TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AWG-ERIF-5-8

TEST CASE ID AWG-ERIF-5

Bird Strike on Rigid Plate

Tested with LS-DYNA® R9.0 Revision 108899

Tuesday 16th August, 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-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.

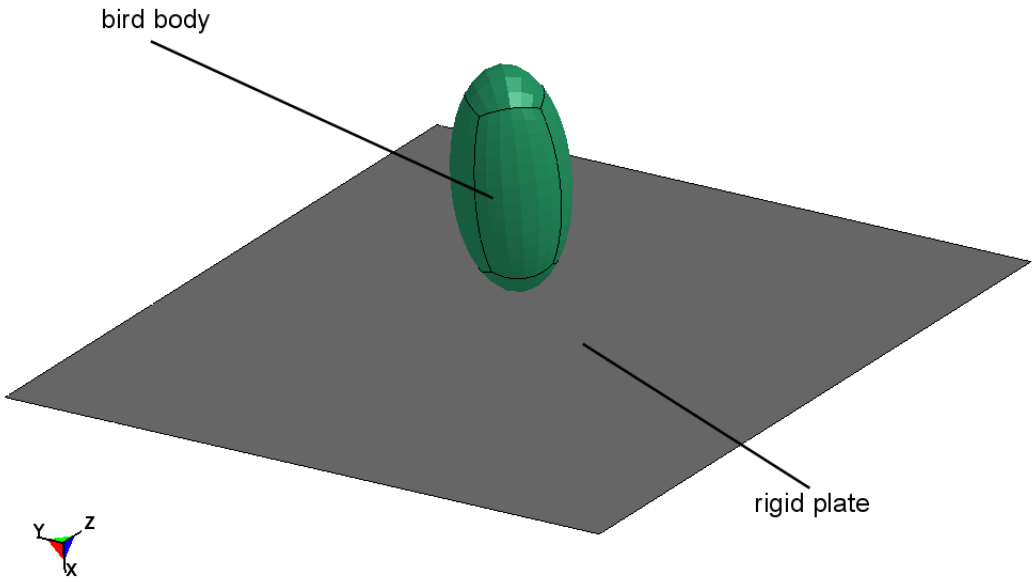

Figure 1: Model sketch: Simplified bird geometry impacting a rigid plate

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. Additional information on the models can be found in table 3.

FEA Model information			
Sub Test Case ID [1]	1	2	3
Modelling approach	Lagrangian	ALE	SPH
Nodes	15278	115652	42289
Solid elements	432	84800	-
Solid materials	1	1	-
Shell elements	14400	16230	14400
Shell materials	1	2	1
SPH nodes	-	-	27648
SPH materials	-	-	1
Parts	2	3	2
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

