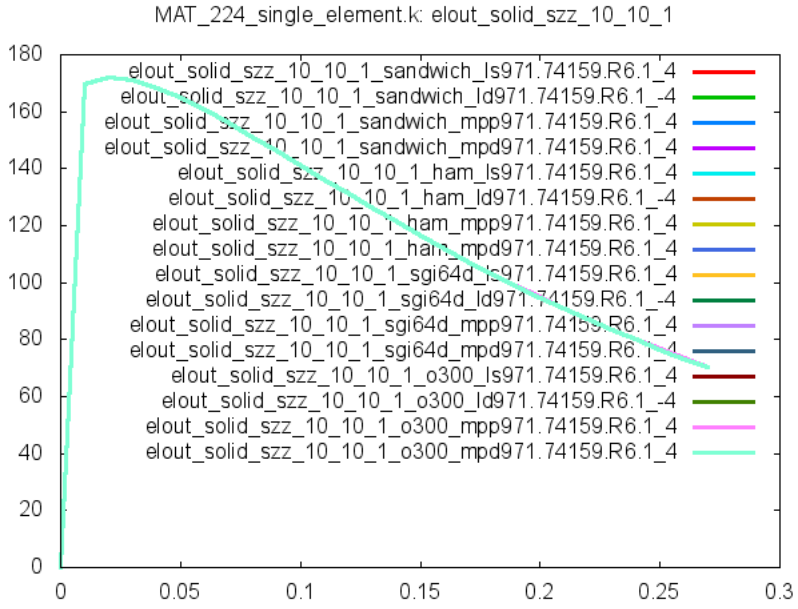

Figure 12: Cross platform results, zz stress element id 10, sub test case ID 1

5.3.11 Sub Test Case ID 1 - Test Target 11

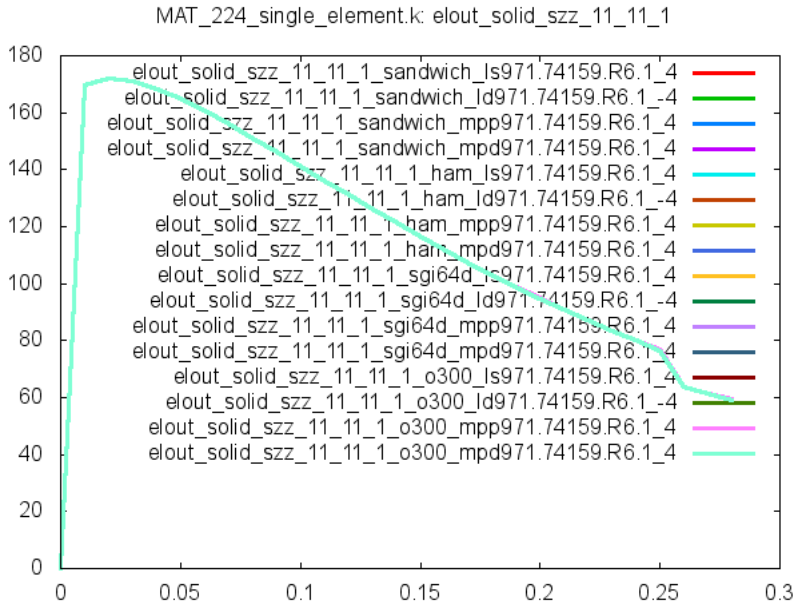

Figure 13: Cross platform results, zz stress element id 11, sub test case ID 1

5.3.12 Sub Test Case ID 1 - Test Target 12

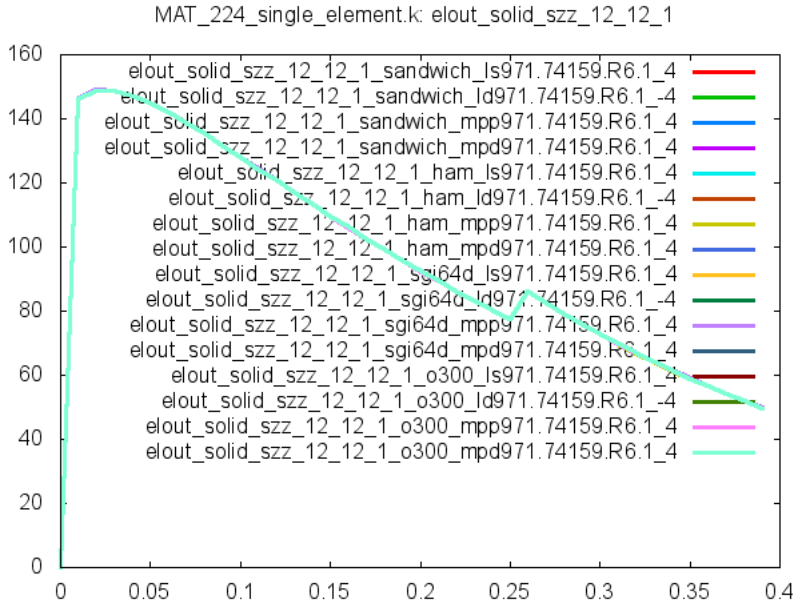

Figure 14: Cross platform results, zz stress element id 12, sub test case ID 1

