TEST CASE DOCUMENTATION AND TESTING RESULTS

ANSYS-QA-LS-DYNA-AWG-CI-10-13

TEST CASE ID AWG-CI-10

Seat Base Frame Tube Bending

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

Monday 24th April, 2023

Warranty Disclaimer:

Document Information	
Confidentiality	**external use**
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Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case AWG-CI-10. 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	Seat Base Frame Tube Bending
Test Case ID	AWG-CI-10
Test Case Status	active
Test Case Classification	Application Benchmark
Test Case Source	Boeing
Tested Keyword	*ELEMENT_SOLID *ELEMENT_SHELL *MAT_ELASTIC *MAT_PIECEWISE_LINEAR_PLASTICITY *BOUNDARY_SPC_NODE *BOUNDARY_DESCRIBED_MOTION *CONTACT_AUTOMATIC_SINGLE_SURFACE
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-10 is to model a thin-walled tube representative of an aircraft seat base frame using shell elements and subjected to two different load conditions, a three-point bending load and a cantilevered bending load.

3.2 Test Case Description

An aluminum thin-walled tube that is representative of an aircraft seat frame is modeled using shell elements and subjected to three-point bending (Subcase 1) and cantilevered bending (Subcase 2) loads as shown in Figure 1.
The three-point bending model consists of an aluminum tube with length 23.4614 inches, diameter 1.5612 inches, and thickness 0.188 inches simply supported with 1-inch diameter solid steel cylinders at the tube ends. The tube is loaded in the center by a 1-inch diameter solid steel cylinder depressing the tube top surface.
The cantilever bending model consists of an aluminum tube with length 16.4728 inches, diameter 1.5612 inches, and thickness 0.188 inches that is fully constrained in all six degrees of freedom at the clamped end. The tube is loaded at the free end with a nodal load set.

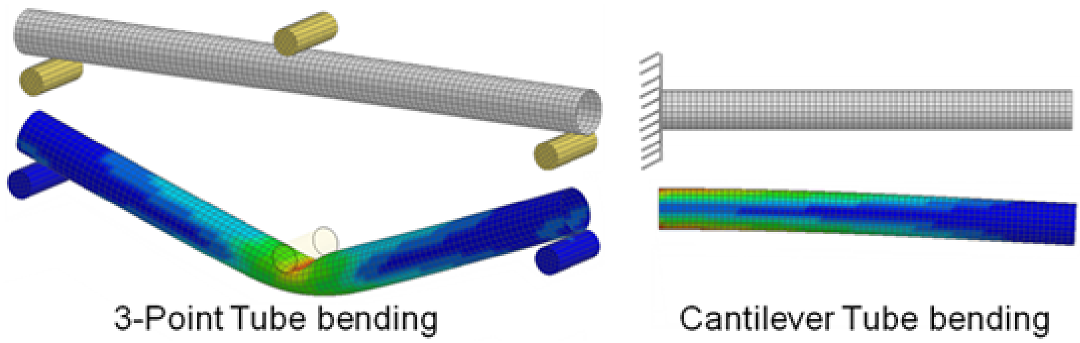

Figure 1: Tube with 3-Point and Cantilever Bending.

3.3 Model Description

This test case consists of an aluminum thin-walled tube that is modeled using shell elements and subjected to three-point bending (Subcase 1) and cantilevered bending (Subcase 2) loads. Both subcases use units of inch, second, and pound-force. Details for each of the models are outlined below.

