TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AWG-ERIF-5-17

TEST CASE ID AWG-ERIF-5

Bird Strike on Rigid Plate

Tested with LS-DYNA® R12.0 Revision 148708

Friday 11th December, 2020

LSTC
Livermore Software Technology Corp.

Warranty Disclaimer:

The test case(s) described herein are for illustrative purposes only. LSTC does not warrant that a user of these or other LS-DYNA features will experience the same or similar results or that a feature will meet the user's particular requirements or operate error free. FURTHERMORE, THERE ARE NO WARRANTIES, EITHER EXPRESS OR IMPLIED, ORAL OR WRITTEN, WITH RESPECT TO THE DOCUMENTATION AND SOFTWARE DESCRIBED HEREIN INCLUDING, BUT NOT LIMITED TO ANY IMPLIED WARRANTIES (i) OF MERCHANTABILITY, OR (ii) FITNESS FOR A PARTICULAR PURPOSES, OR (iii) ARISING FROM COURSE OF PERFORMANCE OR DEALING, OR FROM USAGE OF TRADE OR. THE REMEDIES SET FORTH HEREIN ARE EXCLUSIVE AND IN LIEU OF ALL OTHER REMEDIES FOR BREACH OF WARRANTY.

Document Information	
Confidentiality	**external use**
Document Identifier	LSTC-QA-LS-DYNA-AWG-ERIF-5-17
Author(s)	Prepared by LS-DYNA® Aerospace Working Group
Number of pages	24
Date created	Friday 11th December, 2020
Distribution	LS-DYNA® Aerospace Working Group / internal LSTC QA

Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case AWG-ERIF-5. 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	Bird Strike on Rigid Plate
Test Case ID	AWG-ERIF-5
Test Case Status	active
Test Case Classification	Example
Test Case Source	LS-DYNA Aerospace Working Group
Tested Keyword	*MAT_009 (MAT_NULL)
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-5 is the comparison of results from different modelling approaches for a bird strike analysis. The consistency of the modelling approaches, as well as the cross cpu architecture consistency of LS-DYNA® for this impact simulation is evaluated by performing calculations of three sub test cases with different modelling approaches for the bird (see table 4).

3.2 Test Case Description

This Test Case contains a bird strike analysis (see figure 1) using a simplified ellipsoidal geometry for the bird impacting a rigid plate.

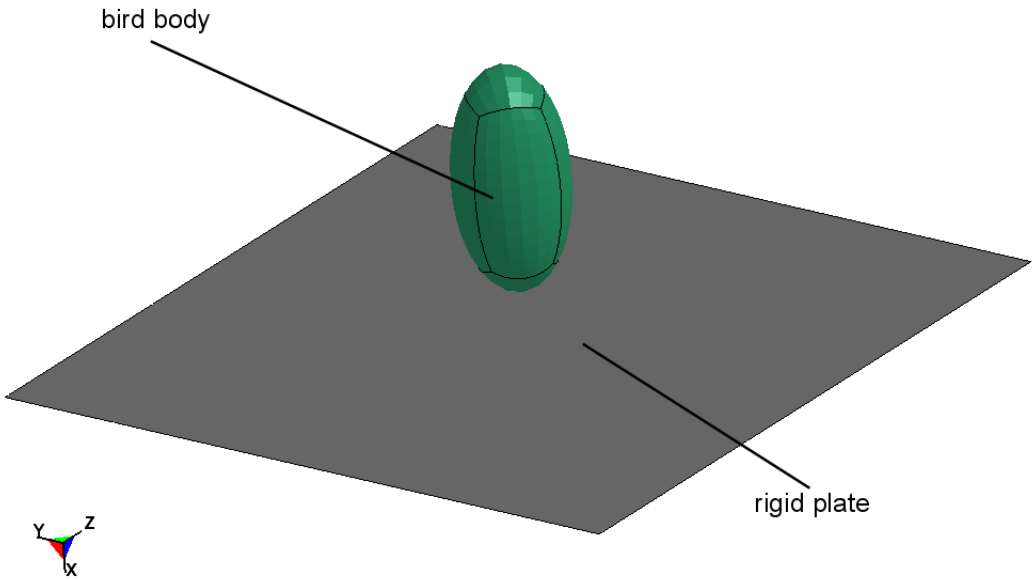

Figure 1: Model sketch: Simplified bird geometry impacting a rigid plate

A summary of the model set-up can be found in table 2.

Physical Model Information	
plate geometry	30”x30”
plate material	rigid
bird geometry	Ellipsoid, polar radius = 10” , equatorial radii = 5”
bird material	unknown
bird velocity	v_x = 4200 in/s

Table 2: Model set-up data

3.3 Model Description

Three sub test cases are defined here that use different model approaches for the numerical representation of the bird (see table 4). The first one is a Lagrangian approach which discretizes the bird geometry via solid elements, see figure 2. The second sub test case is an Arbitrary-Lagrangian-Eulerian (ALE) approach which represents the bird and the air by a volume fraction distribution in an ALE computational domain discretized by solid elements, see figure 3. The third sub test case is a Smooth Particle Hydrodynamics (SPH) approach which represents the bird material by SPH particles, see figure 4. The fourth sub test case is a Structured ALE (S-ALE) approach, the result is almost identical to ALE with a shorter calculation time. The fifth sub test case is S-ALE plus trimming ALE elements far away from the point of interest to save calculation time even more. The result, for example, impulse, remains the same as ALE approach. Additional information on the models can be found in table 3.

FEA Model information					
Sub Test Case ID [1]	1	2	3	4	5
Modelling approach	Lagrangian	ALE	SPH	S-ALE	S-ALE trim
Nodes	15278	115652	42289	115652	64740
Solid elements	432	84800	-	84800	43652
Solid materials	1	1	-	1	1
Shell elements	14400	16230	14400	16230	16230
Shell materials	1	2	1	2	2
SPH nodes	-	-	27648	-	-
SPH materials	-	-	1	-	-
Parts	2	3	2	3	3
Plate geometry	30”x30”				
Plate material	*MAT_RIGID				
Bird geometry	Ellipsoid, major axis = 10” , minor axis = 5”				
Bird velocity	v_x = 4200 in/s				
Bird material	*MAT_NULL				
Units	in (length), s (time), lbf-s^2/in (mass), psi (stress), lbf-in (energy)				

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

Table 3: FEA Model Information

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

Sub Test ID	Modelling Approach	Input Deck Name
1	Lagrangian, see figure 2	flat_rigid_plate_lagrangian_bird_strike_1.1.k
2	Arbitrary-Lagrangian-Eulerian (ALE), see figure 3	flat_rigid_plate_ALE_bird_strike_1.2.k
3	Smooth Particle Hydrodynamics (SPH), see figure 4	flat_rigid_plate_sph_bird_strike_1.0.k
4	Structured Arbitrary-Lagrangian-Eulerian (S-ALE)	flat_rigid_plate_SALE_bird_strike_1.4.k
5	S-ALE plus trimming	flat_rigid_plate_SALE_bird_strike_1.5.k

