TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AEROQA-2-1-18

TEST CASE ID AEROQA-2-1

Fan Rig Blade-Off Test, Generic Fan Rig Model

Tested with LS-DYNA® R12.0 Revision 148708

Friday 11th December, 2020

LSTC
Livermore Software
Technology Corp.

Warranty Disclaimer:

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Contents

1 Introduction

1.1 Purpose of this Document

This document specifies the test case AEROQA-2-1. 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	Fan Rig Blade-Off Test, Generic Fan Rig Model
Test Case ID	AEROQA-2-1
Test Case Status	active
Test Case Classification	Qualitative Study
Test Case Source	NCAC
Tested Keyword	n/a
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-2-1 is the qualitative study of a fan blade-off event on a generic fan rig model.
The reliability and consistency of LS-DYNA® as a finite element solver is evaluated by performing an analyses on the generic fan rig model for this fan blade-off event (see table 4).

3.2 Test Case Description

This QA Test Case contains a fan blade-off event on a generic fan rig model (see figure 1). The generic fan rig model contains geometry for all major components of a fan rig, as well as generic material data describing the material behavior.

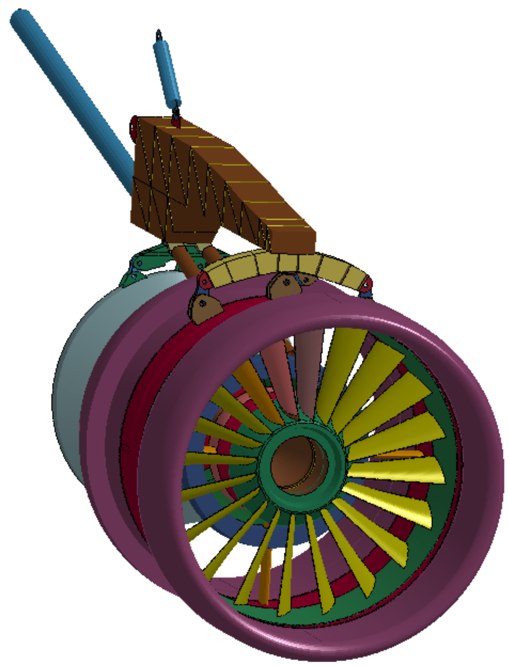

Figure 1: Model sketch: Generic fan rig model

Table 2 contains a short summary of the physical model set up.

Physical Model Information	
Fan	40” fan diameter, 20 wide chord blades, integrally bladed disk, Ti6-4 type material
Shaft	Hollow fan shaft, SS-304 type material, wall thickness of 0.2”
Containment case	Solid wall AL2024 type material containment case
Bearing (3 sets)	The ball bearing reacts thrust and radial loads while the two roller bearings react to radial loads

Table 2: Model set-up data

3.3 Model Description

The model geometry is discretized with shell and solid elements for the structural parts (see figure 2). The number of elements for the model can be found in table 3.
The initialization of the stresses for the rotating parts are done in a previous (implicit) calculation.