Table 4: Specification of sub test cases

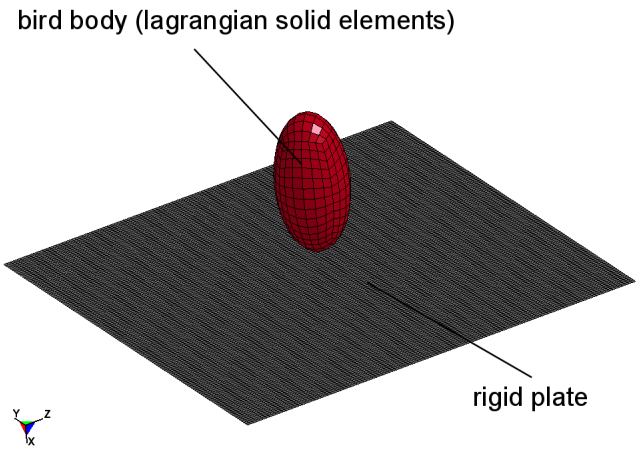

Figure 2: FEA model: Sub Test Case 1 - Lagrangian approach

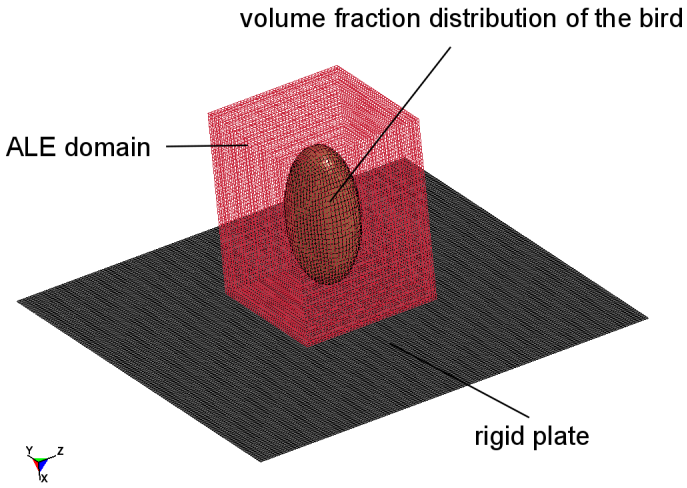

Figure 3: FEA model: Sub Test Case 2 - ALE approach

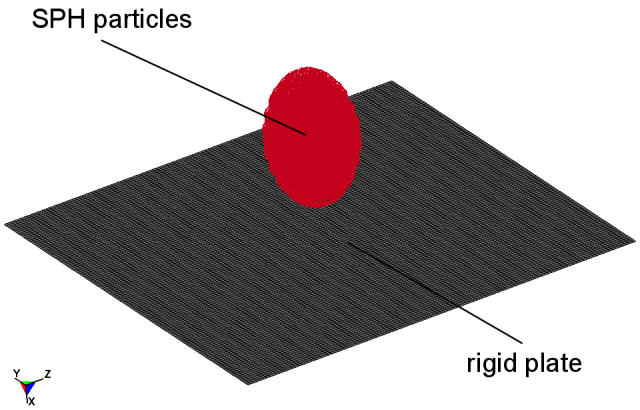

Figure 4: FEA model: Sub Test Case 3 - SPH approach

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]	
1	kinetic energy	part	10	910004	11	binout/matsum file
2	internal energy	part	10	910004	11	binout/matsum file
3	resultant interface forces	master x	1	-	1	binout/rcforc file
4	fluid-structure interaction data	fx	-	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 and part 11 in the SPH 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:

- 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.
- 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.

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-5 completed with all combinations of software and hardware defined in section 5.1 (3 * 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 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	**FAILED**

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® 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:
'flat_rigid_plate_sph_bird_strike_1.0.k: matsum_kinetic_energy_10' states that the input deck for sub test case 1 was used to calculate these results. The component displayed is the kinetic energy of part 10 derived from the 'matsum' output file.

Legend:
'matsum_internal_energy_10_sandwich_ls971.108899.R9.0_4' states that the graph shows the kinetic energy of part 10 derived from the 'matsum' 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

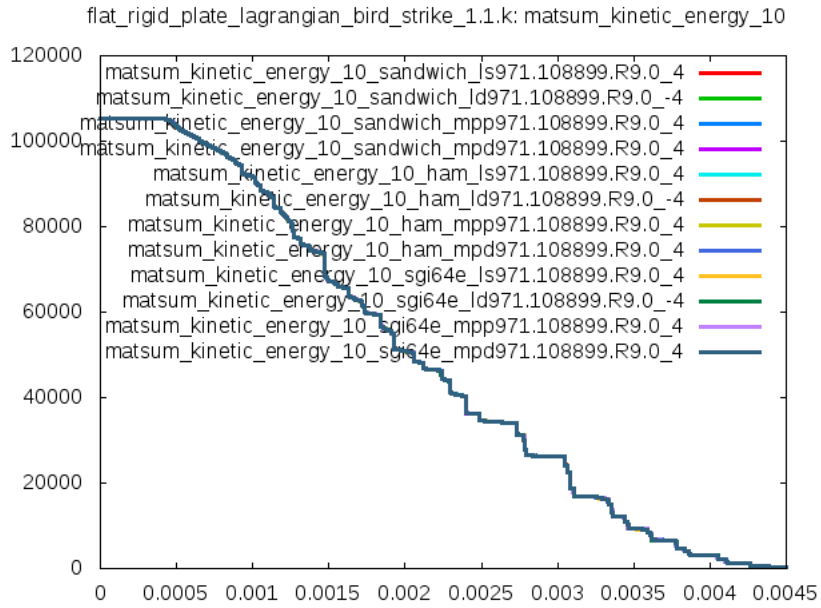

Figure 5: Cross platform results, kinetic energy part 10 (bird body), sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