Table 4: Specification of sub test cases

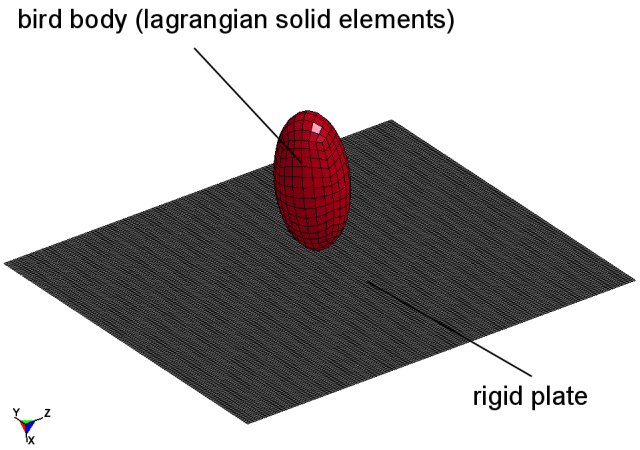

Figure 2: FEA model: Sub Test Case 1 - Lagrangian approach

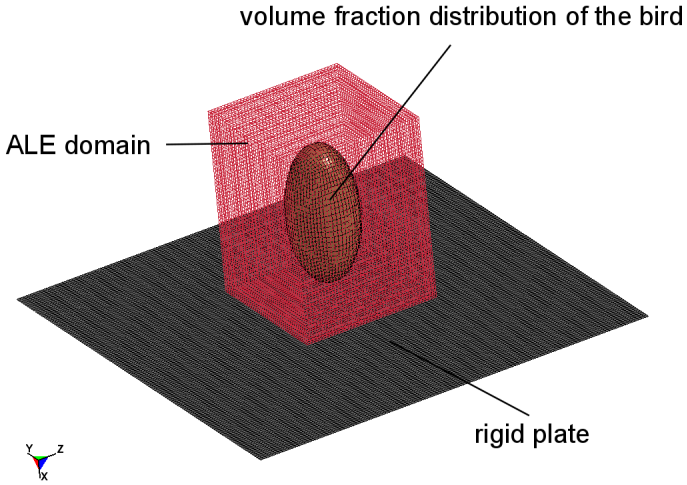

Figure 3: FEA model: Sub Test Case 2 - ALE approach

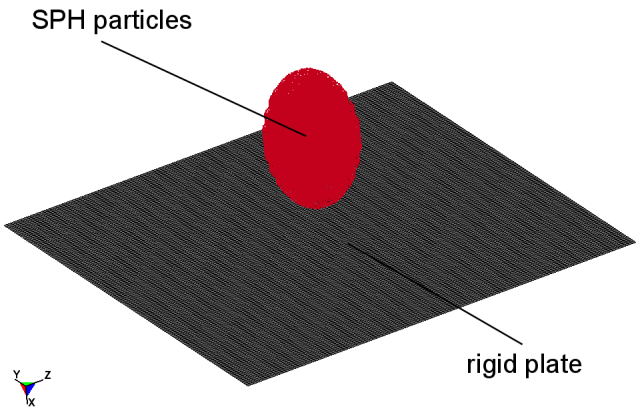

Figure 4: FEA model: Sub Test Case 3 - SPH approach

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[1]	2[1]	3[1]	4[1]	5[1]	
1	kinetic energy	part	10	910004	11	910002	910002	binout/matsum file
2	internal energy	part	10	910004	11	910002	910002	binout/matsum file
3	resultant interface forces	master x	1	-	1	-	-	binout/rcforc file
4	fluid-structure interaction data	fx	-	200002	-	200002	200002	binout/dbfsi file

[1] This ID referes to the sub test case ID, see table 4.

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

The targets 1 and 2 are used to evaluate the cross cpu architecture consistency of the different sub test cases and targets 3 and 4 to evaluate the impulse consistency of the different sub test cases (see section 4.2). The bird is represented by part 10 in the Lagrangian approach, part 910004 in the ALE approach, part 11 in the SPH approach, part 910002 in the S-ALE approach, and part 910002 in the S-ALE trim approach.

4.2 Pass/Fail Criteria

These are the Pass/Fail criteria used for the cross cpu architecture consistency test for the sub test cases and the impulse consistency test of the Test Case ID AWG-ERIF-5.

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

- The test case target data falls within the corridor bounds.
- For test case target 3 and 4, the maximum distance between an x-y pair of a slope of the averaged impulse of all cpu architecture/software version combination of a sub test case to at least one x-y pair of the averaged impulse of all cpu architecture/software version combinations of the sub text cases is 20% of the maximum slope value. For this criteria only the time interval [0.0 sec : 0.0045 sec] is considered.

Otherwise the consistency tests fail.

The test case corridors are upper and lower bounds for the test case targets. The corridors of the sub test cases 1-3 were defined based on the test target data obtained with LS-DYNA® R10.1 Revision 123136 binaries, and those of the sub test cases 4 and 5 were based on the test target data obtained with LS-DYNA® R11.0 Revision 130010 binaries. The corridors are obtained by the following process:

- For a specific test case target, interpolate the data from different platform and executable (R10.1 Revision 123136, or R11.0 Revision 130010) 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 (R10.1 Revision 123136, or R11.0 Revision 130010) 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 [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	R12.0	148708	SMP	SP	ls971.148708.R12.0
LS-DYNA®	971	R12.0	148708	SMP	DP	ld971.148708.R12.0
LS-DYNA®	971	R12.0	148708	MPP	SP	mpp971.148708.R12.0
LS-DYNA®	971	R12.0	148708	MPP	DP	mpd971.148708.R12.0

[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-5 completed with all combinations of software and hardware defined in section 5.1 (5 * 2 * 4 total calculation runs).

Details on the test results can be found in the section 5.3.

The table 8 cross cpu architecture consistency and impulse 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**
4	**PASS**
5	**PASS**

Table 8: Test results summary for Test Case ID AWG-ERIF-5

5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-ERIF-5 for LS-DYNA® R12.0 Revision 148708.

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_5: flat_rigid_plate_sph_bird_strike_1.0.k' states the test case ID 5 and name of the input deck for sub test case 3.

Legend:

'glstat_internal_energy,ham,ls971.148708.R12.0,4' states that the graph shows the internal energy derived from the 'glstat' output file for an input deck which was calculated on the 'ham' platform with a LS-DYNA® R12.0 Revision 148708 binary (SMP, single precision) on four processors.

