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Comparison of experimentally identified modal properties of components using experimental modal analysis and acoustic holography

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Abstract: This paper is a comparison of experimental investigation of modal properties of two different methods – experimental modal analysis and acoustic holography (SoNAH method). Comparison is made for a simple system. Good agreement between both methods has been found.

Keywords: Experimental Modal Analysis; SoNAH, Acoustic Holography

1. Introduction

Acoustic holography is an advanced method especially designed to locate noise sources. However, it can also be used to detect dynamic behavior of bodies using non-contact measurement. The aforementioned methods are based on reconstruction of sound field in the plane near the surface of vibrating bodies [1].

There is currently no uniform method to investigate the entire possible frequency range. A proper evaluation method (SoNAH, Beamforming ...) must be used depending on the method and hardware configuration used. Although limits of frequency ranges are reported in specialized literature, it is necessary to verify the precise range through measurement.

In this paper, we focus on comparative measurements - we decided to compare the results acquired by two methods for obtaining of modal properties. In addition to the SoNAH method for acoustic holography, we decided to investigate modal properties using experimental modal analysis. As the investigation body, we chose a clutch cover for its good modal properties and easy handling.

2. Experimental Modal Analysis [2]

To compare the obtained results, we used experimental modal analysis as the reference method, which is similar to acoustic holography in its nature [2]. There is a fundamental difference in approach of the two methods – in experimental modal analysis, the body is excited by a pre-defined force, the transfer function of the body is analyzed and natural frequencies and natural waveforms are monitored. The acoustic holography method does not provide us with the transfer function of the

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system and therefore it is not necessary to define the excitation pulse. We can trace shapes of the body´s natural vibrations from the distribution of acoustic pressure levels of the radiated noise in the analyzed frequency bands. However, it is necessary to ensure good separation of the measured body from other noise sources. Parasitic noise may render the experiment useless.

2.1. Results obtained using experimental modal analysis

For detection of deformed shapes and natural frequencies, the selected component was loosely attached in space to ensure free behavior of the body. The component was then excited by an impulse hammer and the response was measssured by the accelerometer. We used the hammer made by Bruel & Kjaer type 8206-001, the type 4374 accelerometer was made by the same company. For measurements, we chose a 36-node network - see Fig 1. Excitation was repeated at every point (5 times), we measured frequency response function and then we evaluated natural frequencies from them. As a reference frequency range, we chose the interval from 20 to 1600 Hz. All natural frequencies and shapes were evaluated within this range - see Table 1. The frequency response functions obtained by measuring are shown in Fig 2. Deformed shapes for comparison with the acoustic holography method are in Fig. 3 and Fig. 4.

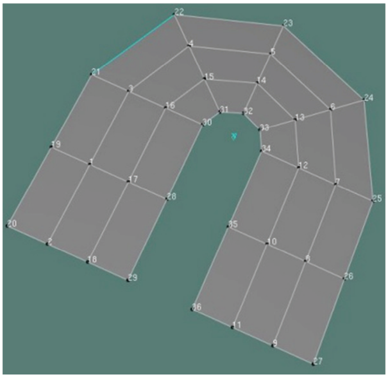

Fig. 1. Geometry and Measurement Network

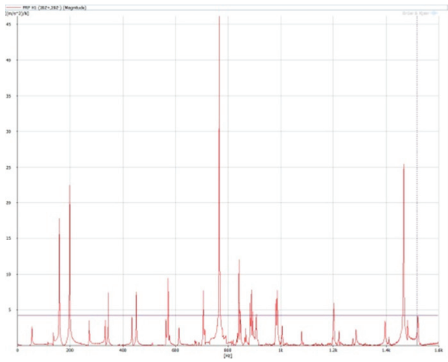

Fig. 2. Frequency Response Function, EMA

Table 1. Natural frequencies evaluated using experimental modal analysis

No	Frequency [Hz]	No	Frequency [Hz]	No	Frequency [Hz]
1	53,5	6	272	11	511
2	114,25	7	332,75	12	562,75
3	136,25	8	343,75	13	571,5
4	158,75	9	433,25	14	612,25
5	197,5	10	450	15	705