5.3.13 Sub Test Case ID 1 - Test Target 13

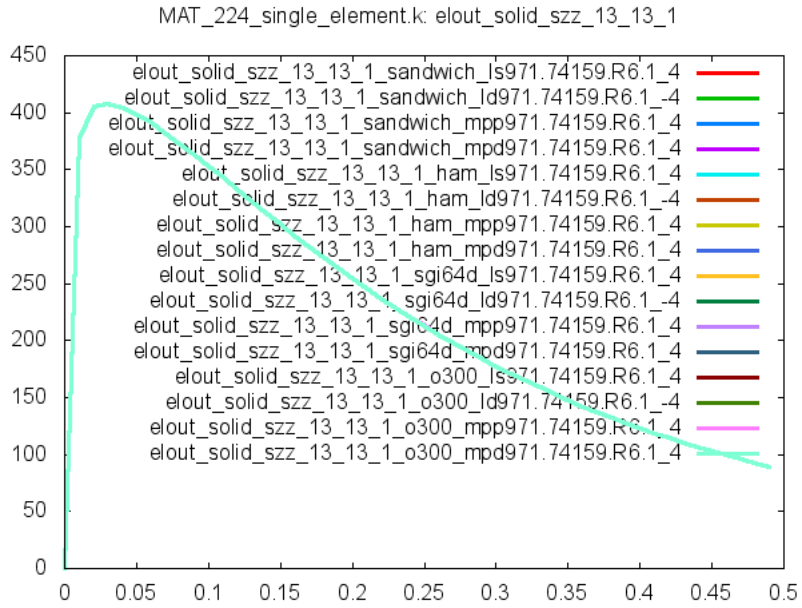

Figure 15: Cross platform results, zz stress element id 13, sub test case ID 1

5.3.14 Sub Test Case ID 1 - Test Target 14

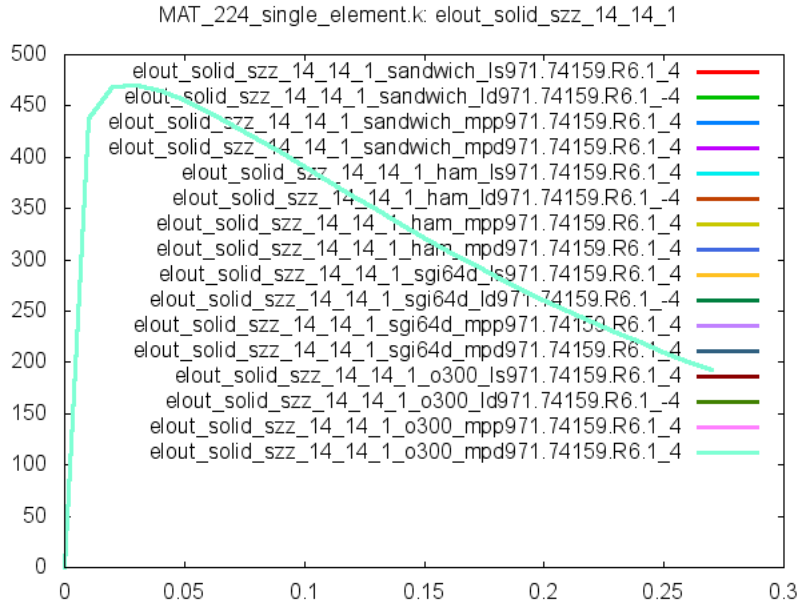

Figure 16: Cross platform results, zz stress element id 14, sub test case ID 1

5.3.15 Sub Test Case ID 1 - Test Target 15

