

IMAC XXIX Round Robin Operational Modal Analysis

February 2011 Version 3



CAE Software and Services

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Introduction

This report gives an overview of the OMA test cases that were performed in the framework of the Operational Modal Analysis Round Robin for IMAC XXIX.

Calibration 1 – General Moderately Damped System

Introduction

This is an analytical dataset; the dataset is generated from a simple five degree-offreedom system. The system was excited at all five DOFs using random excitation. The sampling rate was 256Hz. The mass, stiffness and damping matrix are given by:

$$M = 2.5 \times \begin{bmatrix} 100 & 0 & 0 & 0 & 0 & 0 \\ 0 & 140 & 0 & 0 & 0 \\ 0 & 0 & 12 & 0 & 0 \\ 0 & 0 & 0 & 180 & 0 \\ 0 & 0 & 0 & 0 & 20 \end{bmatrix}$$
(1)
$$K = 10^{6} \times \begin{bmatrix} 9 & -5 & 0 & 0 & 0 \\ -5 & 11 & -6 & 0 & 0 \\ 0 & -6 & 12.5 & -6.5 & 0 \\ 0 & 0 & -6.5 & 14.5 & -8 \\ 0 & 0 & 0 & -8 & 15 \end{bmatrix}$$
(2)
$$C = 10^{-2} \times \begin{bmatrix} 325 & -25 & 0 & 0 & 0 \\ -25 & 45 & -20 & 0 & 0 \\ 0 & -20 & 32 & -12 & 0 \\ 0 & 0 & -12 & 19 & -7 \\ 0 & 0 & 0 & -7 & 27 \end{bmatrix}$$
(3)

Settings of the FEMtools MPE toolbox

The following settings were used to identify the modal parameters in with the FEMtools MPE.

Parameter	Value
Maximum order	40
Minimum frequency	0.015
Maximum frequency	128
Minimum damping ratio [%]	0
Maximum damping ratio [%]	10
Maximum frequency deviation [%]	1
Maximum damping deviation [%]	5
Exponential windowing [%]	0

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Fast stabilization	No
Reference channels	3, 4, 5
XPS blocksize	16384

Table 1: The settings used to identify the modal parameters in FEMtools.

Extracted Modal Parameters

The following modal parameters were extracted in FEMtools:

Mode	Frequency [Hz]	Damping [%]	MPC [%]	MPD [º]	Max MAC
1	12.534	1.19	99.69	6.76	23.43
2	22.088	1.09	99.93	2.52	8.98
3	34.849	2.12	98.23	31.71	5.39
4	88.518	0.50	100.00	0.22	8.98
5	104.807	0.85	99.99	1.66	23.43

Table 2: The modal parameters extracted by the FEMtools MPE.



Figure 1: The stabilization chart (left) and the autoMAC of the extracted modes (right).

Comparison

Figure 2 compares the results obtained by the various participants of the IMAC XXIX round robin.



Figure 2: Comparison of the results obtained by the participants of the IMAC Round Robin.

Calibration 2 – General Lightly Damped System

Introduction

This is an analytical dataset; the dataset is generated from a simple five degree-offreedom system. The system was excited at all five DOFs using random excitation. The sampling rate was 256Hz. The mass, stiffness and damping matrix are given by:

$$M = 2.5 \times \begin{bmatrix} 100 & 0 & 0 & 0 & 0 \\ 0 & 140 & 0 & 0 & 0 \\ 0 & 0 & 12 & 0 & 0 \\ 0 & 0 & 0 & 180 & 0 \\ 0 & 0 & 0 & 0 & 20 \end{bmatrix}$$
(4)
$$K = 10^{6} \times \begin{bmatrix} 9 & -5 & 0 & 0 & 0 \\ -5 & 11 & -6 & 0 & 0 \\ 0 & -6 & 12.5 & -6.5 & 0 \\ 0 & 0 & -6.5 & 14.5 & -8 \\ 0 & 0 & 0 & -8 & 15 \end{bmatrix}$$
(5)
$$C = 10^{-2} \times \begin{bmatrix} 120 & -5 & 0 & 0 & 0 \\ -5 & 25 & -10 & 0 & 0 \\ 0 & -10 & 15 & -20 & 0 \\ 0 & 0 & -20 & 10 & -25 \\ 0 & 0 & 0 & -25 & 7 \end{bmatrix}$$
(6)

Settings of the FEMtools MPE toolbox

The following settings were used to identify the modal parameters in with the FEMtools MPE.

Parameter	Value
Maximum order	40
Minimum frequency	0.015
Maximum frequency	128
Minimum damping ratio [%]	0
Maximum damping ratio [%]	10
Maximum frequency deviation [%]	1
Maximum damping deviation [%]	5
Exponential windowing [%]	0
Fast stabilization	No
Reference channels	1, 3, 5
XPS blocksize	102400

Table 3: The settings used to identify the modal parameters in FEMtools.

