TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AWG-ERIF-12-15

TEST CASE ID AWG-ERIF-12

Single Rotating Fan Blade

Tested with LS-DYNA® R11.1 Revision 139325

Tuesday 13th August, 2019

LSTC
Livermore Software
Technology Corp.

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1 Introduction

1.1 Purpose of this Document

This document specifies the test case AWG-ERIF-12. 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	Single Rotating Fan Blade
Test Case ID	AWG-ERIF-12
Test Case Status	active
Test Case Classification	Example
Test Case Source	CCSU
Tested Keyword	*CONTROL_DYNAMIC_RELAXATION, *LOAD_BODY_RZ, *CONTROL_ACCURACY
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-12 is the comparison of results from different cpu architectures for a single rotating fan blade. The model demonstrates a stable solution for the rotation of a blade. Specifically, the blade internal and kinetic energy should remain constant as the blade is rotated. An implicit analysis is required first to apply the rotational centrifugal load or preload to the blade. This analysis is followed by an explicit rotation of the blade where the stability of the blade internal and kinetic energies are evaluated. The implicit and explicit analyses are completed in one-step analysis by using the keyword input *CONTROL_DYNAMIC_RELAXATION with IDRFLAG=5.
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 a single blade as shown in Figure 1. The blade has a centrifugal load applied in an implicit solution that is followed by a 360-degree rotation of the blade in an explicit solution.

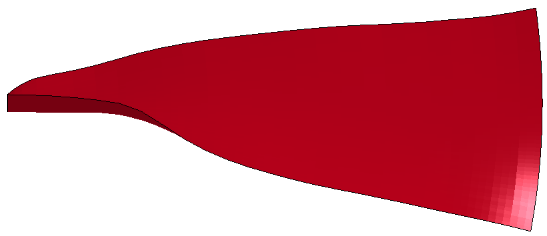

Figure 1: Model sketch: Single fan blade

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

Physical Model Information	
Blade rotational velocity	$617.32 rad/sec = 11,800 rpm (z - axis)$
Blade material	non linear

Table 2: Model set-up data

3.3 Model Description

The model is a single blade consisting of one part. Three different element formulations, solid, shell and thick shell elements, are used for discretization resulting in three Sub Test Cases. The three Sub Test Cases are shown in Figure 2. The number of nodes, elements, and material specifications for the model are provided in Table 3. The blade material is not related to a specific material and can be chosen as appropriate.
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.

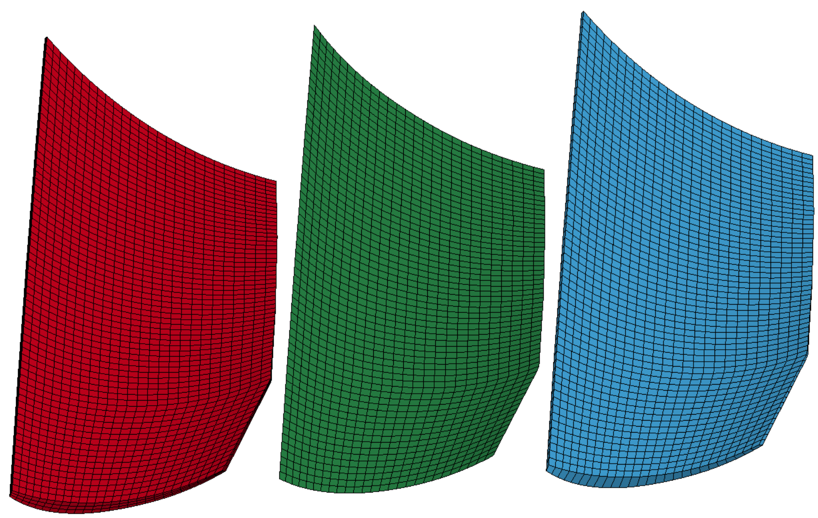

Figure 2: FEA model: Model Sub Test Cases, solid (red), shell (green) and thick shell elements (blue)

FEA Model information			
Sub Test Case ID [1]	1	2	3
Modeling approach	solid elements	shell elements	thick shell elements
Nodes	4234	1647	3294
Elements	4104	1560	1560
Materials	1	1	1
Parts	1	1	1
Blade material	*MAT_JOHNSON_COOK, *EOS_GRUNEISEN		
Rotational velocity	$\omega_z = 617.32 rad/sec = 11,800 rpm$		
Unit system	in (length), sec (time), $lbf \cdot sec^2/in$ (mass), lbf/in^2 (stress), $lbf \cdot in$ (energy)		