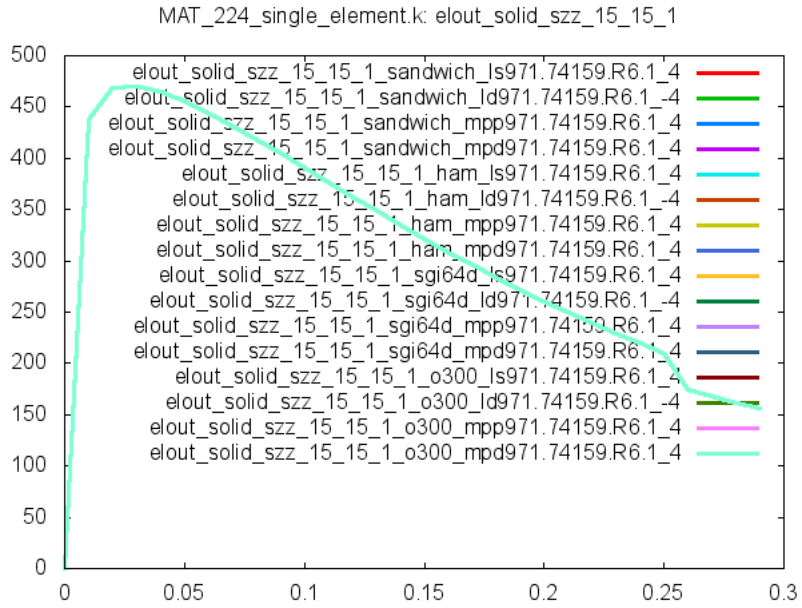

Figure 17: Cross platform results, zz stress element id 15, sub test case ID 1

5.3.16 Sub Test Case ID 1 - Test Target 16

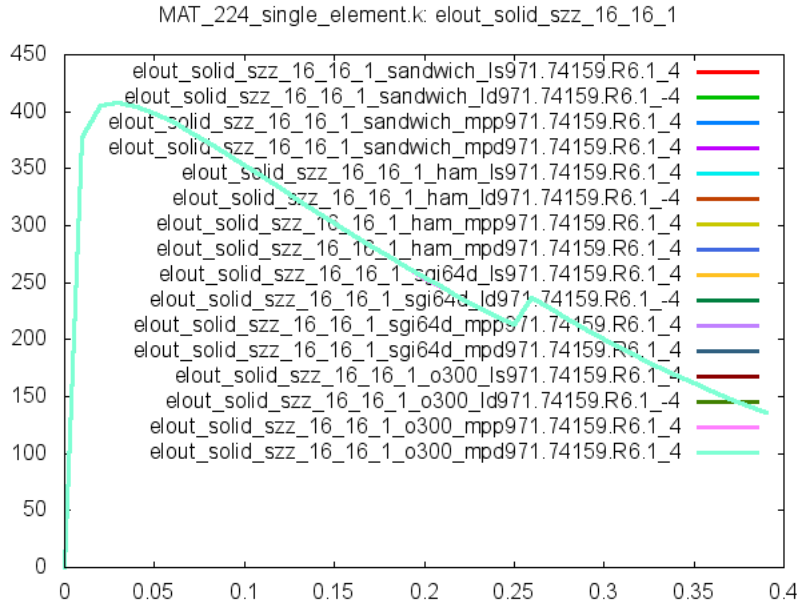

Figure 18: Cross platform results, zz stress element id 16, sub test case ID 1

5.3.17 Sub Test Case ID 1 - Test Target 17

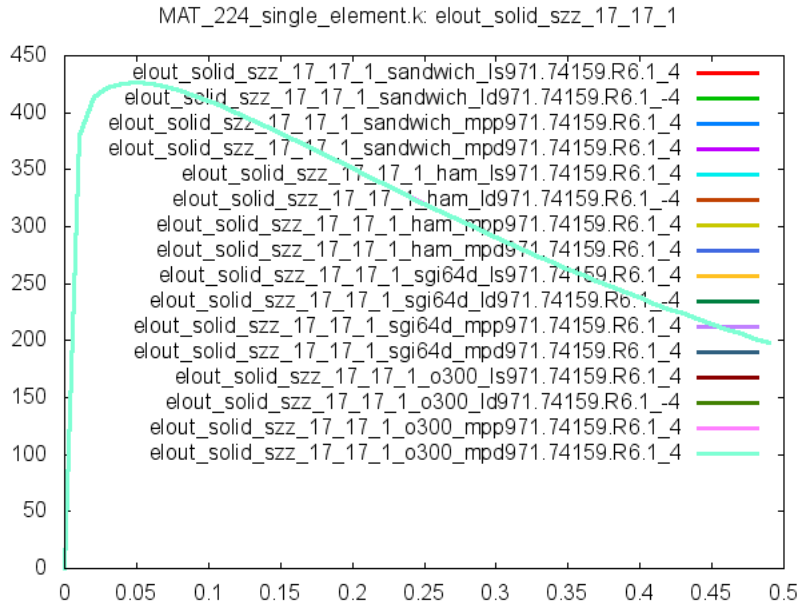

Figure 19: Cross platform results, zz stress element id 17, sub test case ID 1