5.3.1 Sub Test Case ID 1 - Test Target 1

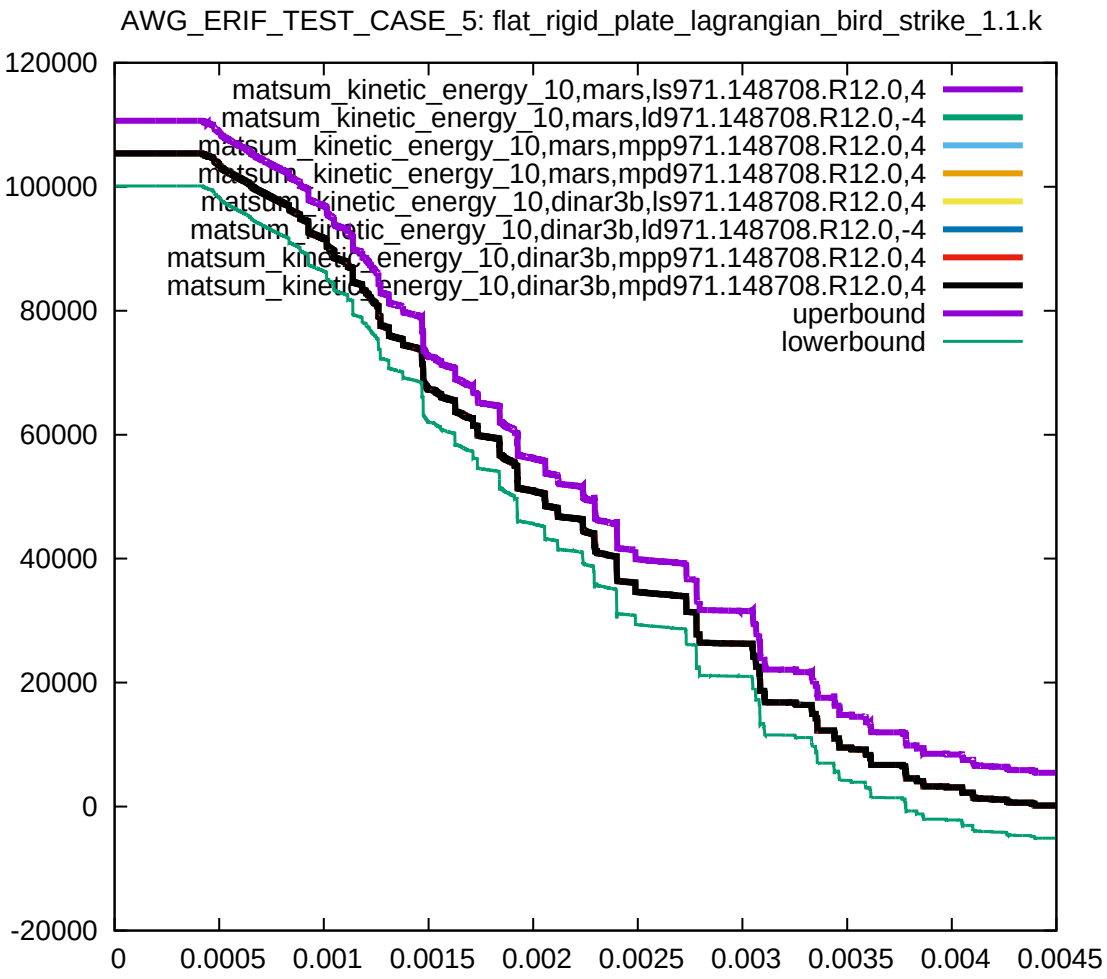

Figure 5: Cross platform results, kinetic energy part 10 (bird body), sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

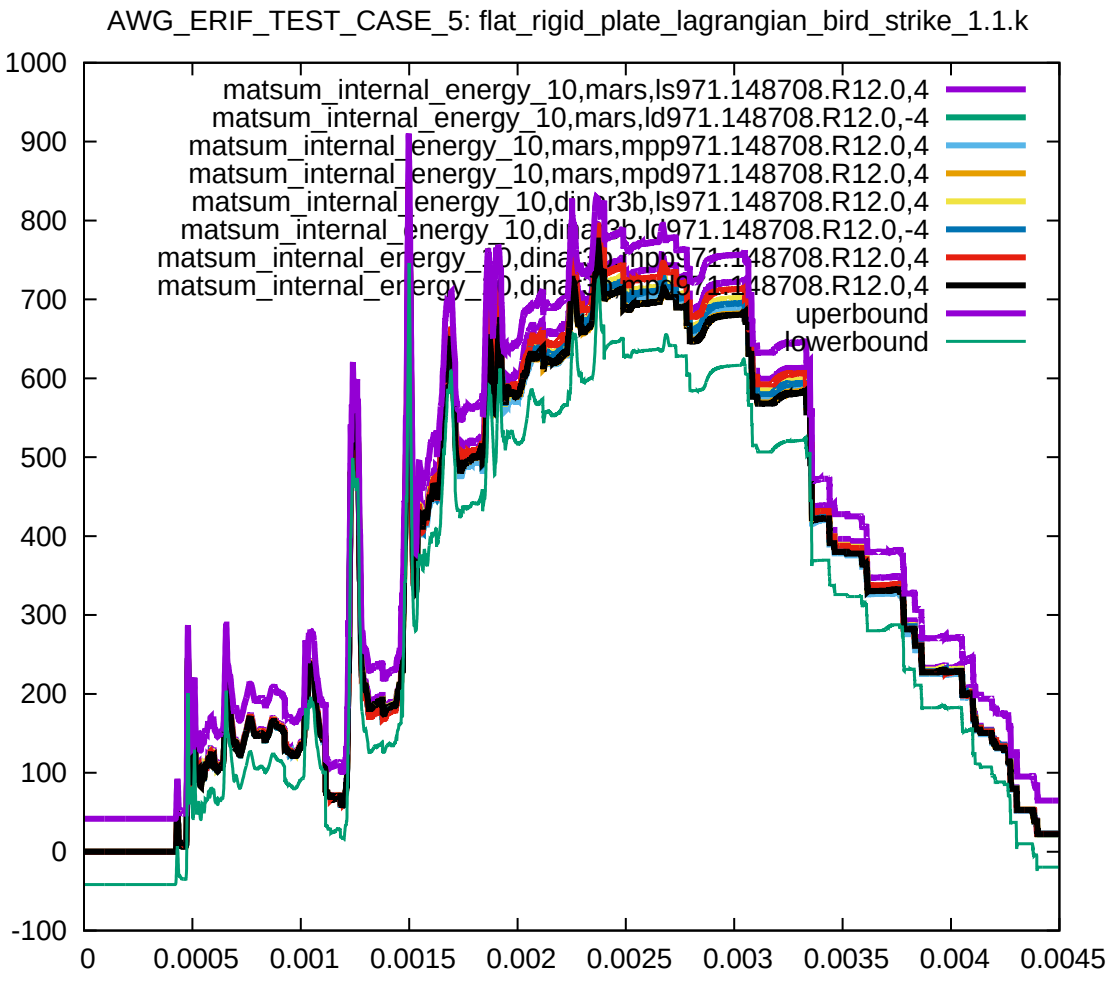

Figure 6: Cross platform results, internal energy part 10 (bird body), sub test case ID 1