3.3.1 Three-Point Tube Bending

The tube (PID=1) uses material model (MID=3) *MAT_PIECEWISE_LINEAR_PLASTICITY, fully integrated shell elements (ELFORM=16), and hourglass (HGID=3) type IHQ=8 that includes warping stiffness for shells.
The top indenter cylinder (PID=2) and bottom support cylinders (PID=4) use a steel material model (MID=1) *MAT_ELASTIC, constant stress solid element (ELFORM=1), and hourglass (HGID=5) type IHQ=6 for solid elements.
Contact between the steel cylinders and aluminum tube is defined using *CONTACT_AUTOMATIC_SINGLE_SURFACE with a 0.30 static coefficient of friction.
The top indenter cylinder uses *BOUNDARY_PRESCRIBED_MOTION_NODE with z-translational displacement (DOF=3, VAD=2) defined on a load curve (LCID=1).
The tube centerline is constrained in x-translation and mid-plane is constrained in y-direction.
The tube indenter is constrained in x and y translations.
The support cylinders have centerlines constrained in the x, y, and z translations.

3.3.2 Cantilever Tube Bending

The tube (PID=1) uses material model (MID=1) *MAT_ELASTIC, fully integrated shell elements (ELFORM=16), and hourglass (HGID=3) type IHQ=8 that includes warping stiffness for shells.
The tube fixed end (negative-y end) is fully constrained in all six degrees of freedom and the mid-plane top and bottom is constrained in x-translation.
The tube free end (positive-y end) is given a prescribed load in the z-direction using *LOAD_NODE_SET with load curve LCID=1.

Model information		
	Subcase 1 - 3-Point Tube Bending	Subcase 2 - Cantilever Tube Bending
Nodes	4183	1480
Shell Elements	2036	1452
Solid Elements	1536	
Parts	3	1

Table 2: FEA Model Information

Model information	
Test Case ID	Input Deck Name
1	seat_base_frame_tube_3-PointBend.k
2	seat_base_frame_tube_Cantilever.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	Z-component Displacements	Node	479	binout/nodout
2	Von-Mises Stress	Element	980	binout/elout
3	Von-Mises Stress	Element	981	binout/elout
4	Von-Mises Stress	Element	993	binout/elout
5	Von-Mises Stress	Element	994	binout/elout
6	CPU Time			d3hsp file

Table 4: Test Case Targets Subcase 1 - 3-Point Tube Bending

Test Case Targets				
Target number	Output	component type	component id	retrieved from
7	Z-component Displacements	Node	656	binout/nodout
8	Von-Mises Stress	Element	353	binout/elout
9	CPU Time			d3hsp file

Table 5: Test Case Targets Subcase 2 - Cantilever Tube Bending

4.2 Pass/Fail Criteria

These are the Pass/Fail criteria used for the Validation of the Test Case ID AWG-CI-10.

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-10 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-10

5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-CI-10 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: Z-component Displacement

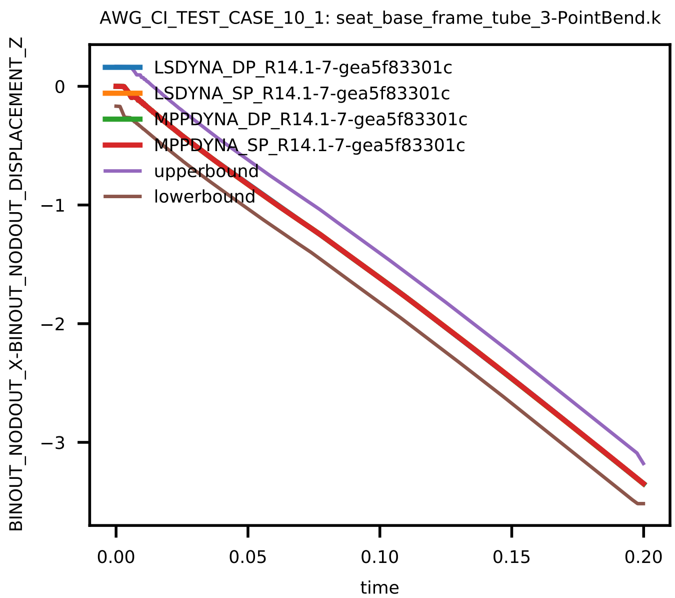

Figure 2: Z-component Displacement of Node 479.