5.3.18 Sub Test Case ID 1 - Test Target 18

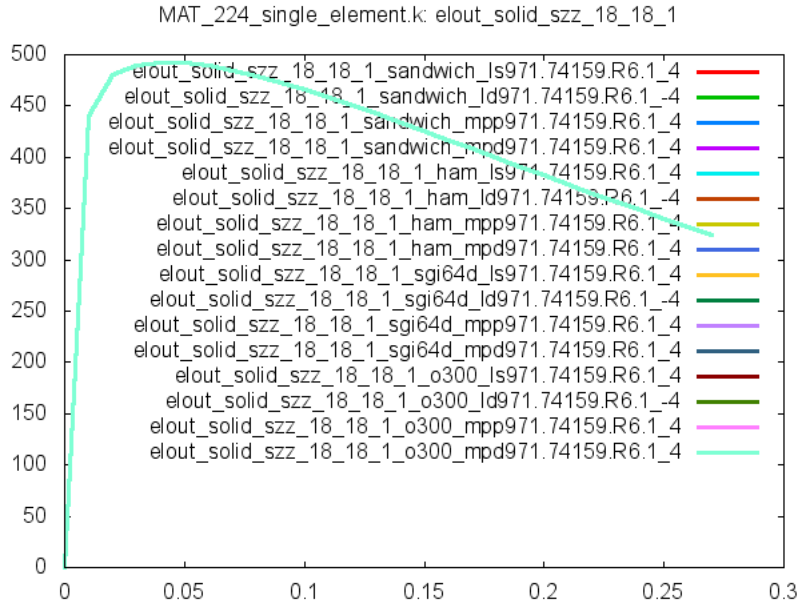

Figure 20: Cross platform results, zz stress element id 18, sub test case ID 1

5.3.19 Sub Test Case ID 1 - Test Target 19

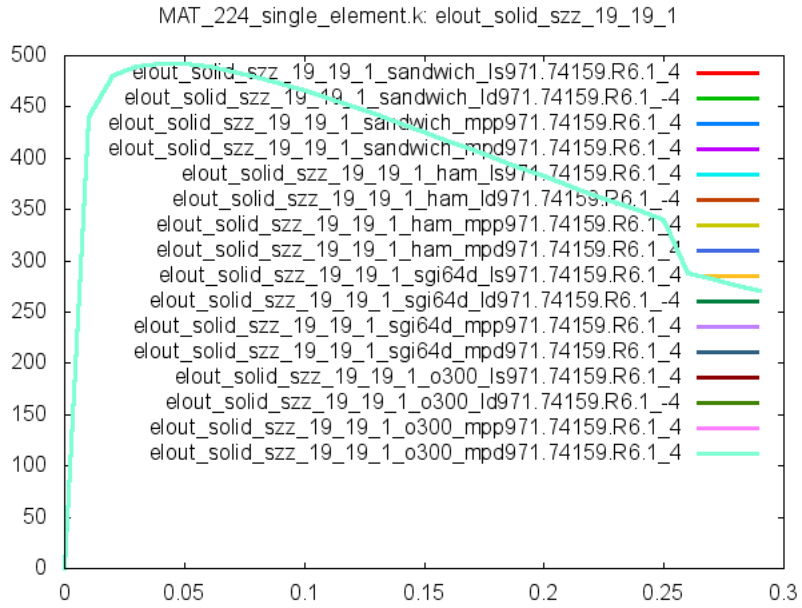

Figure 21: Cross platform results, zz stress element id 19, sub test case ID 1

5.3.20 Sub Test Case ID 1 - Test Target 20