5.3.3 Sub Test Case ID 2 - Test Target 1

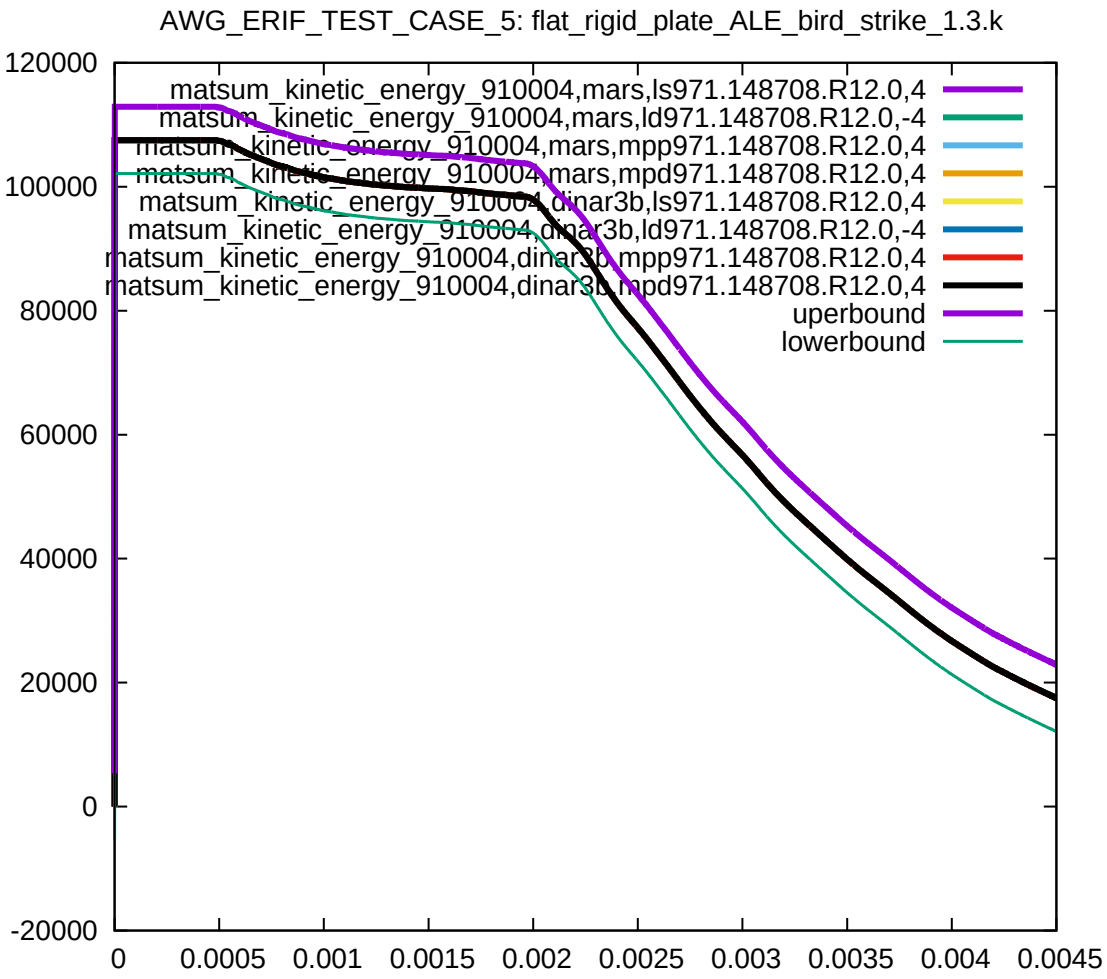

Figure 7: Cross platform results, kinetic energy part 910004 (bird body), sub test case ID 2