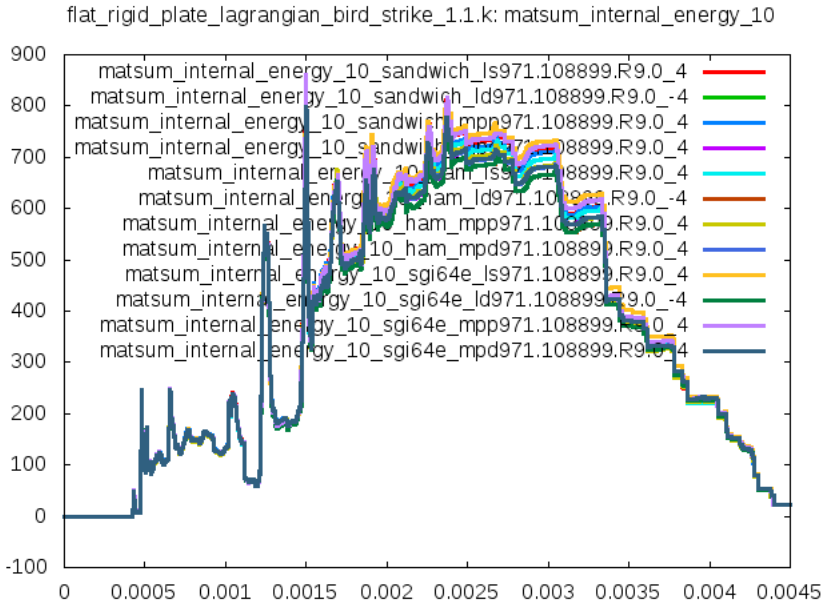

Figure 6: Cross platform results, internal energy part 10 (bird body), sub test case ID 1

5.3.3 Sub Test Case ID 2 - Test Target 1

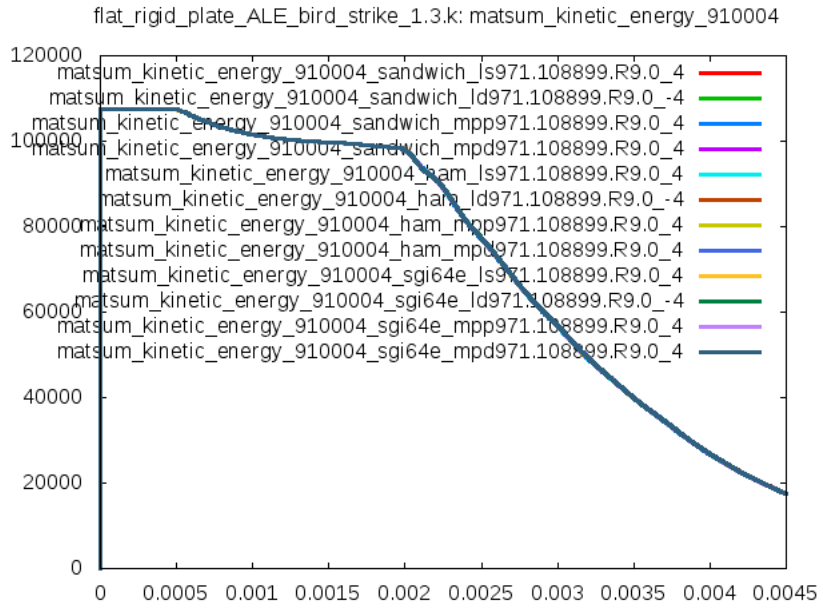

Figure 7: Cross platform results, kinetic energy part 910004 (bird body), sub test case ID 2