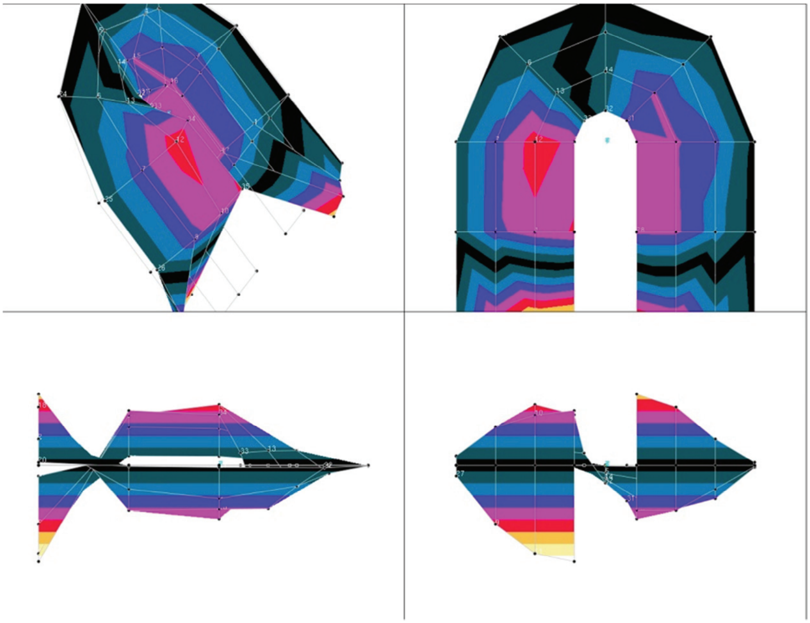

Fig. 3: Deformed shape for frequency 332,75 Hz, EMA

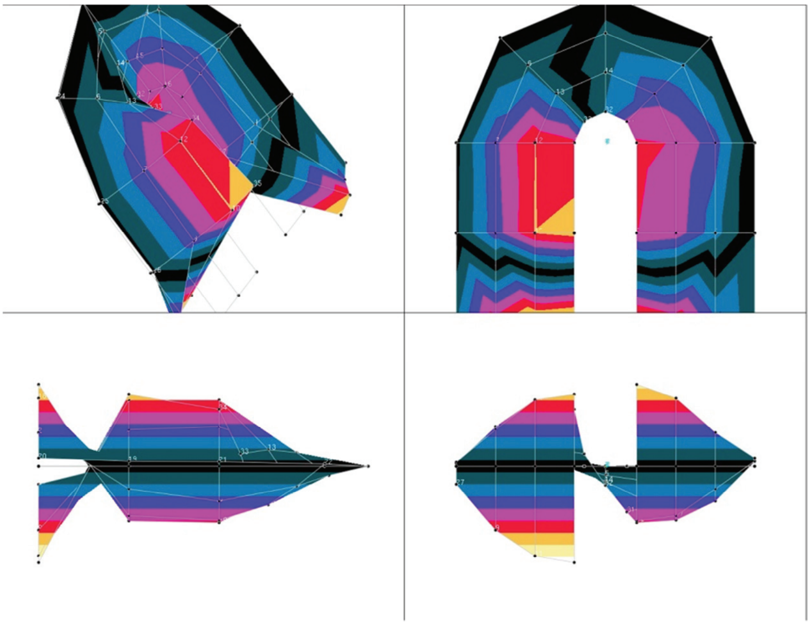

Fig. 4: Deformed shape for frequency 343,75 Hz, EMA

3. Near Field Acoustic Holography

As a second method to determine modal properties of components we chose SONAH - acoustic holography in near field. The microphone array is located very close to the monitored component; the usual measuring distance is 10 cm, which what we used in the test. The analytical algorithm of the method is suitable for evaluation of frequency ranges below than 1.5 kHz. The measured frequency range is dependent on the spatial configuration of the microphone array. For the purposes of measurement, we used Bruel & Kjaer circular microphone array type WA - 1558 with 36 Bruel & Kjaer measuring microphones type 4957, which are deployed in the field at irregular intervals. The diameter of the circular field is one meter (Fig. 5).

