

The Results Comparison of Experimental and Operational Modal Analysis of a Fixed Cantilever

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Abstract The aim of this article is to compare the results of experimental and operational modal analysis of cantilever fixed on the one side. The results of both measurements are consequently validated by numerical method.

Keywords: *experimental modal analysis, operational modal analysis, cantilever*

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1. Introduction

Determination of modal parameters (natural frequencies, damping and mode shapes) of real systems is one of the most conventional operations by dynamic characteristics investigation of the bodies. Experimental modal analysis (EMA) is one of the most common used methods for their investigation. In some cases its using is not convenient or it is too complicated or time-consuming, then the operational modal analysis (OMA) comes in [1,2].

Both the analyses were used for investigation of modal parameters of the fixed cantilever (Figure 1).



Figure 1. Measured cantilever fixed on the one end

2. The Brief Theoretical Principle of EMA

The basic principle of EMA method is to find the response model, i.e. the appropriate set of measured frequency response functions. The frequency response function can be expressed in various forms, for example as a quotient of output and input, motion and force or response and excitation. In general, there are three types of frequency response functions – receptance, mobility and accelerance (sometimes denoted as inertance) – according to used response parameter. Receptance can be expressed as a quoting of displacement and force, mobility

as a quoting of velocity and force and accelerance as a quoting of acceleration and force.

Thus, by EMA method there is need to know information of both input and output (excitation and response) so at least two-channel measuring device has to be used.

For excitation of a structure the various techniques can be used:

- Dynamic excitation – various shakers with harmonic, periodic or stochastic signal
- Impulse excitation – modal hammer, abrupt release from deformed position

For response measuring the various transducers are used:

- piezoelectric accelerometers, laser Doppler velocimeter

The modal results of measured structure strongly depends on sort of fixation. In general, there are three typical possibilities how to fix the measured structure and each one has its pros and cons:

- free-free: the structure is usually hung on soft springs. This method of fixation is used when comparison with numerical results is being performed
- fixed: boundary conditions of real and numerical structure are generally not same because real fixation is not ideal
- in situ: if modal parameters of real boundary conditions are needed [3,4,5,6].

3. Determination of Modal Parameters by Numerical Methods

With regard to unknown material properties of investigated cantilever, we did not intend by numerical simulation to authentically describe its natural frequencies and mode shapes, but only its approximate determination. That is way we did not intend by numerical model its fixation to the frame by screws but we chose one its

surface as fixed. From such acquired mode shapes it was possible to determine approximate position of nodes for investigated natural frequencies and on this knowledge we could determine convenient location of reference transducer by operational modal analysis.

4. Determination of Modal Parameters by Experimental Modal Analysis

There was used a 6-channel measuring module Pulse from Brüel & Kjær (Figure 2a) as a measuring device for both methods, as a vibration transducer was used mono-axial accelerometer Brüel & Kjær, type 4507B (Figure 2b) and as a exciter was used modal hammer Brüel & Kjær, type 8206 with plastic tip (Figure 2c).



Figure 2.a) Modul Pulse b) Monoaxial accelerometer c) Modal hammer

There was created 16 evenly distributed points on the cantilever and every that point was measured step by step by the accelerometer while the excitation was realized at the particular point (roving accelerometer/ fixed excitation). The highest measured frequency (span) was chosen at 2000Hz with frequency resolution of 1.25Hz. The measurement at every point was performed 3 times and then averaged.

5. Determination of Modal Parameters by Operational Modal Analysis

In contrast to EMA which need to have data from input (excitation) for its computational algorithm, OMA can work without them. However, some demands on excitation exist; it should be broadband and stochastic [3].

For this purpose served us above-mentioned modal hammer which exciting frequency range is known and in our case satisfactory. There were used 5 mono-axial accelerometers for acceleration measurement, all the type 4507B, from which one was set as a reference. Its positioning was chosen upon results of numerical simulation on the cantilever free-end. Remaining accelerometers were gradually shifted from one investigated point to another whereby created 4 measuring sequences.

The measuring software setting was equal to the EMA one, i.e. frequency span was 2000Hz with frequency resolution of 1.25Hz. Compared to EMA there is need to set up the time required for measurement or in other words the number of averaging. In our case it was 27.2s or 100 averages.

