TEST CASE DOCUMENTATION AND TESTING RESULTS

ANSYS-QA-LS-DYNA-AWG-CI-5-9

TEST CASE ID AWG-CI-5

Bolted Flange Subjected to Tensile Load

Tested with LS-DYNA® R12.2 Revision 0-g0294a6e436

Monday 6th February, 2023

Ansys

Warranty Disclaimer:

The test case(s) described herein are for illustrative purposes only. ANSYS 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	ANSYS-QA-LS-DYNA-AWG-CI-5-9
Author(s)	Prepared by LS-DYNA® Aerospace Working Group
Number of pages	18
Date created	Monday 6th February, 2023
Distribution	LS-DYNA® Aerospace Working Group / internal ANSYS QA

Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case AWG-CI-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	Bolted Flange Subjected to Tensile Load
Test Case ID	AWG-CI-5
Test Case Status	active
Test Case Classification	Application Benchmark
Test Case Source	Boeing
Tested Keyword	*ELEMENT_SOLID *ELEMENT_BEAM *CONSTRAINED_NODAL_RIGID_BODY *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-5 is to investigate the behavior of different connection methods for modeling a bolted flange subject to a tensile load. The three methods include a 3D-solid model, a 1-D spot weld beam model, and a nodal rigid body model. These connections are often found in aircraft seat back attachments.

3.2 Test Case Description

Three models of a bolted flange connection subject to a tensile load are compared. The flange consists of two L-shaped channels with length 2.25 in, width 1.08 in, height 0.70 in, and thickness 0.16 in. The channels are fastened with two $1/4$ inch bolts each using three different types of bolted connections including 3-D solid elements, 1-D spot weld beams, and nodal rigid body elements.

3.3 Model Description

The model consists of two L-shape formed channels connected using two $1/4$ in fasteners. The channels are modeled using 0.1-inch solid elements with two elements through the thickness. The bolts are modeled using 3-D solid elements, 1-D spot weld beams, and nodal rigid body elements. The 3-D solid elements use the default (type 1) constant stress solid elements. The 1-D spot weld beam elements and the nodal rigid body elements use rigid spider connections defined using *CONSTRAINED_NODAL_RIGID_BODY.
In all three models, the lower L-shaped channel is constrained in all three coordinate directions and a displacement is prescribed in the axial direction on the upper channel as shown in Figure 1. Bolt preload is defined in the 3-D solid model using *INITIAL_STRESS_SECTION and in the 1-D beam element model using *INITIAL_AXIAL_FORCE_BEAM. No preload is used in the nodal rigid body bolt model.

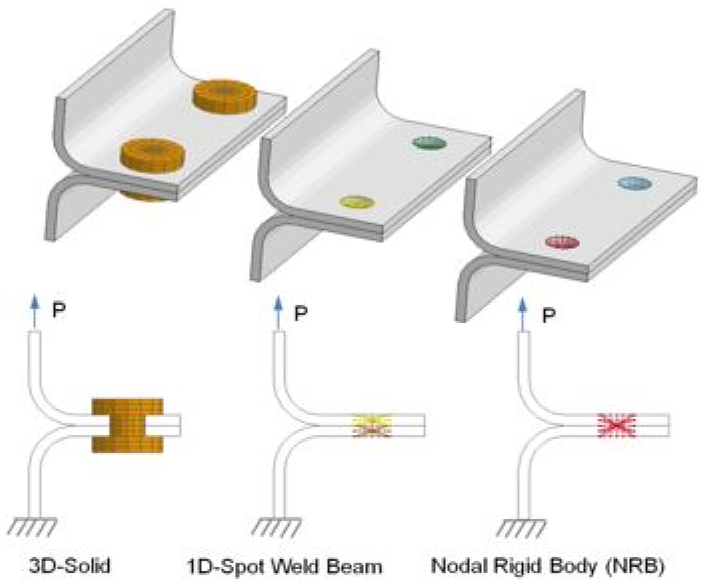

Figure 1: Bolted Flange Models

The bolts use a simple elastic material model with Young's Modulus 29.1E6 psi and Poisson Ratio 0.31. The L-shaped channels use a piecewise-linear plasticity model with Young's Modulus 10.4E6 psi, Poisson Ratio 0.33, yield stress 61,358 psi, and effective plastic failure strain 6.77%.