5.3.4 Sub Test Case ID 2 - Test Target 2

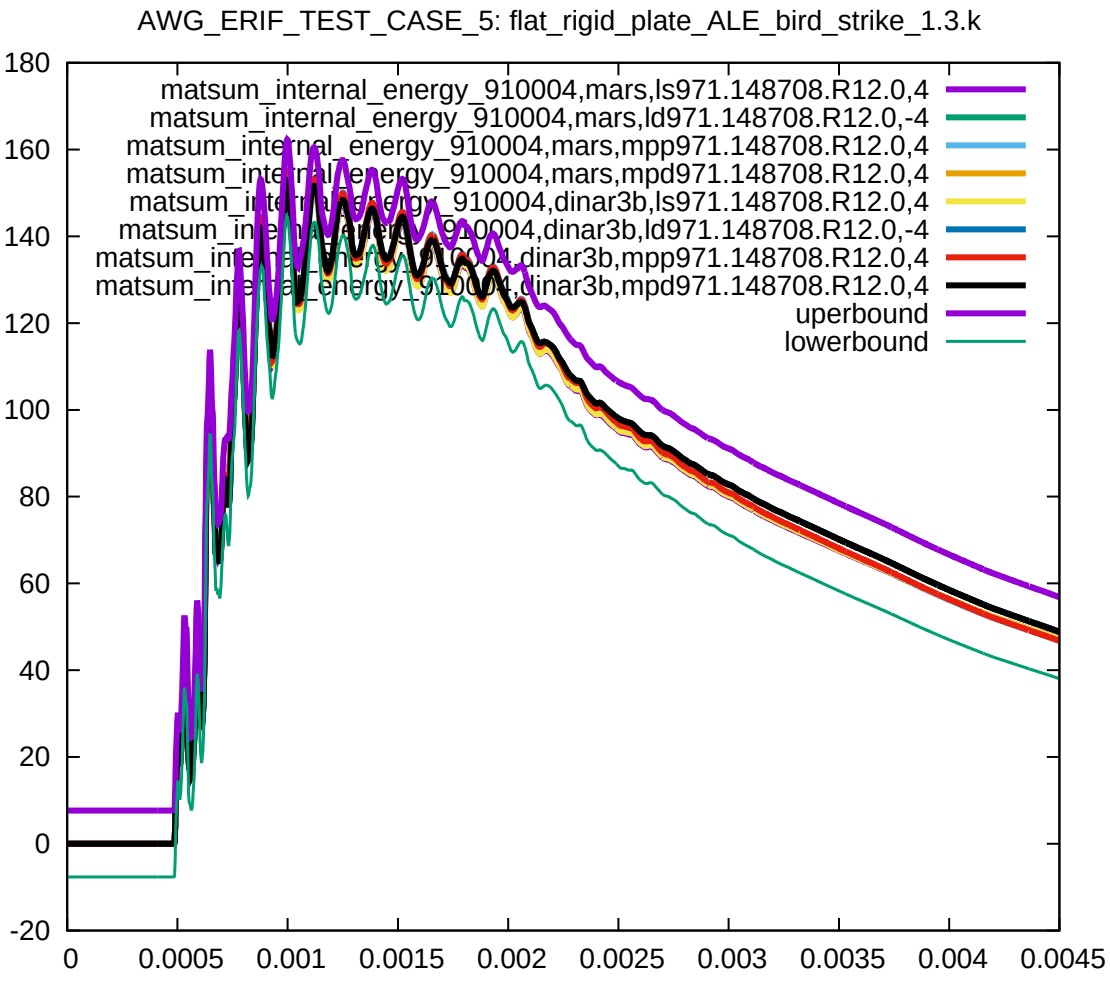

Figure 8: Cross platform results, internal energy part 920004 (bird body), sub test case ID 2

5.3.5 Sub Test Case ID 3 - Test Target 1

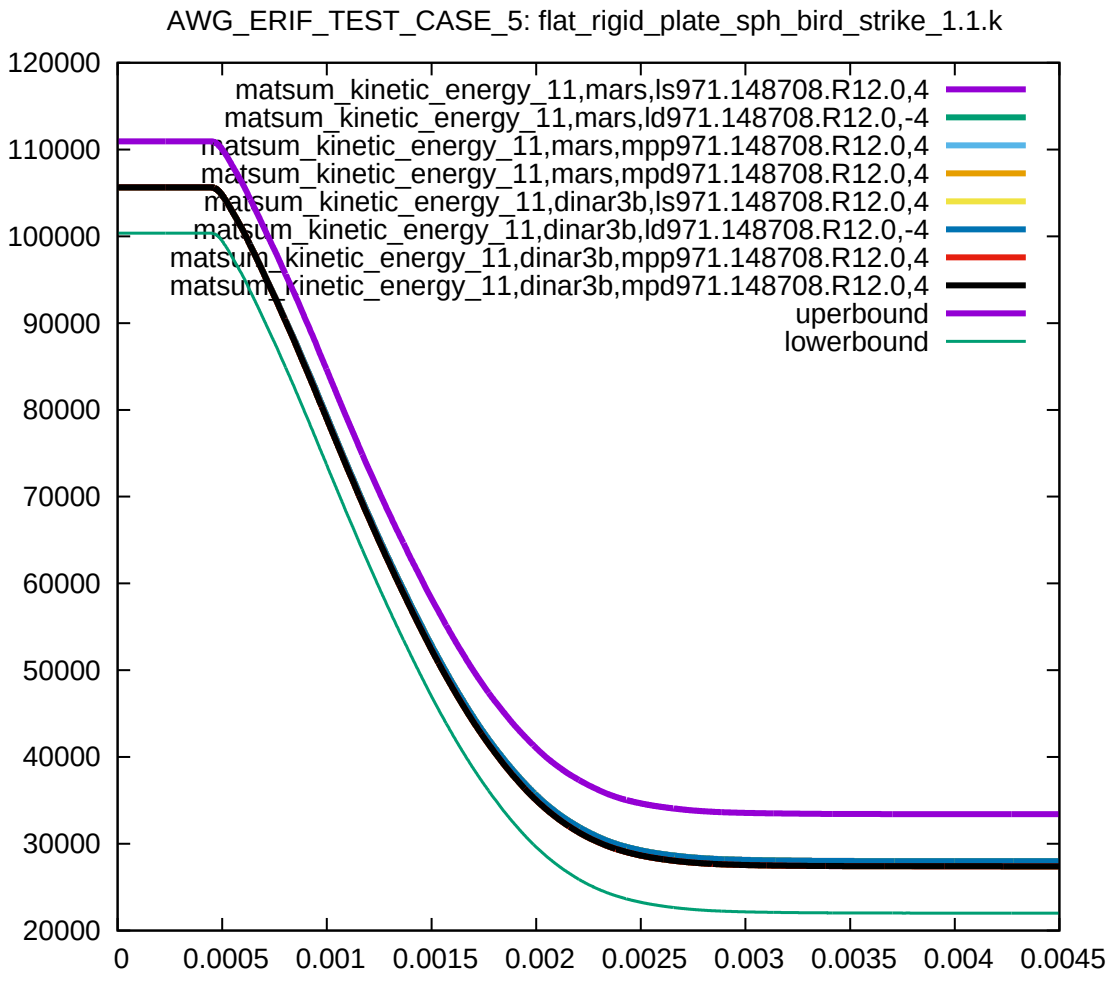

Figure 9: Cross platform results, kinetic energy part 11 (bird body), sub test case ID 3