6. The Results of Particular Measurements

There are presented the results of natural frequencies f_n of investigated cantilever acquired by FEM, EMA and OMA methods in the table (Table 1). The natural frequencies inscribed to table are in unit of Hertz [Hz].

Table 1. Comparison of natural frequencies f_n of FEM, EMA and OMA methods

order of f_n / used method	FEM	EMA	OMA
1.	18,687	18,75	16,8
2.	92,273	93,1	92,8
3.	240,26	246,3	233.6
4.	460,78	468,8	456
5.	754,16	761,3	746.4
6.	1119,7	1131	1110
7.	1556,6	1569	1551

From (Table 1) is evident that natural frequencies measured by OMA method are lower than those by EMA method. This decrease of natural frequencies by OMA method was caused by bigger weight of cantilever due to using of five accelerometers instead of one.

There is presented first seven mode shapes, in order from first to seventh, acquired by FEM method in the (Figure 3).

There is presented first seven mode shapes, in order from first to seventh, acquired by EMA method in the (Figure 4).

There is presented first seven mode shapes, in order from first to seventh, acquired by OMA method in the (Figure 5).

It is necessary to say that there were investigated only bending mode shapes for all the methods. Motion of point 2, as it is possible to see in (Figure 4), or in (Figure 5) for 2nd, 5th, 6th and 7th mode shape is caused by that this point is not situated exactly in place of fixation. Further, there is from (Figure 4) and (Figure 5) possible to see for 2nd mode shape that between point 15 and 16 the node was occurred. This one is caused by imperfect fixation which was realized by two screws as it is possible to see in (Figure 1). Such location of screws enabled slight movement of cantilever in fixed area. On reliable course display of higher mode shapes it would be necessary to increase the number of measured points.

