TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AWG-ERIF-3-7

TEST CASE ID AWG-ERIF-3

Rubber Projectile Impacting a Rigid Plate

Tested with LS-DYNA® R9.0 Revision 108899

Saturday 9th July, 2016

LSTC
Livermore Software Technology Corp.

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Contents

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.

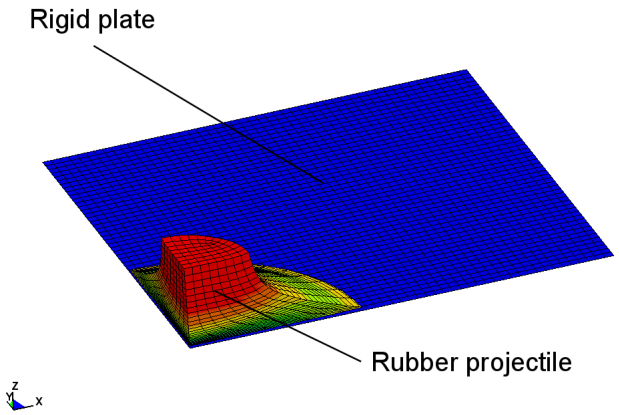

Figure 1: FEA model: Rubber Projectile Impacting a Rigid Plate

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^2/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

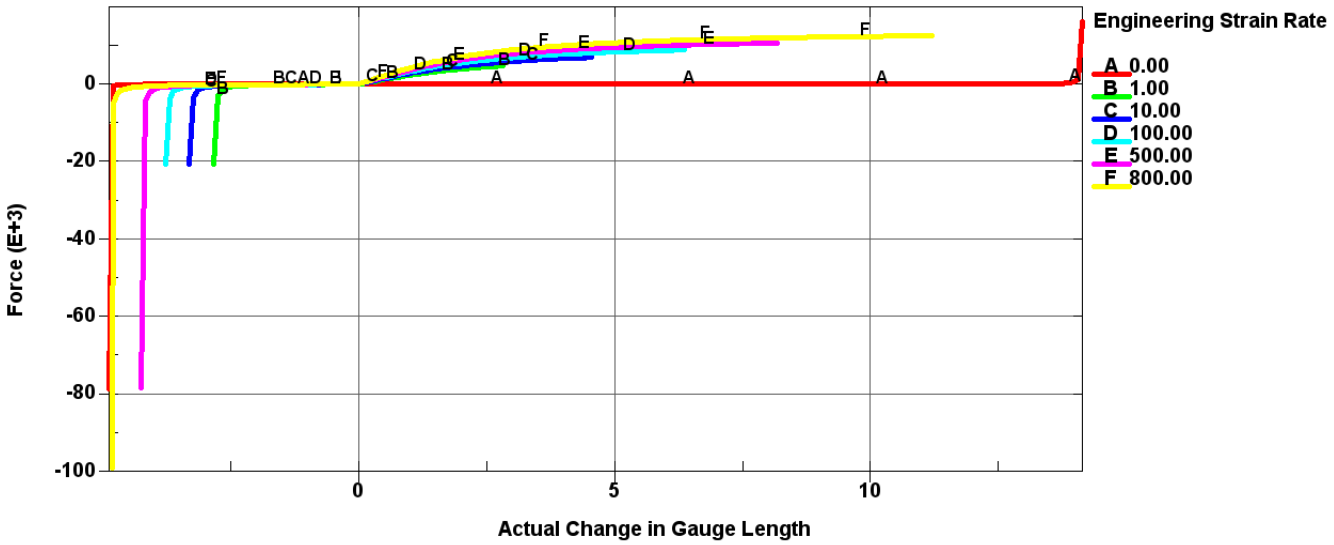

Figure 2: Force versus actual change in gauge length for different engineering strain rates for sub case 1

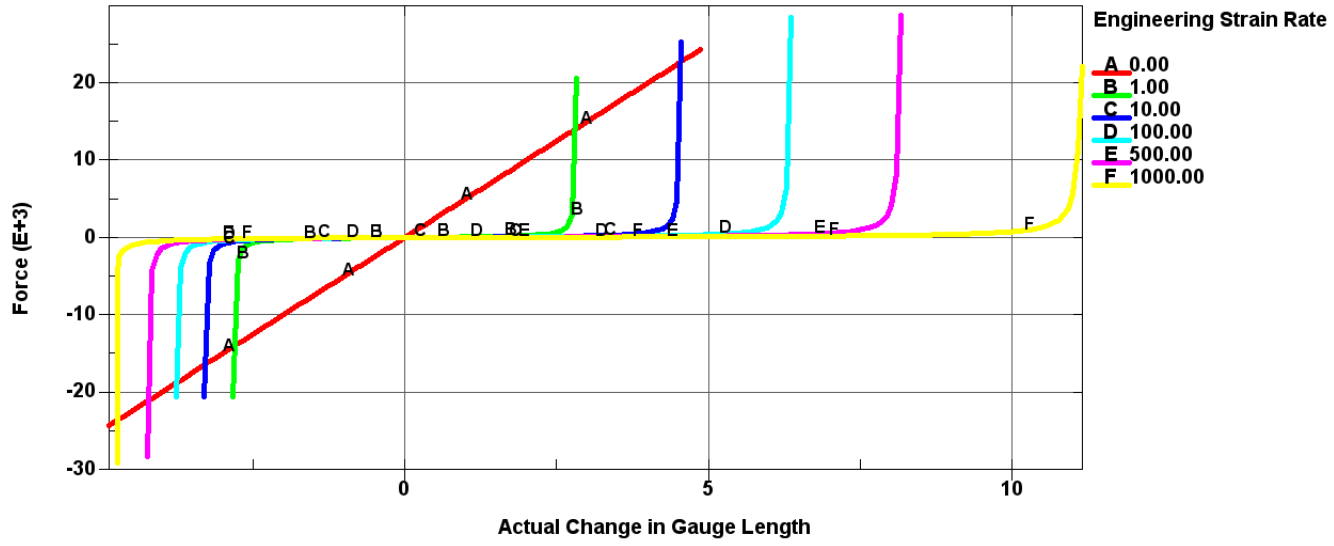

Figure 3: Force versus actual change in gauge length for different engineering strain rates for sub case 2

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).

