TEST CASE DOCUMENTATION AND TESTING RESULTS

ANSYS-QA-LS-DYNA-AWG-CI-9-11

TEST CASE ID AWG-CI-9

I-Beam Web Section - Leg Structure

Tested with LS-DYNA® R14.1 Revision 7-gea5f83301c

Monday 24th April, 2023

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Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case AWG-CI-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	I-Beam Web Section - Leg Structure
Test Case ID	AWG-CI-9
Test Case Status	active
Test Case Classification	Application Benchmark
Test Case Source	Boeing
Tested Keyword	*ELEMENT_SOLID *ELEMENT_SHELL *MAT_ELASTC *MAT_PIECEWISE_LINEAR_PLASTICITY *BOUNDARY_SPC_NODE *BOUNDARY_DESCRIBED_MOTION
Member of Test Suite	AWG CI SUITE
Metadata	AWG CI

Table 1: Test Case Summary

3 Test Case Specification

3.1 Test Case Purpose

The purpose of Test Case ID AWG-CI-9 is to compare the deformation and failure of an I-beam subjected to three-point bending that has the web section modeled using fully integrated solid and shell elements. The I-beam model is representative of a portion of an aircraft seat leg.

3.2 Test Case Description

An aluminum 7050-T7451 I-beam that is representative of a portion of an aircraft seat leg is subjected to three-point bending. Deformation and failure of the I-beam web section using shell elements (Subcase 1) and solid elements (Subcase 2) is compared.
The I-beam is 11 inches long by 1.4 inches high and the web section is 1.0 inches thick and has 11 equally spaced 0.6 inch diameter holes. The I-beam is supported from the bottom by 1-inch diameter steel cylinders near the ends that are spaced 9 inches apart and are resting on a rigid wall as shown in Figure 1.

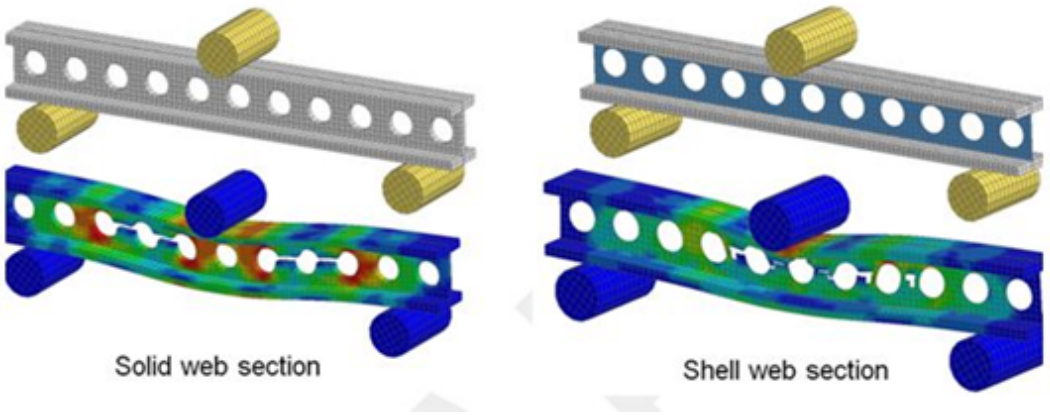

Figure 1: I-Beam with Solid and Shell Web Sections.

3.3 Model Description

This test case compares the deformation and failure of an aluminum 7050-T7451I-beam modeled using fully integrated solid (ELFORM=2) and shell (ELFORM=16) element types that use Flanagan-Belytschko viscous hourglass control (IHQ=2).
The I-beam is loaded by a 1-inch diameter steel cylinder contacting the top center of the beam flange using *BOUNDARY_PRESCRIBED_MOTION_NODE input specifying a displacement curve (LCID=2). The I-beam is supported from the bottom with two 1-inch diameter steel cylinders nine inches apart that rest on a rigid wall. Contact between the cylinders and I-beam flange is defined using *CONTACT_ERODING_SINGLE_SURFACE with a 0.30 coefficient of static friction. In addition, the mid-plane is constrained in the direction normal to the web face.
The steel cylinders are modeled using *MAT_ELASTIC (001) and the aluminum I-beam is modeled using *MAT_PIECEWISE_LINEAR_PLASTICITY (024) with a specified plasticity curve. The downward (y-direction) displacement is determined for the bottom flange by tracking the bottom center node (node 2084) and the von Mises stress is determined for two elements in the bottom flange surrounding the target node (elements 4731 and 2603).
The models use units of inch, second, pound-force.