Model information	
Nodes	10702
Solid elements	6624
Nodal Rigid Bodies	6
Parts	9
Units	in (length), s (time), lbf-s^2/in (mass), lbf (force,) psi (stress)

Table 2: FEA Model Information

Model information	
Test Case ID	Input Deck Name
1	bolted_flange_tensile_loading.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	Effective Plastic Strain	Element	1283	d3plot file
2	Effective Plastic Strain	Element	3405	d3plot file
3	Effective Plastic Strain	Element	7353	d3plot file
4	Cross-Section Force	Z-Force	10: Solid Element	binout/secforc file
5	Cross-Section Force	Z-Force	11: 1-D Spotweld Beam	binout/secforc file
6	Cross-Section Force	Z-Force	12: Nodal Rigid Body	binout/secforc file
7	CPU Time			d3hsp file

Table 4: Test Case targets for Test Case ID AWG-CI-5

4.2 Pass/Fail Criteria

These are the Pass/Fail criteria used for the Validation of the Test Case ID AWG-CI-5.

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 5 and the results are calculated with software versions defined in table 6.

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 5: Used Platforms and CPU Type's

Product	Version	Release	Revision	Parallel type [1]	Precision [2]	executable
LS-DYNA®	971	R12.2	0-g0294a6e436	SMP	SP	ls971.0-g0294a6e436.R12.2
LS-DYNA®	971	R12.2	0-g0294a6e436	SMP	DP	ld971.0-g0294a6e436.R12.2
LS-DYNA®	971	R12.2	0-g0294a6e436	MPP	SP	mpp971.0-g0294a6e436.R12.2
LS-DYNA®	971	R12.2	0-g0294a6e436	MPP	DP	mpd971.0-g0294a6e436.R12.2

[1] MPP = Massively Parallel Processing, SMP = Symmetric Multiprocessing

[2] SP = single precision, DP = double precision

Table 6: Tested LS-DYNA® version

5.2 Results Summary

Table 7 contains the results of the Test Case ID AWG-CI-5 completed with all combinations of software and hardware defined in section 5.1 (1 * 1 * 4 total calculation runs).
Details on the test results can be found in the section 5.3.

The table 7 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**

Table 7: Results summary for Test Case ID AWG-CI-5

5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-CI-5 for LS-DYNA® R12.2 Revision 0-g0294a6e436.

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 Test Target 1: Effective Plastic Strain

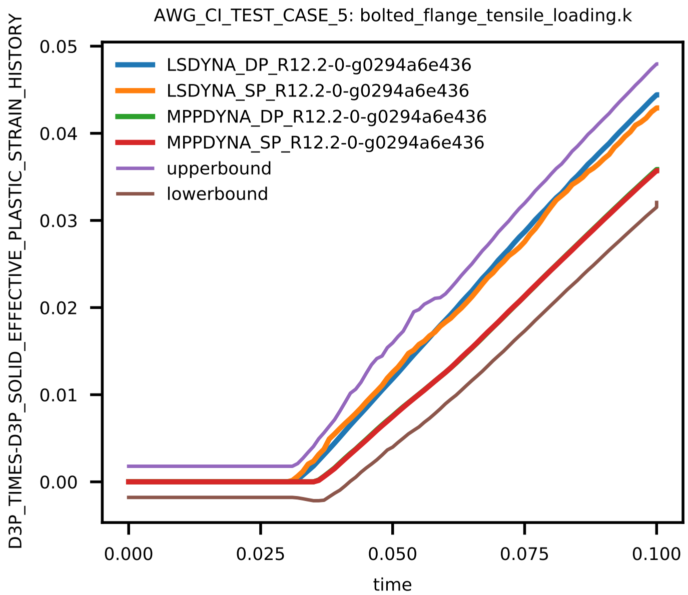

Figure 2: Effective Plastic Strain of element 1283.