5.3.6 Sub Test Case ID 3 - Test Target 2

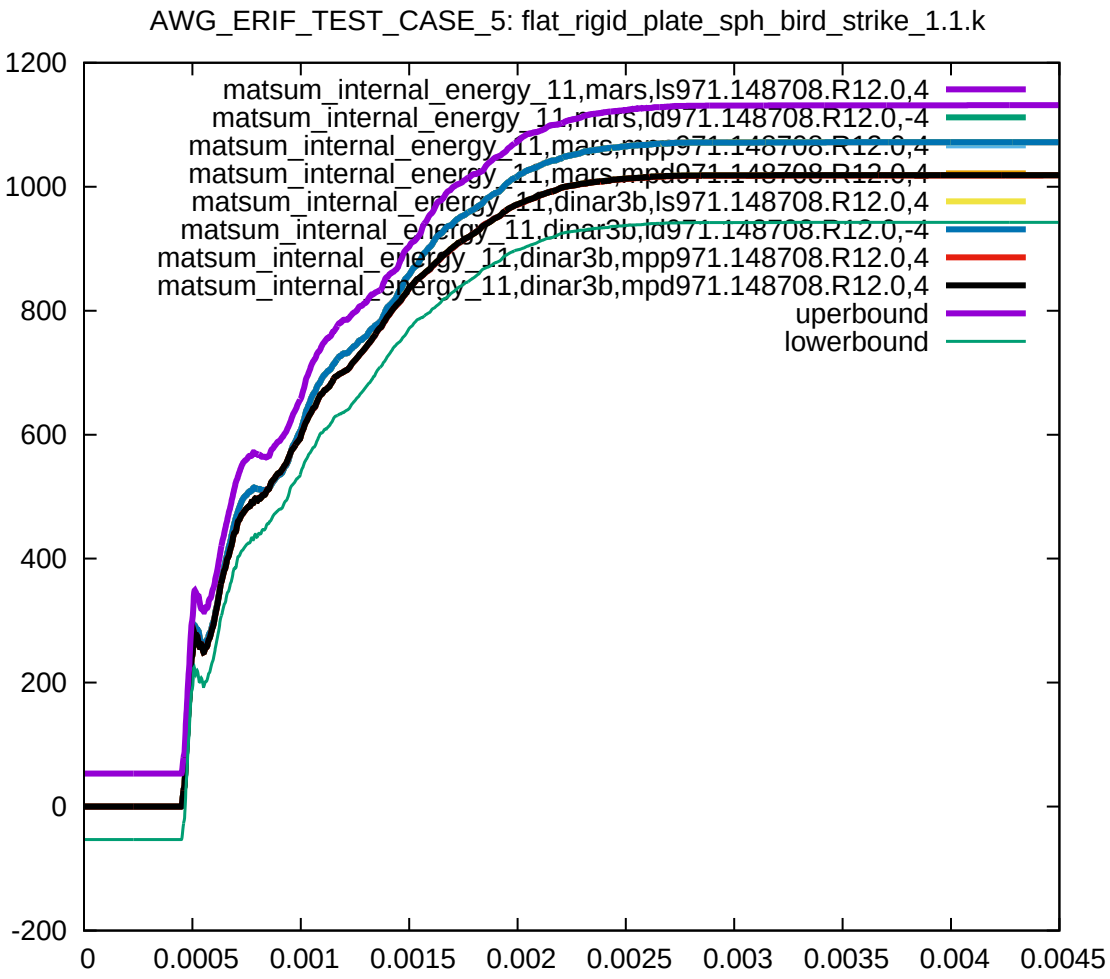

Figure 10: Cross platform results, internal energy part 11 (bird body), sub test case ID 3

5.3.7 Sub Test Case ID 4 - Test Target 1

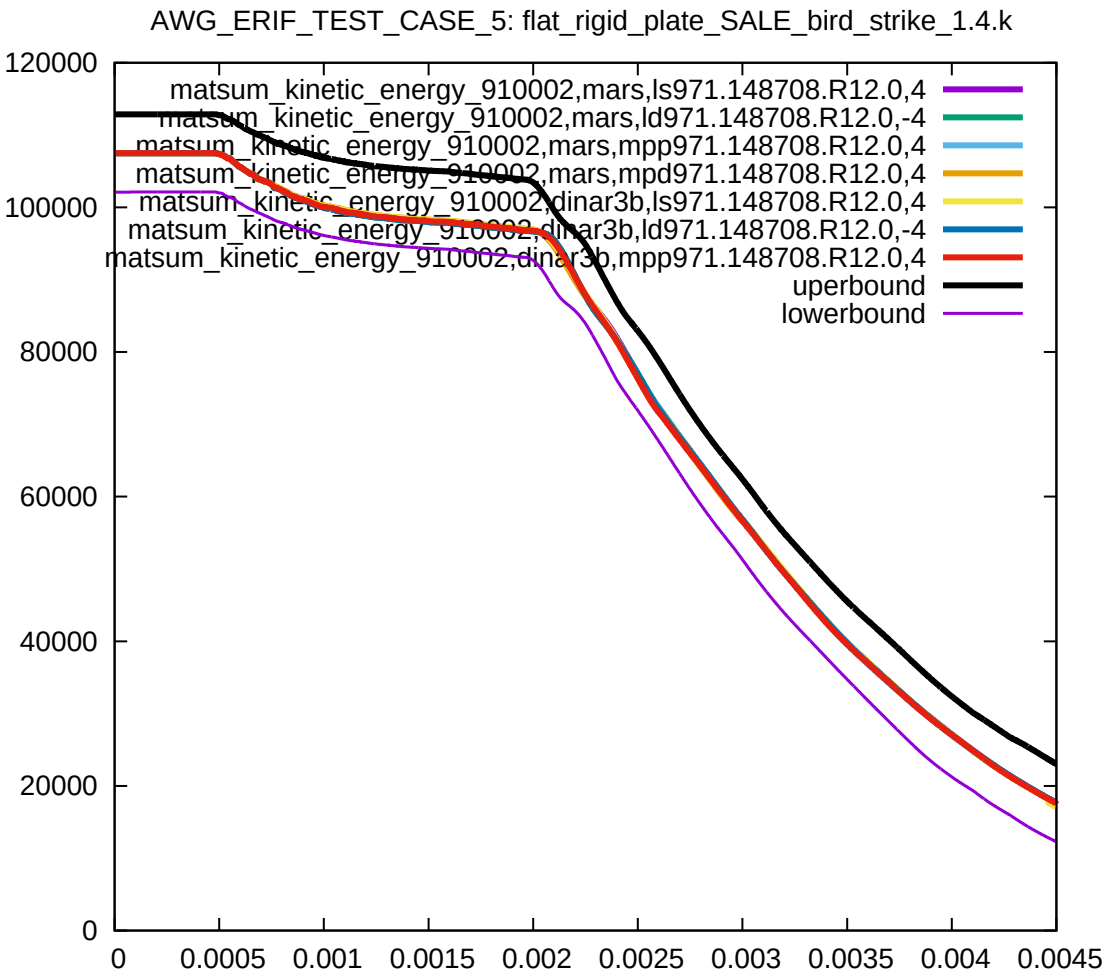

Figure 11: Cross platform results, kinetic energy part 910002 (bird body), sub test case ID 4