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 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.

Otherwise the cross cpu architecture consistency test fails.

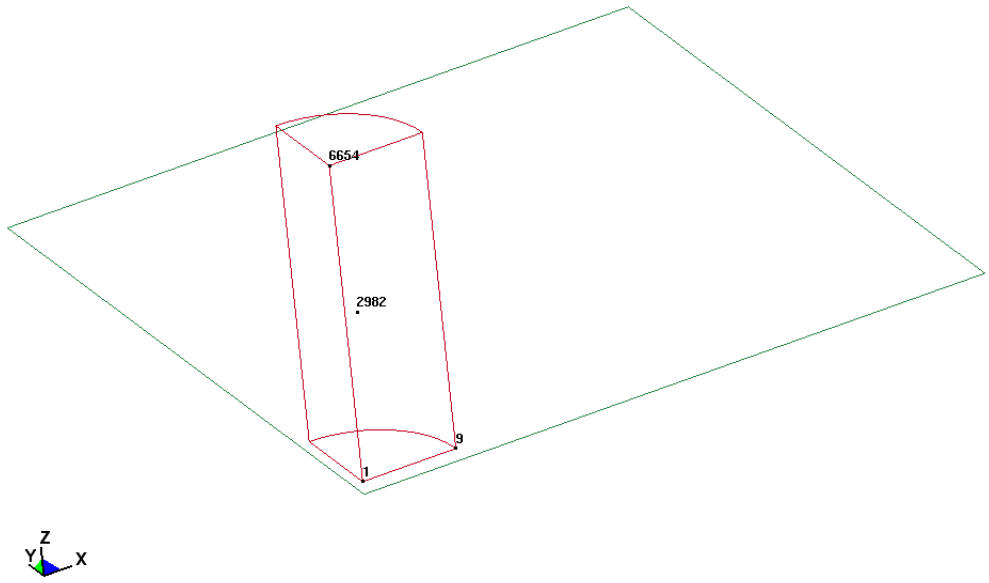

Figure 4: Location of target nodes

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]
sandwich	SUSE LES 11.1	Intel® Xeon® E7- 8837 @ 2.67GHz	Platform MPI 8.2.0.0	4
ham	CentOS 5.4	AMD® Opteron ® 8435 @ 800MHz	Platform MPI 8.1.0.0	4
sgi64e	SUSE LES 9.4 [2]	Intel® Itanium® 2 @ 1.6GHz	SGI MPT 1.13	4

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

[2] SGI PROPACK 4

Table 6: Used Platforms and CPU Type's

Product	Version	Release	Revision	Parallel type [1]	Precision [2]	executable
LS-DYNA®	971	R9.0	108899	SMP	SP	ls971.108899.R9.0
LS-DYNA®	971	R9.0	108899	SMP	DP	ld971.108899.R9.0
LS-DYNA®	971	R9.0	108899	MPP	SP	mpp971.108899.R9.0
LS-DYNA®	971	R9.0	108899	MPP	DP	mpd971.108899.R9.0

[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-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	**PASS**
2	**PASS**

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® R9.0 Revision 108899.

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:
'5-rate-curve-atan-ten-tan-unload2.k: glstat_internal_energy' states that the input deck for sub test case 1 was used to calculate these results. The component displayed is the internal energy derived from the 'glstat' output file.

Legend:
'glstat_internal_energy_sandwich_ls971.108899.R9.0_4' states that the graph shows the internal energy derived from the 'glstat' output file for an input deck which was calculated on the 'sandwich' platform with a LS-DYNA® R9.0 Revision 108899 binary (SMP, single precision) on four processors.

5.3.1 Sub Test Case ID 1 - Test Target 1

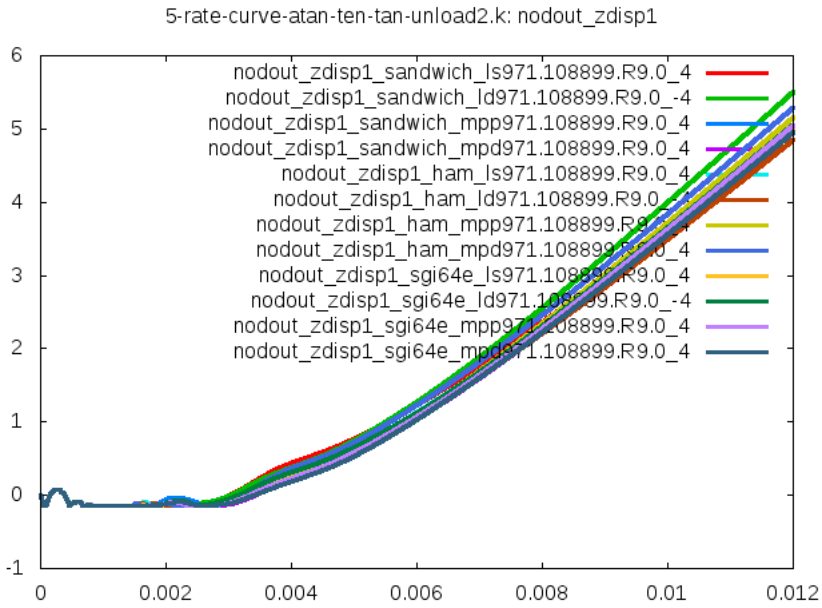

Figure 5: Cross platform results, z-displacement node 1, sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