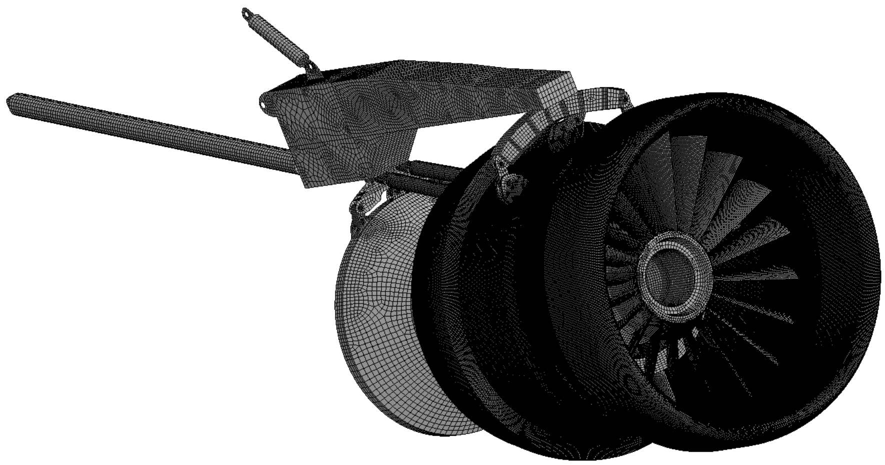

Figure 2: FEA model: Generic fan rig model

FEA Model information	
Nodes	1566914
Shell elements	364482
Shell parts	22
Solid elements	944676
Solid parts	18
Parts	40
Unit system	in (length), s (time), lbf-s^2/in (mass), psi (stress), lbf-in (energy)

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_GRM_002.k

Table 4: Specification of sub test cases

The material definitions and loading conditions 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	part 48	-	binout/matsum file
3	kinetic energy	part 48	-	binout/matsum file
4	rigid body velocity	part 42 [1]	x	binout/matsum file
5	rigid body velocity	part 42 [1]	y	binout/matsum file
6	rigid body velocity	part 42 [1]	z	binout/matsum file

[1] It was changed from part 48 to part 42 when testing with LS-DYNA® 9.1

Table 5: Test Case targets for QA Test Case ID AEROQA-2-1

In table 5 part 48 is the released blade.
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-2-1.

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. The corridors of the test case targets 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 combinations, so that the time domain is the same.
- Calculate the upper and lower bounds by:

$$bound_{up}(i) = max(i) + 0.5 \times [max(i) - min(i)] + 0.15 \times peak$$
$$bound_{low}(i) = min(i) - 0.5 \times [max(i) - min(i)] - 0.15 \times peak$$

  where $max(i)$, $min(i)$ are the maximum and minimum values at the i_{th} time step across all platforms and executable 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]
sand1	SUSE LES 11.0	Intel® Xeon® E5-2680 @ 2.70GHz	Platform MPI 08.02.00.00	16

[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	R12.0	148708	MPP	DP	mpd971.148708.R12.0

[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-2-1 completed with all combinations of software and hardware defined in section 5.1 (1 * 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 AEROQA-2-1

5.3 Result Details

The following subsections contain detailed results for the Test Case ID AEROQA-2-1 for LS-DYNA® R12.0 Revision 148708.

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 result file name, output, platform, executable and number of cpu's separated by comma. A minus sign before the number of cpu's refers to the compatibility option for SMP calculations (see [1] for details on this option).

Example for title and legend:

Title:

'AWG_ERIF_TEST_CASE_2_1: FBO_GRM_002.k' states the test case ID 2_1 and name of the input deck for sub test case 1.

Legend:

'glstat_internal_energy,ham,ls971.148708.R12.0,4' states that the graph shows the internal energy derived from the 'glstat' output file for an input deck which was calculated on the 'ham' platform with a LS-DYNA® R12.0 Revision 148708 binary (SMP, single precision) on four processors.