5.3.4 Sub Test Case ID 2 - Test Target 2

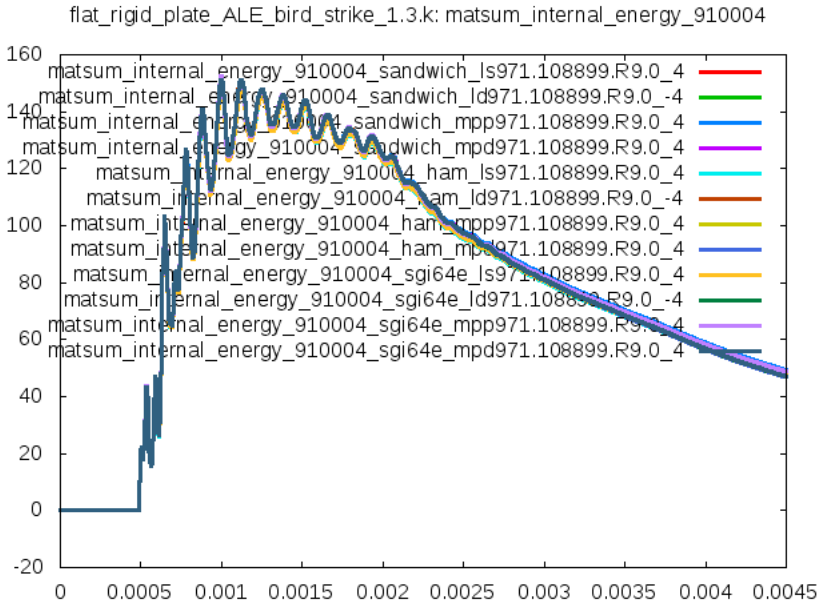

Figure 8: Cross platform results, internal energy part 920004 (bird body), sub test case ID 2

5.3.5 Sub Test Case ID 3 - Test Target 1

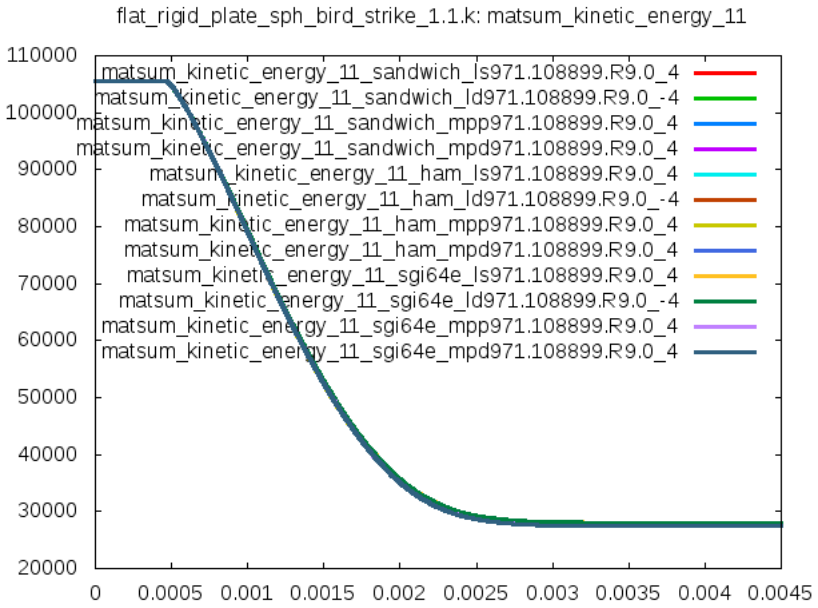

Figure 9: Cross platform results, kinetic energy part 11 (bird body), sub test case ID 3