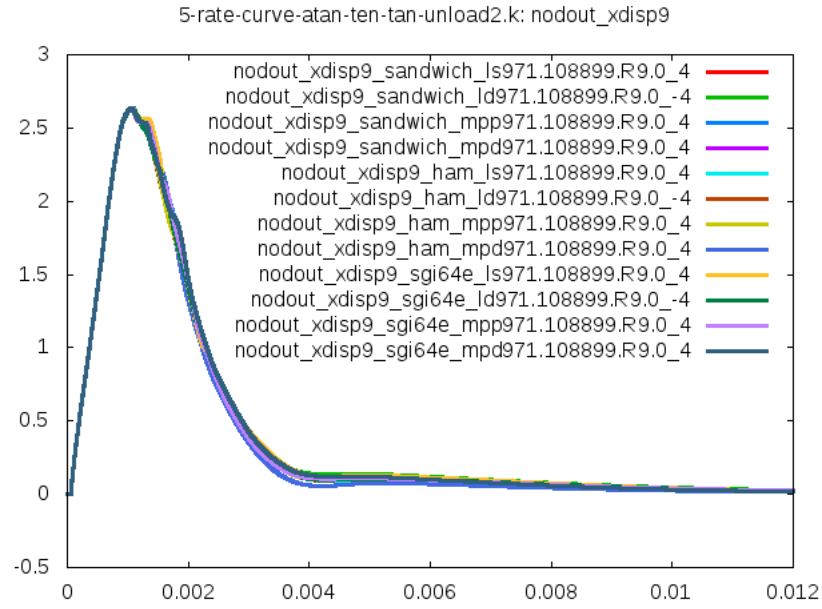

Figure 6: Cross platform results, x-displacement node 9, sub test case ID 1

5.3.3 Sub Test Case ID 1 - Test Target 3

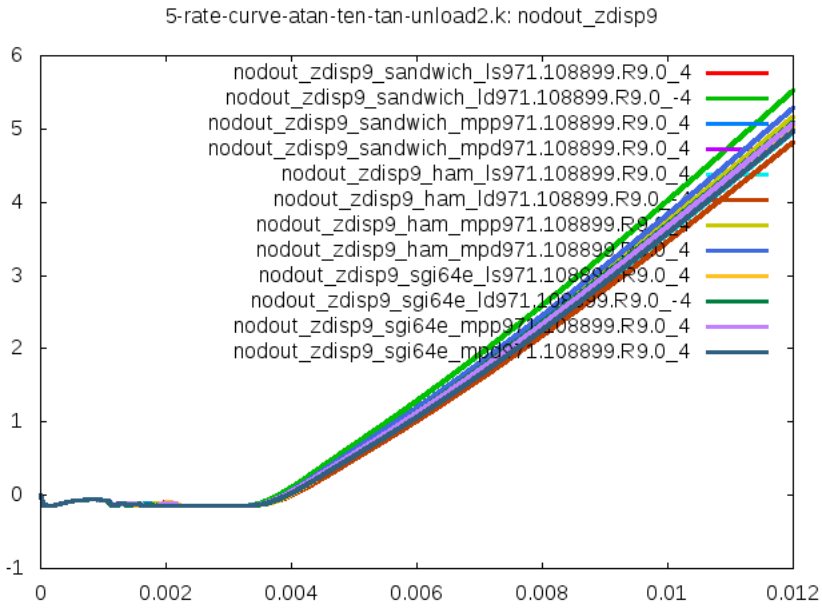

Figure 7: Cross platform results, z-displacement node 9, sub test case ID 1

5.3.4 Sub Test Case ID 1 - Test Target 4

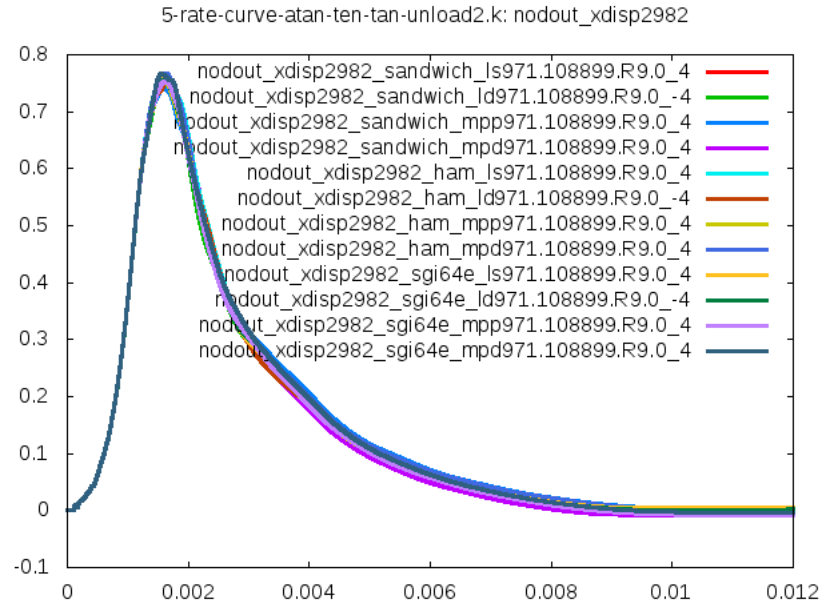

Figure 8: Cross platform results, x-displacement node 2982, sub test case ID 1

5.3.5 Sub Test Case ID 1 - Test Target 5

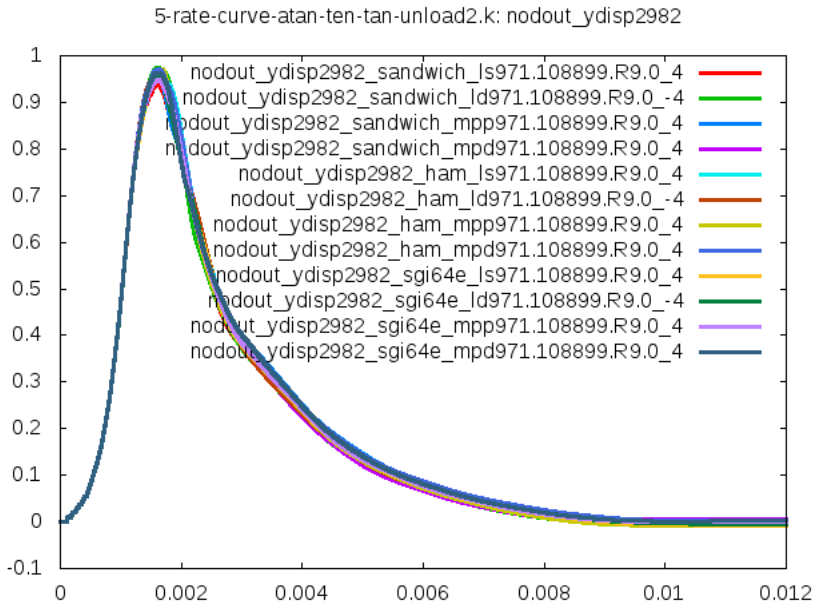