5.3.1 Sub Test Case ID 1 - Test Target 1

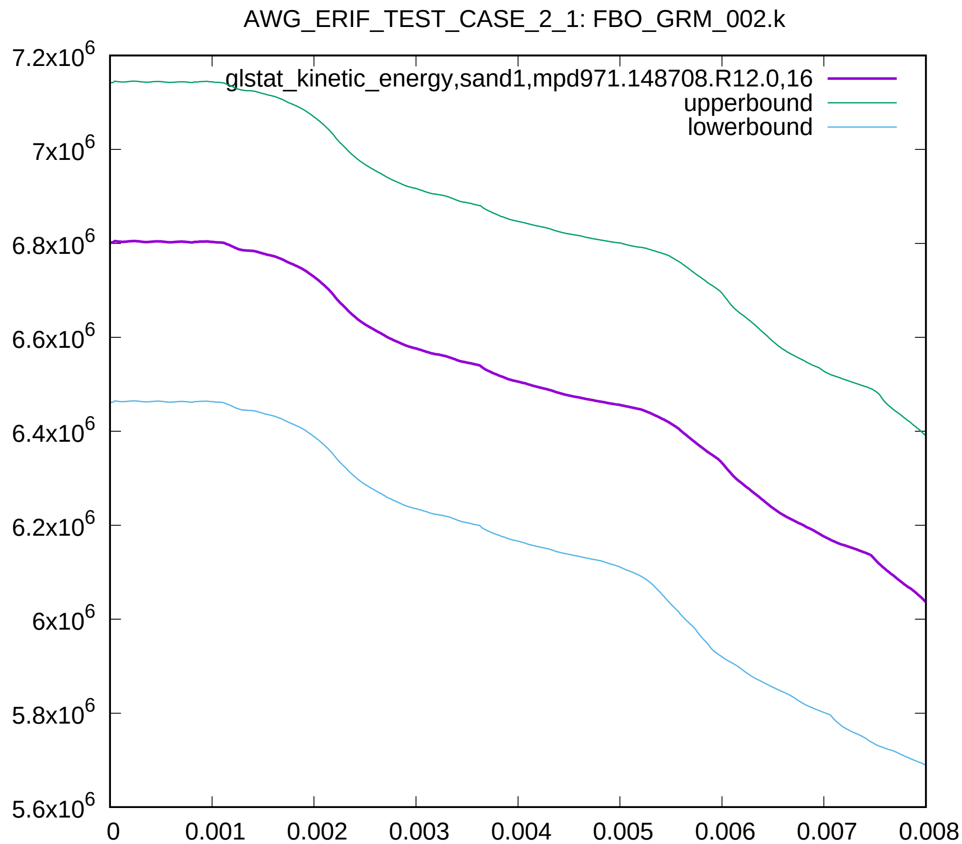

Figure 3: Global kinetic energy, sub test case ID 1

5.3.2 Sub Test Case ID 1 - Test Target 2

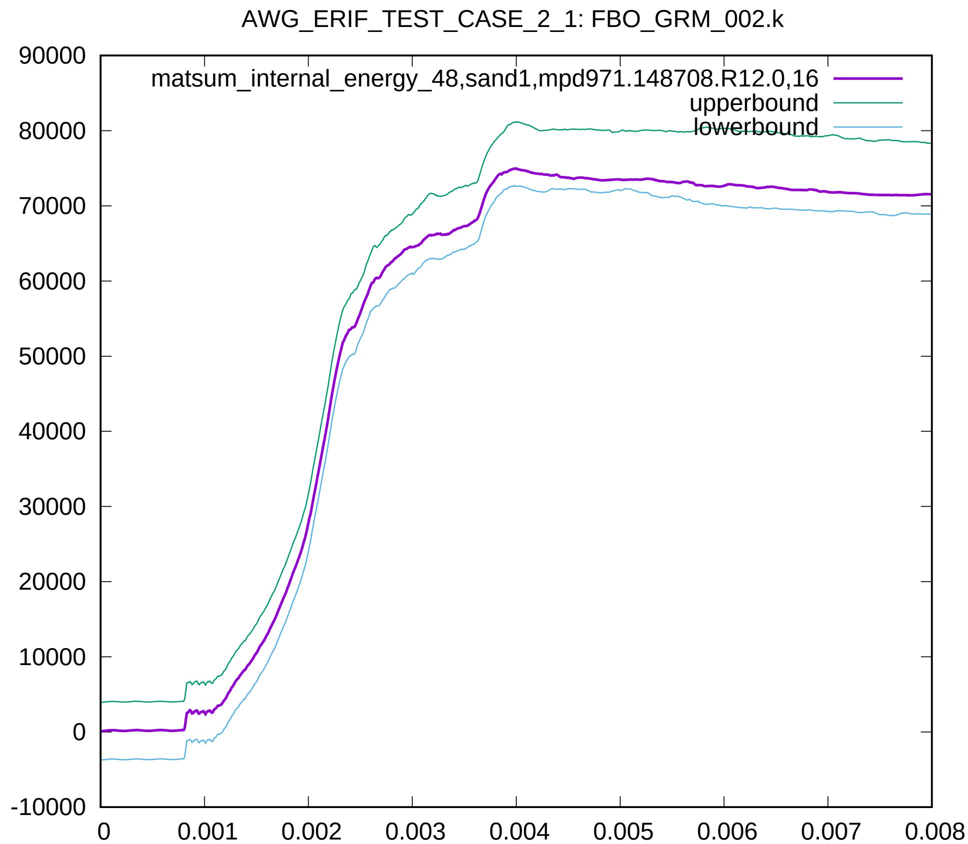