5.3.8 Sub Test Case ID 4 - Test Target 2

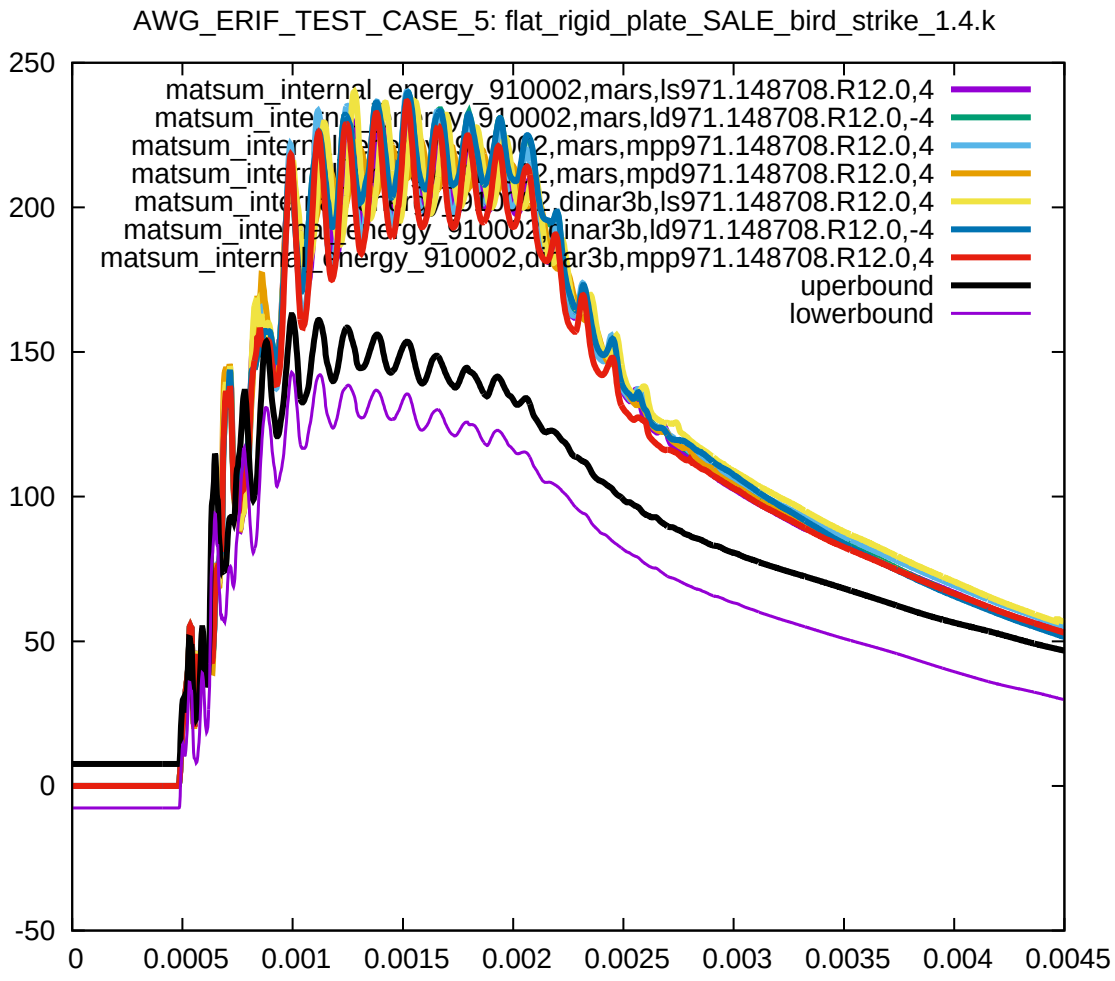

Figure 12: Cross platform results, internal energy part 910002 (bird body), sub test case ID 4

5.3.9 Sub Test Case ID 5 - Test Target 1

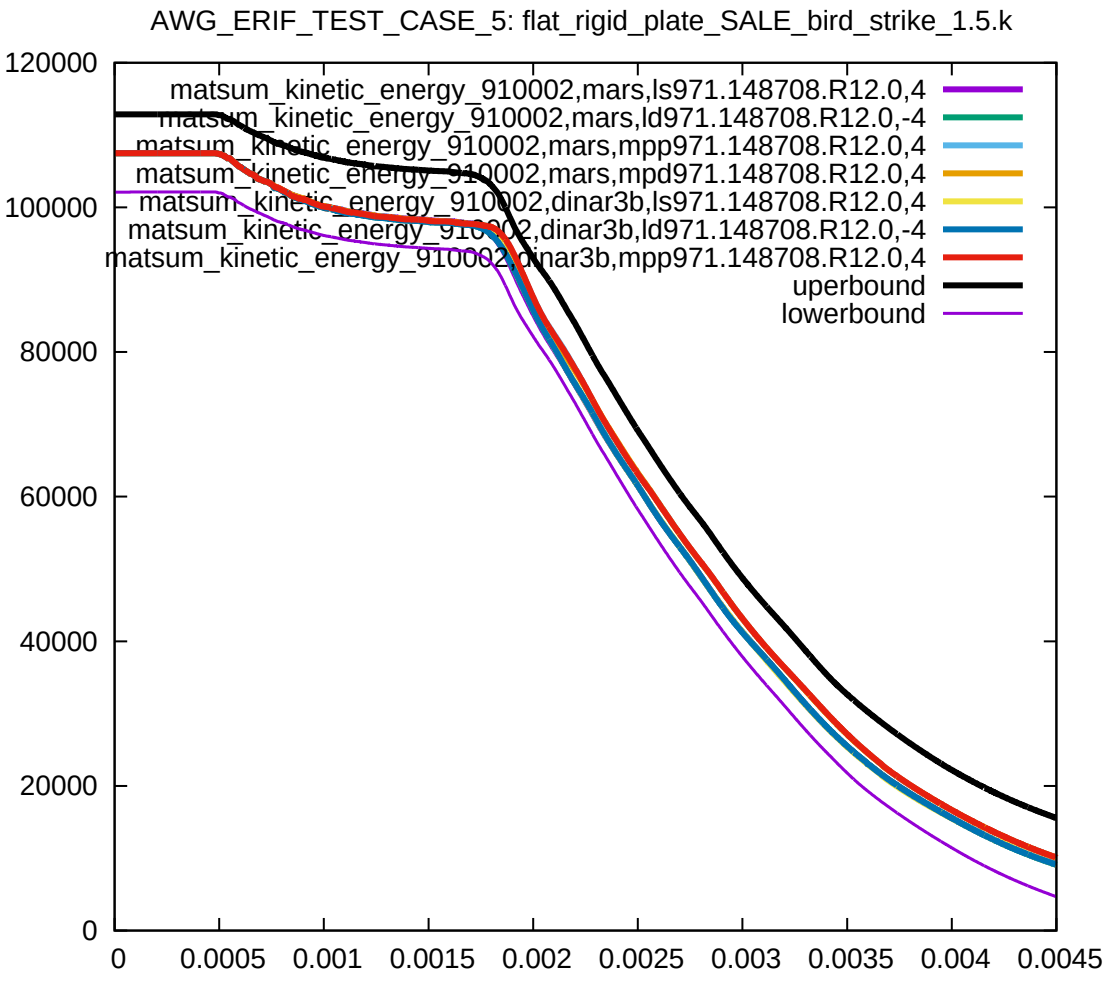

Figure 13: Cross platform results, kinetic energy part 910002 (bird body), sub test case ID 5