Figure 9: Cross platform results, y-displacement node 2982, sub test case ID 1

5.3.6 Sub Test Case ID 1 - Test Target 6

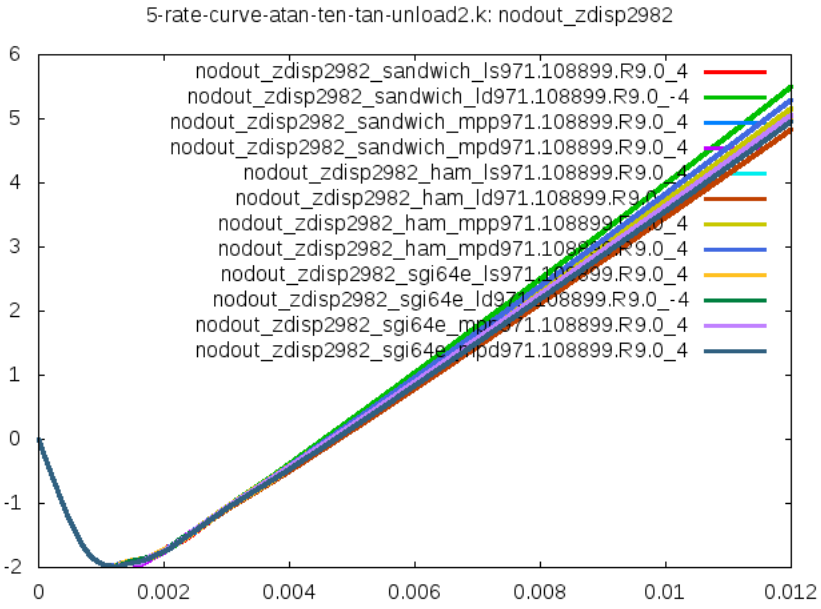

Figure 10: Cross platform results, z-displacement node 2982, sub test case ID 1

5.3.7 Sub Test Case ID 1 - Test Target 7

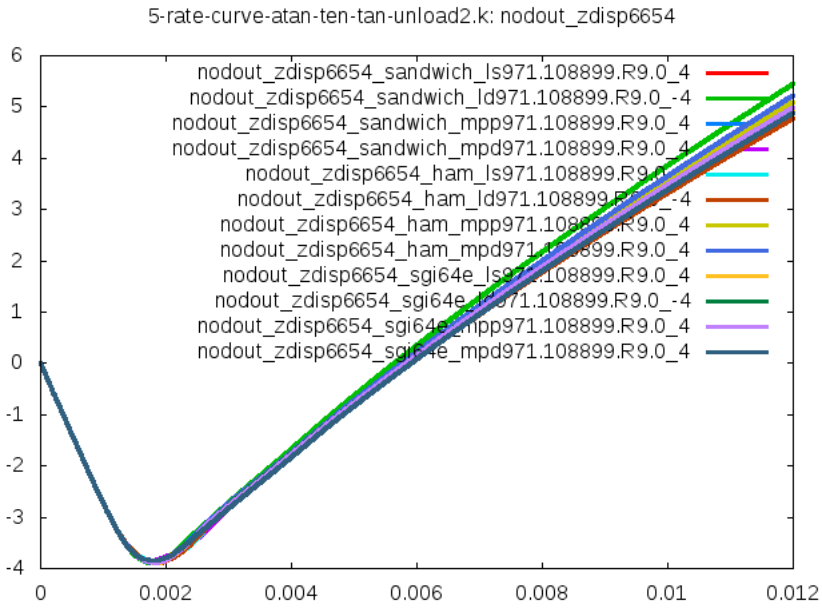

Figure 11: Cross platform results, z-displacement node 6654, sub test case ID 1

5.3.8 Sub Test Case ID 1 - Test Target 8

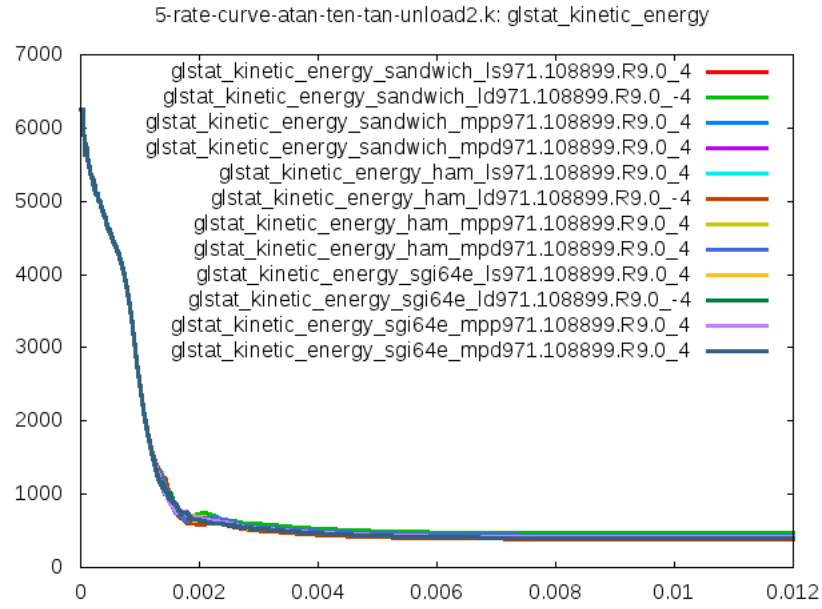