[1] Sub Test Case ID refers to the ID's in table 4

Table 3: FEA Model Information

Sub Test Case ID	Input Deck Name
1	single_fan_blade_one_revolution__solid __type_1.k
2	single_fan_blade_one_revolution__shell__type_16.k
3	single_fan_blade_one_revolution__thickshell__type_5.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	matsum	internal energy	1	binout/matsum file
2	matsum	kinetic energy	1	binout/matsum file

Table 5: Test Case targets for Test Case ID AWG-ERIF-12

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-12.

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:

$$bound_{up}(t) = max(t) + 0.2 \times [max(t) - min(t)] + 0.05 \times peak$$
$$bound_{low}(t) = min(t) - 0.2 \times [max(t) - min(t)] - 0.05 \times peak$$
$$bound^{a}_{up}(t) = bound_{up}(t) + (limit_{up} - peak1)$$
$$bound^{a}_{low}(t) = bound_{low}(t) + (limit_{low} - peak2)$$

  where $max(t)$, $min(t)$ are the maximum and minimum values at the time point t 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, $bound_{up}(t)$ and $bound_{low}(t)$ are the upper and lower bounds before adjustment, $peak1$ and $peak2$ are the maximum value of $bound_{up}(t)$ and the minimum value of $bound_{low}(t)$ across the whole time domain respectively, $limit_{up}$ and $limit_{low}$ are given limits the test case target should not exceed, and $bound^{a}_{up}(t)$ and $bound^{a}_{low}(t)$ are the adjusted upper and lower bounds based on $limit_{up}$ and $limit_{low}$.

  - Sub Test Case 1
    - For test case target 1, $limit_{up} = 63.9633$, $limit_{low} = 62.6967$. This is a 1% tolerance interval of the initial internal energy of 63.33 $lbf \cdot in$.
    - For test case target 2, $limit_{up} = 126826$, $limit_{low} = 124314$. This is a 1% tolerance interval of the initial kinetic energy of 125570 $lbf \cdot in$.
  - Sub Test Case 2
    - For test case target 1, $limit_{up} = 65.7909$, $limit_{low} = 63.2109$. This is a 2% tolerance interval of the initial internal energy of 64.51 $lbf \cdot in$.
    - For test case target 2, $limit_{up} = 126523$, $limit_{low} = 124017$. This is a 2% tolerance interval of the initial kinetic energy of 125270 $lbf \cdot in$.
  - Sub Test Case 3
    - For test case target 1, $limit_{up} = 64.0643$, $limit_{low} = 62.7957$. This is a 1% tolerance interval of the initial internal energy of 63,43 $lbf \cdot in$.
    - For test case target 2, $limit_{up} = 126785$, $limit_{low} = 124274$. This is a 1% tolerance interval of the initial kinetic energy of 125530 $lbf \cdot in$.

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

[1] 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 [1]	Precision [2]	executable
LS-DYNA®	971	R11.1	139325	SMP	DP	ld971.139325.R11.1
LS-DYNA®	971	R11.1	139325	MPP	DP	mpd971.139325.R11.1

[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-12 completed with all combinations of software and hardware defined in section 5.1 (3 * 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	**PASS**
2	**PASS**
3	**PASS**

Table 8: Results summary for Test Case ID AWG-ERIF-12

5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-ERIF-12 for LS-DYNA® R11.1 Revision 139325.

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_12: single_fan_blade_one_revolution__solid__type_1.k' states the test case ID 12 and name of the input deck for sub test case 1.

Legend:
'glstat_internal_energy,ham,ls971.139325.R11.1,4' 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® R11.1 Revision 139325 binary (SMP, single precision) on four processors.