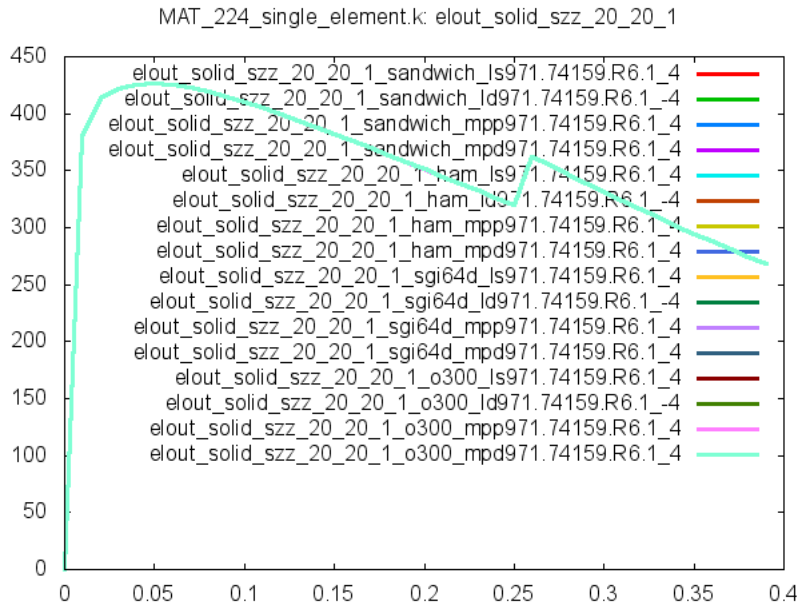

Figure 22: Cross platform results, zz stress element id 20, sub test case ID 1

5.3.21 Sub Test Case ID 1 - Test Target 21

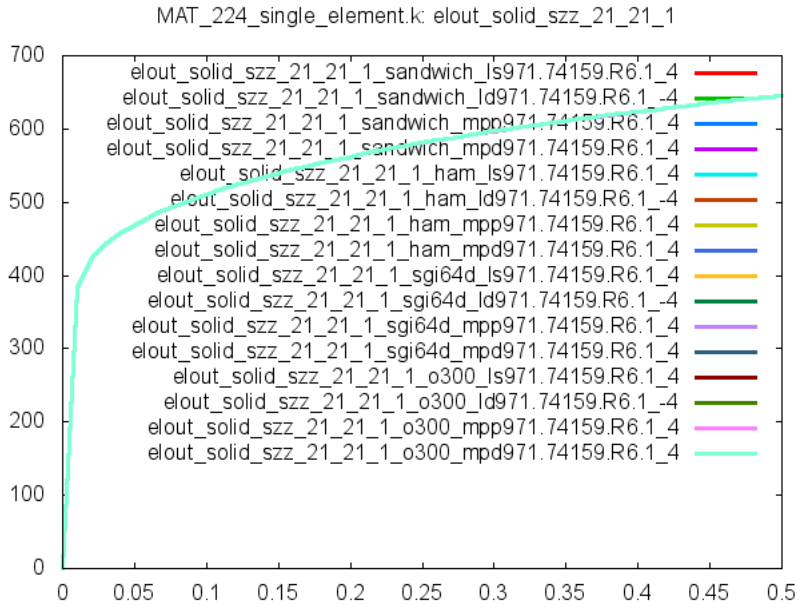

Figure 23: Cross platform results, zz stress element id 21, sub test case ID 1

5.3.22 Sub Test Case ID 1 - Test Target 22

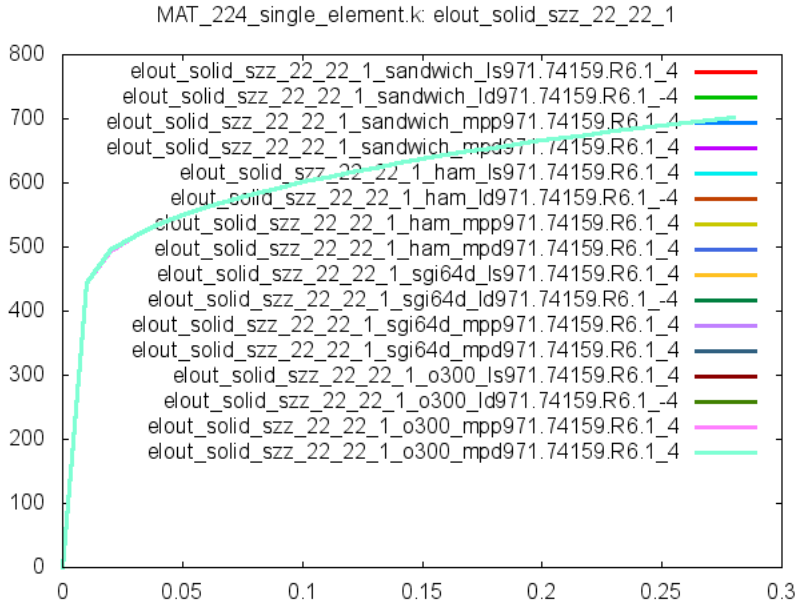

Figure 24: Cross platform results, zz stress element id 22, sub test case ID 1