Figure 12: Cross platform results, global kinetic energy, sub test case ID 1

5.3.9 Sub Test Case ID 1 - Test Target 9

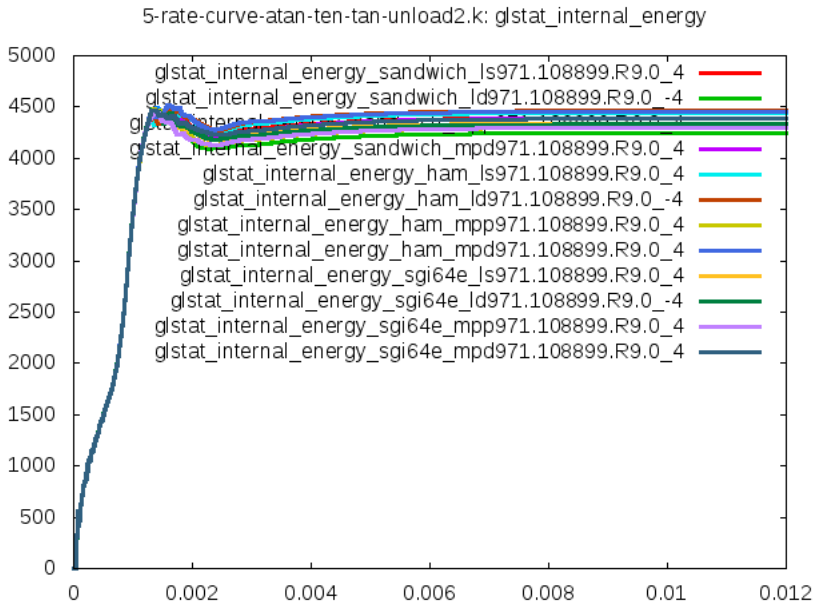

Figure 13: Cross platform results, global internal energy, sub test case ID 1

5.3.10 Sub Test Case ID 1 - Test Target 10

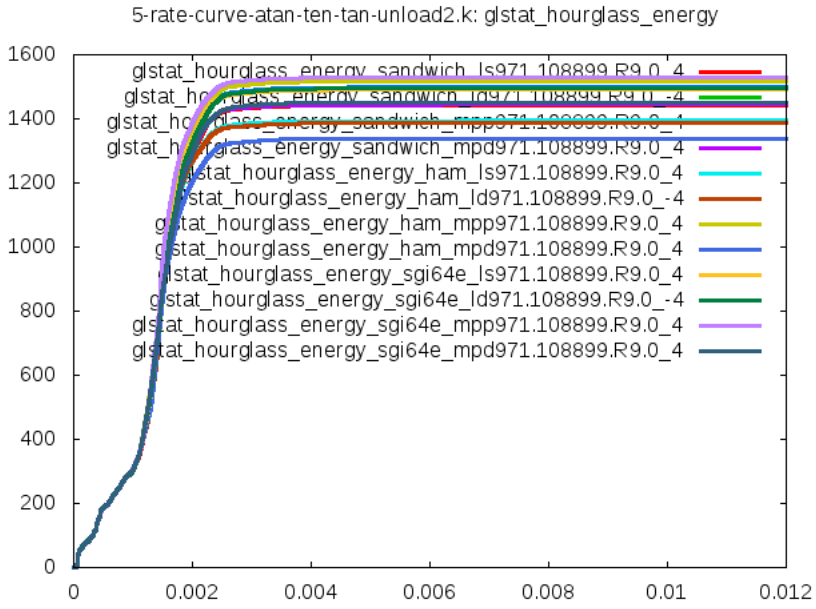

Figure 14: Cross platform results, global hourglass energy, sub test case ID 1

5.3.11 Sub Test Case ID 2 - Test Target 1

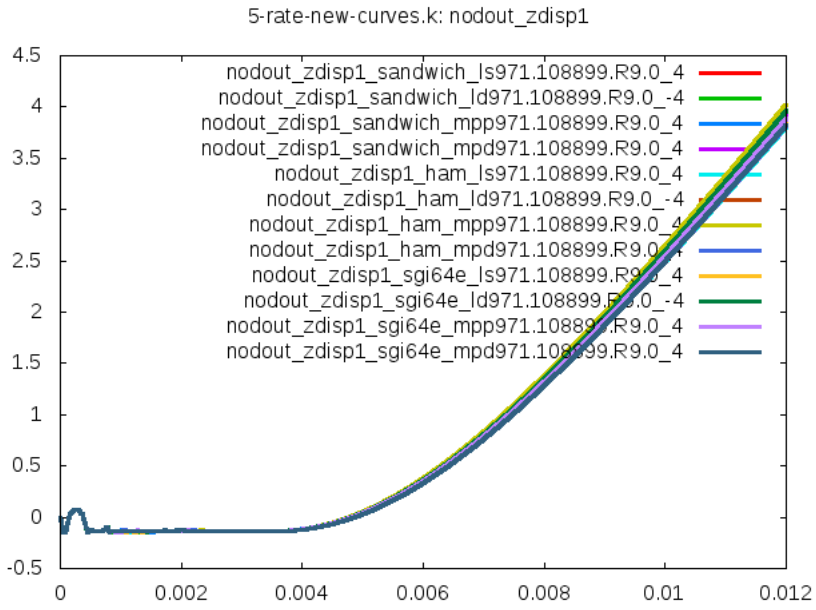

Figure 15: Cross platform results, z-displacement node 1, sub test case ID 2