5.3.1 Sub Test Case ID 1 - Test Target 1

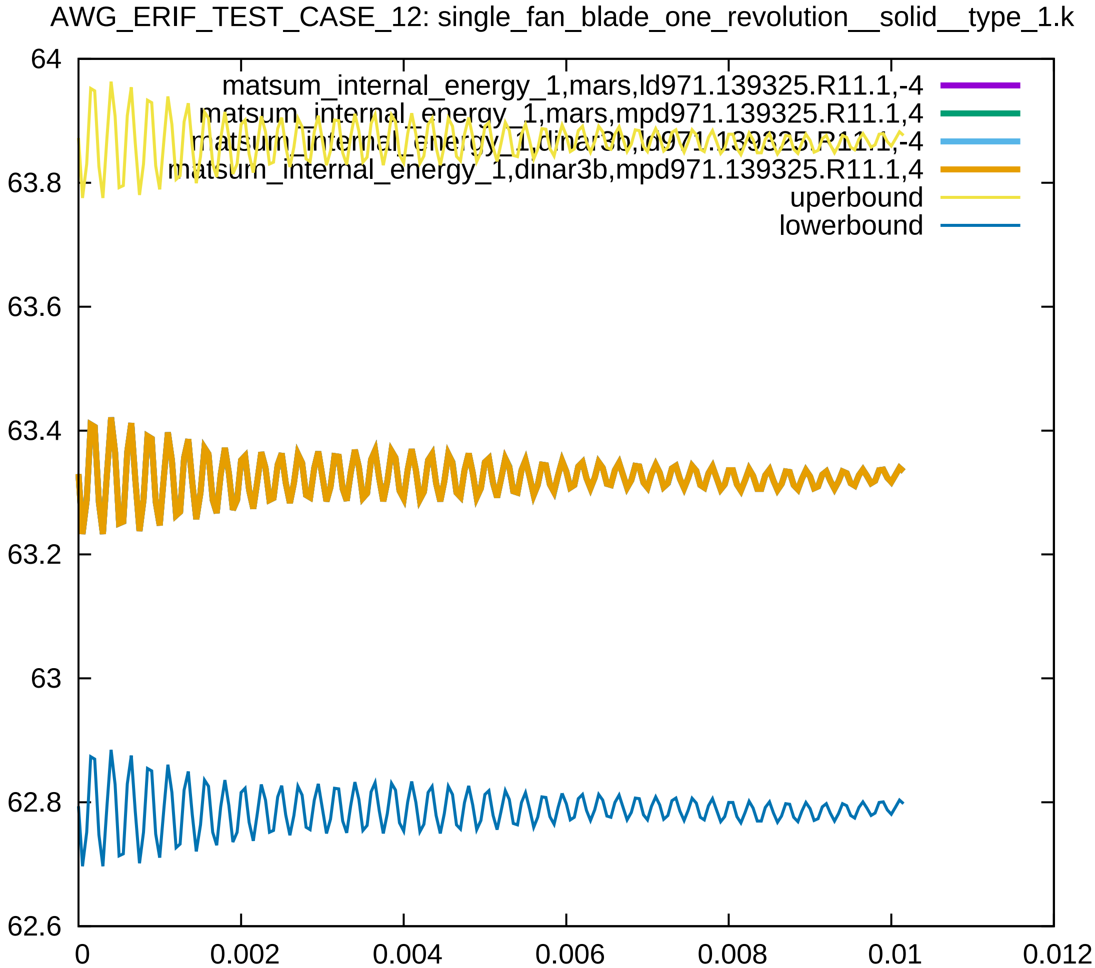

Figure 3: Cross platform results, internal energy part 1, sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