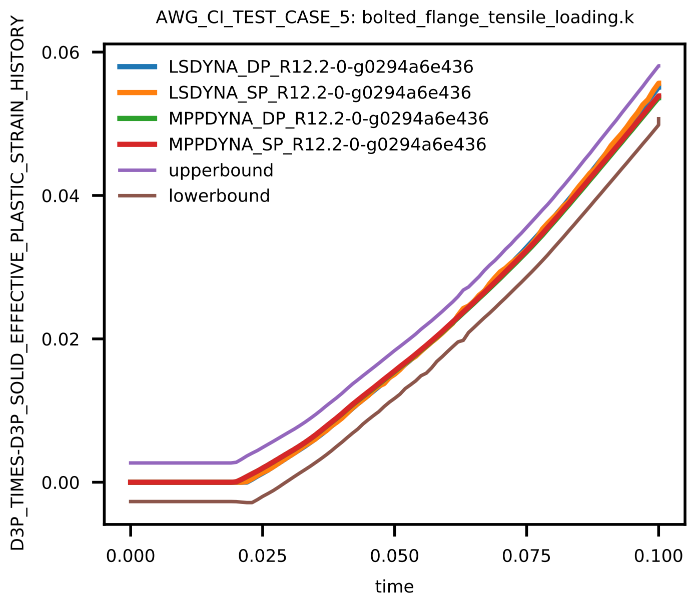

Figure 3: Effective Plastic Strain of element 3405.

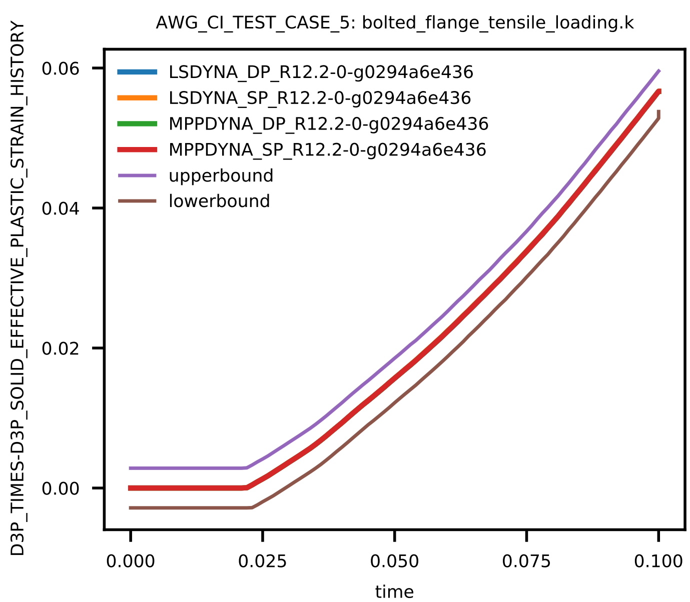

Figure 4: Effective Plastic Strain of element 7353.

5.3.2 Test Target 2: Cross-Section Force of Solid Element

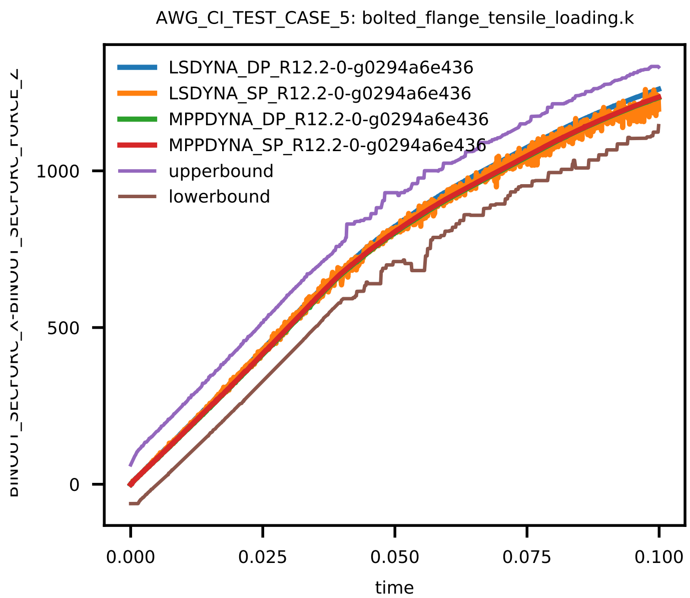

Figure 5: Cross-Section Force of Solid Element, id 10.