5.3.12 Sub Test Case ID 2 - Test Target 2

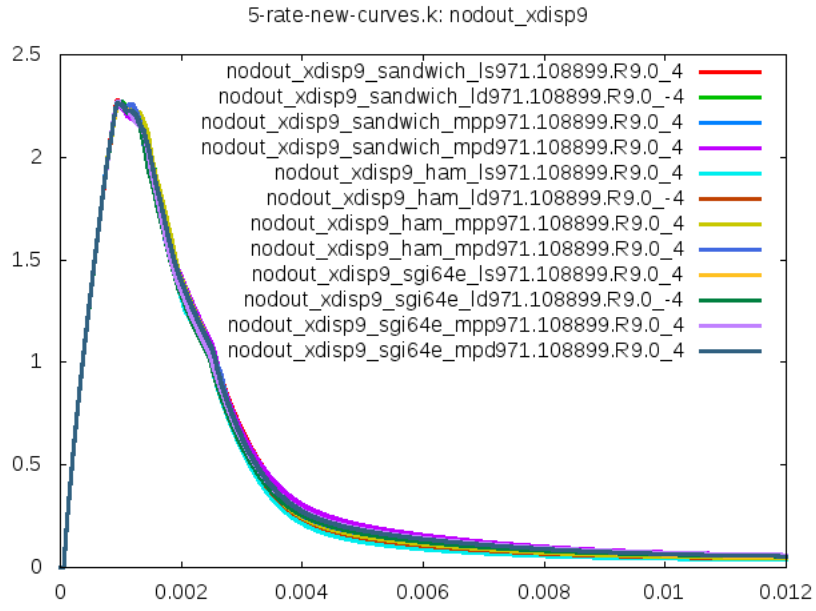

Figure 16: Cross platform results, x-displacement node 9, sub test case ID 2

5.3.13 Sub Test Case ID 2 - Test Target 3

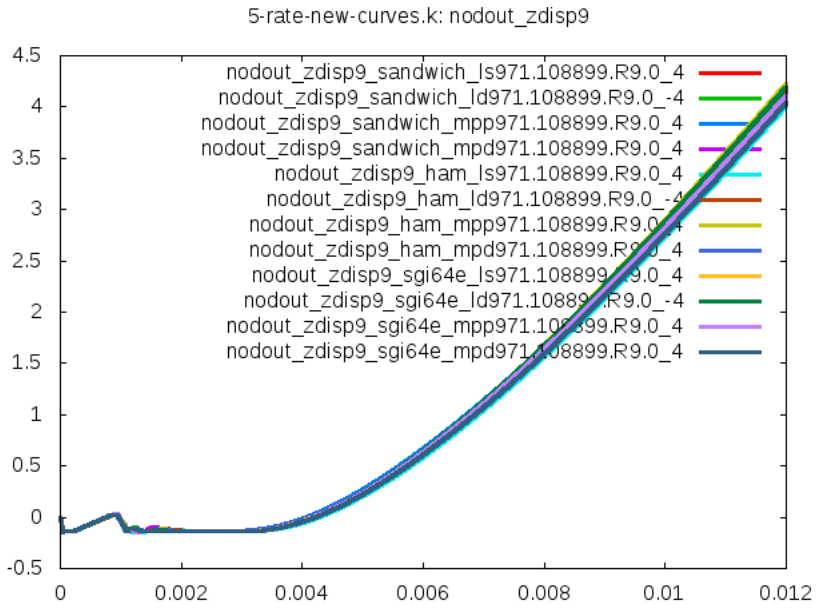

Figure 17: Cross platform results, z-displacement node 9, sub test case ID 2

5.3.14 Sub Test Case ID 2 - Test Target 4

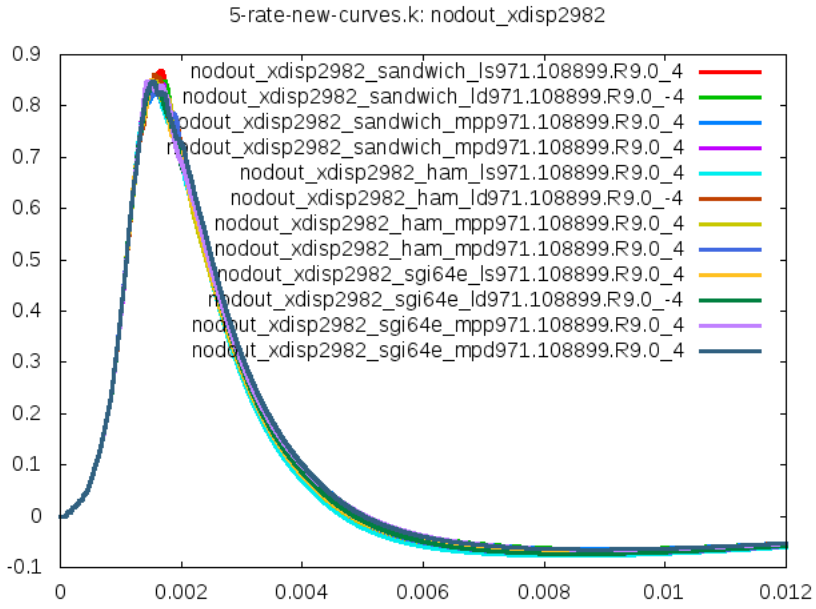

Figure 18: Cross platform results, x-displacement node 2982, sub test case ID 2