5.3.6 Sub Test Case ID 3 - Test Target 2

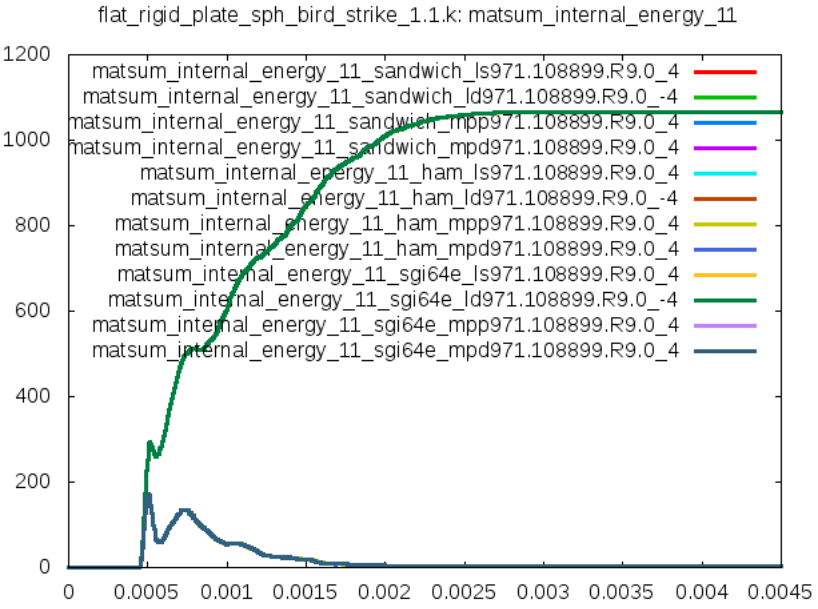

Figure 10: Cross platform results, internal energy part 11 (bird body), sub test case ID 3

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

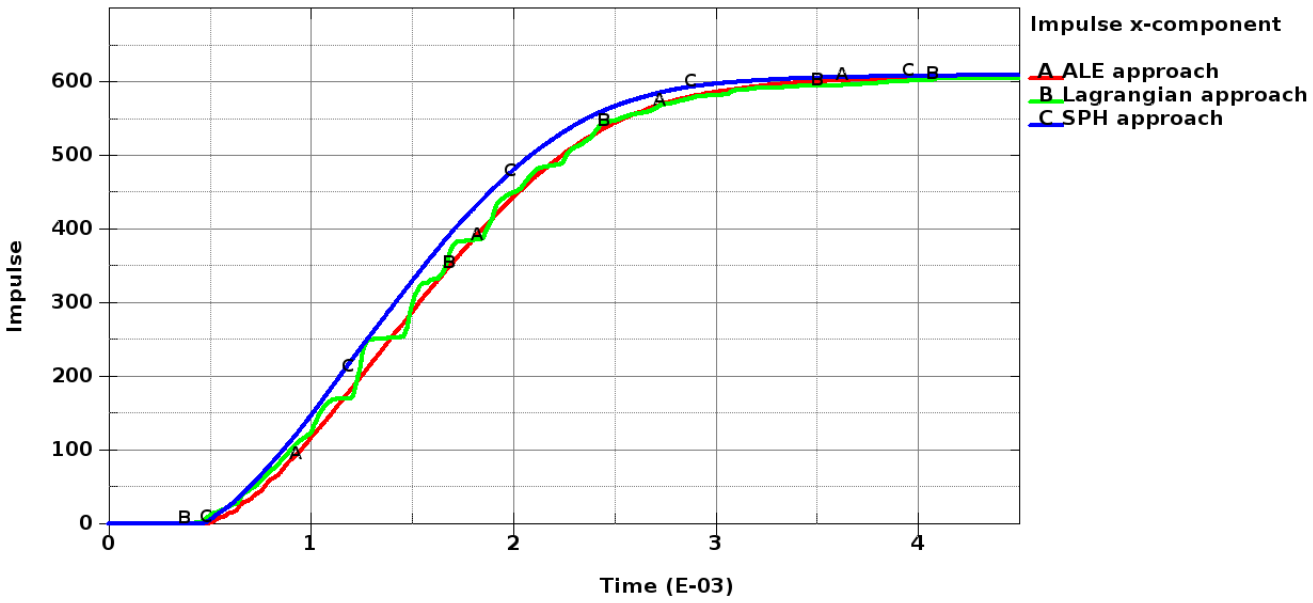

Figure 11: Platform averaged impulse for the different modelling approaches

References

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