Fig. 5: Round slice microphone array used by experiments

3.1. Results obtained by acoustic holography

For the purposes of the test, the clutch cover was excited by a blow hammer. The impact force was not recorded, because the algorithm does not operate with the transfer function of the body structure. Data recording lasting 10 seconds was triggered simultaneously with the excitation pulse. The test was repeated 5 times, which verified the experiment repeatability.

The recorded data were evaluated by the SoNAH algorithm and FFT frequency analysis. With regard to the microphone array configuration we chose the reference frequency interval in the range from 50 to 1100 Hz for 1600 spectral lines. Constant band width for the frequency analysis was 10 Hz. We monitored natural waveforms in individual narrow frequency bands, while natural frequencies of the observed component were put into the centers of the appropriate intervals - see Table 2. The frequency response is shown in Fig 6. An example of natural waveforms is in Fig 7.

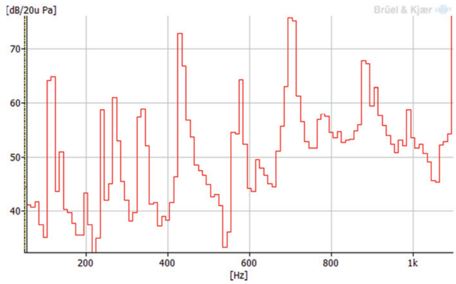

Fig. 6. Frequency response, constant bandwith 10 Hz, SoNAH

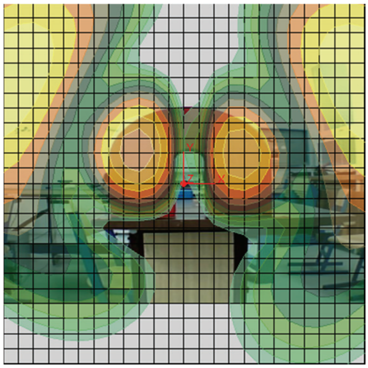

Fig. 7. Intensity map, range 335 Hz to 345 Hz

Table 2. Natural frequencies evaluated using acoustic holography

No	Frequency [Hz]	No	Frequency [Hz]
1	120	6	430
2	140	7	560
3	240	8	580
4	270	9	620
5	340	10	700

4. Summary

Comparison of results shows a relatively good agreement between the methods used. It is obvious that the experimental modal analysis may provide clear and accurate results. However, it is necessary to perform a large number of measurements depending on the density of nodes in the measurement network, if we wish to detect the natural waveforms as well. In contrast, measurements using acoustic holography can be done very quickly. However, the microphone array must cover the entire surface of the measured component. The price for easier measurement is lower precision of localization of natural frequencies. This is due to the bandwidth used in the analysis.

The aforementioned findings confirm the results of comparative measurements. Comparison of compiled natural frequencies tables reveals that the acoustic holography method did not allow capturing of all natural frequencies of the monitored component. Another disadvantage is the inaccurate frequency identification, which may lie anywhere within the evaluated band. In our measurements, we analyzed 10 Hz bandwidth - mean frequencies of the identified bands are plotted in Table 2. Distribution maps of sound pressure levels within natural frequency bands also represent oscillation nodes on the surface of the observed body. However, the method allows determining of only approximate location of the nodal point; the localization accuracy depends on the microphone array geometry used. The method of noise source localization does not allow for detecting of surface displacement in the nodal point, which is something that experimental modal analysis does allow.

In conclusion, we may sum up that identification of modal properties using acoustic holography is feasible. Its advantage is relatively fast and productive performance of experiments, whereby we may identify natural frequency of the reference body and natural waveforms from one measurement. However, it is impossible to determine the exact values of natural frequencies while some natural frequencies may disappear in the background noise. Therefore the acoustic holography method cannot fully replace experimental modal analysis. However, it can be used as an additional measurement in location measurement of noise sources, or whenever it is impossible to make contact measurements.

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References

[1] Williams, Earl G.: *Fourier Acoustics: Sound Radiation and Nearfield Acoustical Holography,* (Academic Press, London, 1999). ISBN 978-0127539607

[2] Miláček, S.: *Modální analýza mechanických* kmitů (České vysoké učení technické, 2001). ISBN 9788001023334