5.3.15 Sub Test Case ID 2 - Test Target 5

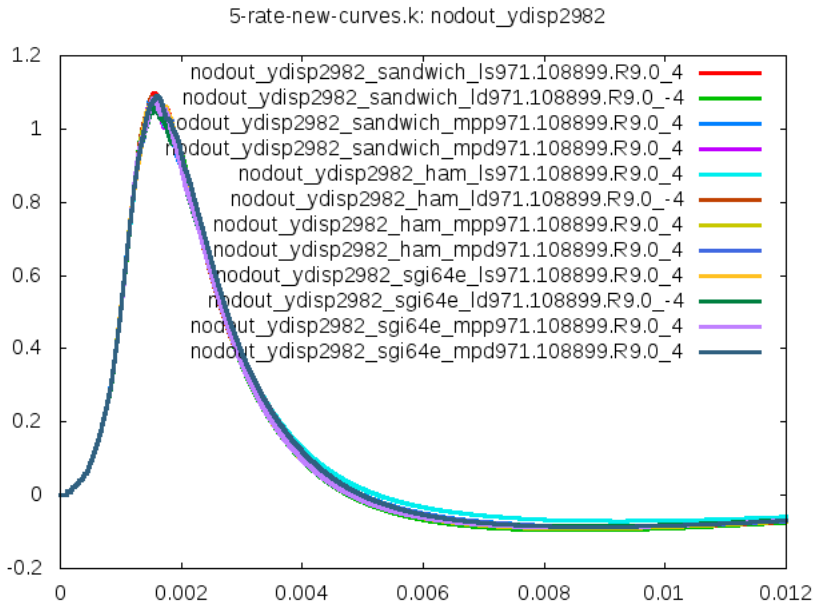

Figure 19: Cross platform results, y-displacement node 2982, sub test case ID 2

5.3.16 Sub Test Case ID 2 - Test Target 6

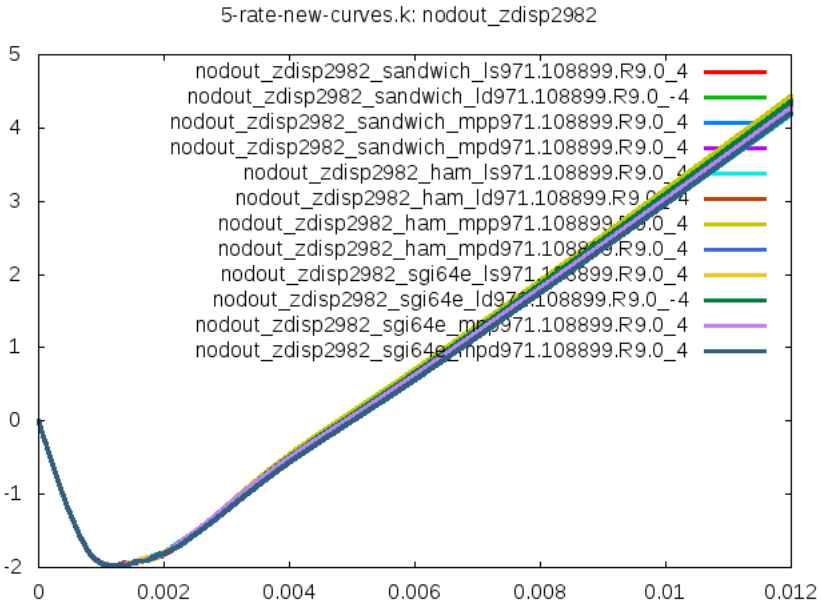

Figure 20: Cross platform results, z-displacement node 2982, sub test case ID 2

5.3.17 Sub Test Case ID 2 - Test Target 7

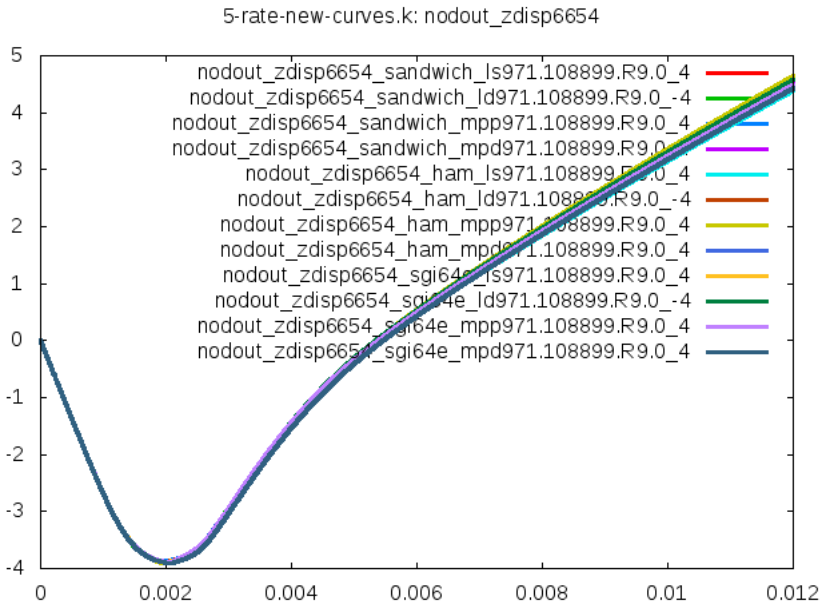

Figure 21: Cross platform results, z-displacement node 6654, sub test case ID 2

5.3.18 Sub Test Case ID 2 - Test Target 8