5.3.2 Subcase 1, Test Target 2: Von Mises Stress

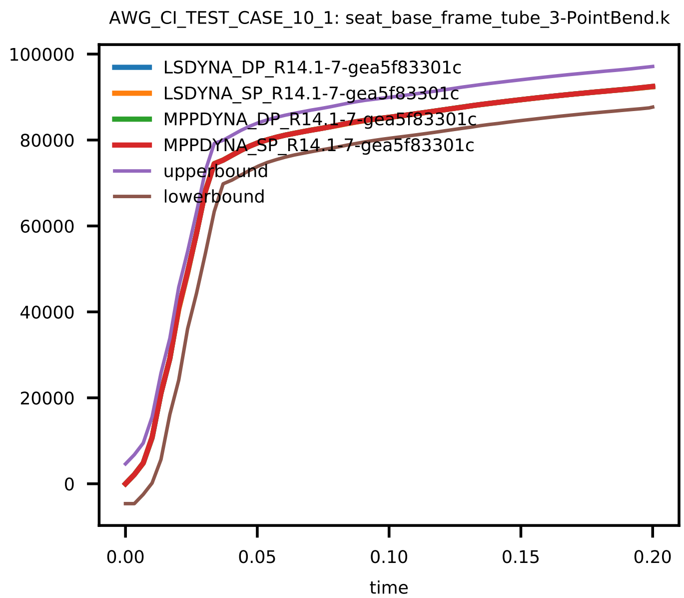

Figure 3: Von Mises Stress of Element 980.

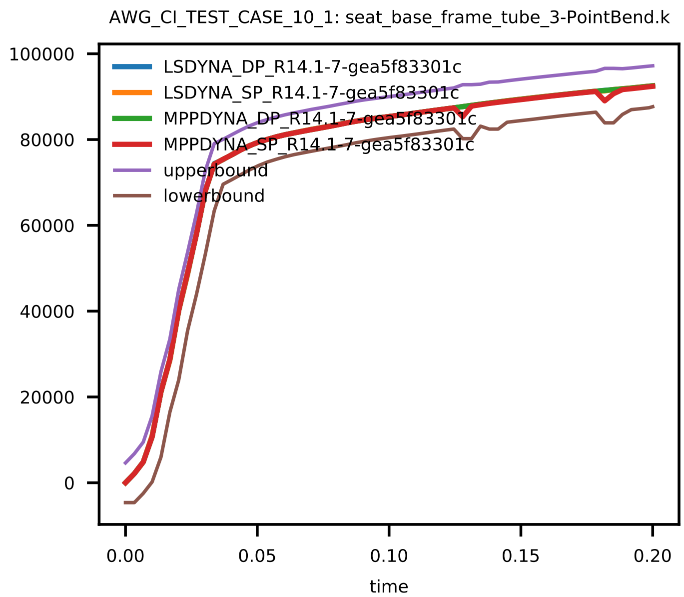

Figure 4: Von Mises Stress of Element 981.

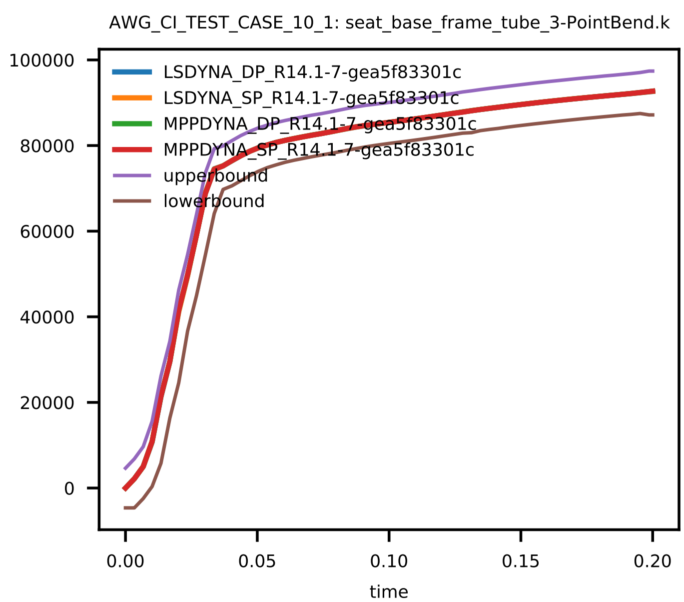

Figure 5: Von Mises Stress of Element 993.