5.3.10 Sub Test Case ID 5 - Test Target 2

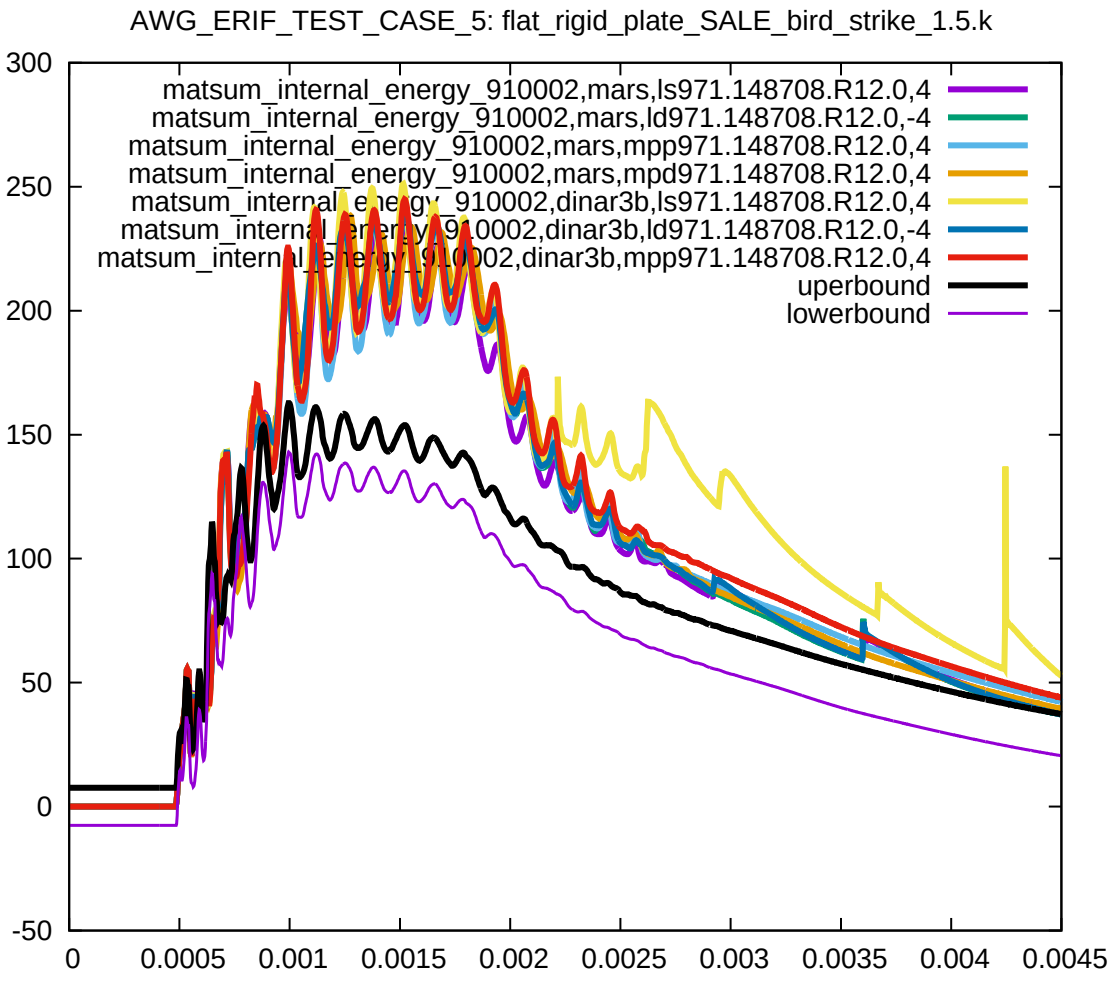

Figure 14: Cross platform results, internal energy part 910002 (bird body), sub test case ID 5

5.3.11 Test Case AWG-ERIF-5 - Test Target 3 and 4

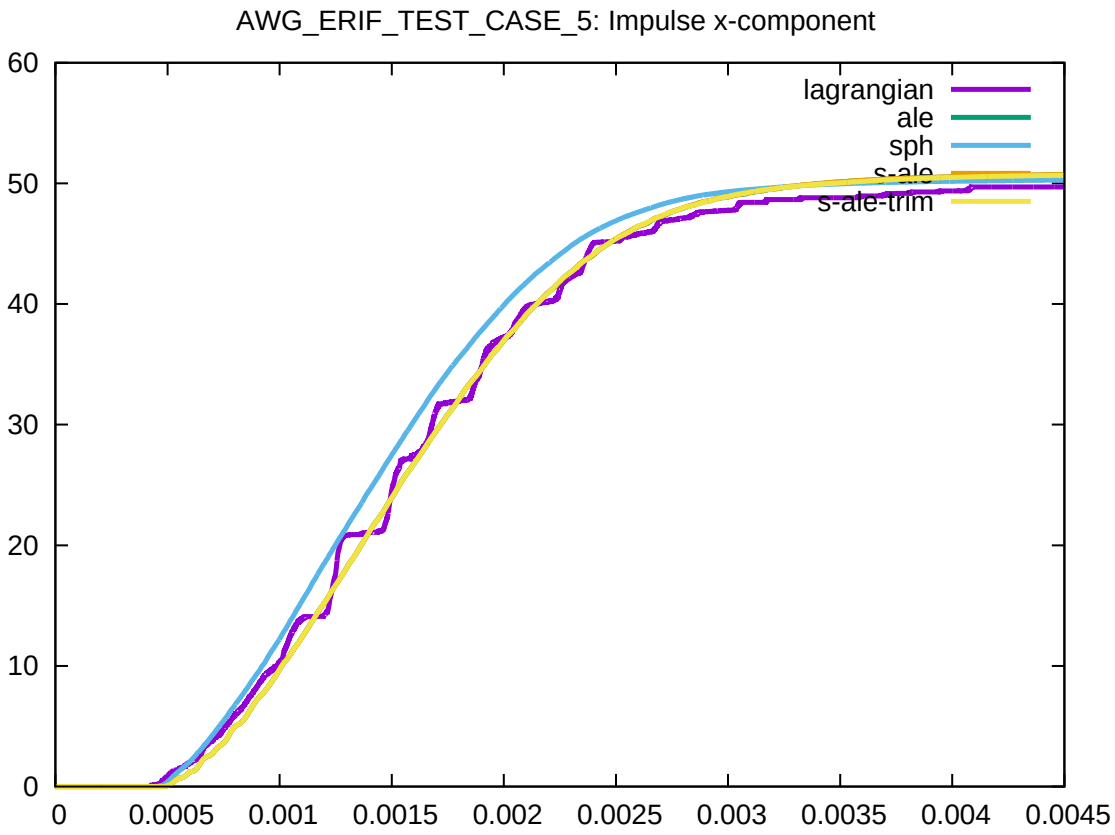

Figure 15: Platform averaged impulse for the different modelling approaches

References

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