Model information		
	Subcase 1 - Shell Elements	Subcase 2 - Solid Elements
Nodes	6930	7978
Shell Elements	528	
Solid Elements	3968	5024
Parts	4	4
Rigid Walls	1	1

Table 2: FEA Model Information

Model information	
Test Case ID	Input Deck Name
1	ibeam_shells.k
2	ibeam_solids.k

Table 3: Specification of sub test cases

4 Test Specifications

4.1 Test Case Targets

Test Case Targets				
Target number	Output	component type	component id	retrieved from
1	Y-component Displacements	Node	2084	binout/nodout
2	Von-Mises Stress	Element	2603	binout/elout
3	Von-Mises Stress	Element	4731	binout/elout
4	CPU Time			d3hsp file

Table 4: Test Case Targets Subcase 1 - Shell Elements

Test Case Targets				
Target number	Output	component type	component id	retrieved from
5	Y-component Displacements	Node	2084	binout/nodout
6	Von-Mises Stress	Element	2603	binout/elout
7	Von-Mises Stress	Element	4731	binout/elout
8	CPU Time			d3hsp file

Table 5: Test Case Targets Subcase 2 - Solid Elements

4.2 Pass/Fail Criteria

These are the Pass/Fail criteria used for the Validation of the Test Case ID AWG-CI-9.

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® R14.0 Revision 114 binaries by the following process:

- For a specific test case target, interpolate the data from different platform and executable (R14.0 Revision 114) 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 (R14.0 Revision 114) 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.

For CPU Time target, it holds:

$$bound_{up}^{CPU\,Time} = 2 \times Max + 1$$
$$bound_{low}^{CPU\,Time} = 0$$

where Max is the maximum CPU Time (in seconds) across all platforms and executable (R14.0 Revision 114) combinations the test case was calculated with and $bound_{up}^{CPU\,Time}$ and $bound_{low}^{CPU\,Time}$ are the upper and lower bounds.

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]
cdcvdce7mbu01	CentOS 7.9	Intel® Xeon® E5- 2680 v4 @ 2.40GHz	Platform MPI ISV Edition 08.3.0.2 [10692] Linux x86-64	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	R14.1	7-gea5f83301c	SMP	SP	ls971.7-gea5f83301c.R14.1
LS-DYNA®	971	R14.1	7-gea5f83301c	SMP	DP	ld971.7-gea5f83301c.R14.1
LS-DYNA®	971	R14.1	7-gea5f83301c	MPP	SP	mpp971.7-gea5f83301c.R14.1
LS-DYNA®	971	R14.1	7-gea5f83301c	MPP	DP	mpd971.7-gea5f83301c.R14.1

[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-CI-9 completed with all combinations of software and hardware defined in section 5.1 (1 * 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 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**

Table 8: Results summary for Test Case ID AWG-CI-9

5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-CI-9 for LS-DYNA® R14.1 Revision 7-gea5f83301c.

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 type, branch and the revision of the executable.

5.3.1 Subcase 1, Test Target 1: Y-component Displacement

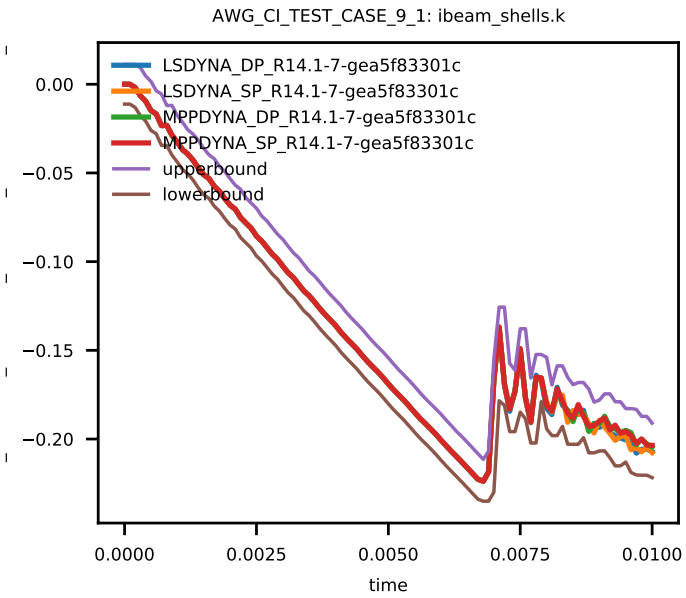

Figure 2: Y-component Displacement of Node 2084.