Figure 4: Internal energy part 48 (released blade), sub test case ID 1

5.3.3 Sub Test Case ID 1 - Test Target 3

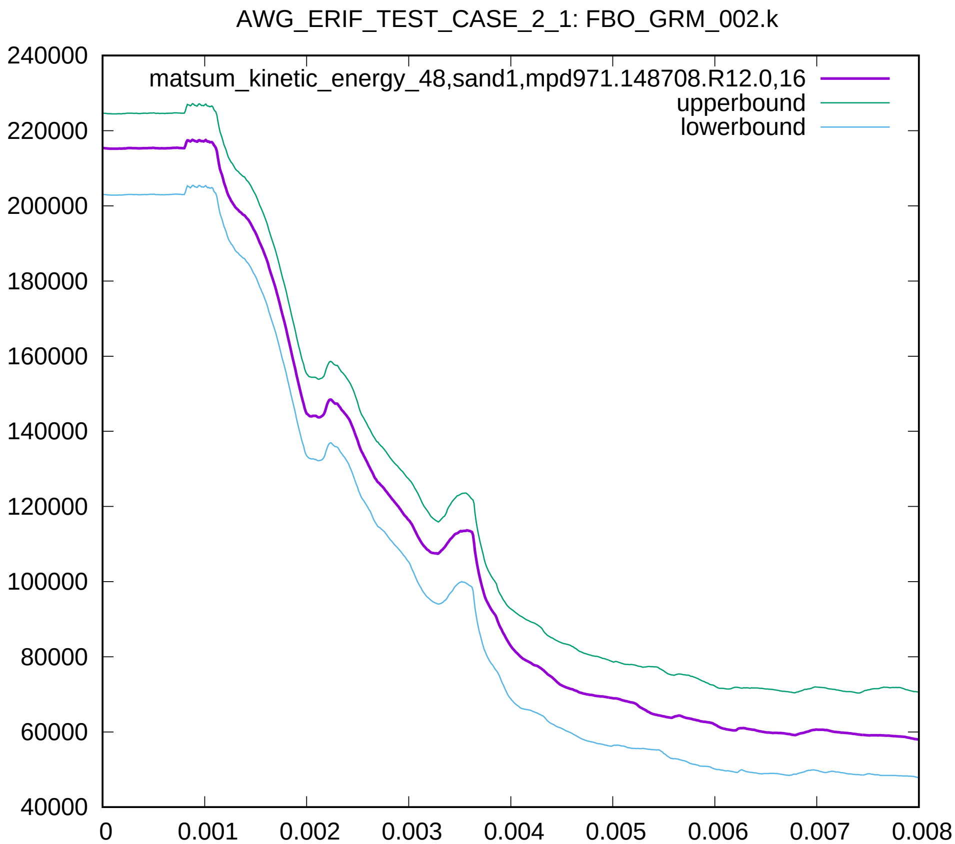

Figure 5: Kinetic energy part 48 (released blade), sub test case ID 1

5.3.4 Sub Test Case ID 1 - Test Target 4

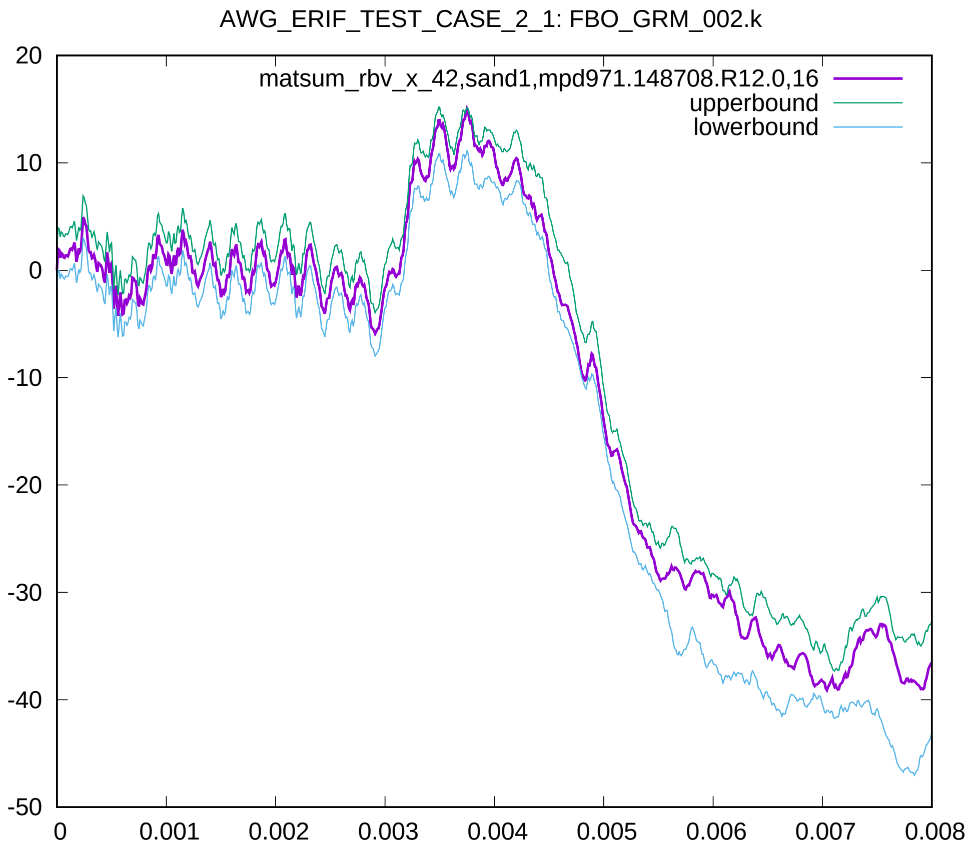

Figure 6: Rigid body velocity (x-component) part 42 (released blade), sub test case ID 1

