

TEST CASE DOCUMENTATION AND TESTING RESULTS

ANSYS-QA-LS-DYNA-AWG-ERIF-4-28

TEST CASE ID AWG-ERIF-2-2

Fan Blade-Off Containment Test, Generic Soft Wall Containment

Tested with LS-DYNA® R12.2 Revision 223-gcef54b474c

Friday 5th July, 2024



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1 Introduction

1.1 Purpose of this Document

This document specifies the test case AWG-ERIF-2-2. 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 | Aerospace Working Group Internal Use |
| Test Case Name | Fan Blade-Off Containment Test, Generic Soft Wall Containment |
| Test Case ID | AWG-ERIF-2-2 |
| Test Case Status | active |
| Test Case Classification | Qualitative Study |
| Test Case Source | Honeywell Engines, Systems and Services Arizona State University (ASU) |
| Tested Keyword | *MAT_DRY_FABRIC, *MAT_TABULATED_JOHNSON_COOK |
| Testing Method | example |
| Member of Test Suite | AEROQA SUITE |
| Metadata | AEROQA |

Table 1: Test Case Summary

3 Test Case Specification

3.1 Test Case Purpose

The purpose of QA Test Case ID AWG-ERIF-2-2 is the qualitative study of a fan blade-out event for containment. Details of the containment model for the fan can be found in [2], and details of the fabric material model can be found in [1].

The reliability and consistency of LS-DYNA® as a finite element solver is evaluated by performing an analyses on the containment model for this fan blade-out event (see table 4).

3.2 Test Case Description

This QA Test Case contains a fan blade-out containment test (see figure 1). The model contains two fan blades (the released blade and the following blade), all the blade platforms, the fan containment case, and the Kevlar fabric containment layer. The red coded fan blade in figure 1 is the released blade.

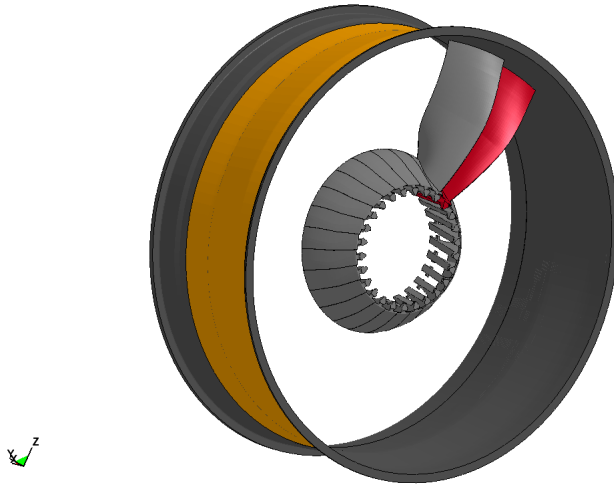


Figure 1: Model sketch: Fan Blade-Out Containment Test, Generic Soft Wall Containment

Table 2 contains a short summary of the physical model set up. Details on the sub model of the engine can be found in [2]. The materials are not further specified and can be chosen in the finite element model as appropriate.

| Physical Model Information | |
|-----------------------------|-----------------|
| Fan case diameter | approx. 42.72" |
| fabric material | Kevlar® |
| number of fabric layers | 88 |
| Initial rotational velocity | 880.00 (x-axis) |

Table 2: Model set-up data

3.3 Model Description

The model geometry is discretized with solid elements for the fan containment case, fan blades and blade platforms. The fabric is discretized with one layer of shell elements (see figure 2). The number of elements and material specifications for the model can be found in table 3. The material for the fan blades and the fan containment case are not related to a specific material and can be chosen as appropriate.

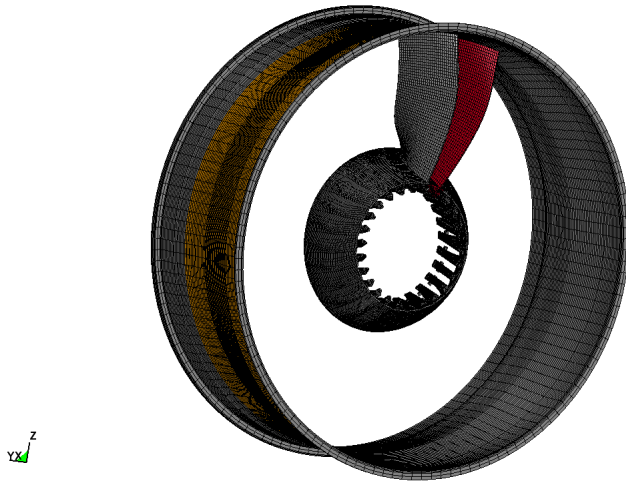


Figure 2: FEA model: Fan Blade-Out Containment Test, Generic Soft Wall Containment

| FEA Model information | |
|-----------------------------|--|
| Nodes | 150778 |
| Solid elements | 77900 |
| Thick shell elements | 10625 |
| Shell elements | 5250 |
| Parts | 6 |
| Number of shell layers | 1 |
| Fabric layers per shell | 88 |
| Fabric material | *MAT_DRY_FABRIC ¹ |
| Containment material | *MAT_TABULATED_JOHNSON_COOK |
| Initial rotational velocity | $\omega_x = 880.00$ |
| Unit system | in (length), s (time), lbf-s ² /in (mass), lbf (force), psi (stress), lbf-in (energy) |

