TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AEROQA-2-2-1

TEST CASE ID AEROQA-2-2

Fan Blade-Out Containment Test, Generic Soft Wall Containment

Tested with LS-DYNA® R6.0.0 Revision 71381

Tuesday 7th February, 2012

LSTC
Livermore Software Technology Corp.

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Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case AEROQA-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-Out Containment Test, Generic Soft Wall Containment
Test Case ID	AEROQA-2-2
Test Case Status	under consideration
Test Case Classification	Qualitative Study
Test Case Source	Honeywell Engines, Systems and Services Arizona State University (ASU)
Tested Keyword	*MAT_USER_DEFINED_MATERIAL_MODELS (ASU material model Version 1.3)
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 AEROQA-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 [3], and details of the fabric material model can be found in [2].
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.

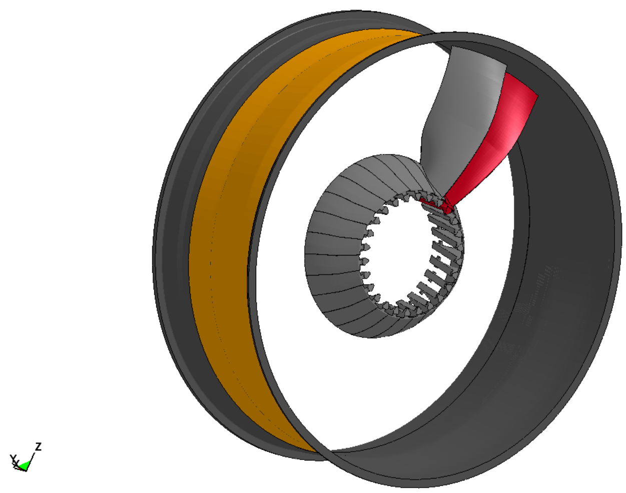

Figure 1: Model sketch: Fan Blade-Out Containment Test, Generic Soft Wall Containment

Table 2 contains a short summary of the physical model set up. Details on the sub model of the engine can be found in [3]. 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®
fabric areal density	0.02275 g/cm^2
Initial rotational velocity	1.056 (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.

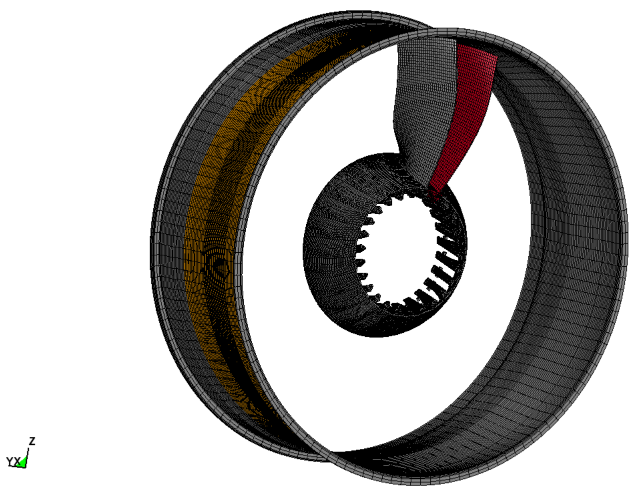

Figure 2: FEA model: Fan Blade-Out Containment Test, Generic Soft Wall Containment

FEA Model information	
Nodes	150778
Solid elements	88525
Solid materials	5
Shell elements	5250
Shell materials	1
Parts	6
Number of shell layers	1
Fabric layers per shell	n/a
Fabric material	*MAT_USER_DEFINED_MATERIAL_MODELS (ASU material model Version 1.3) [1]
Initial rotational velocity	$\omega_x = 1.056$
Unit system	in (length), ms (time), Mlbf-ms^2/in (mass), Mlbf (force), Mpsi (stress), Mlbf-in (energy)

[1] For details on this user material see [2]

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	GEM_2_2.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

Table 5: Test Case targets for QA Test Case ID AEROQA-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 AEROQA-2-2.

A sub test case passes if the following criteria are reached:

- The test case target 1 (global kinetic energy) is bounded.
- The test case target 2 (global internal energy) is bounded.

Otherwise the test fails.