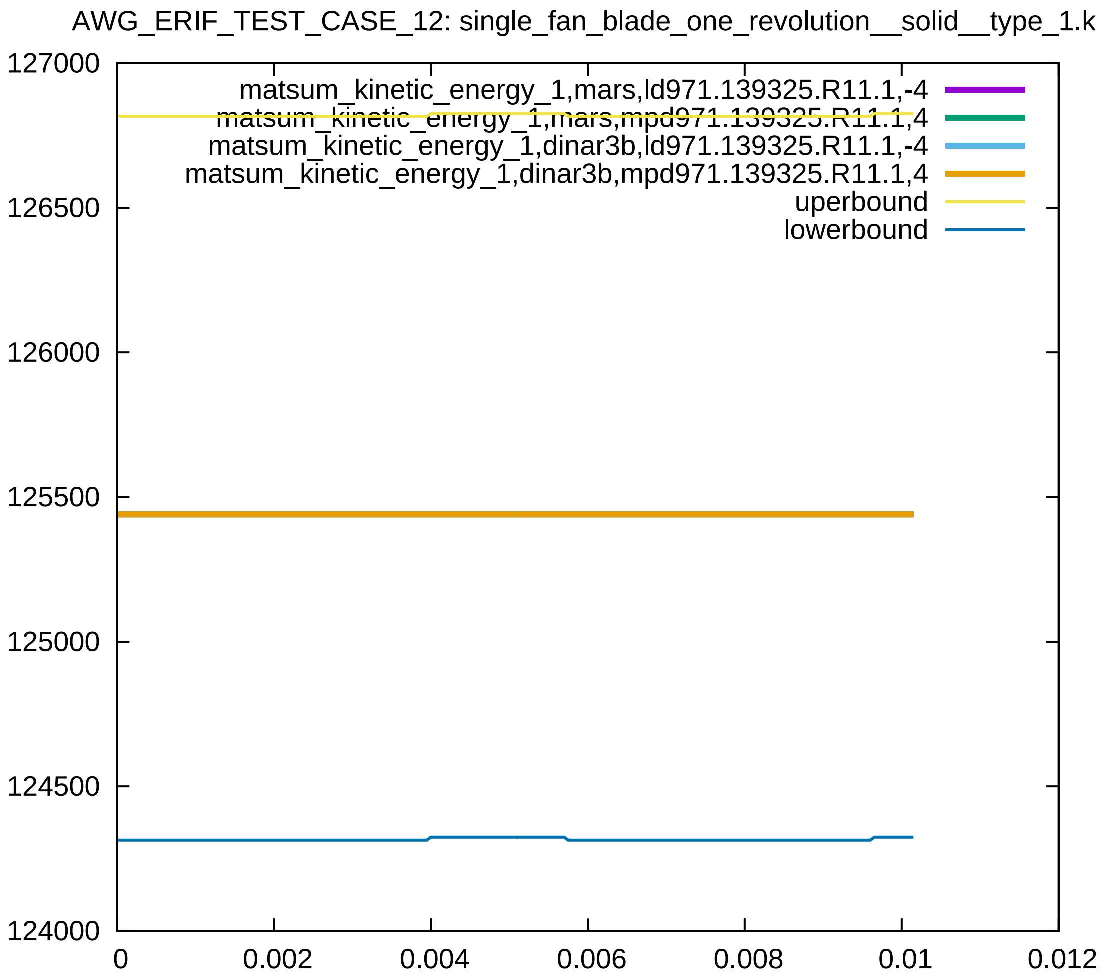

Figure 4: Cross platform results, kinetic energy part 1, sub test case ID 1

5.3.3 Sub Test Case ID 2 - Test Target 1

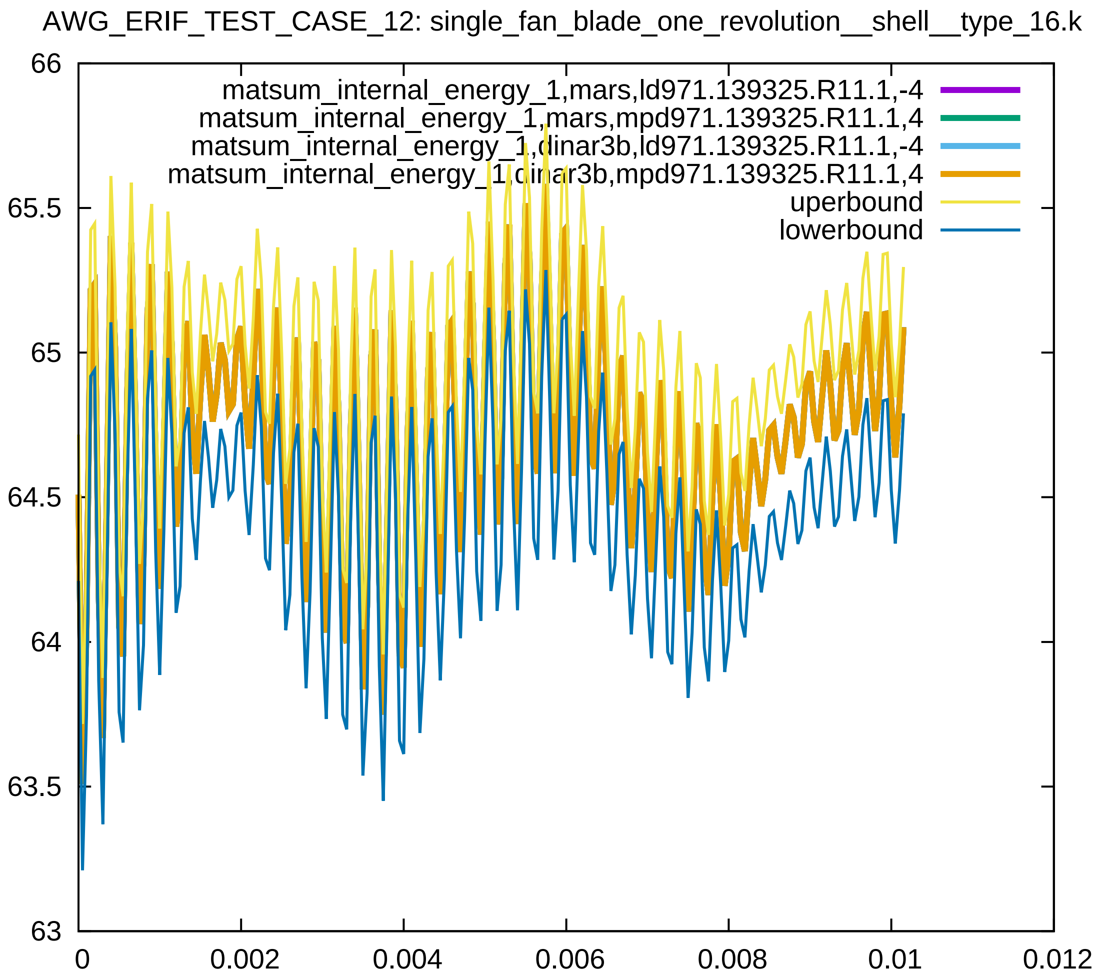