¹ For details on this material see [1]

Table 3: FEA Model Information

A summary of the test case can be found in table 4.

| Sub Test Case ID | Input Deck Name |
|------------------|-----------------|
| 1 | fbo.k |

Table 4: Specification of sub test cases

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

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 | kinetic energy | global | - | binout/glstat file |
| 2 | internal energy | global | - | binout/glstat file |
| 3 | hourglass energy | global | - | binout/glstat file |
| 4 | sliding interface energy | global | - | binout/glstat file |

Table 5: Test Case targets for QA Test Case ID AWG-ERIF-2-2

The targets are used to evaluate the numerical stability of the sub test case (see section 4.2).

4.2 Pass/Fail Criteria

These are the Pass/Fail criteria used for the evaluation of the Test Case ID AWG-ERIF-2-2.

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® R9.0 Revision 108899 binaries by the following process:

- For a specific test case target, interpolate the data from different platform and executable (R9.0 Revision 108899) 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 (R9.0 Revision 108899) 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 | Memory Option |
|---------------|------------------|---|--------------------------|------------------------------|---------------|
| cdcvdce7mbu01 | CentOS 7.9 | Intel® Xeon® Gold 6238R @ 2.20GHz | Platform MPI 08.3.0.2 | 8 | |

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 | R12.2 | 223-gcef54b474c | SMP | DP | ld971.223-gcef54b474c.R12.2 |
| LS-DYNA® | 971 | R12.2 | 223-gcef54b474c | MPP | DP | mpd971.223-gcef54b474c.R12.2 |

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 QA Test Case ID AWG-ERIF-2-2 completed with all combinations of software and hardware defined in section 5.1 (1 * 2 * 2 total calculation runs).

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

The table 8 validation 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 8: Test results summary for QA Test Case ID AWG-ERIF-2-2

5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-ERIF-2-2 for LS-DYNA® R12.2 Revision 223-gcef54b474c.

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.

Example for title:

Title:

'AWG_ERIF_TEST_CASE_2_2: fbo.k' states the test case ID 2_2 and name of the input deck for sub test case 2.

5.3.1 Sub Test Case ID 1 - Test Target 1

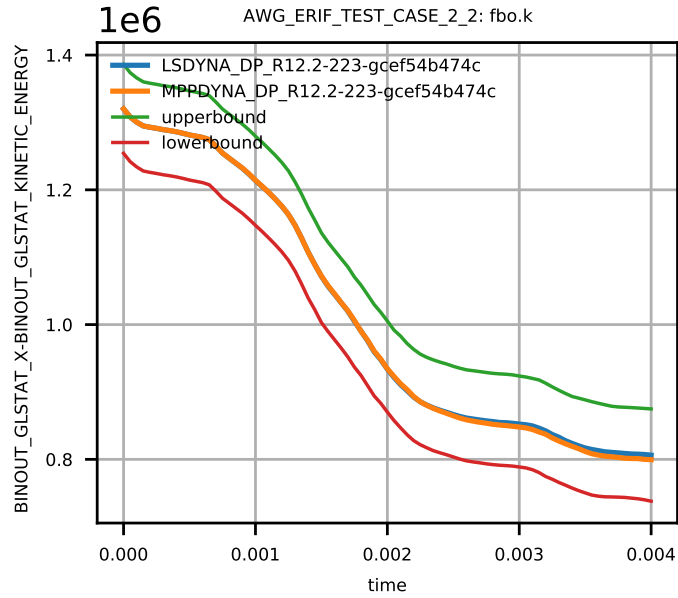


Figure 3: Cross platform results, global kinetic energy, sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