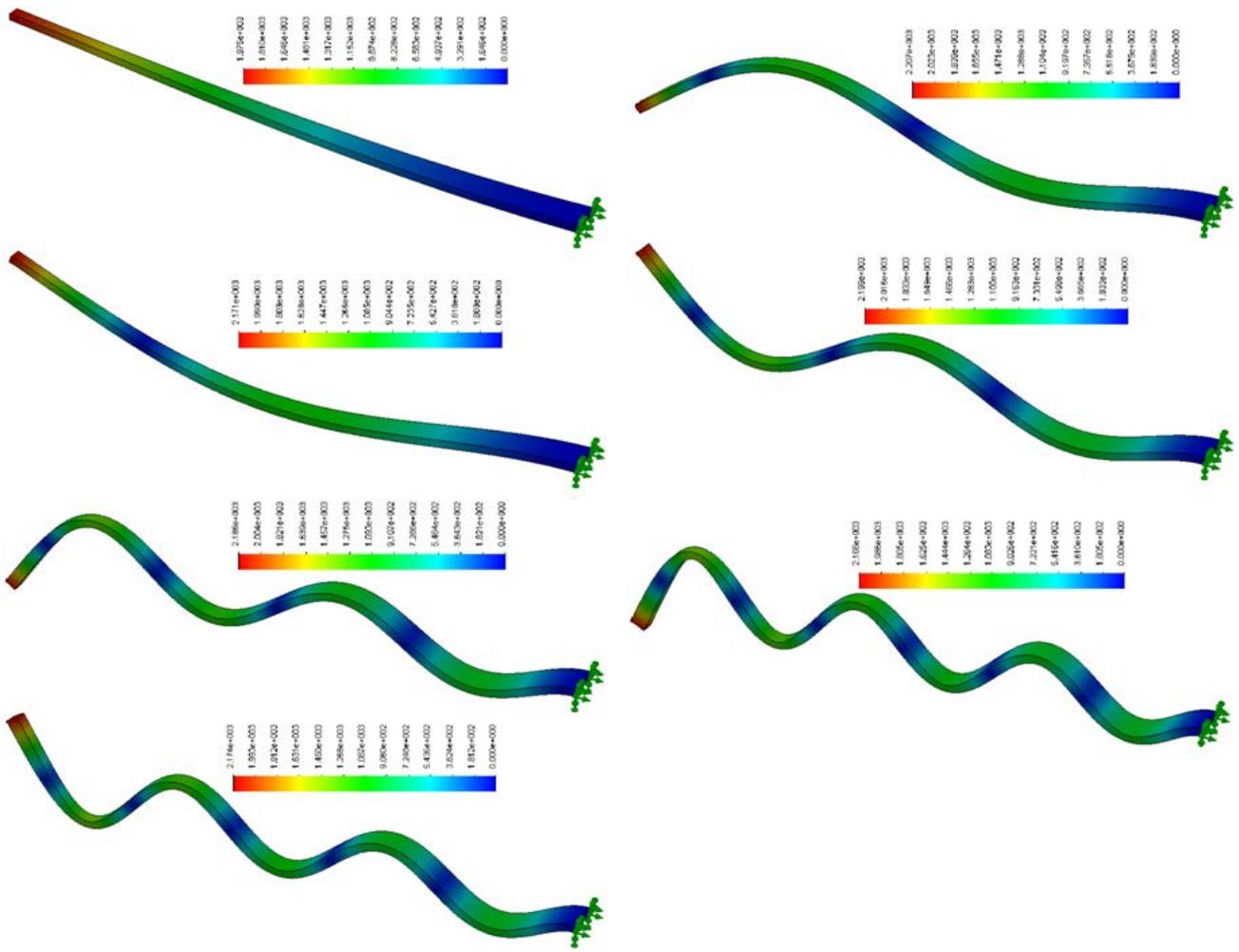


Figure 3. The mode shapes acquired by FEM method

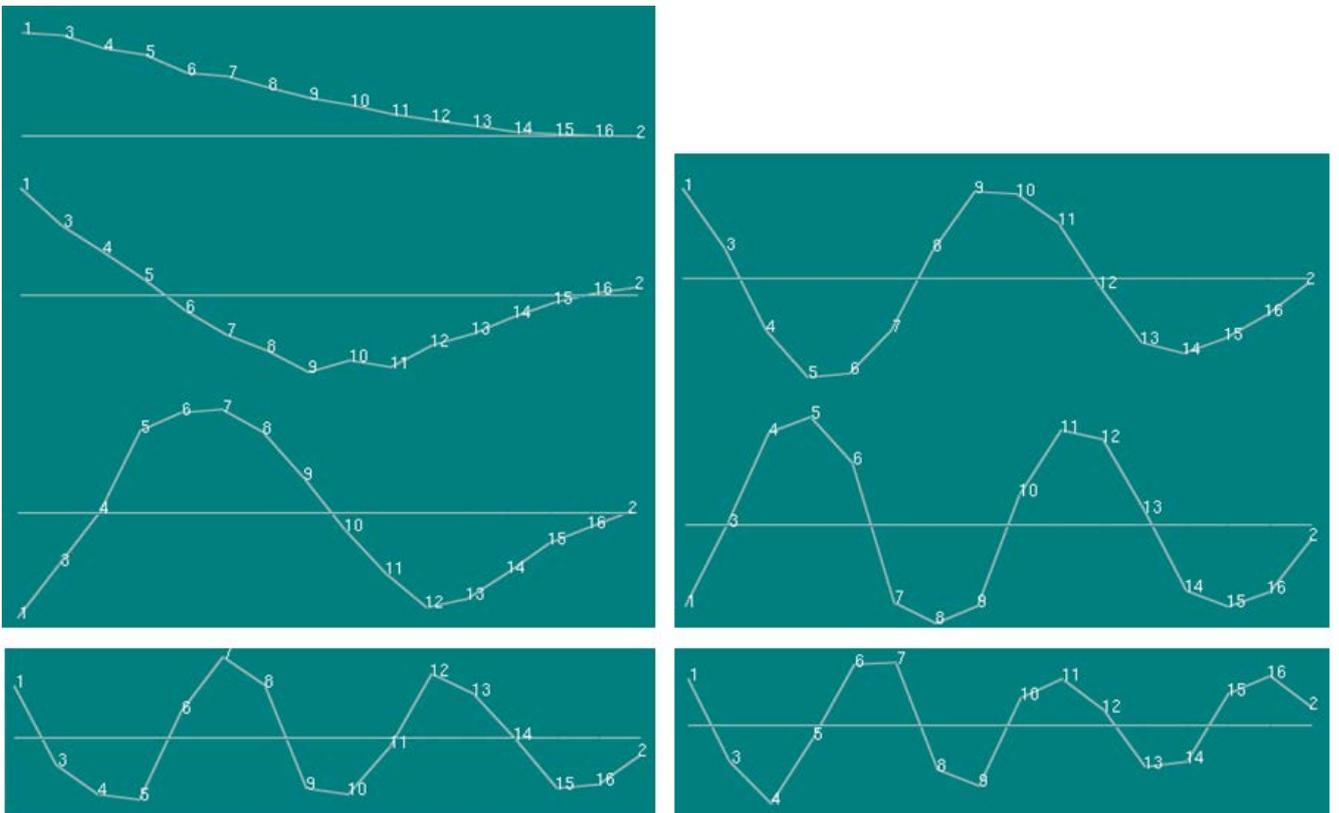


Figure 4. The mode shapes acquired by EMA method

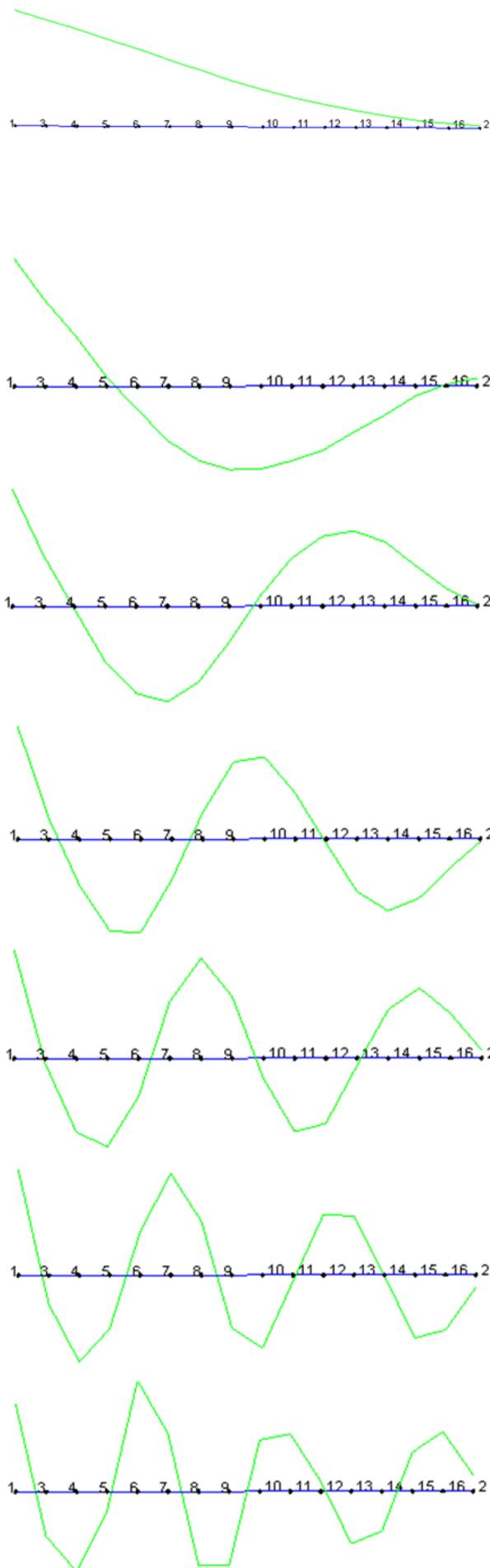


Figure 5. The mode shapes acquired by OMA method

7. Conclusion

Experimental and also operational modal analysis has its pros and cons. EMA method is very sensitive on excitation form. On the other hand OMA method does not need input data but its results are very influenced by positioning of measuring transducer.

From mode shapes measured by EMA and OMA methods and on the other hand by FEM method it is possible to see the influence of body fixation on their shape. The real fixation results in the creation of new node. Natural frequencies by OMA method are lower than those acquired by/with EMA method as a consequence of using of more measuring transducers.

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