Figure 5: Cross platform results, internal energy part 1, sub test case ID 2

5.3.4 Sub Test Case ID 2 - Test Target 2

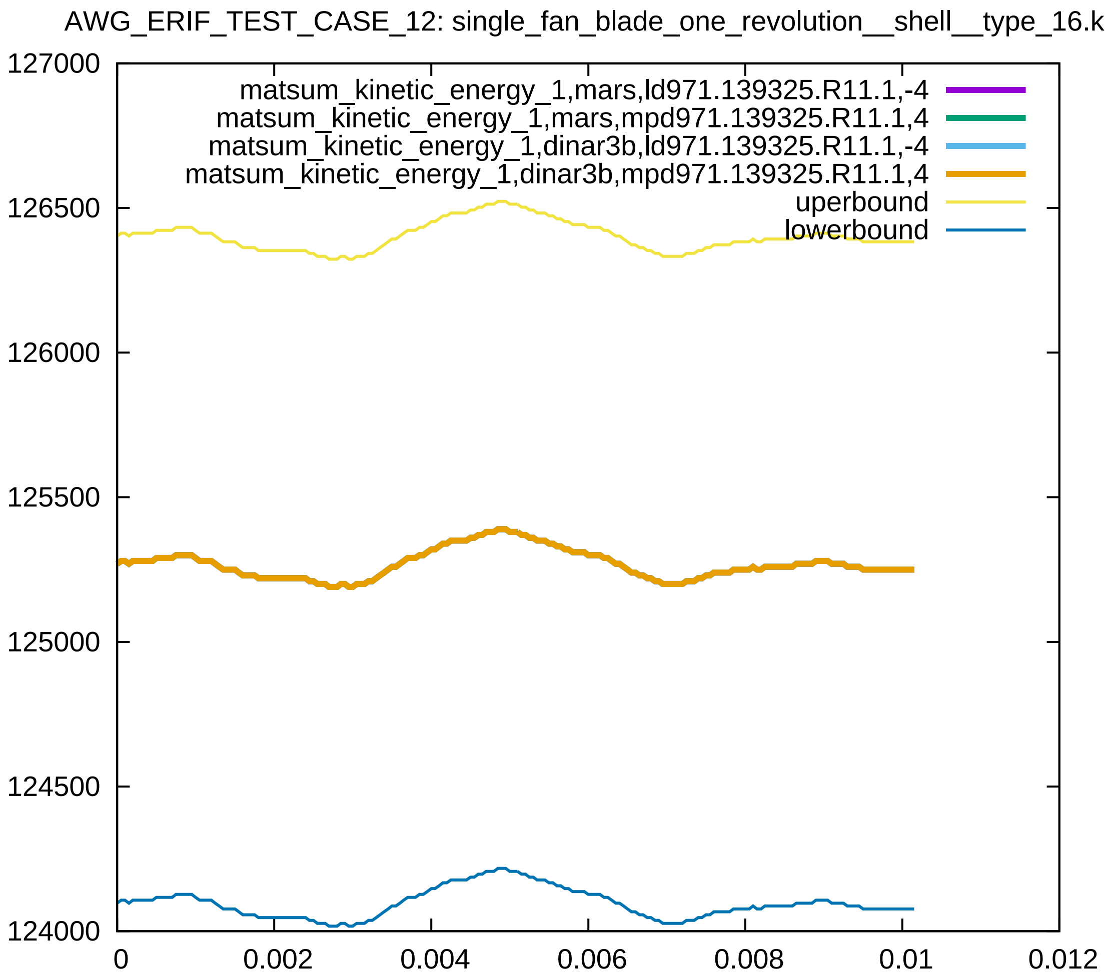

Figure 6: Cross platform results, kinetic energy part 1, sub test case ID 2