5.3.2 Subcase 1, Test Target 2: Von Mises Stress

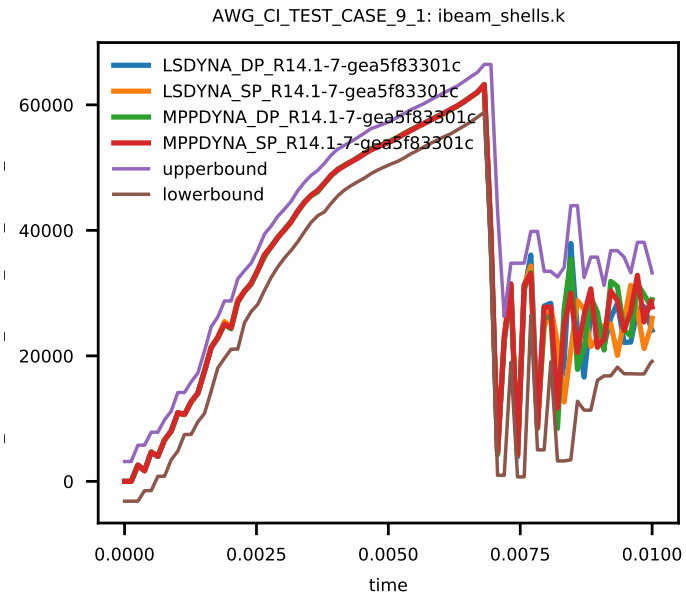

Figure 3: Von Mises Stress of Element 2603.

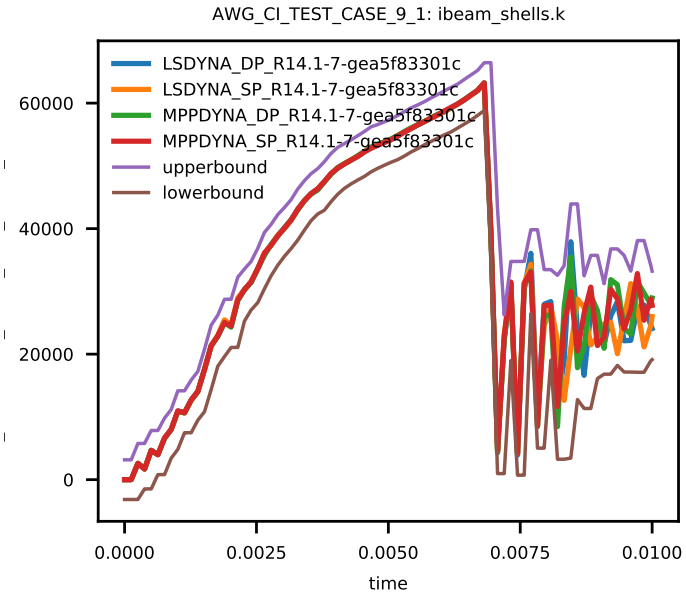

Figure 4: Von Mises Stress of Element 4731.

5.3.3 Subcase 1, Test Target 3: CPU time

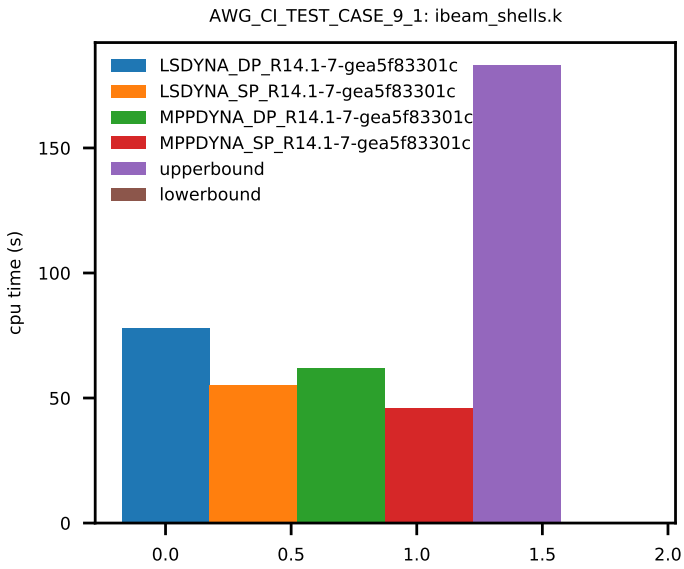

Figure 5: CPU Time Comparison.

5.3.4 Subcase 2, Test Target 1: Y-component Displacement

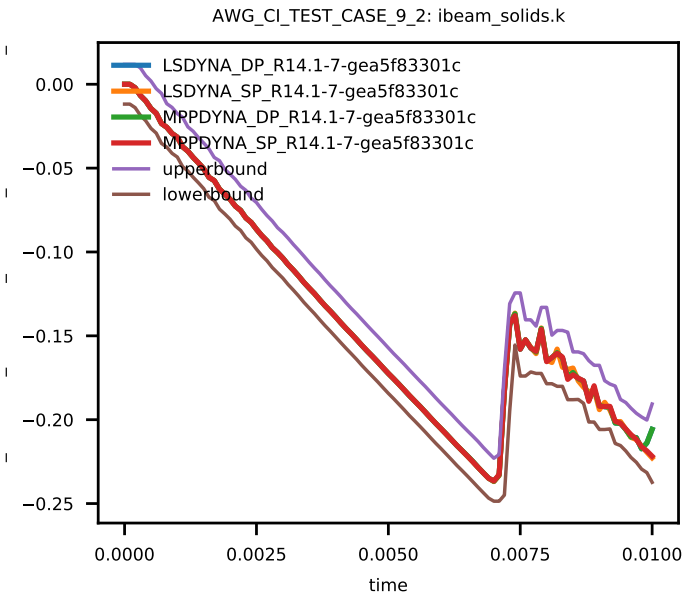

Figure 6: Y-component Displacement of Node 2084.