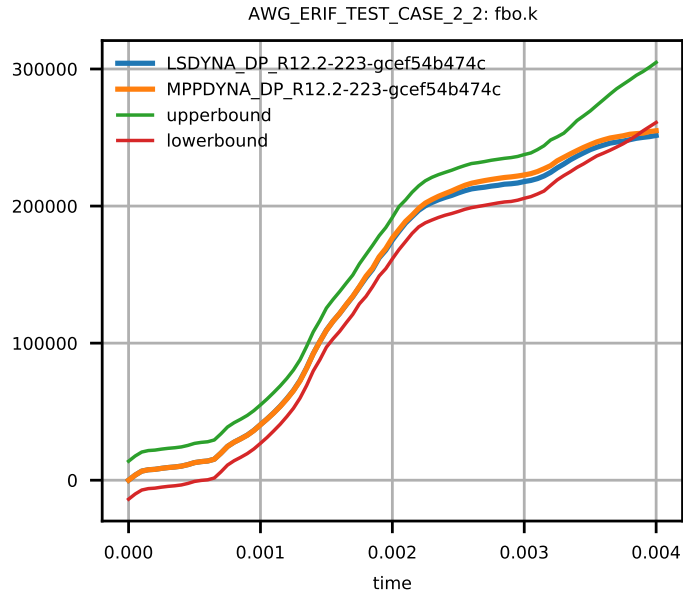


Figure 4: Cross platform results, global internal energy, sub test case ID 1

5.3.3 Sub Test Case ID 1 - Test Target 3

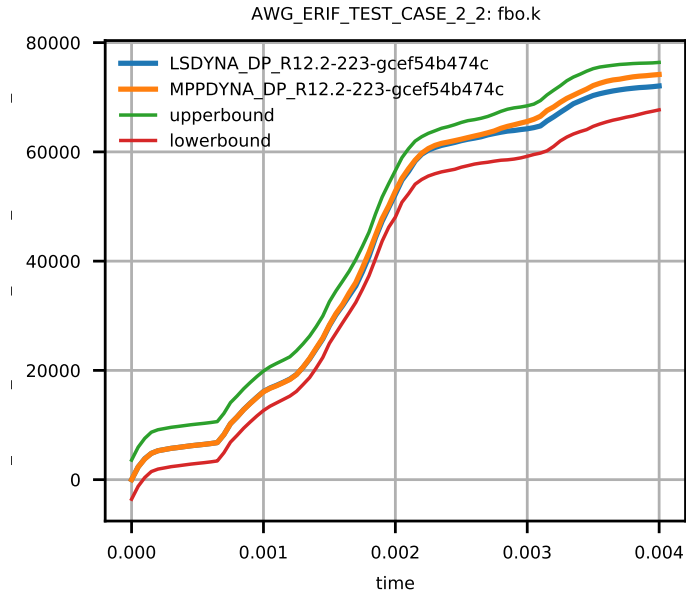


Figure 5: Cross platform results, global hourglass energy, sub test case ID 1

5.3.4 Sub Test Case ID 1 - Test Target 4

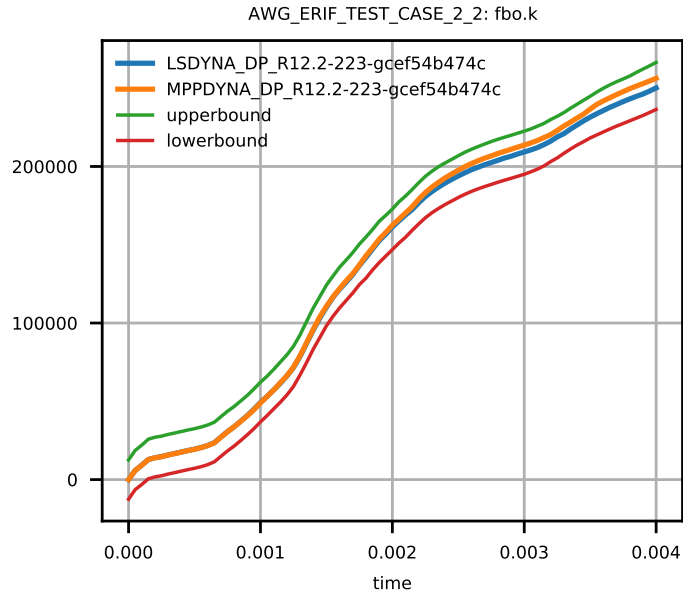


Figure 6: Cross platform results, global sliding interface energy, sub test case ID 1

References

- [1] S. D. RAJAN, B. MOBASHER, Z. STAHLECKER, S. BANSAL, D. ZHU, M. MOREA, AND K. DHANDAPANI, *Explicit Finite Element Modeling of Multilayer Composite Fabric for Gas Turbine Engine Containment Systems, Phase III Part 1: Arizona State University Material Model and Numerical Simulations*, Final Report DOT/FAA/AR-10/23,P1, U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Research, Washington, D.C. 20591, January 2011.
- [2] I. V. VINTILESCU, *Explicit Finite Element Modeling of Multilayer Composite Fabric for Gas Turbine Engine Containment Systems, Phase II Part 4: Model Simulation for Ballistic Tests, Engine Fan Blade-Out, and Generic Engine*, Final Report DOT/FAA/AR-08/37,P4, U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Research, Washington, D.C. 20591, February 2009.