Extracted Modes

Mode	Frequency [Hz]	Damping [%]	MPC [%]	MPD [º]	Max MAC
1	12.524	0.02	100.00	0.02	23.57
2	22.080	0.01	100.00	0.01	9.18
3	34.887	0.10	100.00	0.10	3.39
4	88.525	0.00	100.00	0.00	9.18
5	104.783	0.00	100.00	0.00	23.57

The following modal parameters were extracted in FEMtools:

Table 4: The modal parameters extracted by the FEMtools MPE.



Figure 3: The stabilization chart (left) and the autoMAC of the extracted modes (right).

Comparison

Figure 4 compares the results obtained by the various participants of the IMAC XXIX round robin.



Figure 4: Comparison of the results obtained by the participants of the IMAC Round Robin.

Calibration 3 – Proportional Heavily Damped System

Introduction

This is an analytical dataset; the dataset is generated from a simple five degree-offreedom system. The system was excited at all five DOFs using random excitation. The sampling rate was 256Hz. The mass, stiffness and damping matrix are given by:

$$M = 2.5 \times \begin{bmatrix} 100 & 0 & 0 & 0 & 0 \\ 0 & 140 & 0 & 0 & 0 \\ 0 & 0 & 12 & 0 & 0 \\ 0 & 0 & 0 & 180 & 0 \\ 0 & 0 & 0 & 0 & 20 \end{bmatrix}$$
(7)
$$K = 10^{6} \times \begin{bmatrix} 9 & -5 & 0 & 0 & 0 \\ -5 & 11 & -6 & 0 & 0 \\ 0 & -6 & 12.5 & -6.5 & 0 \\ 0 & 0 & -6.5 & 14.5 & -8 \\ 0 & 0 & 0 & -8 & 15 \end{bmatrix}$$
(8)

C = 1.3M + 0.0004K

(9)

Settings of the FEMtools MPE toolbox

The following settings were used to identify the modal parameters in with the FEMtools MPE.

Parameter	Value
Maximum order	40
Minimum frequency	0.015
Maximum frequency	128
Minimum damping ratio [%]	0
Maximum damping ratio [%]	10
Maximum frequency deviation [%]	1
Maximum damping deviation [%]	5
Exponential windowing [%]	0
Fast stabilization	No
Reference channels	1, 3, 5
XPS blocksize	16384

Table 5: The settings used to identify the modal parameters in FEMtools.

Extracted Modes

Mode	Frequency [Hz]	Damping [%]	MPC [%]	MPD [º]	Max MAC
1	12.505	2.51	100.00	0.89	92.96
2	22.065	3.11	100.00	0.12	3.85
3	34.873	4.59	100.0	1.61	5.19
4	88.166	9.00	97.53	28.36	52.96
5	103.907	9.27	70.79	49.00	92.96

The following modal parameters were extracted in FEMtools:

Table 6: The modal parameters extracted by the FEMtools MPE.



Figure 5: The stabilization chart (left) and the autoMAC of the extracted modes (right).

Comparison

Figure 6 compares the results obtained by the various participants of the IMAC XXIX round robin.



Figure 6: Comparison of the results obtained by the participants of the IMAC Round Robin.

Wind Turbine Blade

Introduction

A scaled model of a wind turbine blade (see Figure 7) is considered to evaluate the performance of OMA techniques on simple experimental structure. The structure was fixed at the root and was excited by means of random tapping for about 5 minutes. The sample rate was 512 Hz and the frequency range of interest is up to 200 Hz. Responses were measured in all three directions at 16 locations.



Figure 7: Scaled model of a wind turbine blade.

Settings of the FEMtools MPE toolbox

The following settings were used to identify the modal parameters in with the FEMtools MPE.

Parameter	Value
Maximum order	60
Minimum frequency	0.2
Maximum frequency	200
Minimum damping ratio [%]	0
Maximum damping ratio [%]	10
Maximum frequency deviation [%]	1
Maximum damping deviation [%]	5
Exponential windowing [%]	0
Fast stabilization	No
Reference channels	1, 6, 13
XPS blocksize	3072

Table 7: The settings used to identify the modal parameters in FEMtools.