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	hpmpi	4
ham	CentOS 5.4	AMD® Opteron ® 8435 @ 800MHz	hpmpi	4
sgi64d	SUSE LES 9.4	Intel® Itanium® 2 @ 1.6GHz	hpmpi	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	R6.0.0	71381	SMP	SP	ls971.71381.R6.0.0
LS-DYNA®	971	R6.0.0	71381	SMP	DP	ld971.71381.R6.0.0
LS-DYNA®	971	R6.0.0	71381	MPP	SP	mpp971.71381.R6.0.0
LS-DYNA®	971	R6.0.0	71381	MPP	DP	mpd971.71381.R6.0.0

[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 QA Test Case ID AEROQA-2-2 completed with all combinations of software and hardware defined in section 5.1 (1 * 4 * 3 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 AEROQA-2-2

5.3 Result Details

The following subsections contain detailed results for the QA Test Case ID AEROQA-2-2 for LS-DYNA® R6.0.0 Revision 71381.

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:
'GEM_2_2.k: glstat_kinetic_energy' states that the input deck for sub test case 1 was used to calculate these results. The component displayed is the global kinetic energy derived from the 'glstat' output file.

Legend:
'glstat_kinetic_energy_sandwich_ls971.71381.R6.0.0_4' states that the graph shows the global kinetic energy derived from the 'glstat' output file for an input deck which was calculated on the 'sandwich' platform with a LS-DYNA® R6.0.0 Revision 71381 binary (SMP, single precision) on four processors.

5.3.1 Sub Test Case ID 1 - Test Target 1

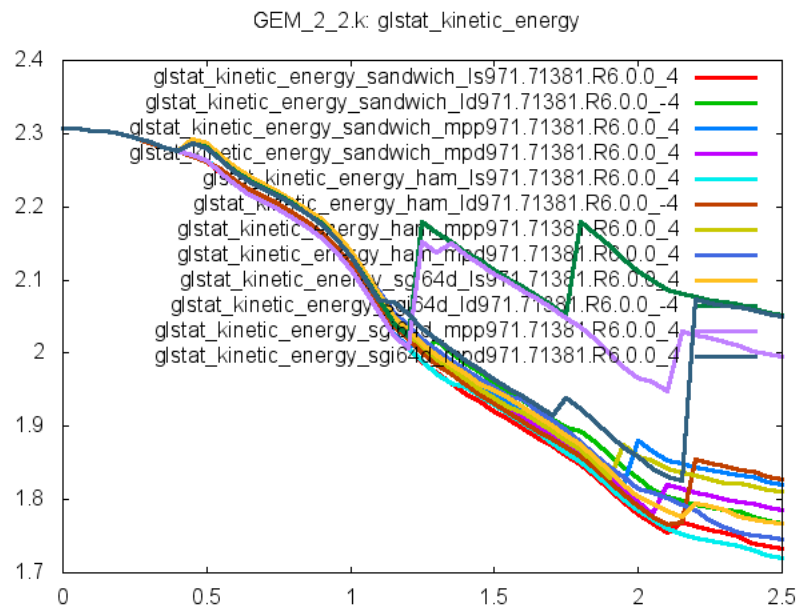

Figure 3: Cross platform results, global kinetic energy, sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

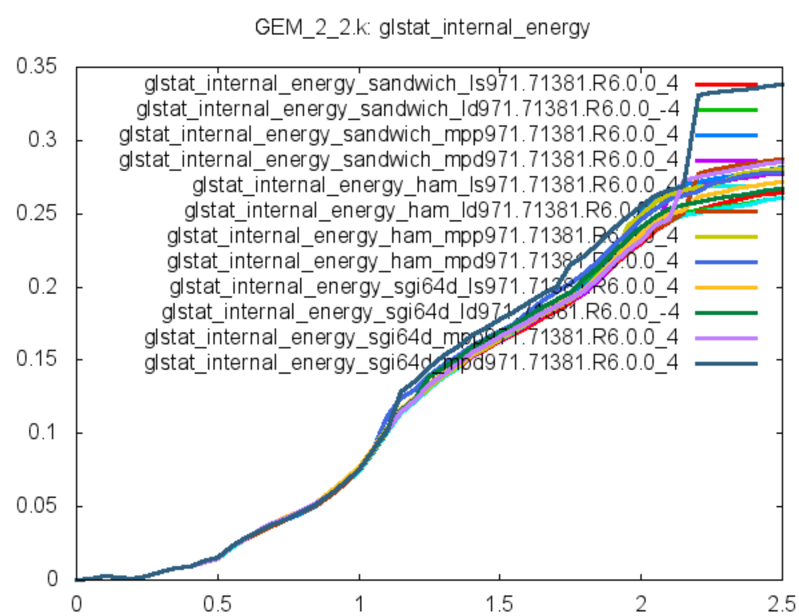

Figure 4: Cross platform results, global internal energy, sub test case ID 1

References

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

[2] 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.

[3] 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.