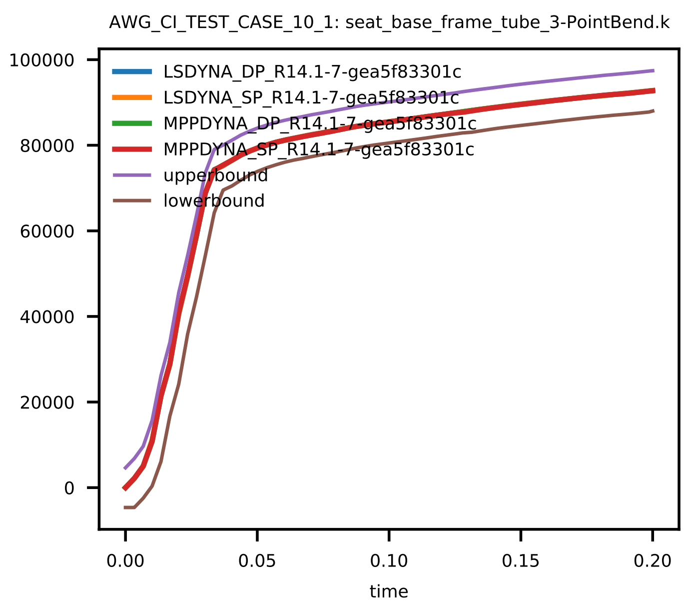

Figure 6: Von Mises Stress of Element 994.

5.3.3 Subcase 1, Test Target 3: CPU time

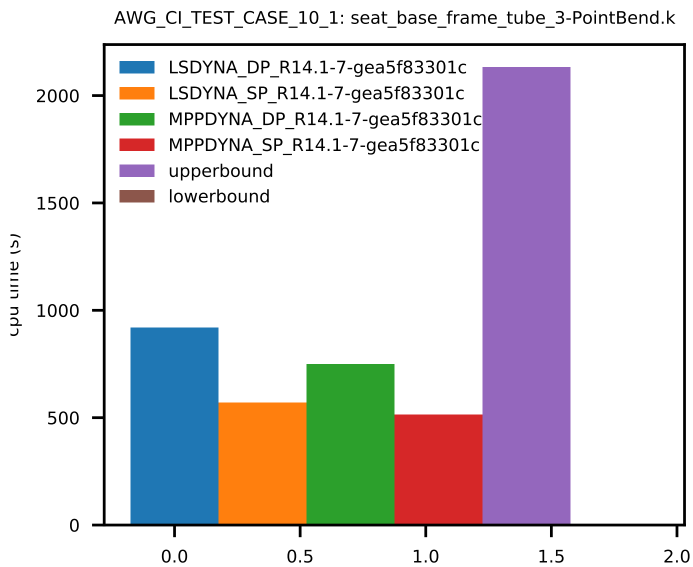

Figure 7: CPU Time Comparison.