5.3.5 Sub Test Case ID 3 - Test Target 1

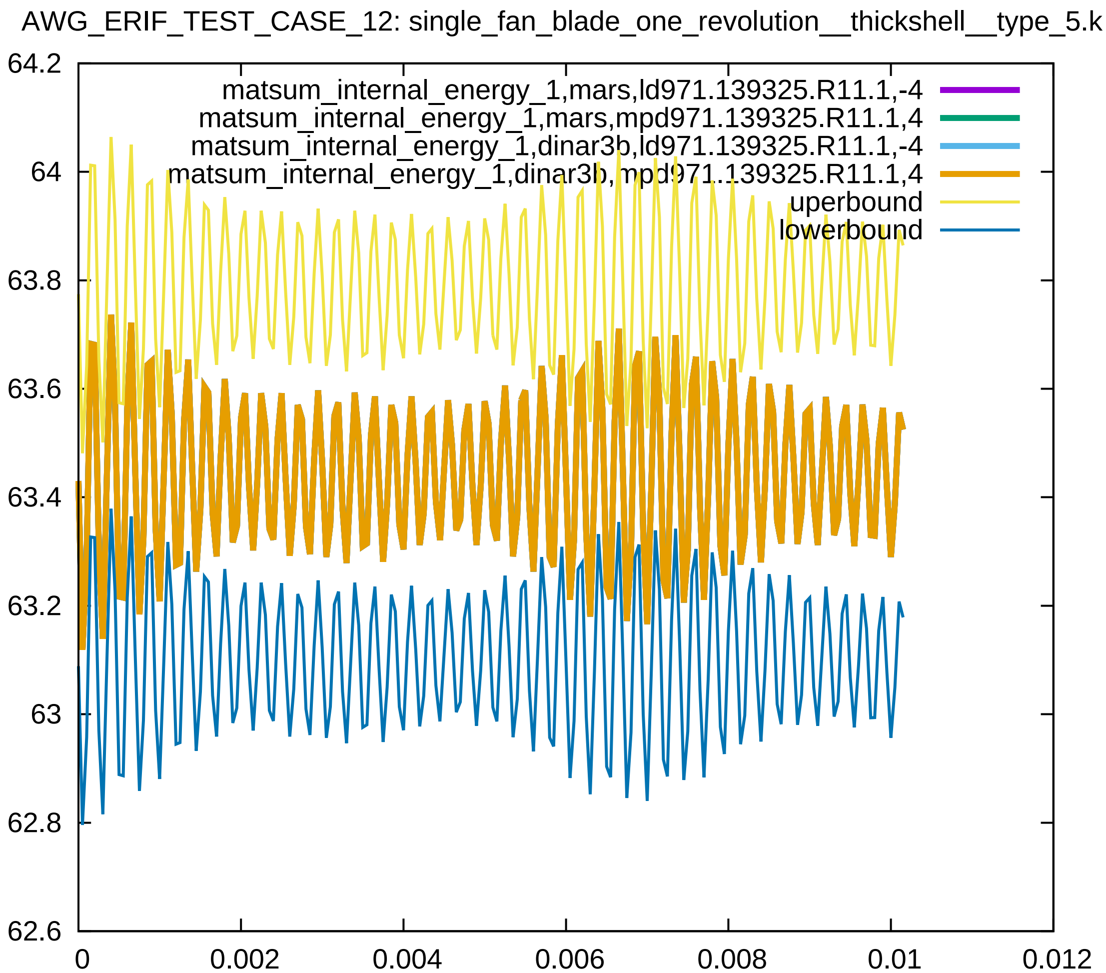

Figure 7: Cross platform results, internal energy part 1, sub test case ID 3