5.3.3 Test Target 3: Cross-Section Force of 1-D Spotweld Beam

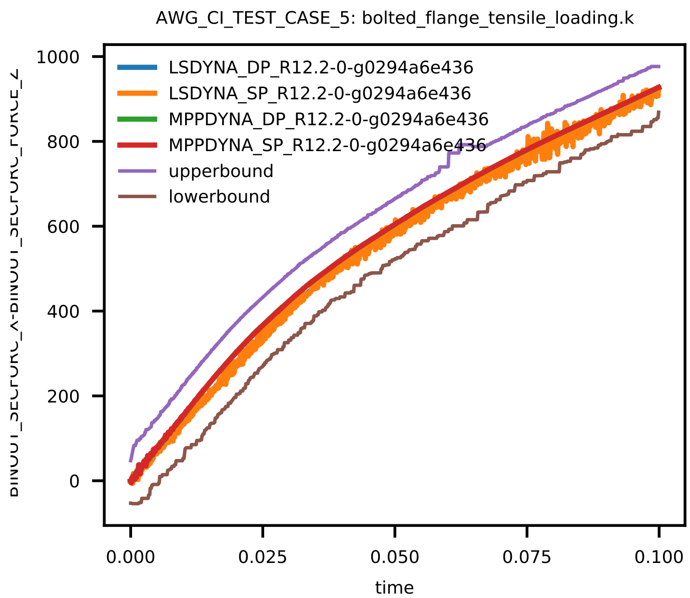

Figure 6: Cross-Section Force of Spotweld Beam, id 11.

5.3.4 Test Target 4: Cross-Section Force of Nodal Rigid Body

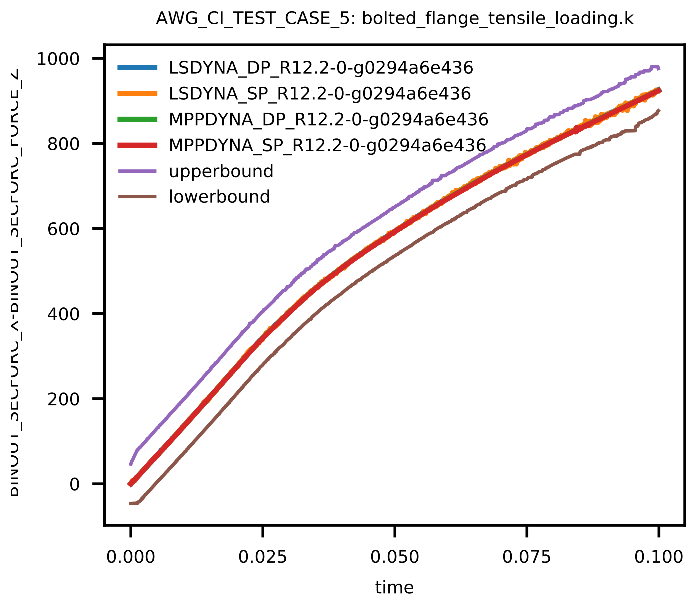

Figure 7: Cross-Section Force of Nodal Rigid Body, id 12.

5.3.5 Test Target 3: CPU time

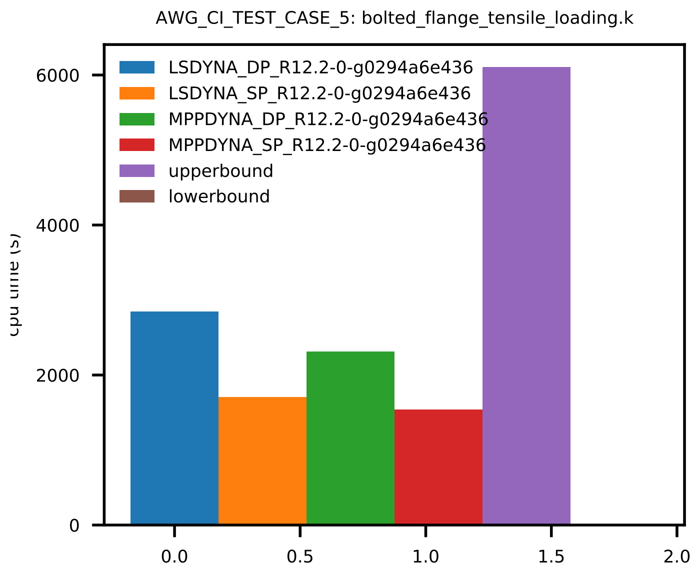

Figure 8: CPU Time Comparison.

References