5.3.23 Sub Test Case ID 1 - Test Target 23

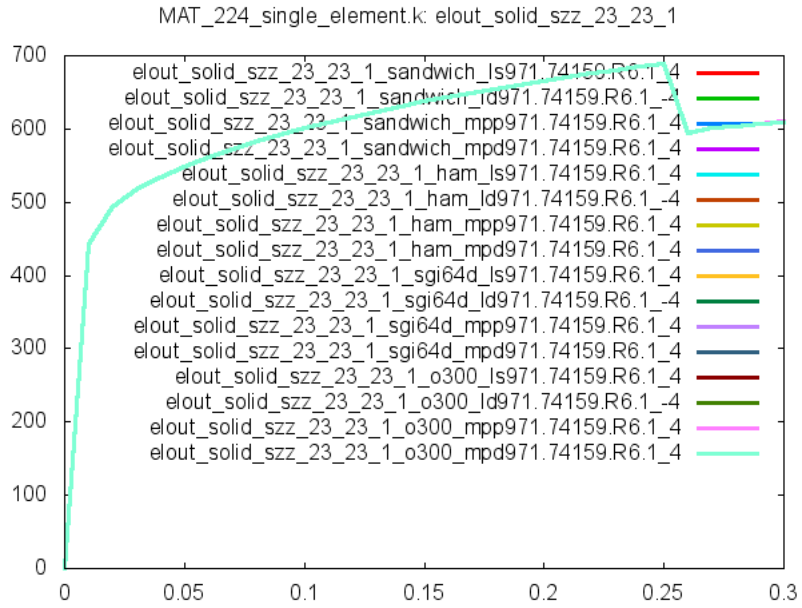

Figure 25: Cross platform results, zz stress element id 23, sub test case ID 1

5.3.24 Sub Test Case ID 1 - Test Target 24

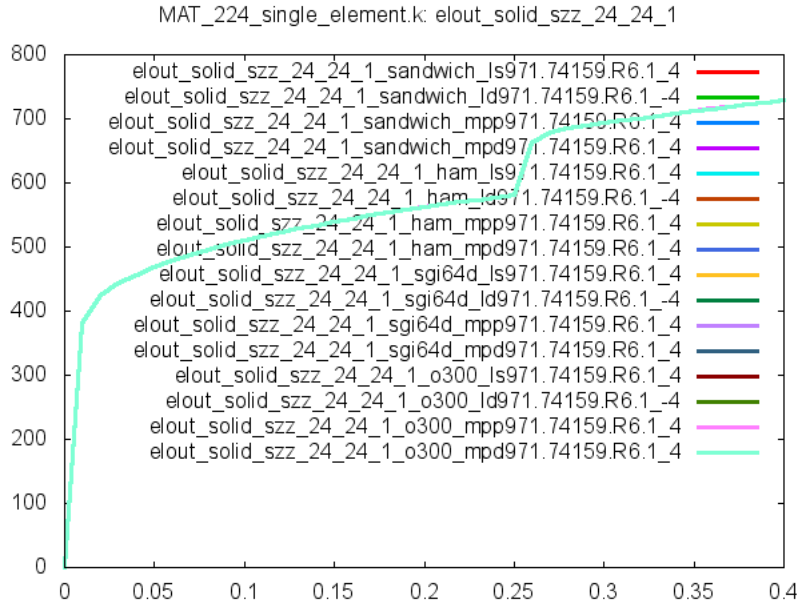

Figure 26: Cross platform results, zz stress element id 24, sub test case ID 1

References

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