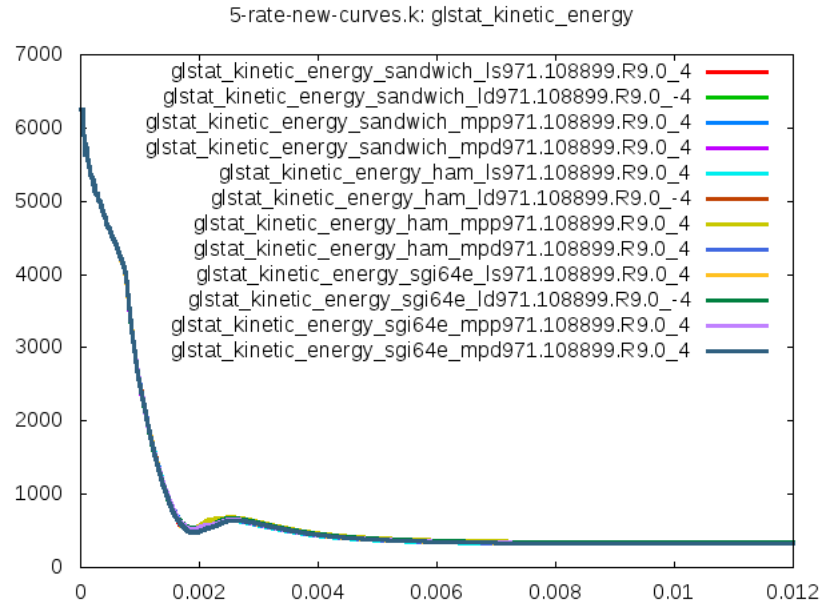

Figure 22: Cross platform results, global kinetic energy, sub test case ID 2

5.3.19 Sub Test Case ID 2 - Test Target 9

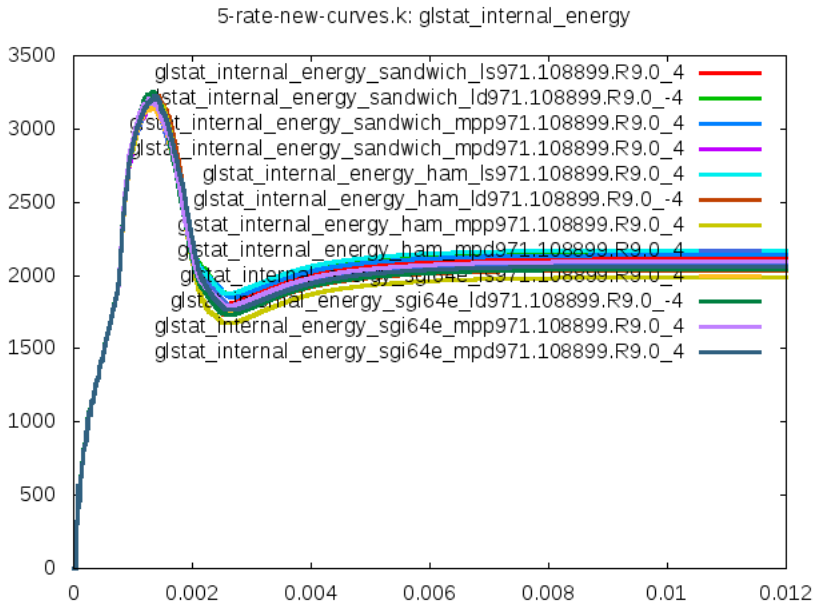

Figure 23: Cross platform results, global internal energy, sub test case ID 2

5.3.20 Sub Test Case ID 2 - Test Target 10

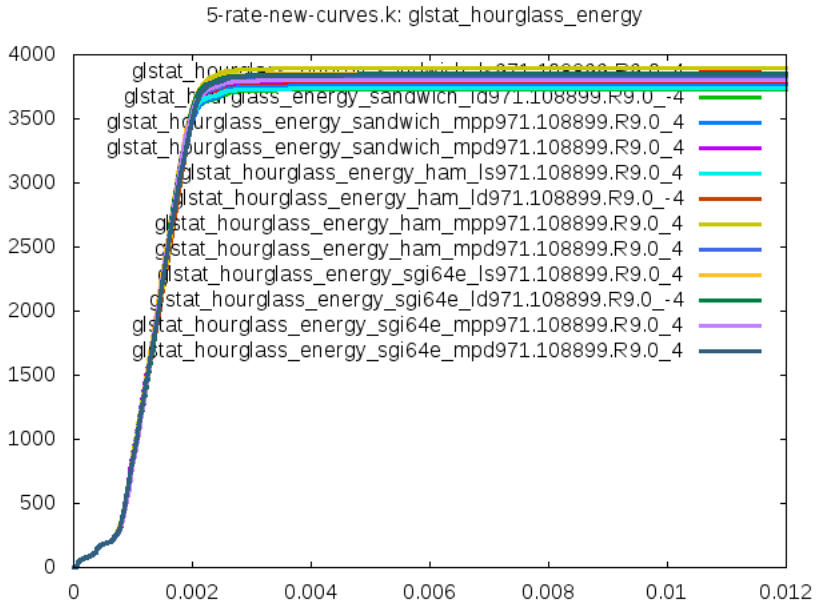

Figure 24: Cross platform results, global hourglass energy, sub test case ID 2

References

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