5.3.5 Subcase 2, Test Target 2: Von Mises Stress

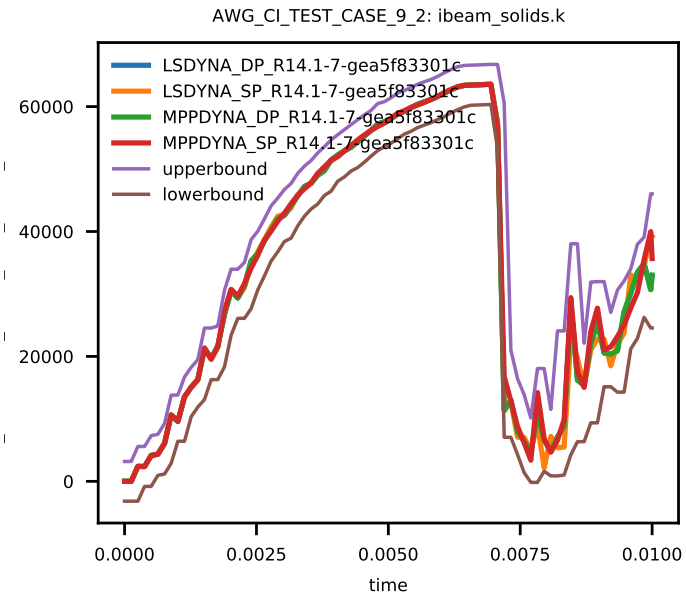

Figure 7: Von Mises Stress of Element 2603.

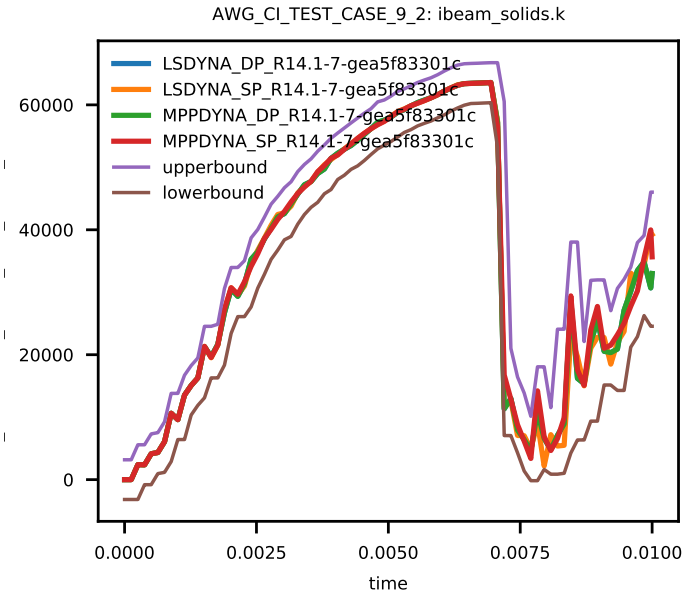

Figure 8: Von Mises Stress of Element 4731.

5.3.6 Subcase 2, Test Target 3: CPU time

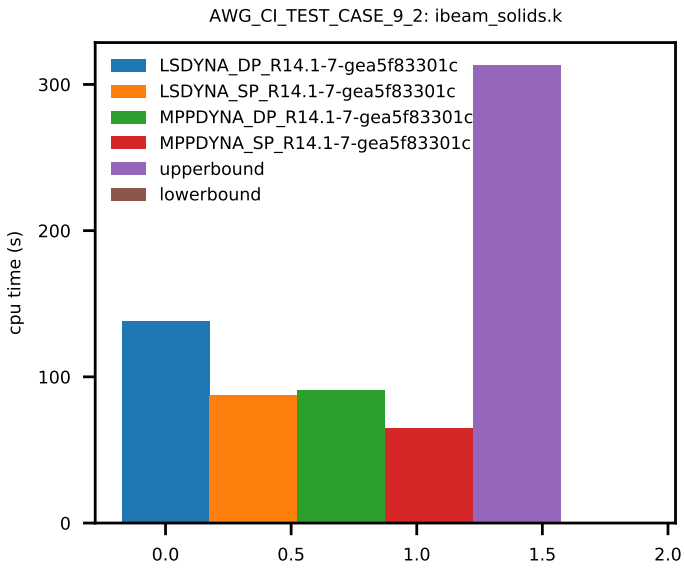

Figure 9: CPU Time Comparison.

References