5.3.6 Sub Test Case ID 3 - Test Target 2

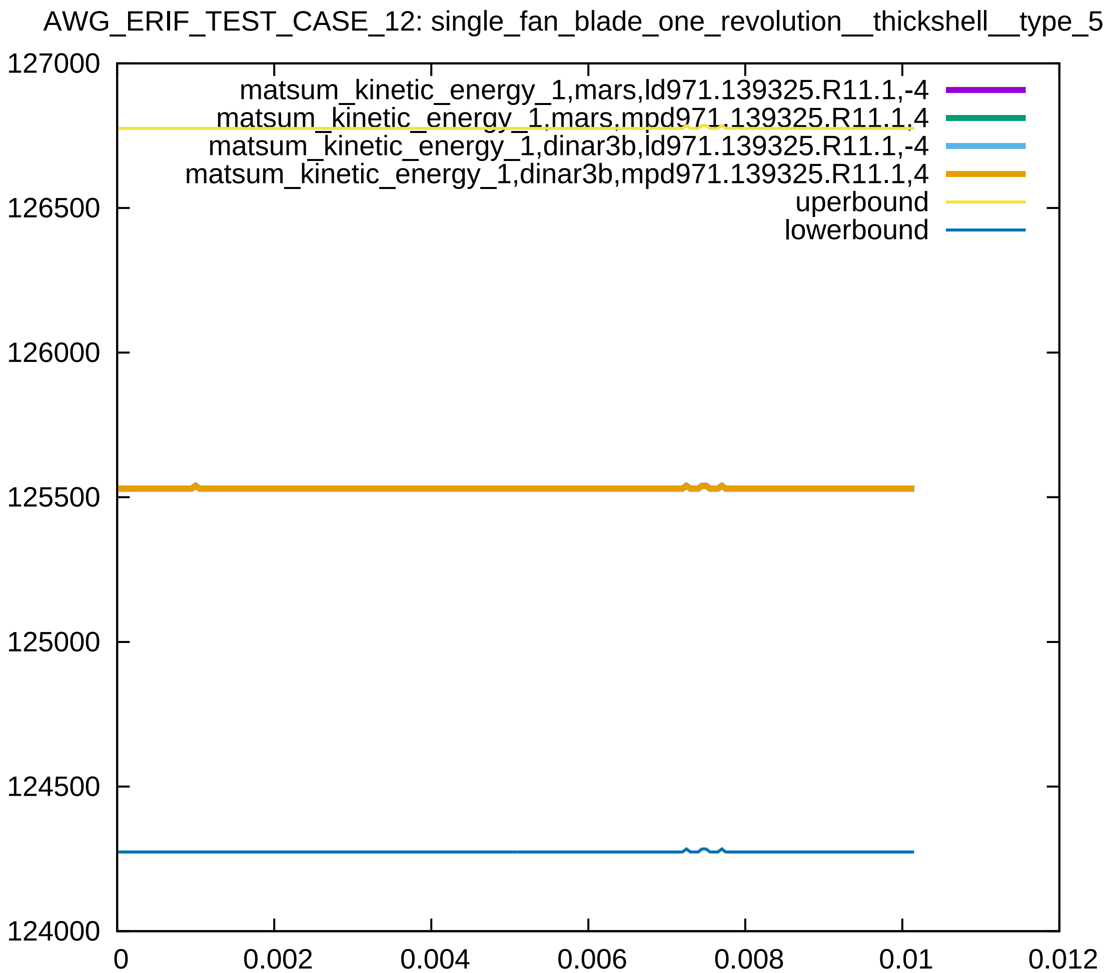

Figure 8: Cross platform results, kinetic energy part 1, sub test case ID 3

References

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