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

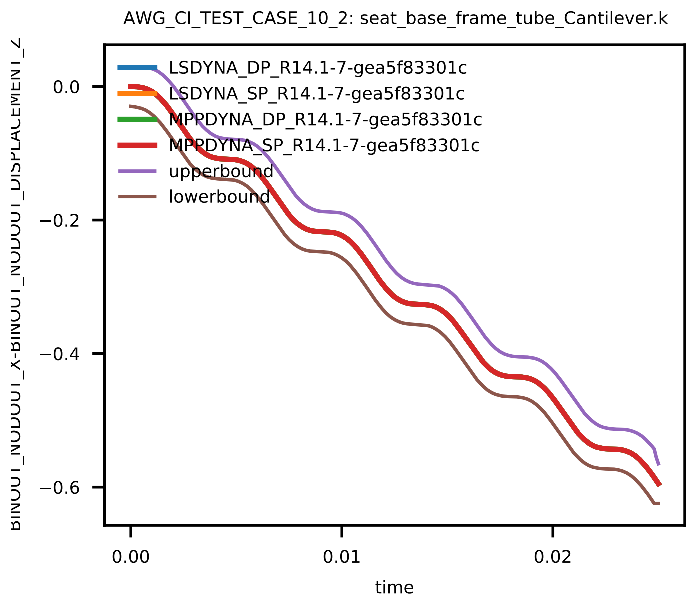

Figure 8: Z-component Displacement of Node 656.

5.3.5 Subcase 2, Test Target 2: Von Mises Stress

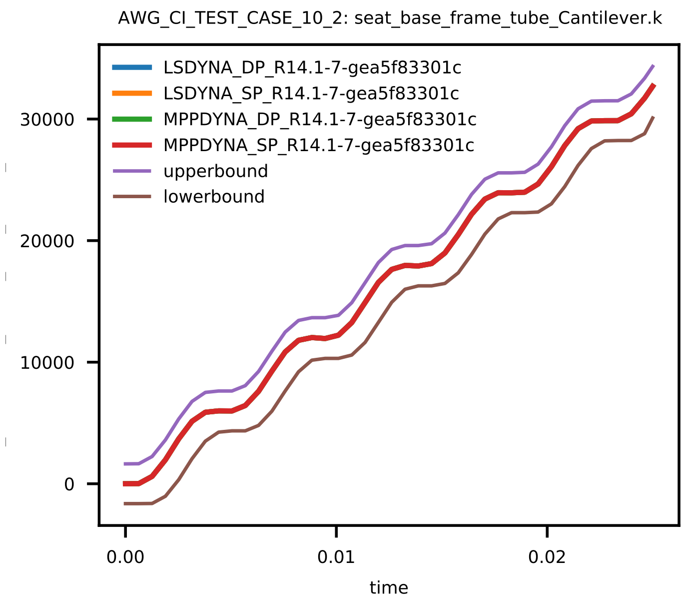

Figure 9: Von Mises Stress of Element 353.

5.3.6 Subcase 2, Test Target 3: CPU time

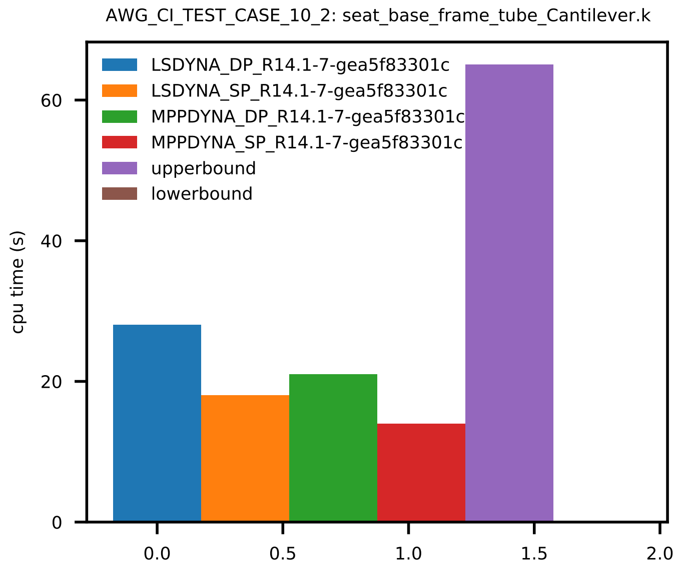

Figure 10: CPU Time Comparison.

References