5.3.5 Sub Test Case ID 1 - Test Target 5

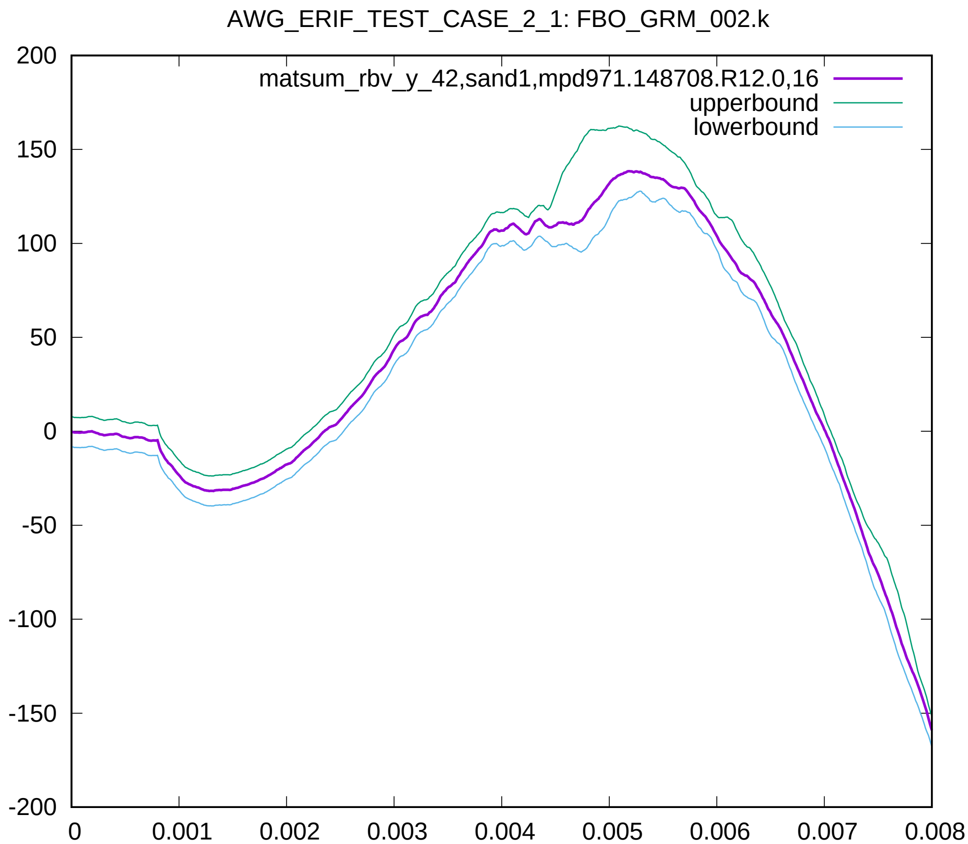

Figure 7: Rigid body velocity (y-component) part 42 (released blade), sub test case ID 1

5.3.6 Sub Test Case ID 1 - Test Target 6

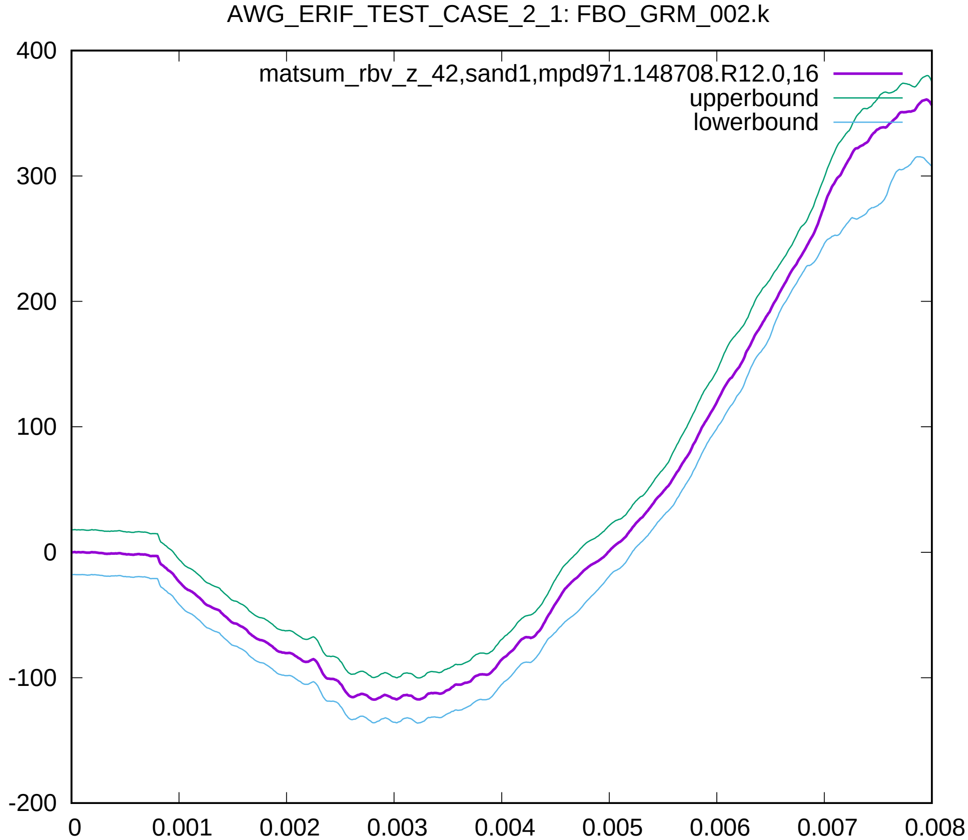

Figure 8: Rigid body velocity (z-component) part 42 (released blade), sub test case ID 1

References

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