Extracted Modes

The following modal	parameters were extracted in FEMtools:
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Mode	Frequency [Hz]	Damping [%]	MPC [%]	MPD [º]	Max MAC
1	7.26	4.43	97.77	52.65	39.52
2	7.61	5.62	92.92	34.54	39.52
3	9.91	5.13	98.49	34.54	39.52
4	27.20	2.00	99.96	2.84	82.45
5	44.79	1.36	99.95	52.13	28.83
6	49.78	1.74	99.97	6.43	63.15
7	59.39	1.26	99.49	39.65	47.61
8	63.96	1.66	99.75	5.62	72.32
9	71.73	0.82	97.98	29.50	80.79
10	73.25	0.93	93.12	29.72	80.79
11	77.27	1.06	99.92	20.22	52.29
12	86.50	1.43	97.60	40.70	27.77
13	93.37	1.00	99.01	41.73	52.29
14	93.68	1.04	93.79	46.71	23.54
15	103.50	1.23	96.30	34.48	32.58
16	106.58	0.94	64.68	46.53	57.12
17	107.63	0.86	90.75	43.03	31.02
18	112.83	0.29	80.60	50.70	75.40
19	117.66	0.89	90.36	54.35	30.83
20	125.26	1.11	80.13	57.73	61.08
21	128.80	0.92	96.94	22.95	87.54
22	136.84	0.77	92.69	34.33	93.61
23	141.76	0.94	86.01	41.97	91.12
24	145.35	0.77	96.14	24.49	77.56
25	150.35	0.78	86.58	61.42	91.12

Table 8: The modal parameters extracted by the FEMtools MPE.



Figure 8: The stabilization chart (left) and the autoMAC of the extracted modes (right).

Mode-1 (7.26 Hz) and mode 2 (7.61 Hz) are two closely spaced modes. The first mode mainly deflects in the transverse direction, while the second mode mainly deflects the structure in the in-plane direction. Mode 13 and 14 are also a couple of two closely spaced modes.



Figure 9: The first couple of closely spaced modes, mode 1 (left) and mode 2 (right).

Comparison

Figure 6 compares the results obtained by the various participants of the IMAC XXIX round robin.



Figure 10: Comparison of the results obtained by the participants of the IMAC Round Robin.

Ship

Introduction

The dataset was collected on a roll-on roll-off ship. During the tests the engine was operating at 123 rpm. The data is collected for a period of 90 minutes. The sampling frequency is 128 Hz. Frequency range of interest is 0-10 Hz. Ship has a four bladed propeller with controllable pitch.



Figure 11: The tested roll-on roll-off ship.

Settings of the FEMtools MPE toolbox

The following settings were used to identify the modal parameters in with the FEMtools MPE.

Parameter	Value
Maximum order	80
Minimum frequency	0.2
Maximum frequency	10
Minimum damping ratio [%]	0
Maximum damping ratio [%]	10
Maximum frequency deviation [%]	1
Maximum damping deviation [%]	5
Exponential windowing [%]	No
Fast stabilization	No
Reference channels	1, 2
XPS blocksize	16384

Extracted Modes

The following modal parameters were extracted in FEMtools:

Mode	Frequency [Hz]	Damping [%]	MPC [%]	MPD [º]	Max MAC
1	1.34	1.72	99.42	4.27	21.98
2	2.02	1.08	99.87	35.66	96.31
3	2.05	0.07	99.43	37.32	96.31
4	2.29	0.94	96.11	27.24	74.55
5	2.95	1.49	99.45	28.23	50.19
6	3.29	1.35	98.71	57.96	69.27
7	3.37	0.36	98.08	12.42	69.27
8	3.44	1.19	89.73	45.64	48.05
9	3.80	1.00	80.95	38.82	44.22
10	3.96	0.58	97.39	30.99	61.24
11	4.10	0.04	92.08	50.72	85.00
12	4.28	0.73	94.48	34.26	85.00
13	4.51	0.88	99.62	24.55	61.24
14	5.02	1.43	91.59	30.10	31.89
15	5.10	0.70	77.84	41.57	28.34
16	5.29	0.68	66.65	54.63	18.73
17	5.88	0.79	92.35	48.92	51.78
18	6.88	0.60	77.29	58.66	52.79
19	8.20	0.05	96.93	18.14	96.40

Table 9: The modal parameters extracted by the FEMtools MPE.



Figure 12: The stabilization chart (left) and the autoMAC of the extracted modes (right).

The table below presents the mode shape of the first four modes that were identified. Note that the points of the left side of the ship (the line with 5 points) were only measured in the Z direction. This is the reason why this side is not deformed on the plot of mode-2.





Mode-1: First out-of-plane bending

Mode-2: First in-plane bending



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Mode-37: Second out-of-plane bendingMoFigure 13: The shape of the first four identified modes.

Mode-4: First torsional mode

Comparison

Figure 6 compares the results obtained by the various participants of the IMAC XXIX round robin.



Figure 14: Comparison of the results obtained by the participants of the IMAC Round Robin.